



# **Scheme of Instructions**

Jan-Apr 2025 Term

## Preface

The Scheme of Instruction (Sol) and Student Information Handbook (Handbook) contain the courses and rules and regulations related to student life in the Indian Institute of Science. The courses listed in the Sol and the rules in the Handbook are primarily meant for post-graduate students of the Institute. Undergraduate students are allowed to credit or audit the courses listed in the Sol with the consent of the instructors.

The course listings are in conformance with the Divisional structure of the Institute, with the courses of each department of a Division listed in a separate subsection. For instance, all courses of the Aerospace Engineering department have the prefix AE, and are listed in the Aerospace Engineering subsection within the Mechanical Sciences Division. The only exception to this pattern is the Electrical Sciences Division, where the courses are organized under the sub-sections E0 through E9, according to the areas to which they belong. For instance, all Computer Science and Automation courses of the Electrical Sciences Division have the prefix E0, and are found in the corresponding sub-section, although the instructors come from all four departments of the division. The course codes are given in the Table of Contents.

The listing of each course consists of the course number, the title, the number of credits and the semester. The course number indicates both the department and the level of the course. For instance, MA 205 indicates that the course is offered by the Mathematics department and is at the 200 level. Such 200 level courses are either basic or second level graduate courses. The 300 level courses are advanced courses primarily meant for research scholars, but can also be taken by course students who have the appropriate background; these courses can be taken only with the consent of the instructors. Most courses are offered only once a year, either in the August or in the January semester. Very few selected courses are offered in the summer term.

The number of credits is given in the form M:N, where M indicates the number of lecture credits and N the number of laboratory credits. Each lecture credit corresponds to one lecture hour per week, while each laboratory credit corresponds to a 3-hour laboratory class. Thus, a course with 2:1 credits indicates that it has 2 lecture hours and one 3-hour laboratory session each week, while a course with 3:0 credits indicates a course with 3 lecture hours and no laboratory session.

The Institute offers research-based doctoral programmes and Master's programmes that are both course-based and research-based. Each course-based Master's programme consists of core courses, electives and a dissertation project. Details of the requirements can be found under the course listing of the departments or divisions that offer them. Student are assigned faculty advisors who will advise them in selecting and dropping courses, and monitor progress through the academic program. In order to register for a course, each student needs the approval of both the faculty advisor and the course instructor. The number and type of courses taken in the first and subsequent semesters depend on the programme and department the student is registered in – the faculty advisor and the Department Curriculum Committee (DCC) will guide the students on the core and elective courses they should register for. Students are permitted to claim an exemption from core courses on the basis of having taken them earlier. Details of how to claim such an exemption are given in the Student Information Handbook.

The Institute follows a grading system, with continuous assessment. The course instructor first aggregates the individual marks of each student from the class tests, assignments and final examination scores. These marks are then mapped to letter grades, and only the grade is announced. The point values of grades are as follows: A+:10, A: 9, B+: 8, B: 7, C:6, D:5, F: 0. The grades A+ through D are passing grades, and F is a failing grade.

All the course-based programmes have a specified set of core courses. The doctoral and research-based Master's programmes may have specific core courses, which depend on the division and department. Students

in research programmes have to take a minimum number of credits as part of their Research Training Program (RTP). For PhD students in Science, the RTP consists of a minimum of 12 credits. For PhD students in Engineering who join with a post-graduate degree, the RTP requirement is a minimum of 12 credits. For PhD students in Engineering who join with under-graduate degree, the RTP consists of a minimum of 24 credits. Similar RTP requirements apply for students who upgrade or continue their registration from the Masters programmes of the Institute. For the research-based Master's degree, the RTP consists of minimum 12 credits. The Integrated PhD programme has 64 credits. Research students have the option of crediting courses beyond the RTP requirement as detailed in the Student Information Handbook.

Detailed information with regard to the regulations of the various programmes and the operation of different aspects of Institute activities are given in the Student Information Handbook. Students are urged to read this material carefully, so that they are adequately informed.

Chair  
Senate Curriculum Committee

# Division of Biological Sciences

## Preface

This Division includes the Department of Biochemistry, Centre for Ecological Sciences, Department of Microbiology and Cell Biology, Molecular Biophysics Unit, Department of Molecular Reproduction, Development and Genetics, Centre for Neurosciences, Centre for Infectious Disease Research and the Central Animal Facility. Students from a variety of disciplines such as biology, chemistry, physics and medicine are admitted into the Division for research work leading to a PhD degree.

Each Department/Centre/Unit offers courses on specialized topics designed to provide students with the necessary theoretical background and introduction to laboratory methods. There are specific requirements for completing the Research Training Programme for students registering for research conferments at the Institute. For individual requirements, the students are advised to approach the Departmental Curriculum Committee.

The Department of Biochemistry offers a programme of study concentrating on a molecular approach towards understanding biological phenomena. The programme of instruction consists of lectures, laboratory work, and seminar assignments. In addition to formal course work, students are required to participate in group seminars, departmental seminars and colloquia.

The Center for Ecological Sciences has excellent facilities for theoretical as well as experimental research in plant and animal ecology and the social behavior of insects. The programme of instruction consists of lectures, laboratory work, seminars and special assignments.

The Department of Microbiology and Cell Biology offers courses in microbiology, infectious diseases, eukaryotic genetics, advances in immunology, plant and cell culture, and recent advances in molecular biology and genetic engineering. The students are expected to participate in seminars on recent advances in these fields.

The Molecular Biophysics Unit offers courses which cover recent developments in molecular biophysics, biopolymer conformation, structure and interactions of biomolecules and biophysical techniques.

The courses offered in the Department of Molecular Reproduction, Development and Genetics include those on endocrinology, reproduction signal transduction, genetics, gene expression and development.

The research interests in the Centre for Neuroscience spans from molecules to behavior. The courses offered would enable the students to gain fundamental knowledge in molecular and cellular neuroscience, systems and cognitive neuroscience. In addition, students will be expected to actively participate in seminars, journal clubs and lab rotations.

The Centre for Infectious Disease Research (CIDR) is involved in two primary activities: First, providing the intellectual and infrastructural support for infectious disease research. Second, enable researchers to perform studies in the Bio-safety Level-3 (BSL-3) facility, a state-of-the-art bio-containment space to perform research with high infectious organisms, e.g. *Mycobacterium tuberculosis* etc.

The Central Animal Facility provides standardized pathogen free, conventionally bred animals for biochemical experiments and also has facilities for research involving non-human primates.

Prof. Usha Vijayaraghavan

Dean,

Division of Biological Sciences

**DB 250 ( JAN ) 2 : 0**

This Division includes the Department of Biochemistry, Centre for

Flow Cytometry, Flow Cytometry and Microscopy, Flow Cytometry: Problems, Parameters, Probes and Principles. Light and Matter, Optical Systems, Light Sources, Light Collection, Detectors, Flow Systems, Electronic Measurements, Analog Signal Processing, Digital Signal Processing, Performance: Precision, Sensitivity and Accuracy, Data Analysis, Computer Systems for Flow Cytometry, Compensation and Multiparameter Data Analysis, Flow Sorting, Extrinsic Parameters, Intrinsic parameters, Fluorescent labels and Protein dyes, Nucleic Acid dyes and uses, Measurement of cell surface and Intracellular Antigens, Signal Amplification and other techniques, Kinetic measurements and Functional Probes.

**William Rasican Surin**

**Pre-requisites :** None

**References :** Practical Flow Cytometry, Howard M Shapiro

# Biochemistry

## Preface

### BC 201 ( AUG ) 2 : 0

#### Cell Biology

**Pre-requisites** : None

**References** :

### BC 202 ( AUG ) 2 : 0

#### Proteins: Structure and Function

Purification and characterization of enzymes/proteins. Determination of primary/secondary/tertiary/quaternary structures.conformational properties of polypeptide chains; Mechanism of Protein folding;. Enzyme catalysis – steady state kinetics, allosteric enzymes, kinetics of interactions of ligands,protein engineering,enzyme mechanisms.

**Pre-requisites** : None

**References** : None

### BC 203 ( AUG ) 3 : 0

#### General Biochemistry

Biochemistry of carbohydrates and lipids. Cell membrane: structure and function. Metabolism: basic concepts and design, glycolysis and citric acid cycle, oxidative phosphorylation, bioenergetics, fatty-acid metabolism,integration and regulation of metabolism,pentose phosphate pathways and gluconeogenesis. Photosynthesis.Protein translation and regulation, cellular protein transport and protein turnover, biosynthesis and catabolism of amino acids and nucleotides, signal transduction. DNA structure, replication and repair. Transcription, regulation of gene expression in prokaryotes and eukaryotes. Recombinant DNA technology.

**Pre-requisites** : None

**References** : None

**BC 205 ( JAN ) 2 : 0****Fundamentals of Physiology and Medicine**

Introduction to human embryology and congenital anomalies (RB), Cardiovascular system; Respiratory system; Endocrine system ; Digestive system; Renal Physiology; Physiology and common Pathologies /disorders associated with these systems; Medical and surgical interventions (SME).

**Sandeep M Eswarappa , Ramray Bhat**

**Pre-requisites :** None

**References :** 1. Ganong's Review of Medical Physiology, 25th Edition (McGraw-Hill Education), 2. Guyton and Hall Textbook of Medical Physiology (Saunders Publication), 3. Harrison's Principles of Internal Medicine (McGraw-Hill Education), 4. Davidson's Principles and Practice of Medicine

**BC 207 ( JAN ) 2 : 0****Proteomics in Practice**

**Utpal Tatu**

**Pre-requisites :** None

**References :** Course offers introduction to proteomics, 2D gel electrophoresis techniques for resolution of proteins, mass spectrometry principles and applications in proteomics. Study of post translational modifications, Databases (NCBI, Swiss-prot and MSDB) and their uses, software (protein pilot, mascot and gpm) uses for proteomic analysis. Introduction to quantitative proteomics and techniques (i-TRAQ

**BC 209 ( JAN ) 2 : 0****Dissertation Project**

The dissertation project is aimed at training students to review recent literature in specialized areas of research. Students to review recent lit

**Sathees C. Raghavan**

**Pre-requisites :** None

**References :** None

**BC 210 ( JAN ) 3 : 0****Molecular Basis of Ageing and Regeneration**

Model systems for studying Ageing and Regeneration (such as Planaria, Hydra, Salamander); Role of cellular processes such as transcription, translation, posttranslational modifications; Signalling mechanisms; Cellular Senescence; Genetic basis of Ageing and longevity; Ageing and Diseases; Organ Senescence; Obesity/ Diabetes/Cardiovascular diseases/Muscle degeneration; Interventions to delay ageing and/or enhance life span.

**Purusharth Rajyaguru**

**Pre-requisites :** None

**References :**

Principles of Regenerative Biology by Bruce Carlson., Regeneration developmental Biology by Scott F Gilbert (6th

**BC 306 ( AUG ) 3 : 0****Essentials in Immunology**

Adaptive and innate immunity, inflammation, antibody structure and function, the complement system, antigen - antibody interaction, cells and organs of the immune system, B cell activation, immunoglobulin genes, molecular basis of antibody diversity, T cell receptors, T cell activation, major histocompatibility complex, antigen processing and presentation, lymphokines, transcription factors, hypersensitivity, autoimmunity, immunological techniques. Immunological disorders and therapy.

**Pre-requisites :** None

**References :** None



**BC 303 ( JAN ) 2 : 0****Single-Molecule Approaches in Biology**

This course is designed to provide a holistic picture of microscopy, starting from traditional diffraction-limited imaging to advanced super-resolution imaging and single-molecule approaches and their applications in biology. The course will begin by introducing the basics of light microscopy and the limitations of traditional imaging techniques. We will explore the historical aspects of photon detectors, which are at the heart of microscopy. Various microscopy techniques will be introduced, including confocal two-photon, 4Pi, Total Internal Reflection Fluorescence, and Fluorescence Lifetime Imaging.

We will cover both ensemble-averaging super-resolution techniques such as STED and SIM, as well as Single Molecule Localization Microscopy-based techniques like PALM, STORM, and PAINT. Additionally, the course will delve into the historical background of single-molecule imaging approaches and their evolution, while discussing the advantages and limitations of these methodologies. We will explore how these techniques can be utilized to measure individual enzyme kinetics, nucleic acid structure and dynamics, and protein-DNA interactions. Furthermore, we will examine how these techniques can be applied to investigate a wide range of biological phenomena, such as protein folding and chromatin structure.

**Rahul Roy , Mahipal Ganji**

**Pre-requisites :** None

**References :** 1) Microscopy Biophysics of DNA-Protein Interactions: From Single Molecules to Biological Systems by Mark C. Williams and L. James Maher  
 2) Handbook of Single Molecule Biophysics by Peter Hinterdorfer and Antoine van Oijen

# Ecological Sciences

## Preface

The Center for Ecological Sciences has excellent facilities for theoretical, experimental and field based research in plant and animal ecology, evolution and behaviour. The programme of instruction consists of lectures, laboratory work, seminars and special assignments.

## EC 204 ( JAN ) 2 : 1

### Evolutionary Biology

This course offers an in-depth, hands-on look at the basic principles of evolutionary biology, and discusses the recent advancements and the major ideas in the field. The course has a special emphasis on phylogenetics, population genetics, molecular evolution, genome evolution, and offers exposure to a wide range of theoretical and practical aspects for understanding the micro- and macroevolutionary processes that shape the diversity of life on earth.

### Praveen Karanth K

**Pre-requisites** : None

**References** : Futuyma, D. J., Evolutionary Biology (Third Edition), Sinauer Associates, 1998. Li

## EC 301 ( AUG ) 2 : 1

### Animal Behaviour : Mechanisms and Evolution

History and classical ethology; sensory processing and neural maps; Learning and memory; hormones and behavior; behavioral genetics; navigation and communication; optimality approaches and evolutionary models to understand strategies for foraging, competition, group living, sexual selection and mate choice, parental care and family conflicts, predator-prey interactions; theoretical, integrative and computational approaches to studying animal behaviour.

**Pre-requisites** : None

**References** : Alcock, J., Animal Behaviour - An Evolutionary Approach (Sixth Edition), Sinauer Associates, 1998~ Neuroethology – J. M. Camhi (1984) Sinauer Associates, Sunderland~ Behavioural Ecology: An Evolutionary Approach. J. R. Krebs & N. B. Davies (1991) Blackwell Press, Oxford~ Sensory Ecology, Behaviour and Evolution by Martin Stevens (2013) Cambridge University Press

**EC 305 ( AUG ) 2 : 1****Quantitative Ecology : Research Design and Inference**

The scientific process in ecology; framing ecological questions; elements of study design; confronting ecological models with data; understanding the nature of data; statistical hypothesis testing; linear models, regression, ANOVA; generalised linear models; statistical modelling strategies.

**Pre-requisites** : None

**References** : Hilborn,R. and Mangel,M., The Ecological Detective: Confronting Models with Data. Princeton University Press, Princeton~Zuur A, Ieno EN and GM Smith 2007 Analysing ecological data. Springer~Crawley MJ 2007 The R Book. John Wiley & Sons

**EC 202 ( AUG ) 2 : 1****Ecology: Pattern and Process**

History of ecology; interactions between organisms and the environment; ecological niche; distribution of species and communities; basic population biology; interspecific interactions; community assembly; diversity, richness and abundance; ecosystem structure and function; species concepts; ecological and evolutionary processes (dispersal and diversification); island biogeography; meta-population biology; macroecology.

**Pre-requisites** : None

**References** : • A.E. Magurran, Measuring Biological Diversity, Blackwell Publishing, 2004. • J.H. Brown and M.V. Lomolino, Biogeography (Second Edition), Sinauer Associates, 1998. Pianka, E.R. Evolutionary Ecology. Eric R. Pianka, e-book, 2011.

**EC 206 ( JAN ) 2 : 1****Evolutionary Genetics**

This course will emphasise teaching genetic principles and evolutionary mechanisms that generate the stupendous complexity in nature. The course will begin with discussions on evolutionary cosmology, including the origin of the Universe, Solar System, Earth, and life on our planet as we know it. Following this would be a series of lectures explaining the genetic mechanisms that generate variation in nature and how evolution operates on it. The course will then introduce various tools of the trade, including 'omics' technologies and associated bioinformatics, that have made it possible to address broad, interesting, and challenging questions in diverse fields of biology, including ecology, evolutionary biology, genetics, and biomedical research. This course will end with discussions on other interesting topics, including evolutionary development, evolutionary medicine, human evolution, and broader applications of evolutionary reasoning.

The course will consist of lectures, discussions and hands-on bioinformatic practical sessions. Practical sessions will introduce students to various aspects of data acquisition, processing, and analyses, while theory classes will provide in-depth knowledge of the underlying principles. At the end of the course, a final examination will be conducted to evaluate student performances.

**Kartik Sunagar**

**Pre-requisites** : A basic understanding of genetics and molecular biology is desirable but not mandatory.

**References** : 1. Evolutionary biology. Douglas J. Futuyma (1998). 3rd Sinauer Associates Inc, Publishers, Sunderland. 2. Evolutionary Analysis, Fifth Edition by Jon Herron Scott Freeman. 3. Bioinformatics and Functional Genomics, Pevsner (3rd edition). 4. Practical Computing for Biologists, Haddock and Dunn.

**EC 309A ( AUG ) 3 : 0****Ecosystems and Global Change**

This course will consist of lectures, readings and discussion, and a final class-project. It will have two 1-hr long sessions every week. In lectures, the instructor will cover topics related to ecosystem ecology, biogeochemical cycles, feedbacks between global change and ecosystem functions. The overall aim will be to introduce the different aspects of global change (e.g., rising CO<sub>2</sub>, altered precipitation, nutrient deposition, land-use and land-cover change, etc.) and their linkages with ecosystem functions. Through assigned readings, students will develop a broad understanding of how biogeochemistry provides a common premise to understand these linkages. Students will be evaluated upon their performance in a mid-semester exam, and a final class-project. The class-project is envisioned to be a review or synthesis (e.g., meta-analysis of primary literature) of a topic that is relevant to ecosystem ecology or global change.

**Pre-requisites**

No specific pre-requisites

**References** : Schlesinger WH, and E Bernhardt (2013). Biogeochemistry: An analysis of global change. 3rd ed, 688 pp. Academic Press. ISBN9780123858740. Chapin FS, PA Matson, and P Vitousek (2011). Principles of terrestrial ecosystem ecology. 2nd ed, 529 pp. Springer. ISBN9781441995025.

**EC 102 ( JAN ) 2 : 0****Process of Scientific Thinking**

The goal of this course is to discuss approaches of scientific practice and directly address research conduct. By starting with a historical perspective of various philosophies of science and discussing the challenges of following these philosophies in practice, students get a formal understanding of the process of science. Specifically, we will have a series of lectures, discussions and assignments on:

- Philosophy of science
- Ethics in conducting, writing, and publishing science, including plagiarism
- How to read and review scientific literature critically

For the philosophy of science module, we will lay out the process of scientific thinking – deduction, induction and Inference by Best Explanation. We will explore the history of modern scientific thought, from the Popperian hypothetico-deductive method to Kuhnian paradigms, using examples of scientific revolutions in the field of biology. We will also explore concepts such as reductionism, emergence and uncertainty.

For the module in Ethics, we will draw from UGC's guidelines on Research and Publication ethics ([https://www.ugc.ac.in/pdfnews/9836633\\_Research-and-Publication-Ethics .pdf](https://www.ugc.ac.in/pdfnews/9836633_Research-and-Publication-Ethics.pdf)). This will involve lectures and exercises in identifying forms of scientific misconduct (falsification, fabrication and plagiarism). We will use historical and current examples of academic dishonesty, and also address best practices in publication ethics, including the importance of identifying predatory journals and the consequences of research misconduct. Beyond the UGC guidelines, this module will have a series of lectures on best practices for replicable research, which will cover issues that arise when designing studies, collecting data, curating data, analysing data, and interpreting results. Finally, we will discuss the ethics of citations and authorship in the field of Biology.

In the final module, we will use the philosophical approaches (covered in the first module) and tools of research conduct (covered in the second module) to critically read literature in Biology. Using a rubric that the students develop together in the course, we will evaluate the inductive/deductive process used and the inferences drawn in these papers, as well as the importance of transparency and replicability of data. We will end with an examination of how honesty can and should be included in the narrative of modern scientific publications.

**Maria Thaker**

**Pre-requisites** : None

**References** : Samir Okasha. 2016. Philosophy of Science: a very short introduction.

# Neuroscience

## Preface

### NS 201 ( AUG ) 2 : 0

#### Systems Neuroscience

Neuronal biophysics, sensation & perception, motor systems

**Pre-requisites** : None

**References** :

### NS 202 ( AUG ) 2 : 0

#### Molecular and Cellular Basis of Behaviour

Neuroanatomy, neurotransmitter systems, synaptic transmission, pre- and post-synaptic organization and its relationship to synaptic physiology, synaptic plasticity, learning and memory.

**Pre-requisites** : None

**References** : None

### NS 203 ( AUG ) 2 : 0

#### Cognitive Neuroscience

Methods in cognitive neuroscience, attention, decision making, executive functions, emotion, reward and motivation.

**Pre-requisites** : None

**References** : None

**NS 204 ( AUG ) 2 : 0****Developmental Neuroscience**

Basic neuroanatomy of the central and peripheral nervous systems, neurogenesis, cell migration, cellular determination and differentiation, Neuronal growth cone and axon growth, Cell death in the nervous system, synapse formation, refinement of synaptic connections, astrocyte development and functions, oligodendrocyte development and functions, microglia development and functions.

**Pre-requisites** : None

**References** : None

**NS 211 ( JAN ) 3 : 0****Optical Spectroscopy and Microscopy**

Transition probabilities; Time dependent perturbation theory; Interaction with strong fields, Second Quantization; Origin of Spontaneous emission; characteristics of stimulated emission; Absorption and emission. Emergence of biophysical methods such as CD, Fluorescence spectroscopy, Energy transfer and other such methods from the above principles. Non-linear optics ; Lasers; Pulsed and CW lasers; Multi photon excitation; optical microscopy; diffraction limit; principles of laser scanning microscopes; photo detection; optical microscope in bits and pieces.

**Balaji J**

**Pre-requisites** : None

**References** : None

**NS 303 ( JAN ) 3 : 0****Topics in Systems and Cognitive Neuroscience**

This is mainly a paper reading course. Every week, students are given 2-3 papers to read, and these papers are critically discussed during the class. The class is divided into 3 modules that cover different aspects of sensory and cognitive neuroscience such as sensory encoding, perception and object recognition, attention, decision-making, motor systems, and cognitive control. They are also asked to write grant proposals based on the papers and topics that they have covered.

**Aditya Murthy , Sridharan Devarajan , Srikanth Padmala**

**Pre-requisites** :

**References** : Original Papers

**NS 304 ( JAN ) 3 : 0****Topics in Molecular and Cellular Neuroscience**

Critical reading and grant writing on various topics in molecular and cellular neuroscience. This is an advanced graduate reading course focusing on historical and current papers relevant to the Developmental and Cellular Neuroscience, Neuronal Circuits, Synaptic Transmission and Learning and Memory. The module will consist of weekly readings as well as a grant proposal at the end. Typically the students will be provided with ~4-5 articles per topic for reading with the emphasis on the methods used in the field and the unanswered problems in the field. The course will have the following topics for the syllabus: i) Learning and Memory ii) Synaptic Physiology and Neuroanatomy iii) Developmental Neuroscience and Neural circuits governing behavior

**Deepak Kumaran Nair , Arnab Barik**

**Pre-requisites**

NS202 and NS201

:

**References** : Will be provide during the course. Research articles will be selected from the contemporary research and provided.

# Microbiology and Cell Biology

## Preface

### MC 202 ( JAN ) 2 : 0

#### Developmental Genetics

Current Opinion in Genetics and Development/ Cell Biology/Plant Biology •Trends in Genetics/ Cell Biology/ Biochemistry • Principles of Development by Wolpert and co-authors• Mechanisms in Plant Development by Leyser and Day• Plant Physiology by Taiz and Zeiger •Ecological Developmental Biology by Scott Gilbert and David Epel•R.V. Stanier,E. A. Adelberg and J. L. Ingraham, General Microbiology, Macmillan Press.

**Utpal Nath , Samay Ravindra Pande**

**Pre-requisites** : None

**References** : Logic and techniques of molecular genetic analysis. Understanding interaction networks using genetics and genomics. Illustrating the application of genetic analysis to specific developmental pathways in model eukaryotes and prokaryotes. Some examples are genetic and epigenetic mechanisms of cell fate determination and signaling pathways in development, embryo and organ patterning,

### MC 203 ( AUG ) 3 : 0

#### Essentials in Microbiology

Fascinating world of microbes; Principles of microscopy; Microbial taxonomy, Microbial diversity, evolution and genomics; Mechanisms of horizontal gene transfer including genome transplantation, Microbes as model systems of development, Microbes as bioreactors and sensors; bioremediation; bacterial cell structure and function; Bacterial physiology and nutrition; Bacteriophages, Plasmids and Transposons; Understanding and combating bacterial pathogenesis; Antibiotics mechanisms of drug resistance and mode of action; Quorum sensing and biofilms; Host-pathogen interactions and mechanisms of immune surveillance; PRR and their role in pathogenesis; TH subsets and modulation by pathogens; Diagnostics and vaccine development; Origin of cellular life; Biogeography of microbial diversity (is everything everywhere?); Host associated and free-living microbes; Mechanisms of microbial interactions; Causes, consequences, and evolution of physiological heterogeneity in bacterial populations; Bac

**Pre-requisites** : None

**References** : "Stanier, R.V., Adelberg E.A and Ingraham J.L., GENERAL MICROBIOLOGY, Macmillan Press, Fourth edition Westrich, G.A. and Lechmann M.D., MICROBIOLOGY, Macmillan Press, Fifth Edition Atlas R.M., MICROBIOLOGY: FUNDAMENTALS AND APPLICATIONS, Macmillan Press Second Edition Goldsby, R. A., Kindt T. J., Osborne B. A., Kuby J., IMMUNOLOGY, W. H. Freeman &



**MC 206 ( AUG ) 2 : 0****RNA Biology**

Mechanisms and machinery of transcription in prokaryotes and eukaryotes. RNA splicing and editing. Catalytic RNAs. RNA-protein recognition and interactions. Transcriptional and translational regulation of gene expression. Ribosome heterogeneity. RNA granules and liquid liquid phase separation. mRNA decay in prokaryotes and eukaryotes. RNA modifications. RNA viruses & viroids, and their biology (Negative sense RNA Viruses, Positive Sense RNA Viruses, Retroviruses, Double Stranded RNA Viruses & Viroids). Small RNAs: biogenesis, and their modes of action in regulation of gene expression and chromatin architecture.

**Pre-requisites** :

**References** : "Flint SJ, Enquist L, Racaniello V, Rall GF, Skalka AM. Principles of Virology. 4th ed. ASM Press; 2015. ISBN-10: 1555819338 Knipe DM, Howley PM. Fields Virology. 6th ed. Lippincott: Williams and Wilkins; 2013. ISBN-10: 1451105630 For general RNA Biology: Any standard text book and The RNA World by Gesteland, Cech, and Atkins"

**MC 207 ( AUG ) 3 : 0****Molecular and Cellular Biology**

Genome organisation, structure and complexity. Chromatin structure and remodelling. Protein nucleic acids interactions. DNA replication in prokaryotes and eukaryotes: general rules, mechanisms, and regulation. DNA modifications in epigenetic control of biological processes. DNA repair and recombination. Mechanisms and machinery of transcription in prokaryotes and eukaryotes. RNA splicing and editing. Catalytic RNAs. Transcriptional and translational regulation of gene expression. Protein splicing and repair. Small RNAs: biogenesis, and their modes of action in regulation of gene expression and chromatin architecture. Group discussions and seminars on current topics in Molecular Biology

**Pre-requisites** : None

**References** :

Lewin's Genes X, Lewin, B., Krebs, J.E.

**MC 207 ( AUG ) 3 : 0****Molecular Biology**

Genome organisation, structure and complexity. Chromatin structure and remodelling. Protein nucleic acids interactions. DNA replication in prokaryotes and eukaryotes: general rules, mechanisms, and regulation. DNA modifications in epigenetic control of biological processes. DNA repair and recombination. Mechanisms and machinery of transcription in prokaryotes and eukaryotes. RNA splicing and editing. Catalytic RNAs. Transcriptional and translational regulation of gene expression. Protein splicing and repair. Small RNAs: biogenesis, and their modes of action in regulation of gene expression and chromatin architecture. Group discussions and seminars on current topics in Molecular Biology

**Pre-requisites** : None

**References** : Lewin's Genes X, Lewin, B., Krebs, J.E.

**MC 208 ( AUG ) 2 : 0****Principles of Genetic Engineering**

DNA, RNA, Proteins: composition, isolation, purification and quantification methods. Gene cloning, restriction and modification enzymes. PCR, RT-PCR, Site directed mutagenesis and Nucleic acid sequencing methods. Plasmid vectors including phagemid, cosmid for gene cloning and expression. Bacterial strains for Genetic engineering. Transformation, Transduction and Transfection methods. Preparation and characterization of DNA libraries. Nucleic acid Hybridization, nucleic acid-protein, Protein-protein interaction methods. Methods to modulate gene expression: SiRNA/shRNA technology. Lentivectors and Transduction. Viral genome engineering and applications in gene therapy and vaccines. Plant genetic engineering. Animal cloning and germline modifications. Genome editing by ZFN, TALEN. CRISPR/Cas Systems for DNA and RNA targeting. Genome wide CRISPR screening. Gene Drives and applications. Ethical and Safety issues of Genome editing

**Pre-requisites** : None

**References** : J. Sambrook and D. W. Russell, Molecular Cloning: A Laboratory Manual, 3rd Edn: Vol. I, II, & III, Cold Spring Harbor Laboratory Press. J. J. Greene and V. B. Rao. Recombinant DNA Principles and Methodologies. CRC Press. S. B. Primrose and R. M. Twyman. Principles of Gene Manipulation and Genomics, 7th Edn, Blackwell Publishing. Fred Ausubel and Others. Current Protocols in

**MC 210 ( JAN ) 2 : 0****Molecular Oncology**

The Biology of Cancer, 2nd Edition (2014) by Robert A. Weinberg

**Kumaravel Somasundaram , Annapoorni Rangarajan , Sudha Kumari**

**Pre-requisites** : None

**References**

Introduction to Cancer Biology: Immortalization,

**MC 211 ( JAN ) 3 : 0****Molecular basis of Ageing and Regeneration**

Mechanisms of Ageing and Regeneration; Model systems for studying Ageing and Regeneration; Role of cellular processes such as transcription, translation, posttranslational modifications; Signalling mechanisms; Cellular Senescence; Genetic basis of Ageing and longevity; Ageing and Diseases; Organ Senescence; Obesity/ Diabetes/Cardiovascular diseases/ Muscle degeneration; Interventions to delay ageing and/or enhance life span

**Nagalingam Ravi Sundaresan**

**Pre-requisites** : None

**References** : Principles of Regenerative Biology by Bruce Carlson. <http://www.sciencedirect.com/science/book/9780123694393> 2. Regeneration –Developmental Biology by Scott F Gilbert (6th edition) 3. Hand book of the Biology of Aging, Seventh Edition, by Edward J. Masoro, Steven N. Austad, 2010 4. Molecular Biology of Aging (Cold Spring Harbor Monograph Series).

**MC 212 ( AUG ) 2 : 0****Advances in Cell Biology**

Concepts: Prokaryotic and eukaryotic membrane structure, composition, organization and transport; Organelle structure, function and their biogenesis includes nucleus, endoplasmic reticulum, Golgi, endosomes, lysosomes and lysosome-related organelles, autophagosomes, peroxisomes, mitochondria and chloroplasts; Protein trafficking in-and-out of the organelles; Cytoskeletal elements and organization; Cell adhesion and junctions; Intra and extra cellular signaling; Cell cycle, cell division (asymmetric and symmetric) and stem cells; Cell death and protein homeostasis pathways and Cellular diseases. Methods: Introduction and evolution of light microscopy; Electron microscopy; Cytohistochemistry; Flow cytometry; Pulse-chase and subcellular fractionation; Proteomics and Protein-protein interaction approaches and genome-wide RNAi or small molecular screens to study the various cellular pathways.

**Pre-requisites** : None

**References** : Molecular Biology of The Cell, Fifth edition, Alberts et al.

**MC 205 ( AUG ) 2 : 0****Pathogen - Host interactions and immune evasion mechanisms**

Pathogen - Host interactions and immune evasion mechanisms The vertebrate host has evolved numerous mechanisms to shield itself against the onslaught of the myriad pathogens around it. The host uses toll like receptors to recognize pathogens, and deploys effective weapons from its impressive arsenal to eliminate pathogens. This course will utilize multiple host-pathogen pairs as models to demonstrate the innumerable mechanisms utilized by pathogens of viral, bacterial and parasitic origin to subvert the host and enhance their own survival. Secretion systems of bacteria: Type I, II, III, IV, V overview of ABC exporters and importers, Plant Pathogen interactions (Xanthomonas Citrobactor, Erwinia); Virulence gene expression, intracellular pathogenesis; Signaling by the bacterial components; Innate and adaptive immunity to bacterial pathogens; Quorum sensing, biofilm formation and its role in pathogenesis. Functional mimicry of host complement proteins, secretion of chemokine and cytokine -like molecules, inhibition of NF- $\kappa$ B and apoptosis, inhibition of serine proteases of the host antigen presenting cells to suppress antigen presentation, inhibition of inflammatory responses of the host seen in poxviruses, inhibition of MHC class I presentation of viral antigens by adenoviruses, inhibition of host secretory pathway by herpes viruses, prevention of phagosome acidification and other macrophage functions by Mycobacterium tuberculosis, antigenic variation and suppression of TH1 responses by protozoan pathogens will all be covered. Viral infectious cycle; Induction, regulation and mechanisms of Antiviral innate Immunity; Strategies of Viral evasion and antagonism of antiviral immunity; Mechanisms of Viral Pathogenesis. Interferon (IFN) is the cornerstone of antiviral innate immunity in mammalian cells. We will discuss detection of viral pathogens as foreign entity by mammalian cells, subsequent Interferon (IFN) induction and signaling, antiviral mechanisms of IFN Stimulated Genes (ISGs), Viral evasion and antagonism of IFN mediated immune response.

**Pre-requisites** : None

**References** : (1) David G. Russell and Siamon Gordon, Phagocyte-Pathogen Interactions: Macrophages and the Host Response to Infection, ASM Press, 2009. Knipe, D.M.~

**MC 214 ( JAN ) 2 : 0****Basic and Applied Virology**

Viruses are omnipresent, in and outside of us in the environment, however in recent past they have assumed great public health significance. In last few decades viral pathogens like human immunodeficiency virus (HIV) and hepatitis viruses have caused substantial mortality, morbidity and economic loss all over the world. Moreover, in last one decade we have seen frequent emergence of viral pandemics and outbreaks potential e.g. SARS CoV2, H1N1 Swine Flu, Zika and Ebola. This course is designed to give an overview of fundamental concepts in virology, explain biology and pathogenesis of major viral pathogens and give introduction to applied aspects of virology. Viruses are omnipresent, in and outside of us in the environment, however in recent past they have assumed great public health significance. In last few decades viral pathogens like human immunodeficiency virus (HIV) and hepatitis viruses have caused substantial mortality, morbidity and economic loss all over the world.

**Saumitra Das , Shashank Tripathi , Kesavardana Sannula**

**Pre-requisites :** None

**References**

(1) Fields Virology, 6th Edition, Edited by David M. Knipe and Peter M. Howley. Philadelphia, PA, USA. Lippincott Williams & Wilkins.~

**DB 212 ( JAN ) 0 : 6****Biological Science**

**Aravind Penmatsa**

**Pre-requisites :** None

**References :** None

**DB 327 ( JAN ) 0 : 6****Project- III**

An independent research project to be conducted in the laboratory of a faculty member in the Division of Biology. It is desirable that the project be carried out in the laboratory where Project II was conducted.

**Aravind Penmatsa**

**Pre-requisites :** None

**References :** None

**MC 216 ( JAN ) 1 : 0****Biological Safety: Principles and practices**

1.The Microbiota of Humans and Microbial Virulence Factors 2. Indigenous Zoonotic Agents of Research Animals 3. Biological Safety Considerations for Plant Pathogens and Plant-Associated Microorganisms of Significance to Human Health 4.Laboratory-Associated Infections 5. Viral Agents of Human Disease: Biosafety Concerns 6. Emerging Considerations in Virus Based Gene Transfer Systems 7. Biosafety for Microorganisms Transmitted by the Airborne Route 8. Cell Lines: Applications and Biosafety 9. Allergens of Animal and Biological System

**Amit Singh****Pre-requisites** : None**References** : Biological Safety: Principles and Practices, (2017), Dawn P. Wooley & Karen B. Byers**MC 215 ( JAN ) 2 : 0****Lysosomes and Autophagy**

Lysosomes: Organelle contents and environment, functions, discovery of lysosomes and classical papers and experiments, cargo trafficking into out of lysosomes, position, contact and fusion with other organelles and lysolP. Transcriptional regulation of lysosome biogenesis, spatiotemporal distribution of lysosomes within a cell, lysosome reformation, lysosomal turnover and exocytosis, lysosome as signaling hubs and nutrient sensor, lysosome cell death, dysfunction and associated diseases. Model systems to study lysosome biology and state of the art methods in monitoring lysosomal biology. Autophagy: Discovery of autophagy and classical papers and experiments. Principles and biogenesis mechanisms, types of autophagy, organelles specific autophagy, cross talk between lysosomes and autophagy, and autophagy modulation in diseases. Model systems to study autophagy, signaling transduction pathways that affect autophagy. State of the art methods in monitoring autophagy flux.

**Subba Rao Gangi Setty****Pre-requisites** : None**References** : 1. Lysosomes and Lysosomal Diseases (Methods in Cell Biology, Volume 126) by Platt & Platt, Publisher: Academic Press; 1st edition (February 19, 2015). Reviews: Platt et al., Nat. Rev. Dis. Primers (2018) and Ballabio and Bonifacino, Nat. Rev. Mol. Cell Biol. (2019).

**MC 217 ( JAN ) 2 : 0****Fundamentals of Immunotherapy**

1.Immunotherapy- Definition and history 2. Primer on the immune response to diseases- autoimmunity vs. immunosuppression 3. Introduction to various components of immunity 4.Primer on adaptive immune response: development, function, and regulation 5.Broad classes of immunotherapy-1 6.Broad classes of immunotherapy-2, 7.Checkpoint therapies 8.Antibody drug conjugates 9.Cancer vaccines 10.Protein and immune receptor engineering-1, 11.Protein and immune receptor engineering-2, 12.Innate immune response: development, function, and regulation 13.Inflammation and cell death in immunotherapy outcome-1, 14.Inflammation and cell death in immunotherapy outcome-1, 15.Immunotherapies targeting innate immune cells (macrophages & dendritic cells) 16.Immunotherapies targeting granulocytes and innate-like cells 17. Antigen-presenting cells and adjuvants - vaccines and immunotherapy 18.Immunoengineering-1: ex vivo manipulation of immune cells 19. Immunoengineering-2: in vivo manipulation of immune cells; nanotechnology and intratumoral delivery 20.Immunoengineering-3: Emerging areas in engineering immune cell

**Kesavardana Sannula , Sudha Kumari**

**Pre-requisites :** None

**References :** 1.Review papers on specific topics 2.Textbook: Cancer Immunotherapy Principles and Practice Textbook, 2nd Ed. By Lisa H. Butterfield, Howard L. Kaufman, and Francesco M. Marincola. 3. Textbook: Cellular and Molecular Immunology by Pillai, Lichtman, and Abbas

# Molecular Biophysics Unit

## Preface

### MB 201 ( AUG ) 2 : 0

#### Introduction to Biophysical Chemistry

Basic thermodynamics, ligand binding and co-operativity in biological systems, kinetics, diffusion and sedimentation.

**Pre-requisites :** None

**References :** None

### MB 204 ( AUG ) 3 : 0

#### Molecular Spectroscopy and its Biological Applications

Principles and biological applications of UV-Vis, fluorescence, vibrational and circular dichroism spectroscopy. Mass spectrometry and basics of one- and two-dimensional NMR spectroscopy with applications to peptide and protein structure determination.

**Pre-requisites :** None

**References :** None

### MB 206 ( AUG ) 3 : 0

#### Conformational and Structural aspects of biopolymers

Basic ideas on structure and conformation of simple molecules structural features of proteins and nucleic acids, aspects of biomolecular forces. Higher order structural organization of proteins and nucleic acid.

**Pre-requisites :** None

**References :** None

**MB 207 ( JAN ) 2 : 0****DNA - Protein interaction, Regulation of gene expression, Nanobiology**

Basic concepts on structural basis for macromolecular recognition. Concept of charge in macromolecules, specific and non-specific recognition, symmetry in DNA-protein recognition, structural ensembles, cooperativity, specific examples, story of lambda, restriction enzyme recognition, t-RNA synthetase recognition, promoter-RNA polymerase interaction, inducers and repressors, action at a distance. Single molecular paradigm. Methods to follow nanobiology. DNA-protein recognition at the level of single molecules.

**Amit Kumar Baidya**

**Pre-requisites** : None

**References** : None

**MB 208 ( JAN ) 3 : 1****Theoretical and Computational Neuroscience**

1. Peter Dayan and L. F. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, 2005. 2. Christof Koch and Idan Segev (Eds), Methods in Neuronal Modeling: From Ions to Networks, 1998. 3. Eric De Schutter (Ed.), Computational modeling methods for neuroscientists, 2009. 4. Eugene Izhikevich, Dynamical systems in neuroscience: the geometry of excitability and bursting, 2006. 5. Kenji Doya, Shin Ishii, Alexandre Pouget, Rajesh PN Rao (Eds), Bayesian Brain: Probabilistic Approaches to Neural Coding, 2007. 6. Fred Rieke, David Warland, Rob de Ruyter van Steveninck and William Bialek, Spikes: Exploring the Neural Code, 1999. 7. G. Bard Ermentrout and David H. Terman, Mathematical Foundations of Neuroscience, 2010. 8. Fabrizio Gabbiani and Steven James Cox, Mathematics for Neuroscientists, 2010. 9. Gilbert Strang, Introduction to Linear Algebra, Fourth Edition, 2009.

**Rishikesh Narayanan , S P Arun**

**Pre-requisites** : None

**References** : Need for and role of theory and computation in neuroscience, various scales of modelling, ion channel models, single neuron models, network and multi-scale models, models of neural plasticity. Oscillations in neural systems, central pattern generators, single neuron oscillators, network oscillators information representation, neural encoding and decoding, population codes, hierarchy and

**MB 211 ( AUG ) 3 : 1****Advanced Methods in Molecular Simulations**

Advanced Methods in Molecular Simulations

**Pre-requisites** : None

**References** : None



**MB 214 ( AUG ) 3 : 0****Neuronal Physiology and Plasticity**

Neuronal and synaptic physiology: exquisite insights from simple systems; history of technical advances: electrophysiology, imaging and computation; history of conceptual advances: excitable membranes, action potentials, ion channels, oscillations, synapses, behavioral neurophysiology; complexities of the mammalian neuron; dendritic structure; dendritic ion channels; active properties of dendrites; dendritic spikes and backpropagating action potentials; heterogeneity, diversity and degeneracy in the nervous system; hippocampus as an ideal system for assessing learning and memory; synaptic plasticity: short-term plasticity, long-term potentiation and depression; mechanisms underlying synaptic plasticity; intrinsic plasticity; mechanisms underlying intrinsic plasticity; issues in the credit-assignment problem on mechanisms behind learning and memory.

**Pre-requisites :** None

**References :** None

**MB 303 ( JAN ) 3 : 0****Elements of Structural Biology**

Methods for determining the three dimensional structures of biological macromolecules by X-Ray Crystallography. Biophysical methods to understand structures of proteins and protein- DNA complexes.

**Balasubramanian Gopal**

**Pre-requisites :** None

**References :** None

**MB 305 ( JAN ) 3 : 0****Biomolecular NMR Spectroscopy**

Basic theory of NMR spectroscopy. Classical and theoretical descriptions of NMR spectroscopy. Product operator formalism for description of multi-pulse homo-nuclear and hetero-nuclear NMR experiments. Multidimensional NMR spectroscopy, description of basic homo-nuclear 2D NMR experiments useful for structure determination of biological macromolecules. Experimental aspects of homo-nuclear NMR spectroscopy: data acquisition, processing and interpretation of 2D homo-nuclear spectra. Principles of hetero-nuclear NMR spectroscopy. Analysis of 3D and 4D hetero-nuclear isotope edited NMR pulse sequences. Introduction to relaxation and dynamic processes (chemical and conformational processes) that affect NMR experiments.

**Siddhartha P Sarma , Ashok Sekhar**

**Pre-requisites :** None

**References :** None

**MB 222 ( AUG ) 3 : 0****Electron microscopy and 3D image processing for Life sciences**

Objectives and basic working principles of different types of microscopes. Different types of electron microscopies and their applications. Basic introduction of electron microscopy physics and optics. Principles of image formation, Fourier analysis, Contrast Transfer Function and point spread function (electron scattering, phase contrast, electron-specimen interactions, electron diffraction). Characteristics of various advanced sample preparation, imaging, data collection techniques of bio-molecules for negative staining and cryo-electron microscopy. Basic principles and introduction to single particle cryo-EM structure determination, including Random Conical Tilt Pair, Orthogonal Tilt pair, 3D reconstruction using cryo-electron tomography and sub-tomogram averaging. Latest advancements in methodologies for application to biological systems.

**Pre-requisites :** Basic knowledge in matrix, probability theory, basic physics like optics, light, modern physics, wave nature of electrons, electron phy

**References :** Books and references 1. John J. Bozzola and Lonnie D. Russell (1992). Electron Microscopy (Jones & Bartlett Publishers). 2. Ray F. Egerton (2005). Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM (Springer). 3. Elaine Evelyn Hunter and Malcolm Silver (1993). Practical Electron Microscopy: A Beginner's Illustrated Guide (Cambridge University). 4. Ludwig Reimer

**MB 215 ( JAN ) 2 : 0****Neuronal Ion Transport in Health and Disease**

Neuronal membrane properties, membrane ion channels and transporters, voltage and ligand-gated ion channels, store-operated channels, intracellular calcium signaling, designer channel receptors, optogenetics and chemogenetics, ion channel macromolecular complexes in neuronal transmission, genetic and acquired neuronal channelopathies, the plasticity of ion channels and transporters in neurological disorders: epilepsy, migraine, aging, dementia, amyotrophic lateral sclerosis (ALS) etc.

**Giriraj Sahu****Pre-requisites** :

**References** : 1. Ion Channels of Excitable Membranes: Bertil Hille  
 2. Neurobiology of Brain Disorders: M. Zigmond  
 3. Ion Channels and Disease: Frances M. Ashcroft

**MB 333 ( JAN ) 2 : 1****Advanced course for Cryo-EM sample preparation and 3D image**

This course will be a practical oriented course for advanced students who have prior knowledge of cryo-EM sample preparation, image processing or have attended the MB212 course. This course will mainly focus on a combination of theoretical classes as well as practical classes. Theoretical classes will cover details about cryo-EM sample/grid preparation for single particle analysis and cryo-electron tomography. It will also cover theory and principles behind single particle cryo-EM data collection, data collection for cryo-electron tomography, and Micro-ED. Mathematical and statical aspects behind processes within the cryo-EM structure determination pipeline, such as motion correction, CTF determination, 2D classifications, 3D classifications, tomographic reconstruction and sub tomogram averaging. Principles of cryo-EM map validation, model building and map interpretations will also be covered. Practical classes will be associated with theory classes.

1. TEM operation, sample preparation, and imaging at room temperature and cryo.
2. Cryo EM sample preparation/cartridge preparation/grid insertion.
3. Cryo-EM image acquisition(EPU/LatitudeSandLatitudeT)
4. Cryo-EM image evaluation (good image/bad image)
5. Data processing and 3D reconstruction single particle analysis.
6. Data processing and 3D reconstruction cryo electron tomography.
7. Modelbuilding.
8. Validation of map.

**Somnath Dutta****Pre-requisites** :

Either attend the MB222 course or at least has prior basic references

**References** : Books and references

1. John J. Bozzola and Lonnie D. Russell (1992). Electron Microscopy (Jones & Bartlett Publishers).
2. Eugene Hecht, Optics, 5th Edition Pearson, 18-Oct-2016 - Optics

**MB 202 ( AUG ) 3 : 0****Introduction to Macromolecular X-ray Crystallography**

Crystal morphology and symmetry. Symmetry elements and symmetry operations, point groups, lattice space groups. Production and properties of X-rays, diffraction of X-rays by crystals, Laue equations, Bragg's Law, Fourier transformation and structure factor, reciprocal lattice, experimental phasing methods . Basic ideas of structure determination, Patterson and Fourier methods, refinement procedures.

**Pre-requisites :** None

**References :** Buerger M.J., Elementary Crystallography Woolfson M.M., An Introduction to X-ray Crystallography. Stout H. and Jenson L.H., X-ray Structure Determination, Macmillan, 1968. Macromolecular Crystallography- Bernhard Rupp

# Developmental Biology and Genetics

## Preface

**RD 201 ( AUG ) 2 : 0**

### Genetics

Genetics: Mendelian genetics: Formulation of the laws of heredity, Genes and chromosomes, Morgan, the fruit fly, and classical genetics; Linkage: violation of independent assortment; Recombination frequency and map distances; Gene interactions. Population and evolutionary genetics: Allele frequencies in populations – genetic equilibrium, Factors affecting allele frequency; chromosome mutations: variation in number and arrangement, Extranuclear inheritance, Gene mutation, DNA repair and Transposition. Epigenetics: Overview and concepts, Genomic imprinting, Dosage compensation; X-chromosome inactivation, DNA/RNA methylation and histone modifications, Linking RNA to chromatin, Gene regulation by Polycomb and Trithorax group proteins, Genome organization, Transcriptional bursting, Phase separation; Epigenetics & human diseases/Aging, Transgenerational epigenetic inheritance, climate change adaptation, Epigenomics: Chip-Seq, ATAC-Seq, MeDip-Seq, 4C, HiC, FISH, Pyrosequencing etc. Developmental Genetics: Basic concept in Developmental biology, Genetic and epigenetic basis of developmental pathways in mammals; Sexdetermination & Sex chromosome evolution, Stem cell & regeneration, nuclear transfer, Cellular reprogramming

**Pre-requisites** : None

**References** : 1. Concepts of Genetics by Klug, Cummings, Spencer, Palladino and Killian. 12th edition. 2. Epigenetics by David Allis, Marie-Laure Caparros, Thomas Jenuwein and Danny Reinberg, 2nd edition

**RD 204 ( AUG ) 2 : 0**

### Principles of Signal Transduction in Biological Systems

The course will cover principles of signal transduction and aspects of systemic evaluation of signaling pathways. Detailed analysis of receptors, second messengers and ion channels in various organisms; Methods and techniques of studying signal transduction pathways; signal transduction in bacterial systems and in higher mammalian systems; Mammalian signal transduction mechanisms iGPCRs signaling, MAP kinases, protein kinases, second messenger generating systems, ion channels and other signaling cascades; proteins scaffolding and cellular context will be covered. The course will also cover aspects of studying signal transduction events in living systems using modern microscopic techniques and how spatio-temporal dynamics of signaling pathways regulate cellular physiology. Genetic analysis of signalling pathways in model organisms.

**Pre-requisites** : None

**References** : None

**RD 206 ( JAN ) 2 : 0****Molecular Oncology**

Introduction to Cancer Biology: Immortalization, transformation, metastasis; Causes of Cancer: initiators and promoters, carcinogens, tumor viruses, sporadic and familial cancer; Genetic alterations in cancer; Molecular mechanisms of carcinogenesis: cell culture and animal models; Cancer as a tissue: angiogenesis, role of stroma; Cancer spread; metastasis; Cancer stem cells; Resistance to therapy; Cell cycle and cancer; Oncogenes; Tumor suppressor genes; Epigenetic regulation; Transformation by RNA and DNA tumor viruses; Mouse models of cancer; high-throughput techniques in cancer biology, Precision medicine, targeted therapy; Immune system and Cancer, Immune cell help in Cancer, Immunotherapy and Cancer, Experimental systems of immune-oncology, effects of metabolism and microbiome, caveats in immunotherapy using cell biological approaches

**Annapoorni Rangarajan**

**Pre-requisites** : None

**References** : The Biology of Cancer, 2nd Edition (2014) by Robert A. Weinberg

**RD 212 ( AUG ) 0 : 1****Research Methods in experimental Biology**

This course provides students with laboratory experience in basic molecular biology, fluorescence microscopy, electrophoresis, and blotting. The course also contains specific modules on data presentation, statistics and biosafety measures that the student will undertake. Additional content (10-20%) will be designed by the advisors based on the specific nature of work in individual laboratories. The student will be required to prepare a written report on the work done in the laboratory during the semester including appropriate statistics. The purpose of this course is to allow PhD students to gain expertise in research methodologies, experimental approaches, and analytical thinking common to various research laboratories in the MRDG department. Evaluation will be based on the report prepared by the student, and a presentation made to the faculty of the department at the end of the semester

**Pre-requisites** : Admission into the PhD program in MRDG

**References** : To be decided by individual instructor (faculty of MRDG)

**RD 213 ( AUG ) 2 : 0****Stem cells and Mammalian development**

Early embryonic development: Gametogenesis, Germ cells, Fertilization, Early embryogenesis, Implantation, Gastrulation, Stem cell potency, Embryonic stem cells, Epiblast stem cells, Trophoblast stem cells, Stem cell differentiation, In vitro fertilization (IVF), Induced pluripotent stem cells and regeneration, genetic and epigenetic regulation of developmental pathways, X chromosome inactivation, genomic imprinting. Adult stem cells: Hematopoietic stem cells: Self-renewal, Differentiation, HSC enrichment, Transplantation, leukemia stem cells. Mammary gland development: Ductal morphogenesis, Alveologenesis, Involution and Regeneration, Hormones and Signaling pathways, Mammary stem cells, Breast cancer, Breast cancer stem cells

**Pre-requisites :** None

**References :** References:1) Mammalian Development: Networks, Switches, and Morphogenetic Processes Edited by Patrick P.L. Tam, Children's Medical Research Institute; W. James Nelson, Stanford University; Janet Rossant, The Hospital for Sick Children. ISBN 978-1-936113-24-8 2) The Science of Stem Cells. Author(s): Jonathan M. W. Slack. <https://onlinelibrary.wiley.com/doi/>

# Life Sciences

## Preface

The MSc Life Sciences program is comprised of comprehensive foundational course work combined with a vast selection of electives, leading towards a specialisation in one of five fields of Biology. Students also have labs designed to introduce them to tools and techniques, as well a lecture series and workshops for broader skill development. In the final year, students engage in independent research projects that result in an MSc thesis.

## LS 102 ( AUG ) 1 : 0

### Opportunities and Extensions in Life Sciences - Pa

This course is designed to expose students enrolled in the MSc in Life Sciences programme to opportunities and extensions in the field of biological sciences. The course will be conducted as a series of lectures and workshops by invited guests on topics, such as, IP/ patent laws; Humanities, including science history; Innovation and Entrepreneurship; Artificial intelligence and data analytics; Science Policy, governance and management; opportunities and pitfalls in BioMedical Research; Sci-Art in the alternative medium; Science communication and journalism; including Ethical use of animals & their care; Biosafety and practice.

The course will span two semesters and each month will be devoted to one of the eight numbered topics above. Invited guests will conduct 2-3 lectures / workshop a month (1 hour each) and students will have an assignment or a presentation to conduct for each of the topics that will involve independent research. For example, for the Science Communication session, students will interact with science journalists and will learn how to write a science news article. For the Innovation and Entrepreneurship session, students will meet a biomedical entrepreneur and will be asked to present a business model for a hypothetical biomedical product. Assignments will therefore range from written reports to presentations in class during the month devoted to the session.

**Pre-requisites :** None

**References :** will be provided



**LS 103 ( JAN ) 1 : 0****Opportunities and Extensions in Life Sciences - Part 2**

This course is designed to expose students enrolled in the MSc in Life Sciences programme to opportunities and extensions in the field of biological sciences. The course will be conducted as a series of lectures and workshops by invited guests on topics, such as, IP/ patent laws; Humanities, including science history; Innovation and Entrepreneurship; Artificial intelligence and data analytics; Science Policy, governance and management; opportunities and pitfalls in BioMedical Research; Sci-Art in the alternative medium; Science communication and journalism; including Ethical use of animals & their care; Biosafety and practice.

The course will span two semesters and each month will be devoted to one of the eight numbered topics above. Invited guests will conduct 2-3 lectures / workshop a month (1 hour each) and students will have an assignment or a presentation to conduct for each of the topics that will involve independent research. For example, for the Science Communication session, students will interact with science journalists and will learn how to write a science news article. For the Innovation and Entrepreneurship session, students will meet a biomedical entrepreneur and will be asked to present a business model for a hypothetical biomedical product. Assignments will therefore range from written reports to presentations in class during the month devoted to the session.

**Maria Thaker****Pre-requisites** : None**References** : will be provided**LS 209 ( AUG ) 0 : 2****Laboratory course in Molecular Techniques**

bacterial culturing, vectors, DNA isolation, transformation, cloning, expression and purification of proteins; characterization by western blotting/ ELISA; cell culture, transfection, stable line generation, gene expression analysis by RT-PCR; fluorescence microscopy, immunofluorescence; viability assessment; Alamar blue / MTT assay; flow cytometry and cell sorting. Biophysical techniques - Concept of absorption and spectroscopy. Concept of protein/nucleic acid folding (CD and Fluorescence); Separation of protein and identification (Chromatography and Mass spectrometry); Bioinformatics.

**Pre-requisites** : None**References** : Wilson And Walker's Principles And Techniques Of Biochemistry And Molecular Biology

**LS 208 ( JAN ) 2 : 0****Physiology and Neurobiology**

Physiology: General concepts in histology, embryology and physiology.  
 Cardiovascular physiology: Evolution of circulatory system, heart and vascular system and related diseases. Pulmonary Physiology: Evolution of respiratory mechanisms, lungs, and related diseases. Renal physiology: Evolution of renal system, kidneys, and related diseases. Gastrointestinal physiology: digestion, absorption, fluid balance kidney liver axis. Endocrinology: Hypothalamus, pituitary, thyroid gland, adrenal gland, pancreas. Functions and diseases.

**Neurobiology:**

A brief history of neuroscience and the neuronal doctrine; cell biology of a neuron; biochemical basis of resting membrane potential and action potential; neuronal connectivity, synaptic transmission and plasticity; sensory and motor systems; learning and memory; cognition; brain disorders.

**Ramray Bhat , Ashesh Dhawale**

**Pre-requisites :** None

**References**

1. Principles of Neural Science by Kandel et al (6th Edn)
- 2.

**LS 205 ( JAN ) 3 : 0****Ecology and Evolution**

This course will consist of lectures, readings and in-class discussion sessions led by students. It will have two modules, one for ecology (Sumanta Bagchi) and another for evolution (Praveen Karanth). It will have two 1.5-hr long sessions every week. In lectures, the instructor(s) will cover topics related to history of evolutionary thought, levels and types of selection, systematics, phylogenetics, ecology, biodiversity, ecological interactions, functioning of ecosystems and various threats faced by natural and human-modified ecosystems under global change. Through assigned readings, students will develop a broad understanding of how ecology and evolution provide a basis to understand life on earth. Student learning will be evaluated with a mid-term and an end-semester exam, each worth 50% of total marks. Course topics in Evolution: History of evolutionary theory; Why study evolution; Classification, Diversity of life; Phylogenetics; Levels of selection; Evolution of sex, why two sexes. Anisogamy and mating systems; Types of selection: Sexual selection, Kin selection, frequency depended selection, R vs. K selection; Evolutionary arms race, coevolution. Topics for Ecology: Earth as a biogeochemical system; Geographical variation in distribution of life on earth; Population dynamics and species interactions; Biodiversity: distribution, conservation, and restoration; Ecosystem functions and services; Global change: threats to biodiversity and their mitigation

**Praveen Karanth K , Saskya Daly Van Nouhuys**

**Pre-requisites :** None

- References :**
- Begon, M. JL Harper, and CR. Townsend (2020) Ecology: from individuals to ecosystems. John Wiley & Sons, (or other available ed
  - Evolutionary biology Douglas J. Futuyma (1998) 3rd ed. Sinauer Associates Inc, Weekly assigned readings from instructors

**LS 210 ( JAN ) 0 : 2****Laboratory course in Genetics and Ecology**

Genetics - Basic genetics with *Escherichia coli*, *Saccharomyces cerevisiae*, *Caenorhabditis elegans*, *Drosophila melanogaster*, and *Arabidopsis thaliana* and overview of databases that can be used to understand mutants of each organism. Experiments to understand mating type determination using *S. cerevisiae*. Experiments to demonstrate different patterns of inheritance: genetic crosses and analysis of cross progeny using *D. melanogaster* and *C. elegans*. Studying visual phenotypes and behavioural phenotypes in *D. melanogaster* and *C. elegans*. Learning PCR based genotyping of *C. elegans* mutants. Observing mutants of *A. thaliana*.

Ecology - Key concepts in Ecology, Evolution and Behaviour through field observations, manipulative experiments, and computer simulations. Through field measurements: diversity and distributions of organisms, the concept of niche and trophic ecology. Through manipulative experiments with live animals: competition and sexual selection. Key concepts of material transfer and energy flow through ecosystems. Field measurements of net ecosystem exchange via primary productivity and respiration. Carbon sequestration in biomass and soils. The role of microbes in the Carbon cycle, and Nitrogen cycle. Laboratory experiments to estimate parameters that control rates of photosynthesis, respiration, N-fixation. Emphasis will be on study design and the connection of process to pattern.

**Utpal Nath , Maria Thaker , Kavita Babu , Saravanan Palani , Saskya Daly Van Nouhuys**

**Pre-requisites** : None

**References** : all materials will be provided

**LS 204 ( AUG ) 3 : 0****Biochemistry and Biophysics**

Biophysics - Atoms, molecules, and chemical bonds. Covalent and non-covalent interactions (vdW, H-bond, electrostatic interaction, hydrophobic interaction, p-p, cat-p interaction); Composition of biomolecules (proteins, nucleic acids, carbohydrate, lipids) and their conformational features (Proteins: Rama plot, secondary structure, domains, folds. Nucleic acids: A, B, Z DNA, t-RNA, micro RNA); Folding and stability of proteins and nucleic acids; Principles of biophysical chemistry (concept of acid-base/pH, reaction kinetics and thermodynamics); Application of Spectroscopic techniques to study biomolecular interaction (UV-Vis spectroscopy, Fluorescence spectroscopy, Fluorescence anisotropy, Infrared spectroscopy, Raman spectroscopy, Circular Dichroism spectroscopy, Surface plasmon spectroscopy, and its application to study biomolecular interaction; Methods to study Proteins - Basic techniques like mass spectrometry, X-ray crystallography, NMR, and cryo-EM. Biochemistry - The chemical components of a cell, Structure and function of biological molecules, Protein Structure Function and Dynamics, Metabolic pathways and metabolism as integrated regulated systems, Cell membrane, cellular transport, Enzyme kinetics, complex cellular processes. Bioenergetics, glycolysis, oxidative phosphorylation, coupled reactions, biological energy transducers. Principles of catalysis, enzymes and enzyme kinetics. Metabolism of carbohydrates, lipids, amino acids nucleotides and vitamins.

**Pre-requisites** : None

**References** : The Molecules of Life: Physical and Chemical Principles by John Kuriyan, Boyana Konforti, David Wemmer Biochemistry by Jeremy M. Berg, Lubert Stryer, John Tymoczko, Gregory Gatto Lehninger Principles of Biochemistry by David L. Nelson, Michael M. Cox

**LS 206 ( JAN ) 3 : 0****Developmental Biology and Genetics**

Developmental Biology: Basic concepts in developmental biology; evolution and development; body axis specification in invertebrates; early vertebrate, invertebrate and plant development; gastrulation and neurulation; organogenesis; cell type determination; creation of specific organs (organogenesis); molecular mechanisms underlying morphogenetic movements, differentiation, and interactions during development; fundamental differences between animal and plant development; embryogenesis in plant – classical and modern views; axis specification and pattern formation in angiosperm embryos; organization and homeostasis in the shoot and root meristems; patterning in vegetative and flower meristems; growth and tissue differentiation in plants; stem cells and regeneration; evolution of developmental mechanisms.

Genetics: Mendelian genetics: Formulation of the laws of heredity, Genes and chromosomes, Morgan, the fruit fly, and classical genetics; Linkage: violation of independent assortment; Recombination frequency and map distances; Gene interactions. Population and evolutionary genetics: Allele frequencies in populations – genetic equilibrium, Factors affecting allele frequency. Developmental Genetics: Genetic dissection of developmental pathways (*Drosophila*, mouse, *C. elegans*); Sex determination & Sex chromosomes, chromosome mutations: variation in number and arrangement, Extranuclear inheritance, Gene mutation, Stem cell & regeneration, nuclear transfer. Epigenetics: Overview and concepts, Genomic imprinting, Dosage compensation; X-chromosome inactivation, DNA methylation and histone modifications, Linking RNA to chromatin, Gene regulation by Polycomb and Trithorax group proteins, Genome organization, Transcriptional bursting and allelic expression, Single cell gene expression dynamics, Phase separation; Epigenetics & human diseases/Aging.

Plant development: Plant responses to light, introduction of different photoreceptors, molecular insights of light perception, signaling role of different light in plant development; molecular basis of plant hormone perception and their signaling role in development and physiology; meristem homeostasis, control of flowering; plant responses to pathogen infection, role of lipid in plant immunity; molecular plant nutrition, recent advances in plant abiotic stress response.

**Kavita Babu , Debabrata Laha**

**Pre-requisites :** None

**References :** • Genetics: From Genes to Genomes; Leland Hartwell, Michael Goldberg, Janice Fischer and Leroy Hood. ISBN-13: 9781259700903  
• Epigenetics, Edited by C. David Allis, Marie-Laure Caparros, Thomas Jenuwein and Danny Reinberg. ISBN: 9781936113590  
• Plant Physiology and Development, Sixth Edition; Lincoln Taiz, Eduardo Zeiger, Ian M. Møller, and Angus Murphy. ISBN: 9781605357454

**LS 203 ( AUG ) 3 : 0****Microbiology, Virology and Immunology**

Microbiology - Microbial taxonomy; Microbial diversity, evolution and genomics; Horizontal gene transfer, Microbes as model of development, and as bioreactors and sensors; bioremediation; structure-function of bacterial cell; Bacterial physiology and nutrition; Phages, Plasmids and Transposons; bacterial pathogenesis; Antibiotics: mode of action and mechanisms of resistance; Quorum sensing and biofilms; Host-pathogen interactions and immune surveillance; Diagnostics and vaccine development; Origin of cellular life; Host-associated and free-living microbes; Physiological heterogeneity in bacterial populations; Bacterial predation, and survival strategies. Virology – Introduction to viruses, life cycles of temperate and lytic bacteriophages; Fundamental concepts in virology, biology and pathogenesis of major viral pathogens; Introduction to applied virology. Immunology - Cells and organs of the Immune system, Innate Immunity & Inflammation, B cell Development, Structure-function

**Pre-requisites :** None

**References :** Stanier, R.V., Adelberg E.A and Ingraham J.L., GENERAL MICROBIOLOGY, Macmillan Press, Fourth edition Atlas R.M., MICROBIOLOGY: FUNDAMENTALS AND APPLICATIONS, Macmillan Press Second Edition Goldsby, R. A., Kindt T. J., Osborne B. A., Kuby J., IMMUNOLOGY, W. H. Freeman & Company, New York Travers, J., Shlomchik, W., IMMUNOBIOLOGY, Garland Science

**LS 299 ( AUG ) 0 : 28****Dissertation project**

Dissertation project

**Maria Thaker****Pre-requisites** : None**References** : None**LS 207 ( JAN ) 3 : 0****Fundamentals of Molecular Biology**

Genes and gene-enzyme relation; DNA and heredity; models of DNA structure; DNA structure and topology; Restriction modifications systems; flow of genetic information, Central Dogma of Molecular Biology, Elucidation of genetic code; Translation: Eukaryotic translation, modes of Translational control. The journey of Operons by Jacob and Monod a) Organization of Gene Regulatory Elements in Prokaryotes b) The players of gene regulation: Inducers, Repressors and Co-repressors; Multiple Mechanisms of gene regulations in bacteria; Introduction to Eukaryotic Gene Transcription; Enigma of Epigenetics and Gene regulations a) Orchestration of Gene regulation through Chromatin remodeling b) Learning the language of Histones c) Conversations between DNA, RNA and chromatin; Finding Treasures in the junk: Role of non-coding RNAs in Gene regulation; The Genome Timeline: Structural, Functional and Comparative Genomics

**Tanweer Hussain , Rajakumari Sonaimuthu , Meetal Singh****Pre-requisites** : None

**References** : 1. Watson JD, Baker TA, Bell SP, Gann A and Levine M, Molecular Biology of the Gene, Benjamin-Cummings Publishing Company, 7th edition, 2013  
 2. Alberts B, Johnson A, Lewis J, Raff M, Roberts K and Walter P, Molecular Biology of the Cell, Garland Science 6th Edition

# Division of Chemical Sciences

## Preface

The Division of Chemical Sciences comprises of the Department of Inorganic and Physical Chemistry (IPC), Materials Research Centre (MRC), Department of Organic Chemistry (OC) and Solid State and Structural Chemistry Unit (SSCU). Students with a basic/advanced degree in Chemistry, Physics, Biology, or many branches of engineering are eligible for admission to the doctoral program. In addition, the division also admits B.Sc. graduates to the Integrated PhD program. Since 2011, the division is also actively engaged in the four-year Bachelor of Science (Research) program and has introduced several courses at the undergraduate level.

The courses offered by various departments carry a two-letter departmental code that is followed by a three digit number; of which, the first digit refers to the course level. In addition, courses offered to the Integrated PhD students are listed separately with another code. The courses offered by the different departments have been grouped as follows:

CD	Integrated Ph D
IP	Inorganic and Physical Chemistry
MR	Materials Research Centre
OC	Organic Chemistry
SS	Solid State and Structural Chemistry

Each department/centre/unit offers courses on basic as well as specialized topics designed to provide students with a sound foundation in both theoretical and experimental aspects. There are specified requirements for completing the research training programme (RTP) for students registering under various streams at the Institute. For details concerning these requirements, students are advised to approach the Chair of the Department/Centre/Unit.

The Department of Inorganic and Physical Chemistry provides training in several contemporary areas of theoretical and experimental research, covering all aspects of modern Inorganic and Physical Chemistry. The programme of instruction consists of class lectures, laboratory work and student seminars.

The Materials Research Centre provides students opportunity to learn and train on several modern sophisticated instrumental facilities for the materials preparation, device fabrication and materials and device characterization. The Centre offers courses in various aspects of theoretical and experimental Material Science and on modern materials characterization techniques.

The Department of Organic Chemistry offers courses at both the fundamental and advanced levels in Organic Chemistry, in addition to courses on advanced special topics. The students also undergo training in advanced laboratory methods and are expected to give seminars on contemporary research topics.

The Solid State and Structural Chemistry unit offers several courses in frontier areas of Solid State Chemistry and Surface Sciences, besides basic and advanced courses in Chemical Physics; students of the department will have an opportunity to work in all major topics in solid state chemistry and physics.

Prof. G. Mugesh

Dean

Division of Chemical Sciences

**CD 221 ( JAN ) 3 : 0****Physical Chemistry II: Statistical Mechanics**

Thermodynamics: Basic Ideas and postulates (2), equilibrium conditions (2), thermodynamic potentials and extremum conditions (2), maximum work theorem (1), stability conditions (2), phase transitions (2); Postulates of statistical mechanics (1): Phase space, ensembles, ergodic hypothesis; Ensembles (3): Canonical ensemble, grand canonical ensemble, Isothermal-Isobaric ensemble and Fluctuations; Fermi-Dirac and Bose-Einstein Statistics (2): Derivations in the grand-canonical ensemble and behaviour in the classical limit; Ideal Monatomic and Diatomic Gases (5): Translational, vibrational and rotational partition functions, rigid rotor-harmonic oscillator approximation, thermodynamic functions; Black Body Radiation (2): Stefan-Boltzmann law and Wien's-displacement law; Crystals (2): Einstein and Debye models; Electron Conduction in Metals (2): Contribution to heat capacity at low temperatures; Non-Ideal Gases (3): Virial equation of state, and Virial coefficients in the classical limit; Classical Liquids (6): Distribution functions, radial distribution function and relation to thermodynamic quantities, Ornstein-Zernike equation, PY and HNC closure; Debye-Hueckel Theory (3): Theory for ionic solutions; Ising Model (3): Solutions in one-dimension for different boundary conditions and mean field theory.

**Sai G Ramesh**

**Pre-requisites :** None

**References :** (1) E. Fermi, Thermodynamics; (2) H .B. Callen, Thermodynamics and Introduction to Thermostatistics; (3) D. A. McQuarrie, Statistical Mechanics; (4) D. Chandler, Introduction to Modern Statistical Mechanics; (5) B. Bagchi, Statistical Mechanics for Chemistry and Material Science

**CD 222 ( JAN ) 3 : 0****Material Chemistry**

Structure of solids, symmetry concepts, crystal structure. Preparative methods and characterization of inorganic solids. Crystal defects and non- stoichiometry. Interpretation of phase diagrams, phase transitions. Kinetics of phase transformations, structure property correlations in ceramics, glasses, polymers. Composites and nano-materials. Basics of magnetic, electrical, optical, thermal and mechanical properties of solids.

**Prabeer Barpanda**

**Pre-requisites :** None

**References :** A.R. West, Solid State Chemistry and its Applications John Wiley and Sons, 1984.,J.F. Shackelford, Introduction to Materials Science for Engineers,MacMillan, 1988.,.....

**CD 223 ( JAN ) 3 : 0****Organic synthesis**

Principles of selectivity and reactivity in the use of reagents for oxidation, reduction and bond forming reaction. Planning a synthesis, antithetic analysis, synthons, linear and convergent synthesis.

**Durga Prasada Rao Hari,Vignesh Palani**

**Pre-requisites :** None

**References :** Warren S., Designing Organic Synthesis, 1978,Carruthers W. S.,Some Modern Methods of Organic Synthesis 3rd edition, Cambridge University Press, 1986., Carery, F. A. and Sundberg, R. J., Advanced organic chemistry, Part B, 2nd ed., Plenum, 1984,House, Modern Synthetic Reactions, 1972.,Fuhrhop J. and Penzilin G., Organic Synthesis - Concepts, Methods, Starting Materials, Verlag Chemie 1983.

**CD 224 ( JAN ) 2 : 1****Computers in Chemistry**

Basic Coding: Writing simple expressions, conditionals, loops, arrays, functions, file I/O, modular programming; Basic plotting, data fitting (linear, polynomial regression), Confidence intervals, Numerical Methods - Integration, Differentiation, Root finding, Minimization in 1D, ODEs, Basic Statistical Analysis with Probability Distributions (Gaussian, Uniform, Exponential), Basic use of electronic structure packages such as Gaussian.

**Vivek Tiwari**

**Pre-requisites** : None

**References** : Any accessible book on numerical methods.,.....

**CD 225 ( JAN ) 0 : 4****Physical and Analytical Chemistry Laboratory**

Langmuir adsorption, chemical analysis by potentiometry, conductometry and iodometry methods, pH-metry, cyclic voltammetry, flame photometry, electronic states by uv-visible spectroscopy, IR spectroscopy, solid state chemistry – synthesis of solids and chemical analysis, X-ray diffraction.

**Satish Amrutrao Patil**

**Pre-requisites** : None

**References** : (a) Vogel, A.I, Vogel's text book of quantitative chemical analysis Longman 1989., (b) David R Shoemaker, Carl W. Garland and Nibler J.W., Experiments in Physical Chemistry, McGraw-Hill International Edition, 1989., (c) Relevant literature from Chemical Education (ACS Publications) and other pedagogic Chemistry Journals

**CD 241 ( JAN ) 0 : 14****Research Project****Akkattu T Biju**

**Pre-requisites** : None

**References** : None



# Inorganic and Physical Chemistry

## Preface

### IP 203 ( AUG ) 3 : 0

#### Group Theory and Molecular Spectroscopy

Group theory: Symmetry elements, point groups, representation theory, great orthogonality theorem, SALCs. Time-dependent perturbation theory, light-matter interaction. H-like atoms, angular momenta and selection rules of transitions, multi-electron atoms, term symbols, spin-orbit coupling, Zeeman and linear Stark effects. Rotations and vibrations of diatoms, anharmonic effects, selection rules, electronic structure. Rotations and vibrations of polyatomic molecules, various tops and their properties, normal modes of vibration, selection rules, electronic states and transitions

**Pre-requisites** : None

**References** : (1) I. N. Levine, Molecular Spectroscopy. (2) W. S. Struve, Fundamentals of molecular spectroscopy (3) P. F. Bernath, Spectra of atoms and molecules (2nd Ed.). (4) F. A. Cotton, Chemical Applications of Group Theory

### IP 311 ( AUG ) 3 : 0

#### Bio and Medicinal Inorganic Chemistry

Principles of biochemistry and molecular biology, role of metal ions in biology, principles of coordination chemistry, amino acids and other bioligands, proteins – secondary and tertiary structure, nucleic acids, iron proteins, iron transport, role of zinc in biology – zinc enzymes, biological importance of nickel, copper proteins, redox reactions involving manganese, biological roles of vanadium, cobalt and molybdenum, basic concepts in drug design, metals and health -metal based drugs and mechanism of their action, metalloproteins as drug targets.

**Pre-requisites** : None

**References** : S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry (University Science Books, California)

**IP 312 ( AUG ) 3 : 0****Advanced Organometallic Chemistry**

Structure and bonding in organometallic compounds; reaction types; classes of organometallic compounds: Main-group, transition metal, lanthanide and actinide compounds. Isolobal analogies, metal-metal multiple bonding in organometallic compounds and metal clusters. Organometallic catalysis: hydrogenation, C-C coupling, C-S coupling, hydroboration and hydrosilylation, C-H activation

**Pre-requisites** : None

**References** : Ch. Elschenbroich, Organometallics (3rd edition, Wiley-VCH, Weinheim)

**IP 322 ( JAN ) 3 : 0****Polymer Chemistry**

Concepts and terminology. Principles of polymerization – chain versus step growth process. Kinetics of chain polymerization process, estimation of various rate constants. Determination of molecular weight of polymers and their distribution. Solution properties and chain dimension. Characteristics and mechanisms of various chain polymerizations – radical, cationic, anionic, Ziegler-Natta and ring opening metathesis polymerizations. Living polymerizations – criteria for livingness, newer methods for living polymerizations – GTP, ATRP and TEMPO-mediated radical polymerizations. Copolymerization – random, alternating and block copolymers and kinetic schemes for analysis of copolymerization. Micro-structural analysis of polymers by NMR – estimation of regio- and stereo-regularity in polymers, sequence distribution in copolymers etc., and mechanisms for stereo-regulation.

**Ramakrishnan S**

**Pre-requisites** : None

**References** : (1) Flory P.J., Principles of Polymer Chemistry. (2) Odian G., Principles of Polymerization. (3) Paul C Hiemenz and Timothy P Lodge, Polymer Chemistry

**IP 323 ( JAN ) 3 : 0****Topics in Basic and Applied Electrochemistry**

Electrode kinetics and electrochemical techniques: polarizable and non-polarizable interfaces; current-potential relationship; methods of measurement of kinetic parameters; over potential; symmetry factor and transfer coefficient; mechanistic criteria; diffusion, activation phenomena. Steady state and potential step techniques; polarography; cyclic voltammetry; chrono- methods; convective diffusion systems: rotating disc and ring disc electrodes; microelectrodes; AC impedance techniques - concepts and applications. Applied topics: fundamentals of batteries: primary, secondary, reserve batteries; solid state and molten solvent-batteries; fuel cells. Photo-electrochemical solar cells and conversion of solar energy. Corrosion – fundamentals and applications.

**Sampath S , Chinmoy Ranjan**

**Pre-requisites** : None

**References** : (1) A. J. Bard and L. R. Faulkner, Electrochemical methods: Principles and Applications (Wiley 1990). (2) R. Greef, R. Peat, L. M. Peter, D. Pletcher and J. Robinson, Instrumental Methods in Electrochemistry (Ellis Harwood Ltd., 1985). (3) E. Gileadi, Electrode Kinetics for Chemists, Chemical Engineers and Material Scientists (VCH 1993). (4) C.A. Vincent, Modern Batteries (Edward Arnold, UK

### Astrochemistry

1. Measuring the Universe: Spectroscopy, Doppler shift and lineshape, Hubble constant and the age of Universe (5 Lectures). 2. Big bang to first atom, hydrogen and helium nuclei (3 Lectures). 3. Heavier elements and stars, classes of stars, stellar chemistry, stellar spectra (4 lectures). 4. Interstellar chemistry: Molecules in Space, interstellar medium, chemistry in interstellar space, gas phase reactions, surface reactions (10 Lectures). 5. Meteorite and comet chemistry, meteorite classification, mineralogy, chemical composition of comets (4 Lectures). 6. Planetary Chemistry, formation of earth, radiative heating, planetary atmosphere, atmospheric photochemistry, extrasolar planets (6 Lectures). 7. Laboratory based astrochemistry: a) Experiments, spectroscopy, molecular beams, microwave spectroscopy, cavity enhanced spectroscopy, kinetics and dynamics, b) Theory, chemical modelling, kinetic and dynamical data (10 Lectures).

### Arunan E

#### Pre-requisites

Available to PhD students (1st year onwards), Int PhD students (2nd year onwards), UG students (4th year onwards).

**References** : 1. Claire Vallance, Astrochemistry: From big bang to the present day (World Scientific, 2017). 2. Andrew M. Shaw, Astrochemistry: From Astronomy to Astrobiology (Wiley, 2006). 3. Sun Kwok, Organic matter in the Universe (Wiley-VCH, 2012).

# Materials Research Centre

## Preface

**MR 222 ( JAN ) 3 : 0**

### Chemistry of Materials

Structure of solids, symmetry concepts, crystal structure. Preparative methods and characterization of inorganic solids. Crystal defects and non-stoichiometry. Interpretation of phase diagrams, phase transitions. Kinetics of phase transformations, structure property correlations in ceramics, glasses, polymers. Composites and nano materials. Basics of magnetic, electrical, optical, thermal and mechanical properties of solids.

**Prabeer Barpanda**

**Pre-requisites** : None

**References** : J.F. Shackelford, Introduction to Materials Science for Engineers

**MR 306 ( AUG ) 3 : 0**

### Electron Microscopy in Materials Characterization

Resolution and Rayleigh criterion, electron optics, electron guns and lenses, probe diameter and probe current, electron-specimen interactions, interaction volume. Principles of scanning electron microscopy, imaging modes and detectors. Transmission electron microscopy – elastic and inelastic scattering, modes of operation, diffraction theory, Bragg's law and Laue conditions. Reciprocal space and Ewald sphere construction, Kikuchi lines, convergent beam electron diffraction, diffraction contrast imaging – Howie-Whelan dynamical theory, Thickness and bend contours, imaging defects and strain fields, weak-beam dark field microscopy, phase contrast imaging – Moire fringes, Fresnel fringes and high-resolution imaging.

**Pre-requisites** : None

**References** : Goldstein J.I., Romig A.D. Newbury D.E., Goldstein J.I., Romig A.D. Newbury D.E., Goldstein J.I.

**MR 308 ( JAN ) 2 : 1**

### Computational Modeling of Materials

Introduction to computational modeling of materials, description of atomic interaction, tight binding approximation, Hartree-Fock, molecular orbital method, density functional theory. Applications of these methods in modeling of mechanical, electronic, magnetic, optical, and dielectric properties of materials, design principles of novel materials

**Abhishek Kumar Singh**

**Pre-requisites** : None

**References** : Richard Martin., Electronic Structure: Basic Theory and Practical Methods Cambridge, Richard Martin., Electronic Structure: Basic Theory and Practical Methods Cambridge, Richard Martin.

**MR 309 ( AUG ) 3 : 0****Introduction to Supramolecular Chemistry**

Course description: Supramolecular chemistry is “chemistry beyond the molecule”. It is an interdisciplinary field that covers the physical, chemical and biological properties of complex chemical species held together mainly by non-covalent interactions. This course provides an introduction to the field, and discusses the intermolecular forces that dictate the formation of supermolecules and supramolecular assemblies and their properties. In addition, current trends are discussed using recent publications in this area. Course outline: This course is designed to be modular and includes the following topics: Molecular recognition, Host-Guest Chemistry; Receptors, Coordination and the “Lock and Key” Analogy; Chelate, Conformational and Macrocyclic Effects; Pre- organisation and Complementarity; Thermodynamic and Kinetic Selectivity; Selectivity and Solution Behaviour of Crown Ethers, Cryptands, Spherands; Complexation of Organic Cations; Biological anion receptors; Anti- crowns.

**Pre-requisites** : None

**References** : Supramolecular Chemistry. J. W. Steed, J. L. Atwood, John Wiley and Sons, 2000. • Supramolecular Chemistry. Concepts and Perspectives. J. - M. Lehn. VCH, 1995. • Principles and Methods in Supramolecular Chemistry. H.-J. Schneider, A. Yatsimirsky, John Wiley and Sons.

**MR 310 ( AUG ) 3 : 0****Light emitting materials and devices**

Introduction to organic light-emitting diodes (OLEDs), PLEDs, Perovskite-LEDs and their application, color science, basic working principles of light emitting devices, device fabrication and characterization, practical demonstration of device fabrication. Design, synthesis and characterization of hole injection/transporting, electron injection/transporting and host materials. Types of emitting materials: fluorescence, phosphorescence, TTA, TADF, singlet fission, perovskite, and carbon dots and their application in light emitting devices. Dendrimers and dendronized polymers for light emitting devices. Practical demonstration of device fabrication in the laboratory.

**Pre-requisites** : None

**References** : 1. OLED Fundamentals (Materials, Devices, and Processing of Organic Light-Emitting Diode) by Daniel J. Gaspar and Evgueni Polikarpo 2. Organic light- emitting diodes (OLEDs) by Alastair Buckley 3. Color Vision and Colorimetry Theory and Applications by Daniel Malacara 4. Dendrimers and Other Dendritic Polymers (by Jean M. J. Fréchet and Donald A. Tomalia)

**MR 311 ( AUG ) 3 : 0****Additive Manufacturing: Concepts, process science**

The course content involves concepts on Additive Manufacturing: Concept and importance, Fundamentals of engineering design, Basic elements, STL file format, knowledge on Computer softwares, Structure and properties of engineering materials, Overview of Important AM processes, High energy laser/electron beam, UV/laser-stereolithography, concepts of 3D inkjet printing, Process Science of selected AM process, Binderjet 3D printing, 3D extrusion printing, Laser-powder bed fusion, Directed energy deposition, Scientific case study, Binderjet 3D printing of Ti6Al4V, Binderjet 3D printing of ZrO<sub>2</sub>, Binderjet 3D printing of (Sr, Mg)-phosphate, 3D extrusion printing of Gelatin methacrylate-based hybrid biomaterials inks, DED of stainless steel, L-PBF of Ti6Al4V, Clinical applications of 3D printing, Regenerative engineering, Translational case study: Cranioplasty surgery, Emerging opportunities, AI/ML approaches in 3D printing, Regression analysis of 3D printing process prediction, Classification analysis of AM-part quality, AM under microgravity conditions, Current challenges and future perspectives Topics include: additive processing of polymers, metals, and ceramics; computational design for AM; 3D metrology; material properties; cost/value analysis; and industrialization. Students will gain hands-on experience using state-of-the-art AM equipment to investigate process capabilities, and will learn advanced design software to support labs and assignments. Students will propose project topics such as: design, prototyping and business case analysis of a new AM-enabled product; a new hardware module to improve a machine/process; or an experimental study of process/material performance.

**Pre-requisites** : Additive manufacturing, defined as layer-by-layer deposition of materials as per design of an object, has been playing significant roles across a spectrum of important applications sectors, from aerospace, transportation, energy to healthcare. Against this backdrop and built on the course instructor's decade-long research experience, this course will present the fundamental concepts of

**References** : Reference books: Ian Gibson, David Rosen, Brent Stucker, Mahyar Khorasani; Additive Manufacturing Technologies; Third Edition, Springer, 2021.(<https://link.springer.com/content/pdf/10.1007/978-3-030-56127-7.pdf>) Olaf Diegel, Axel Nordin, Damien Motte; A Practical Guide to Design for Additive Manufacturing; Springer, 2020(<https://link.springer.com/content/pdf/10.1007/978-981-13-8281-9.pdf>)

# Organic Chemistry

## Preface

**OC 203 ( AUG ) 3 : 0**

**Organic Chemistry I**

**Pre-requisites :** None

**References :** None

**OC 231 ( AUG ) 3 : 0**

### **Chemistry of Proteins and Peptides**

Amino acids, peptide synthesis, geometry and oligopeptide conformations. Non-covalent interactions, dynamism in peptides, molecular recognition, Ramachandran plot, Foldamers. Protein architecture, protein-protein interactions, protein stability. Peptide conformational analysis. Protein solubility, pKa, protein aggregates, isofolding, unfolded proteins, membrane proteins. Peptidomimetics, isosteres, folding peptides. Enzymes: mechanisms of selected enzymes, enzyme inhibitors. Important developments in current literature.

**Pre-requisites :** None

**References :** Voet D and Voet J.G. Biochemistry 2nd Edition John Wiley Cysons NY, 1995., Stryer L. Biochemistry 4th Edition, WH. Freeman & Co., N

**OC 301 ( AUG ) 3 : 0****Organic Synthesis II**

Organic synthesis and total synthesis of complex natural products: Advances in C-C bond forming reactions; Olefination reactions; Olefin metathesis including alkyne metathesis; Synthesis of alkynes; Asymmetric addition of Grignard reagents, organozinc and lithium reagents to carbonyl compounds; Directed lithiation, chiral lithium reagents; alkylation of carbonyl compounds including asymmetric alkylation. Addition of organometallic reagents to imines, Asymmetric acetate/ propionate aldol reaction. Asymmetric allylation of carbonyl compounds; Ring forming reactions, Baldwin rules; cyclopentannulations with specific application to triquinanes. Advances in carbocation rearrangements. Inverse electron demand Diels Alder reaction/Hetero Diels Alder reaction: Application of the above in the total synthesis of natural products including natural products of contemporary interest in current literature.

**Pre-requisites** : None

**References** : Wyatt P. and Warren S, Organic Synthesis, Strategy and Control,; Wiley 2007, Nicolaou.

**OC 302 ( AUG ) 3 : 0****Asymmetric Catalysis: From Fundamentals to Frontiers**

Basics of asymmetric catalysis including energetics of reactions; Lewis acid & Lewis base catalysis; Kinetic, Dynamic Kinetic and Parallel Kinetic Resolution; Desymmetrization reactions; Mechanistic studies of asymmetric reactions: nonlinear effects, autocatalysis and autoinduction; Bifunctional, Dual and Multifunctional catalyst systems; Modern aspects of asymmetric catalysis: counterion-directed catalysis, cooperative, dual and merged catalysis, asymmetric photocatalysis etc. Applications of asymmetric catalysis.

**Pre-requisites** : None

**References** : Walsh, P.J., Kozlowski, M.C., Fundamentals of Asymmetric Catalysis

**OC 303 ( AUG ) 3 : 0****Carbohydrate Chemistry**

Structures and conformational itineraries of monosaccharides; Reactions of monosaccharides: reactivity profiles at each carbon center; ring expansions and contractions; reactions at anomeric carbon and epimeric carbons; deoxy sugars; anhydrosugars; protecting group methods; chemical and enzymatic glycosylations to oligosaccharides; glycosidic bond stabilities; naturally-occurring oligo- and polysaccharides and their conformations; chiral auxiliaries and modifications of sugars to carbocycles and heterocycles; aspects of animal and plant polysaccharides, glycoproteins, proteoglycans and glycosaminoglycans; selected natural product synthesis originating from a sugar scaffold.

**Pre-requisites** : None

**References** : Monosaccharides: Their chemistry and their roles in natural products, P. Collins and R. Ferrier, John Wiley & Sons Ltd., Chichester, 1998. Carbohydrates: The essential molecules of life.



# Solid State and Structural Chemistry

## Preface

The Solid State and Structural Chemistry Unit was founded in November 1976 by Bharat Ratna Professor C. N. R. Rao. SSCU has provided major thrust to diverse frontier areas at the intersection of Chemistry, Physics and Biology. Since its beginning, SSCU has fostered a culture of excellence, and it leads IISc in terms of research quality and productivity. The department's research is highly interdisciplinary, spanning frontier areas at the intersection of Chemistry, Physics and Materials Science.

The unit offers graduate level courses in Quantum Chemistry, Advanced Statistical Mechanics, Electrochemistry, Photovoltaics, Energy Research and Crystallography.

## SS 201 ( AUG ) 3 : 0

### Thermodynamics and Statistical Mechanics

Formal principles; conditions for equilibrium, Legendre transformation, Maxwell relations. Phase transitions; classification, Landau theory, universality. Irreversible thermodynamics; thermodynamic forces and fluxes. Onsager relations; illustrative applications to electrochemistry; thermo-electric and thermo-magnetic effects. Introduction to far from equilibrium systems. Basic formulations of statistical mechanics; ensembles, partition functions, relations to thermodynamic functions. Ideal systems; quantum statistics, non-ideal gases, Einstein and Debye Solids. Introduction to statistical mechanics of liquids. Computer simulations; basics of Monte Carlo and molecular dynamics techniques.

**Pre-requisites :** None

**References :** None

## SS 202 ( AUG ) 3 : 0

### Introductory Quantum Chemistry

Basic postulates of quantum mechanics. Exact solutions: harmonic oscillator (ladder operator approach), particle on a ring and a sphere. Linear operators and matrices. Angular momentum, raising and lowering operators and matrices for spin angular momentum. Hydrogenic atoms (without explicit solution of radial equation), many electron atoms and Slater determinants. Approximate methods - perturbation methods, application to many-electron atoms and term symbols. Variational method - Hartree-Fock method for atoms. Hartree-Fock-Roothan method for molecules. Time-dependent perturbation method - absorption and emission.

**Pre-requisites :** None

**References :** None

**SS 205 ( AUG ) 3 : 0****Symmetry and Structure in the Solid State**

Symmetry, point groups and space groups, crystal lattices. Scattering, diffraction, reciprocal lattice. powder diffraction. Single crystal methods. Data collection and processing synchrotron radiation, phase problem in crystallography. Patterson and direct methods, Rietveld refinement, intermolecular interactions electron density analysis. Basics of neutron diffraction, electron diffraction.

**Pre-requisites** : None

**References** : C. Giacavazzo (Ed.) Fundamentals of crystallography, J. D. Dunitz, X-ray analysis and the structure of organic molecules, G. H. Stout and L. H. Jensen

**SS 209 ( AUG ) 3 : 0****Electrochemical Systems**

A large section of the course will be dedicated to principles of electrochemistry which form the foundation of advanced electrochemical systems. A primer to electrochemical fundamentals will be provided to ensure that the course is self-contained with a minimum of pre-requisites. The course will cover electrochemical systems such as batteries, fuel cells, electrochemical transistors, nanoelectrochemical devices such as memristors and elementary electrolyte theory and its applications to confined nano-scale systems.

**Pre-requisites** : None

**References** : Electrochemical Methods: Fundamentals and Applications by Bard and Faulkner~Electrochemical Systems by Newman and Thomas-Alyea~Advanced Batteries by Huggins

**SS 304 ( AUG ) 3 : 0****Solar Energy: Advanced Materials and Devices**

Important Parameters in Photovoltaics, Shockley-Queisser limit, thermodynamic aspects, photon management. Mechanisms of charge separation and transport: junctions, energy transfer, electron transfer. Advanced Photovoltaic Materials (Perovskite, DSSC, Polymer and Colloidal Nanocrystal), Factors affecting photovoltaic performance-exciton diffusion length, charge transport and band-gap. Organic photovoltaic cells-Schottky, Donor-acceptor, heterojunction and bilayer. Methods of photovoltaic Fabrication and photophysics of molecular sensitizers.

**Pre-requisites** : None

**References** : The Physics of Solar Cell-Jenny Nelson, Imperial College Press, Organic Photovoltaics Mechanisms, Materials and Devices-Niyazi Serdar Sariciftci, Physics of Semiconductor Devices-Sze and Ng.

# Chemical Science

## Preface

### CY 215 ( AUG ) 0 : 3

#### Advanced Laboratory - I

Separation of Plant Pigments- Introduction to Thin-layer Chromatography and Column Chromatography; Synthesis of Methyl Benzoate (acid catalysed esterification); Triphenylcarbinol from Phenyl Magnesium Bromide and Methyl Benzoate (Grignard Reaction); Diels-Alder Reaction between Cyclopentadiene and Maleic anhydride; Benzoylation of Amino acid (Schotten-Baumann Reaction); Synthesis of 1,2,3,4,6-penta-O-acetyl glucopyranose; Water mediated Wittig Reaction – synthesis of cinnamates; Benzoin to Benzil; Benzil to Benzilic acid Rearrangement; Clemmenson reduction: Nitrobenzene to N-phenyl hydroxyl amine; Darzen's glycidic ester condensation: Benzaldehyde, ethyl bromoacetate, KOH, benzyltriethylammonium chloride; Synthesis and characterization of acetyl ferrocene; Synthesis and characterization of H<sub>2</sub>TPP, Ni/Cu/Zn-TPP complexes; Synthesis and characterization of HKUST-1; Synthesis and characterization of the polyoxometalate complexes and grafting the Amino Group; Synthesis and Use of a Nic

**Pre-requisites** : None

**References** : (1) A collection of interesting general chemistry experiments, Elias AJ, Universities Press, 2008 (2) Macroscale and Microscale Organic Experiments, Williamson KL and Masters K, Brooks/Cole, 2nd Edition, 2016 (3) A Small Scale Approach to Organic Laboratory Techniques, 3rd Edition, Pavia DL, Lampman GM, Kriz GS and Engel RG, Brooks/Cole Pub Co, 3rd edition, 2010 (4) College

### CY 226 ( JAN ) 0 : 3

#### Advanced Laboratory - II

pH-metry, Potentiometry, Iodometry, Preparation and testing the buffer action of Phosphate buffers, Determination critical micellar concentration (CMC), Conductometry, Determination of equivalent conductance of weak electrolyte at infinite dilution following Kohlrausch law, Determination of rate and activation energy of acid catalyzed Ethyl acetate hydrolysis reaction, Study of first -order kinetics of reaction between potassium persulphate and potassium iodide -determination of rate constants at two different temperatures and activation energy, Langmuir Adsorption, Fluorescence, UV-VIS Spectroscopy, Cyclic Voltammetry, X-Ray diffraction.

#### Satish Amrutrao Patil

**Pre-requisites** : None

**References** : (1) Vogel's Quantitative Chemical Analysis, Mendham J, Pearson Education, 2009

**CY 310 ( JAN ) 0 : 10****Research Project**

To be conducted in individual faculty laboratories in the Division of Chemical Sciences. The students will be allowed to undertake collaborative projects with faculty members from other divisions. The supervisors for research projects will be assigned at the end of second semester, allowing the students to start their interactions with individual research groups, design their projects and initiate research activities.

**Anshu Pandey**

**Pre-requisites** : None

**References** : NONE

**CY 224 ( JAN ) 3 : 0****Chemistry of Biomolecules**

This course will provide a survey of fundamental topics in chemical biology/biochemistry with an emphasis on concepts and tools from chemistry that are employed for biological discovery. The topics include, amino acid structure, properties, and chemistry; Peptides; Proteins; Classification of enzymes and details of a few important proteins/enzymes; Nucleic acid structure, properties, and chemistry; DNA and RNA; Genetic code; DNA sequencing; Polymerase chain reaction; Lipid structure, properties, and chemistry; Membranes; Carbohydrate structure, properties and chemistry; Glycoconjugates and their importance in biology; Enzyme catalysis, mechanism, and kinetics; Fatty acid biosynthesis and metabolism; Biochemical mechanism of protein synthesis; Glycolysis and Krebs cycle; Drugs, drug targets, mechanism of action; Drug toxicity and metabolism; Molecules with metal ions, hormones, secondary metabolites etc.

**Mugesh G , Mrinmoy De**

**Pre-requisites** : None

**References** : 1. Jeremy Berg, John L. Tymoczko, Gregory J. Gatto Jr and Lubert Stryer Biochemistry, WH Freeman; 9th ed. 2019 edition  
 2. Donald Voet, Judith G. Voet Biochemistry, 4th Edition, Wiley, 2011  
 3. Michael B. Smith Biochemistry-An organic chemistry approach

**CY 225 ( JAN ) 3 : 0****Spectroscopic Methods for Structure Determination**

Physical Principles of Spectroscopy, Operating Principles of Spectroscopic Instruments, Physical Methods of Structure Elucidation Structure elucidation of organic compounds using physical methods: Principles underlying the following techniques and their applications in organic chemistry will be discussed. Ultraviolet, Visible, Infrared, NMR (<sup>1</sup>H and <sup>13</sup>C) Spectroscopy, and Mass Spectrometry. Elementary aspects of Electron paramagnetic resonance (EPR) spectroscopy, Mössbauer.

**Jayaraman N , Sharvan Kumar , Uday Maitra**

**Pre-requisites** : None

**References** : (1) Structure Determination of Organic compounds, 4th edition, Ernö Pretsch, Phillipe Bühlmann, Martin Badertscher, Springer, 2009.  
 (2) EPR Spectroscopy: Applications in Chemistry and Biology, Malte Drescher, Gunnar Jeschke, Springer, 2012.

**CY 303 ( JAN ) 3 : 0****Inorganic Chemistry-2: Organometallic Chemistry**

Structure and bonding in organometallic compounds – isolobal analogies, metal carbonyls, carbenes and NHC complexes, olefin and acetylene complexes, alkyls and allyl complexes, metallocenes. Major reaction types – oxidative addition, reductive elimination, insertion, isomerization and rearrangement reactions. Catalytic reactions: metathesis, hydrogenation, allylic activation, C-C coupling reactions, C-X coupling.

**Thilagar P**

**Pre-requisites :** None

**References**

1. Elschenbroich, Ch. 2005 Organometallics, 3rd edition, Wiley-VCH, Weinheim :
2. Gupta, B. D. and Elias, A. J. 2013 Basic Organometallic Chemistry: Concepts, Syntheses and Applications (Second edition)

# Division of EECS

## Preface

The Division of EECS comprises the Departments of Computer Science and Automation (CSA), Electrical Communication Engineering (ECE), Department of Electronic Systems Engineering (ESE), and Electrical Engineering (EE). The courses offered in these departments have been grouped into the following technical areas identified by the following codes, which appear as prefixes to the course numbers.

- E0 Computer Science and Engineering
- E1 Intelligent Systems and Automation
- E2 Communication Systems
- E3 Electronic Devices, Circuits and Technology
- E4 Power and Energy Systems
- E5 High Voltage and Insulation Engineering
- E6 Power Electronics and Drives
- E7 Photonic Devices, Circuits and Systems
- E8 Electromagnetic, Microwaves and Antennas
- E9 Signal Processing, Acoustics and Bioengineering

All the departments in the Division provide facilities for research leading to the PhD and the M Tech (Research) degrees. The following course-based Master's programs are offered individually or jointly by the departments of the Division.

M Tech in Electrical Engineering (EE)

M Tech in Communication and Networks (ECE)

M Tech in Computer Science and Engineering (CSA)

M Tech in Electronics Systems Engineering (ESE)

M Tech in Artificial Intelligence (CSA,ECE,EE,ESE)

M Tech in Signal Processing (EE and ECE)

M Tech in Microelectronics and VLSI Design (ECE and ESE)

The dissertation projects in the above M Tech programs are numbered EE 299, CN 299, CS 299, ES 299, Ai 299, SP 299, and MV 299, respectively. We wish all the students a lively and intellectually rewarding experience in the Division of EECS at the Indian Institute of Science.

Prof. Rajesh Sundaresan

Dean

Division of EECS

# Computer Science and Automation

## Preface

**E0 220 ( AUG ) 3 : 1**

### Graph Theory

Vertex cover, matching, path cover, connectivity, hamiltonicity, edge colouring, vertex colouring, list colouring; Planarity, Perfect graphs; other special classes of graphs; Random graphs, Network flows, Introduction to Graph minor theory

**Pre-requisites** : None

**References** : None

**E0 224 ( AUG ) 3 : 1**

### Computational Complexity Theory

Computational complexity theory is the fundamental subject of classifying computational problems based on their `complexities'. In this context, `complexity' of a problem is a measure of the amount of resource (time/ space/random bits, or queries) used by the best possible algorithm that solves the problem. The aim of this course is to give a basic introduction to this field. Starting with the basic definitions and properties, we intend to cover some of the classical results and proof techniques of complexity theory. Introduction to basic complexity classes; notion of `reductions' and `completeness'; time hierarchy theorem & Ladner's theorem; space bounded computation; polynomial time hierarchy; Boolean circuit complexity; complexity of randomized computation; probabilistically checkable proofs; complexity of counting. References: The book titled `Computational Complexity - A Modern Approach' by Sanjeev Arora and Boaz Barak. Lecture notes of similar courses as and when required.

**Pre-requisites** : None

**References** : None

**E0 225 ( AUG ) 3 : 1****Design and Analysis of Algorithms**

Greedy algorithms, divide and conquer strategies, dynamic programming, max flow algorithms and applications, randomized algorithms, linear programming algorithms and applications, NP-hardness, approximation algorithms, streaming algorithms. References: Kleinberg and Tardos, Algorithm Design, Addison Wesley, 2005. Cormen, Leiserson, Rivest, and Stein, Introduction to Algorithms, 3rd Edition, Prentice Hall, 2009.

**Pre-requisites** : None

**References** : None

**E0 227 ( AUG ) 3 : 1****Program Analysis and Verification**

Dataflow analysis: Lattices, computing join-over-all-paths information as the least solution to a set of equations that model the program statements, termination of dataflow analysis, analysis of multi-procedure programs. Abstract interpretation of programs: Galois connections, correctness of dataflow analysis. Pointer analysis of imperative programs. Program dependence graphs, and program slicing. Assertion reasoning using Hoare logic. Type Systems: Monomorphic and polymorphic type systems, Hindley-Milner's type inference algorithm for functional programs.

**Pre-requisites** : None

**References** : Flemming Nielson, Hanne Riis Nielson, and Chris Hankin: Principles of Program Analysis, Springer, (Corrected 2nd printing, 452 pages, ISBN 3- 540-65410-0), 2005. Benjamin Pierce: Types and Programming Languages, Prentice-Hall India, 2002.

**E0 230 ( AUG ) 3 : 1****Computational Methods of Optimization**

Need for unconstrained methods in solving constrained problems. Necessary conditions of unconstrained optimization, Structure of methods, quadratic models. Methods of line search, Armijo-Goldstein and Wolfe conditions for partial line search. Global convergence theorem, Steepest descent method. Quasi-Newton methods: DFP, BFGS, Broyden family. Conjugate-direction methods: Fletcher-Reeves, Polak-Ribierre. Derivative-free methods: finite differencing. Restricted step methods. Methods for sums of squares and nonlinear equations. Linear and Quadratic Programming. Duality in optimization.

**Pre-requisites** : None

**References** : Fletcher R., Practical Methods of Optimization, John Wiley, 2000.~



**E0 232 ( AUG ) 3 : 1****Probability and statistics****Pre-requisites** : None**References** : None**E0 234 ( JAN ) 3 : 1****Introduction to Randomized Algorithms****Anand Louis , Arindam Khan****Pre-requisites** : None**References** : None**E0 235 ( AUG ) 3 : 1****Cryptography**

Elementary number theory, Finite fields, Arithmetic and algebraic algorithms, Secret key and public key cryptography, Pseudo random bit generators, Block and stream ciphers, Hash functions and message digests, Public key encryption, Probabilistic encryption, Authentication, Digital signatures, Zero knowledge interactive protocols, Elliptic curve cryptosystems, Formal verification, Cryptanalysis, Hard problems.

**Pre-requisites**

:

**References** : Stinson. D. Cryptography: Theory and Practice. Menezes. A. et. al. Handbook of Applied Cryptography.

**E0 240 ( AUG ) 3 : 1****Modeling and Simulation**

**Pre-requisites** : None

**References** : None

**E0 243 ( AUG ) 3 : 1****Computer architecture**

Processor Architecture: Instruction-Level Parallelism,Superscalar and VLIW architecture; Multi-core processors;Memory Subsystem: Multilevel caches,Caches in multi-core processors,Memory controllers for multi-core systems;Multiple processor systems: shared and distributed memory system,memory consistency models, cache coherence, and Interconnection networks;Advanced topics in architecture.

**Pre-requisites** : None

**References** : None

**E0 248 ( JAN ) 3 : 1****Theoretical Foundations of Cryptography**

This course is a complexity-theoretic introduction to Cryptography. Emphasis will be placed on exploring connections between various fundamental cryptographic primitives via reductions. Some of the primitives we will cover are one-way functions, pseudo-random generators, pseudo-random functions,trapdoor permutations, encryption, digital signatures, hash functions, commitments. We will also try to cover some special topics (private information retrieval, zero-knowledge proofs, oblivious transfer etc.).

**Bhavana Kanukurthi , Chaya Ganesh**

**Pre-requisites** : None

**References** : None

**E0 251 ( AUG ) 3 : 1****Data Structures and Algorithms**

Abstract data types and data structures, Classes and objects, Complexity of algorithms: worst case, average case, and amortized complexity. Algorithm analysis. Algorithm Design Paradigms. Lists: stacks, queues, implementation, garbage collection. Dictionaries: Hash tables, Binary search trees, AVL trees, Red-Black trees, Splay trees, Skip-lists, B Trees. Priority queues. Graphs: Shortest path algorithms, minimal spanning tree algorithms, depth-first and breadth-first search. Sorting: Advanced sorting methods and their analysis, lower bound on complexity, order statistics.

**Pre-requisites** : None

**References** : References: A.V. Aho, J.E. Hopcroft, and J.D. Ullman, Data Structures and Algorithms, Addison Wesley, Reading Massachusetts, USA, 1983 T.H. Cormen, C.E. Leiserson, and R.L. Rivest, Introduction to Algorithms, The MIT Press, Cambridge, Massachusetts, USA, 1990 M.A. Weiss, Data Structures and Algorithms Analysis in C++, Benjamin/Cummins, Redwood City, California, USA,

**E0 255 ( JAN ) 3 : 1****Compiler Design**

Control flow graphs and analysis; Dataflow analysis; Static single assignment (SSA); Compiler optimizations; Dependence analysis, Loop optimizations and transformations, Parallelization, Optimizations for cache locality, and Vectorization; Domain-specific languages, compilation, and optimization; Register allocation, Instruction scheduling; Run time environment and storage management; Impact of language design and architecture evolution on compilers.

**Uday Kumar Reddy B**

**Pre-requisites** : None

**References** : References: Aho, A.V., Ravi Sethi and J.D. Ullman: Compilers- Principles, Techniques and Tools, Addison Wesley, 1988. S. Muchnick: Advanced Compiler Design and Implementation, Morgan Kaufman, 1998 Selected Papers.

**E0 256 ( AUG ) 3 : 1****Theory and Practice of Computer Systems Security**

This course will seek to equip students with the fundamental principles and practice of computer systems security. The course will cover the major techniques of offense and defense, thereby educating students to think both as attackers and defenders. By the end of the course, students will have been exposed to the state of the art, and will be equipped with the background to start conducting original research in computer systems security. Core concepts such as basic security goals, threat models, notion of TCB and security policies vs. mechanisms. Operating system primitives for protection, reference monitors, authentication, and authorization. Examples of classic security policies from the literature (e.g., Biba, BLP) and their realization on modern systems. Various forms of hijacking attacks, such as buffer overflows, return-oriented programming, and non-control data attacks, and examples of such attacks as used by exploits in the wild. Design and implementation of defenses such as control-flow integrity, ASLR, privilege separation, capabilities, information-flow control and virtual machine introspection. Attacks and defenses against the Web ecosystem, mobile devices and the cloud platform. Emerging role of modern hardware in improving systems security. Other assorted topics based on current research literature. References: Security Engineering, 2nd Edition, Wiley, by Ross Anderson. <http://www.cl.cam.ac.uk/~rja14/book.html> (free online copy) Research papers from systems security conferences and journals.

**Pre-requisites** : None

**References** : None

**E0 261 ( AUG ) 3 : 1****Database Management Systems**

Design of Database Kernels, Query Optimization, Query Processing, Data Access Methods, Transaction Management, Distributed Databases, Data Mining, Data Warehousing, Main-Memory Databases, Columnar Databases, NoSQL systems.

**Pre-requisites** : None

**References** : Database Systems Concepts, H. Korth, A. Silberschatz and S. Sudarshan, McGraw-Hill~Fundamentals of Database Systems R. Elmasri and S. B. Navathe, Addison-Wesley. ~Database Management Systems R. Ramakrishnan and J. Gehrke, McGraw-Hill. ~Readings in Database Systems M. Stonebraker and J. Hellerstein, Morgan Kaufmann. ~Recent Conference and Journal papers.

**E0 270 ( JAN ) 3 : 1****Machine Learning**

Introduction to Machine Learning, classification using Bayes rule, introduction to Bayes decision theory. Learning as optimization, linear regression. Probabilistic view: ML and MAP estimates. Logistic Regression: Gradient Descent, Stochastic Gradient methods. Hyperplane based classifiers, Perceptron, and Perceptron Convergence Theorem. Support vector machine and kernel methods. Feedforward neural networks, backpropagation algorithm. Autoencoders, Convolutional neural networks, and application to computer vision. The sequence to sequence models, recurrent NN and LSTM and applications to NLP. Undirected Graphical Models, Markov Random Fields, Introduction to MCMC and Gibbs Sampling. Restricted Boltzmann Machine. EM algorithm, Mixture models and K-means, Bayesian Networks, Introduction to HMMs. Generative models: GANs and VAEs.

**Ambedkar Dukkipati**

**Pre-requisites** : None

**References** : Bishop. C M, Pattern Recognition and Machine Learning, Springer, 2006.~Hastie T, Tibshirani R and Friedman J, The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer, 2nd Edition, 2009~Haykin. S, Neural Networks and Learning Systems, Prentice Hall, 3rd Edition, 2009~Goodfellow, Bengio, Courville, Deep Learning, MIT Press, 2017

**E0 271 ( AUG ) 3 : 1****Graphics and Visualization**

Graphics pipeline; transformations; viewing; lighting and shading; texture mapping; modeling; geometry processing - meshing, multi- resolution methods, geometric data structures; visualization - visualization pipeline, data reconstruction, isosurfaces, volume rendering, flow visualization.

**Pre-requisites** : None

**References** : Edward S. Angel and Dave Shreiner. Interactive Computer Graphics: A Top-Down Approach with Shader-Based OpenGL. Pearson, 2011. Dave Shreiner, Graham Sellers, John Kessenich, and Bill Licea-Kane. OpenGL Programming Guide: The Official Guide to Learning OpenGL. Addison-Wesley, 2013. Recent Literature.

**E0 304 ( JAN ) 3 : 1****Computational Cognitive Neuroscience**

This reading course is focused on recent advances computational frameworks in cognitive neuroscience. We will review the state-of-the art in data analysis techniques that permit extracting meaningful information from noisy, high-dimensional brain data (e.g. machine learning and dimensionality reduction) as well as theoretical and computational models of brain function. The course will be organized into four reading modules on Machine learning and classification, Dimensionality reduction, Neural computation and Theory, and Deep convolutional neural networks, discussing recent applications in computational neuroscience. The project will require analyzing large- scale brain datasets, for example, decoding cognitive states from brain imaging data.

**Sridharan Devarajan**

**Pre-requisites** : None

**References** : None

**E0 309 ( JAN ) 3 : 1****Topics in complexity theory**

The theme of this course in the Jan-Apr 2015 semester is arithmetic circuit complexity. Arithmetic circuits are algebraic analogue of boolean circuits that naturally compute multivariate polynomials. The quest for a thorough understanding of the power and limitation of the model of arithmetic circuits (and its connection to boolean circuits) has lead researchers to several intriguing structural, lower bound and algorithmic results. These results have bolstered our knowledge by providing crucial insights into the nature of arithmetic circuits. Still, many of the fundamental questions/problems on arithmetic circuits have remained open till date. The aim of this course is to provide an introduction to this area of computational complexity theory. We plan to discuss several classical and contemporary results and learn about a wealth of mathematical (particularly, algebraic and combinatorial) techniques that form the heart of this subject.

**Chandan Saha**

**Pre-requisites** : None

**References** : None

**E0 334 ( AUG ) 3 : 1****Deep Learning for Natural Language Processing**

Introduction, Multilayer Neural Networks, Back-propagation, Training Deep Networks; Simple word vector representations: word2vec, GloVe; sentence, paragraph and document representations. Recurrent Neural Networks; Convolutional Networks and Recursive Neural Networks; GRUs and LSTMs; building attention models; memory networks for language understanding. Design and Applications of Deep Nets to Language Modeling, parsing, sentiment analysis, machine translation etc.

**Pre-requisites** : None

**References** :

**E0 343 ( JAN ) 3 : 1****Topics in Computer Architecture****Govindarajan R**

**Pre-requisites** : None

**References** : None

**E0 361 ( JAN ) 3 : 1****Topics in Database Systems**

Object-oriented Databases, Distributed and Parallel Databases, Multi-databases, Access Methods, Transaction Management, Query Processing, Deductive Databases, multimedia Databases, Real-Time Databases, Active Databases, Temporal Databases, Mobile Databases, Database Benchmarks, Database Security, Data Mining and Data Warehousing.

**Jayant R Haritsa**

**Pre-requisites** : None

**References** : None

**E0 374 ( JAN ) 3 : 1****Topics in Combinatorial Geometry****Sathish Govindarajan**

**Pre-requisites** : None

**References** : None

**E0 399 ( MAY ) 1 : 2****Research in Computer Science**

Contemporary topics of research in theoretical computer science, computer systems and software, intelligent systems. Motivation and objectives of the course: This course is meant for MTech (CSE) students. The idea behind the course is that a student works on a short research problem to get hands-on experience and also to develop soft skills necessary to conduct research. The 1 credit is for one contact hour per week between the instructor(s) and student(s) for discussion and presentations. The 2 credits is for the research work that the student conducts during the week on the course.

**Pre-requisites** : None

**References** : Recent literature

**E1 254 ( JAN ) 3 : 1****Game Theory**

Introduction: rationality, intelligence, common knowledge, von Neumann - Morgenstern utilities; Noncooperative Game Theory: strategic form games, dominant strategy equilibria, pure strategy Nash equilibrium, mixed strategy Nash equilibrium, existence of Nash equilibrium, computation of Nash equilibrium, matrix games, minimax theorem, extensive form games, subgame perfect equilibrium, games with incomplete information, Bayesian games. Mechanism Design: Social choice functions and properties, incentive compatibility, revelation theorem, Gibbard-Satterthwaite Theorem, Arrow's impossibility theorem, Vickrey- Clarke-Groves mechanisms, dAGVA mechanisms, Revenue equivalence theorem, optimal auctions. Cooperative Game Theory: Correlated equilibrium, two person bargaining problem, coalitional games, The core, The Shapley value, other solution concepts in cooperative game theory. References: Roger B. Myerson, Game Theory: Analysis of Conflict, Harvard University Press, September 1997.

**Siddharth Barman**

**Pre-requisites** : None

**References** : None

**E1 277 ( JAN ) 3 : 1****Reinforcement Learning**

Introduction to reinforcement learning, introduction to stochastic dynamic programming, finite and infinite horizon models, the dynamic programming algorithm, infinite horizon discounted cost and average cost problems, numerical solution methodologies, full state representations, function approximation techniques, approximate dynamic programming, partially observable Markov decision processes, Q-learning, temporal difference learning, actor-critic algorithms.

**Shalabh Bhatnagar , Gagan Chandrashekhar Mallika Thoppe**

**Pre-requisites** : None

**References** : References: D.P.Bertsekas and J.N.Tsitsiklis, Neuro-Dynamic Programming, Athena Scientific, 1996. R.S.Sutton and A.G.Barto, Reinforcement Learning: An Introduction, MIT Press, 1998. D.P.Bertsekas, Dynamic Programming and Optimal Control, Vol.I, Athena Scientific, 2005.

**E1 396 ( AUG ) 3 : 1****Topics in Stochastic Approximation Algorithms**

**Pre-requisites** : None

**References** : None



**E0 205 ( JAN ) 3 : 1****Mathematical Logic and Theorem Proving**

Motivation and objectives of the course: This course is about mathematical logic with a focus on automated reasoning techniques that are useful in reasoning about programs. In the first part of the course we cover Propositional and First-Order logic and some of the classical results like sound and complete proof systems, compactness, and decidability of the satisfiability/validity problems. In the second part we focus on decision procedures for various theories that arise while reasoning about assertions in programs. Syllabus: Zeroth Order/ Propositional Logic:- Proofs in arithmetic - Propositional logic, proof systems - Decision procedure, completeness and compactness First-Order Logic:- Proof systems- Undecidability- Completeness and compactness Theories and Decision Procedures:- Equality and Uninterpreted Functions (EUF)- Linear Arithmetic- Array logics-Nelson-Oppen combination

**Deepak D'Souza****Pre-requisites** : None

**References** : First-order Logic and automated theorem proving, Melvin Fitting, Springer-Verlag, 1990.~Logic for Computer Science - Foundations for Automatic Theorem Proving, Jean H. Gallier.~Computability and logic, George Boolos, John Burgess and Richard Jeffrey, Cambridge U Press, 2007. ~Decision Procedures, Kroening and Strichman, Springer 2008.~An Introduction to Logic, Madhavan Mukund

**E0 207 ( JAN ) 3 : 1****Computational Topology: Theory and Applications**

1. Introduction to topological data analysis via recent applications 2.Mathematical preliminaries from group theory and linear algebra: group homomorphism and isomorphism, quotient group, classification of finitely generated Abelian groups, linear transformations, matrix representations 3.Complexes: Clique, Delaunay, Cech, Rips, random complexes, algorithms for constructing complexes 4. Simplicial homology: chains, cycles, the boundary operator, the homology group, simplicial maps, Betti numbers, Euler-Poincare characteristic, nerve theorem, matrix reduction algorithms 5. Persistent Homology: filtrations, persistence diagrams, barcodes, spanning acycles,algorithms 6. Morse functions: Morse Lemma, Morse-Smale complex, contour tree,Reeb graph, algorithms for construction and simplification, hierarchical representation 7. Random topology: Random complexes, Morse inequalities,Limiting distribution of Betti numbers and persistence diagrams 8. Software:TDA on R, Gudhi, Ripser,Javaplex,

**Vijay Natarajan , Gagan Chandrashekhar Mallika Thoppe****Pre-requisites** : None

**References** : Edelsbrunner, Herbert, and John Harer. Computational topology: an introduction. American Mathematical Soc., 2010.~Hatcher, Allen. Algebraic topology., (2001). ~Current Literature

**E0 208 ( AUG ) 3 : 1****Computational Geometry**

Motivation and objective of the course: Computational Geometry is an area of computer science that looks at the computational aspects of geometric problems such as running time of an algorithm, space occupied by a data structure, design of polynomial time approximation algorithms. This area has been well studied over the last four decades and has found applications in computer graphics, computer-aided design, geographic information systems, robotics, etc. This course will focus on the theoretical aspects of algorithms and data structures for various geometric problems. Syllabus: The list of topics covered in this course include a. Convex hulls: 2-D and higher dimensional convex hulls, output sensitive algorithms, randomized incremental construction b. Intersection detection: Segment intersection, plane sweep technique. c. Geometric data structures for range searching and point location: Segment and interval trees, range trees, kd-tree, persistence. d. Proximity problems: Voronoi diagrams

**Pre-requisites** : None

**References** : [Main textbook] M. de Berg, O. Cheong, M. van Kreveld, and M. Overmars, Computational Geometry: Algorithms and Applications. Springer-Verlag, 3rd ed., 2008. ~Lecture notes on Computational Geometry by David Mount: <https://www.cs.umd.edu/class/spring2012/cmcs754/Lects/cmcs754-lects.pdf> ~ [Additional reference] Sariel Har-Peled. Geometric Approximation Algorithms (Mathematical

**E0 209 ( JAN ) 3 : 1****Principles of Distributed Software**

Distributed and Cloud Computing, by K. Hwang, G. C. Fox, and J.J. Dongarra, Morgan Kaufmann Publishing, 2012 ~ Designing Distributed Systems, by Brendan Burns, O'Reilly, 2018 ~ Online documentation for Akka and Kubernetes ~ Selected research papers ~ <https://azure.microsoft.com/en-us/resources/designing-distributed-systems/> <https://www.amazon.in/Designing-Distributed-Systems-Patterns-Paradigms-ebook/dp/B079YTM4FC>

**Raghavan K V**

**Pre-requisites** : None

**References** : Motivation and objectives of the course : Development of distributed software applications is a very important activity, accelerated in recent years by the increasing predominance of cloud computing. The typical requirements from a modern day distributed application are continuous availability even in the presence of software and hardware faults, ability to scale up or down on-the-fly based on

**CS 299 ( JAN ) 0 : 21****M Tech Project CSA**

M Tech Project

**Gugan Chandrashekar Mallika Thoppe , Chaya Ganesh**

**Pre-requisites** : None

**References** : M Tech Project

**E0 315 ( JAN ) 3 : 1****Measure Theoretic Probability**

Syllabus: Sigma-Field, Construction of Probability Spaces and Measures, Random Variables and Measurability, Independence, Integration and Expectation, Monotone Convergence, Dominated Convergence, almost sure and in- probability convergence, Convergence in Distribution, Central Limit Theorem, Conditional Expectation and Martingales.

**Ambedkar Dukkipati**

**Pre-requisites** : Linear Algebra and Probability (3:1) or equivalent cours

**References** : 1. G.R.Shorack, Probability for Statisticians, Springer, Second Edition, 2017 2. R.Ash and C. Doleans-Dade, Probability and Measure Theory, 1999

**E0 213 ( JAN ) 3 : 0****Quantum Safe Cryptography**

Introduction to cryptography and communication security; Symmetric Key and Asymmetric Key Cryptosystems for data encryption and authentication; Impact of Quantum Computing on currently deployed cryptosystems; Some candidate post-quantum public key encryption and digital signature schemes using Error Correcting Codes, Lattices, Isogeny over Elliptic Curves, Multivariate-polynomials over finite fields, Cryptographic Hash Functions; Protocols for quantum-safe secure communication.

**Sanjit Chatterjee**

**Pre-requisites** :

**References** : (1) Bernstein D.J., Buchmann J. and Dahmen E. (Eds.): Post-Quantum Cryptography, Springer, 2010. (2) Galbraith S.D., Mathematics of Public Key Cryptography, Cambridge University Press, 2012. (3) Menezes A.J., van Oorshot P.C. and Vanstone S.A., Handbook of Applied Cryptography, CRC Press, 1996. (4)Recent research papers in the relevant areas.

**E0 214 ( AUG ) 3 : 0****Applied Linear Algebra and Optimization**

Linear Transformations and Linear Systems, Eigenvalues and Eigenvectors, Matrix Decompositions, Approximations and Completion with applications in Machine Learning and Recommender Systems. Optimization Basics- Gradient based methods, Coordinate descent methods, Newton Methods. Constrained optimization, Duality, and Applications in Machine Learning. Non-convex optimization for Machine Learning - Stochastic Optimization, Projected Gradient Descent and Alternating Optimization.

**Pre-requisites** : None

**References** : i) Charu C Aggarwal, Linear Algebra and Optimization for Machine Learning, Springer, 2020 ii) Recent Literature

**E0 294 ( JAN ) 3 : 1****Systems for Machine Learning**

This course focuses on research and recent developments in hardware systems for machine learning algorithms. Computer systems currently focus on parallel-everything; chip multiprocessors, multithreading, GPUs, parallel software etc., These parallel everything hardware blocks also accidentally stumbled on the gold mine of machine learning algorithms. Machine learning (ML) algorithms at least until recently have relied extensively on matrix algebra, which can be highly parallelized. Hence, mapping these ML algorithms to GPUs, and massive CMPs has been an extremely fruitful exercise resulting in rapid growth in ML performance. While performance improvements still play a large role in ML systems, power and other constraints are equally important parameters. The need to maximize power efficiency has lead to a plethora of new ML accelerators, both in research and academia. At the same time a plethora of ML models have also started to appear with diverse computing needs, from recommender systems to Transformer based natural language processing models. The wide diversity of models and the heterogeneity of the hardware accelerators that run these models is one of the prime subjects of focus in this course. On the data front, ML systems use overwhelming amounts of training data that must be parsed, pre-processed and formatted to feed to the ML computing pipelines. Hence, there is a desire to enable data processing acceleration through near data processing. Novel memory and storage paradigms have been proposed to enable such near data processing. This second important focus of this course is to present a variety of near data processing techniques for ML pipelines. There is no hiding from security breaches in ML (and also in general computing). Security has become a key issue of concern for microarchitectures in the last decade. Data privacy and integrity is also important for ML systems to be trusted in critical application domains, such as medicine and transportation. We will cover privacy and security aspects of ML systems as the third module in this course

**Sumit Kumar Mandal****Pre-requisites** :

**References** : Sze, Chen, Yang and Emer: "Efficient Processing of DNNs," Morgan&Claypool Press. 2021. ISBN: 9781681738321  
 Deep Learning for Computer Architects [https://www.morganclaypool.com/doi/pdfplus/10.2200/S00783ED1V01Y201706\\_CAC041](https://www.morganclaypool.com/doi/pdfplus/10.2200/S00783ED1V01Y201706_CAC041)

**E0 317 ( JAN ) 3 : 0****Probabilistic Methods in Graph Theory and Combinatorics**

Linearity of Expectation Alterations, Second Moment Method, Lovasz Local Lemma, Chernoff bound and its application, Derandomization, Martingales, Markov Chains and Random walks, Entropy and randomness.

**Sunil Chandran L**

**Pre-requisites** : Basic exposure to Probability theory, Graph Theory/Combinatorics.

**References** : (1) N. Alon, J. Spenser, The Probabilistic Methods, WILEY-INTERSCIENCE SERIES IN DISCRETE MATHEMATICS AND OPTIMIZATION (2) Probability and Computing: Randomized Algorithms and Probabilistic Analysis; Mitzen Macher and Eli Upfal, Cambridge University Press.

**E0 318 ( AUG ) 3 : 1****Topics in Geometric Algorithms**

Geometric problems are ubiquitous in Computer Science. Indeed, one often encounters geometric problems—and associated algorithms—in data science applications; examples include geometric proximity problems and hashing methods that exploit the geometry of input points. In addition to critical applications, geometric algorithms connect with mathematical fields such as probability theory and topology. This course will cover algorithmic approaches for addressing topical problems in computational geometry. In particular, we will focus on Geometric Packing, Robot Motion Planning, Art Gallery and Visibility Problems, LSH and Nearest Neighbor, Coresets, Geometric Intersection Graphs, and Fair Partitioning. The course will address recent algorithmic developments in these topics. Further, by way of course projects, we will identify and explore some key open problems in the above-mentioned topics.

**Pre-requisites :** Students should have completed either Computational Geometry (E0 208) or Approximation Algorithms (E0 249). Further, E0 225 (Design and Analysis of Algorithms) is a strict prerequisite.

**References :** Since the course topics span several fields, we will be teaching material from multiple books/sources. Some of them are listed below. a. Sarel Har-Peled, Geometric Approximation Algorithms. American Mathematical Soc., 2011. b. Mark DB, Otfried C, Marc VK, Mark O. Computational geometry algorithms and applications. Springer; 2008. c. Williamson, David P., and David B. Shmoys. The

**E0 308 ( JAN ) 3 : 1****Advanced Data Structures**

The topics of interest in this course will be the following: (1) Orthogonal range-searching: Alstrup-Brodal-Rauhe's grid-based approach, Chan-Larsen-Patrascu's ball-inheritance approach, shallow cuttings for 2-D/3-D dominance ranges. (2) Planar point location via separators, segment trees, persistence. (3) Big-data: external-memory data-structures (such as B-trees, R-trees, Persistent B-trees and Buffer Trees). (4) Dynamic data structures: the logarithmic method, de-amortization, weight balancing, applications to geometric approximation algorithms. (5) Integer data: Hashing, Van Emde Boas Trees, Fusion Trees, tabulation technique, leveraging the word length. (6) Non-orthogonal range searching: Partition Trees, Cutting Trees, Shallow Cuttings. (7) Lower bounds in the pointer-machine model and the cell-probe model; Conditional lower-bounds from fine-grained complexity. (8) Approximate nearest neighbour queries: z-ordering, locality sensitive hashing. (9) Miscellaneous: Amortized analysis, Binomial and fibonacci heaps, union-find structures, dynamic connectivity on a graph, pattern matching on strings.

**Rahul Saladi**

**Pre-requisites :** Students should have completed either Computational Geometry (E0 208)

**References :** There is no single textbook for this topic. The following books, lecture notes, and courses will be useful for learning the topic:

(1) Advanced Data Structures, Timothy Chan (UIUC):

**E0 324 ( JAN ) 3 : 0****Advanced Topics in Optimization for Machine Learning**

- Preliminaries: Lipschitz continuity, Smoothness
- Gradient descent: convergence for smooth non-convex functions, smooth, convex and strongly-convex functions, Nesterov Acceleration, Heavy-Ball momentum and its convergence for quadratics
- Convergence for Stochastic Gradient Descent: convergence for smooth (convex and non-convex) functions, Strongly convex functions, Interpolation, Growth conditions
- Variance reduction, SVRG, SAGA and its convergence
- Second Order Methods
- Subgradient Descent and its convergence for Lipschitz, convex functions
- Online Convex Optimization : Online Gradient Descent, Follow the (regularized) leader and their regret bounds
- AdaGrad : Regret bounds for convex, Lipschitz functions, Accelerated Adagrad, Other Variants
- First order methods for Convex-concave
- Optimization with Uncertainty: Optimization of Conditional Value at Risk

**Chiranjib Bhattacharyya , Anant Raj****Pre-requisites** :

Basic Numerical Optimization Course (E0 230)

- References** :
- Convex Optimization: Algorithms and Complexity, Bubeck, 2014
  - First-order Methods in Optimization, Beck, 2017

# Electrical Communication Engineering

## Preface

### E3 238 ( AUG ) 2 : 1

#### Analog VLSI Circuits

Review of MOS device characteristics, Long channel MOS, Second order effects, MOS small signal parameters and models, MOS capacitance. Concept of  $f_T$ , Bipolar transistors, Small signal parameters of BJTs, Common Emitter/Common source Amplifiers, CB/CG Amplifiers Emitter/Source followers, Source Degeneration, Cascodes, emitter/Source coupled pairs, Current Mirrors, Differential Pairs, Frequency Response, Noise, Feedback, Linearity, Operational Amplifiers: Telescopic and Folded Cascode, Stability and Compensation, Slew rate and setting, Common Mode Feedback

**Pre-requisites** : None

**References** : Behzad Razavi, Design of Analog CMOS Integrated Circuits~Grey, Hurst, Lewis and Meyer, Analysis and Design of Analog Integrated Circuits~Selected Papers and Patents

### E0 259 ( AUG ) 3 : 1

#### Data Analytics

This course will be taught jointly by Professors Ramesh Hariharan, Vikram Srinivasan, and Rajesh Sundaresan. This course will develop modern statistical tools and modelling techniques through hands-on data analysis in a variety of application domains. The course will illustrate the principles of hands-on data analytics through several case studies (8-9 such studies). On each topic, we will introduce a scientific question and discuss why it should be addressed. Next, we will present the available data, how it was collected, etc. We will then discuss models, provide analyses, and finally touch upon how to address the scientific question. Topics will be from astronomy, visual neuroscience, genomics, sports, community networks, epidemiology, and topic modelling.

**Pre-requisites** : Random Processes (E2 202) OR Probability and Statistics (E0 232) OR equivalent.

**References** : There is no text book for this course. Slides of lectures will be available on the course's learning management system on Moodle.

**E1 244 ( JAN ) 3 : 0****Detection and Estimation Theory**

Hypothesis testing, Neyman-Pearson theorem, likelihood ratio test and generalized likelihood ratio test, uniformly most powerful test, multiple-decision problems, detection of deterministic and random signals in Gaussian noise, detection in non-Gaussian noise, sequential detection, introduction to nonparametric testing. Parameter Estimation: Unbiasedness, consistency, Cramer-Rao bound, sufficient statistics, Rao-Blackwell theorem, best linear unbiased estimation, maximum likelihood estimation. Bayesian estimation: MMSE and MAP estimators, Wiener filter, Kalman filter, Levinson-Durbin and innovation algorithms.

**Vaibhav Katewa****Pre-requisites** : None**References** : H. V. Poor, An Introduction to Signal Detection and Estimation, Springer-Verlag, 2nd edition, 1994**E1 245 ( AUG ) 3 : 0****Online Prediction and Learning**

Online classification, Regret Minimization, Learning with experts, Online convex optimization, Multi-armed bandits, Applications sequential investment/portfolio selection, universal lossless data compression, Stochastic games- Blackwell approachability, Learning systems with state-online reinforcement learning

**Pre-requisites** : None

**References** : Prediction, Learning and Games. Nicolo Cesa-Bianchi and Gabor Lugosi, Cambridge University Press, 2006~Online Learning and Online Convex Optimization. Shai Shalev-Shwartz. Foundations and Trends in Machine Learning Vol. 4, No. 2 (2011) 107–194, DOI:10.1561/22000000018 ~Regret Analysis of Stochastic and Nonstochastic Multi-armed Bandit Problems. Sebastien Bubeck and

**E2 201 ( JAN ) 3 : 0****Information Theory**

Entropy, mutual information, data compression, channel capacity, differential entropy, Gaussian channel.

**Rajesh Sundaresan****Pre-requisites** : None**References** : T. M. Cover and J. A. Thomas, Elements of Information Theory, 2nd edition, John Wiley & Sons



**E2 202 ( AUG ) 3 : 0****Random Processes**

The axioms of probability theory, continuity of probability, independence and conditional probability. Random variables and their distribution, functions of a random variable, expectation. Jointly distributed random variables, conditional distribution and expectation, Gaussian random vectors. Convergence of sequences of random variables, Borel-Cantelli Lemma, laws of large numbers and central limit theorem for sequences of independent random variables, Markov inequality. Definition of a random process, stationarity. Correlation functions of random processes in linear systems, power spectral density. Discrete time Markov chains, recurrence analysis, Foster's theorem. The Poisson process.

**Pre-requisites** : None

**References** : A. Kumar, Discrete Event Stochastic Processes: Lecture Notes for an Engineering Curriculum. Online book.

**E2 203 ( JAN ) 3 : 0****Wireless Communication**

Wireless channel modeling; diversity techniques to combat fading; cellular communication systems, multiple-access and interference management; capacity of wireless channels; opportunistic communication and multiuser diversity; MIMO – channel modeling, capacity and transmit and receiver architectures; OFDM.

**Neelesh B Mehta**

**Pre-requisites** : None

**References** : D. Tse and P. Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005.~A. Goldsmith, Wireless Communication, Cambridge University Press, 2005.

**E2 204 ( JAN ) 3 : 0****Stochastic Processes and Queueing Theory**

Basic mathematical modeling is at the heart of engineering. In both electrical and computer engineering, many complex systems are modeled using stochastic processes. This course will introduce students to basic stochastic processes tools that can be utilized for performance analysis and stochastic modeling. Detailed study of processes encountered in various stochastic dynamic systems, such as branching, counting, urns, infections, and queues. Course content: Poisson process, Renewal theory, Markov chains, Reversibility, Queueing networks, Martingales, Random walk.

**Parimal Parag**

**Pre-requisites** : None

**References** : S. M. Ross, Stochastic Processes, Wiley, 2nd Edition, 1996.~E. Cinlar, Introduction to Stochastic processes, Prentice Hall, 1975.~P. Bremaud, Markov Chains: Gibbs Fields, Monte Carlo Simulation, and Queues, Springer, 1999.~J. R. Norris, Markov Chains, Cambridge, 1998. ~F. P. Kelly, Reversibility and Stochastic Networks, Cambridge.

**E2 205 ( AUG ) 3 : 0****Error-Control Coding**

Basics of binary block codes; mathematical preliminaries: groups, rings, fields and vector spaces; convolutional codes and the Viterbi algorithm; belief propagation with application to the decoding of codes; LDPC codes; finite fields, Reed-Solomon and BCH codes.

**Pre-requisites** : None

**References** : R.M. Roth, Introduction to Coding Theory, Cambridge University Press, 2006~T. Richardson and R. Urbanke, Modern Coding Theory

**E2 211 ( AUG ) 3 : 0****Digital Communication**

Representation of signals and systems; Digital modulation techniques and their performance in AWGN channel; optimum receiver structures for AWGN channel; signal design for band-limited and power-limited channels; power and bandwidth efficiency tradeoff; coding and coded modulation techniques – capacity approaching schemes; ISI and equalization; Multichannel and multicarrier systems; Digital communications through fading multipath channels.

**Pre-requisites** : None

**References** : S. Haykin, Digital Communication, Wiley, 1999~J.G. Proakis, Digital Communication, 4th edition

**E2 212 ( AUG ) 3 : 0****Matrix Theory**

Vectors, vector norms, vector algebra, subspaces, basis vectors, Gram-Schmidt orthonormalization. Matrices, matrix rank, matrix norms, determinant, inverse, condition number. Hermitian and symmetric matrices, positive definite matrices, unitary matrices, projection matrices and other special matrices. LDU decomposition, QR decomposition, eigenvalue decomposition, singular value decomposition. Solving linear system of equations using Matrices. Least-squares approach, total least squares approach. Numerical issues. Perturbation theory of matrices. Differentiation of scalar functions of vectors and matrices. Matrix functions of scalar variables, Kronecker product of matrices. Positive matrices, nonnegative matrices, stochastic matrices and Markov chains.

**Pre-requisites** :

**References** : References: Carl D Meyer, Matrix Analysis and Applied Linear Algebra, SIAM Publication, 2000 Theodore Shifrin and Malcolm Ritchie Adams, Linear Algebra: A Geometric Approach, W H Freeman and Company, Second Edition, 2011, Gilbert Strang, Linear Algebra and its Applications, Fourth Edition, Thomson Brooks/Cole, 2007. Horn, and Johnson, Matrix Analysis, Second Edition, Cambridge

**E2 221 ( AUG ) 3 : 0****Communication Networks**

Introduction to networking. TCP and UDP, TCP analysis. IP, optimal routing, algorithms for shortest path routing, routing protocols, Mobile IP. ARQ schemes and analysis, random access, random/slotted ALOHA, splitting algorithms, CSMA-CD, wireless LANs CSMA/CA, IEEE 802.11 MAC. Modelling and performance analysis in networks; deterministic analysis, scheduling; stochastic analysis - traffic models, performance measures, Little's Theorem, M/G/1 model, Priority queueing.

**Pre-requisites :** None

**References :** A. Kumar, D. Manjunath, and J. Kuri, Communication Networking: An Analytical Approach, Morgan Kaufman Publishers, 2004.~D. Bertsekas and R. Gallager, Data Networks, 2nd Edition, Prentice-Hall India, 2002.~J.F. Kurose and K. W. Ross, Computer Networking: A Top-Down Approach Featuring the Internet, Pearson Education Asia, 2001.

**E2 251 ( AUG ) 3 : 0****Communications Systems Design**

Communication link design for AWGN channels; path loss models, noise figure, receiver sensitivity; link budget for deep space communication - a case study. Communication subsystem requirements and specifications: analog/digital front-end, oscillator phase noise, analog/digital up/down conversion, carrier frequency offset (CFO), bandpass sampling, DAC/ADC interface, quantization noise and clipping, dynamic range, ADC selection, automatic gain control (AGC), sampling jitter, CORDIC, I/Q imbalance, DC offset correction, error vector magnitude (EVM), power amplifier (PA) non-linearities. Communication link budget for flat fading channels - a case study. \* Communication link budget for ISI channels - multi-carrier (OFDM) and single-carrier (cyclic-prefixed SC techniques; impact of PA distortions in OFDM, PAPR issues, CFO estimation and correction, SFO estimation and correction. Communication link budget for MIMO wireless and spatial modulation – a case study. Visible light wireless communication

**Pre-requisites :** None

**References :** Tony J. Rappaport. Wireless Receiver Architectures and Design: Antenna, RF, Synthesizers, Mixed Signal and Digital Signal Processing. Academic Press, 2014.~Lydi Smaini. RF Analog Impairments Modeling for Communication Systems Simulation: Application to OFDM-based Transceivers. John-Wiley & Sons, 2012.~Abbas Mohammadi and Fadhel M. Ghannouchi. RF Transceiver Design for MIMO

**E3 220 ( AUG ) 3 : 0****Foundations of Nanoelectronic Devices**

Mathematical foundations of quantum mechanics, operators, bra and ket algebra, time independent and time dependent Schrodinger equation, crystal lattice and Brillouin zone, Bloch theorem, band theory of solids, tight binding, band structure examples (Si, Ge, III-V) in E-k space, effective mass, principles of operation of p-n junction (homo and hetero junction) and MOSFET, single gate versus multiple gates, bound states, effect of confinement, subbands, quantum capacitance, strain effects, tunneling, tunnel diode, intra-band and band to band tunneling in MOSFET, quantum theory of linear harmonic oscillators, phonons in solids, carrier mobility in MOSFET, quantum theory of angular momentum, electron spin.

**Pre-requisites :** None

**References :** D. J. Griffiths, Introduction of Quantum Mechanics, Prentice Hall., A. Ghatak and S. Lokanathan, Quantum Mechanics, Trinity Press., V. K. Thankappan, Quantum Mechanics, New Age. Solid State Physics, N. W. Ashcroft and N. D. Mermin., S. M. Sze, Physics of Semiconductor devices, Wiley-Interscience., Y. Taur and T. H. Ning, Fundamentals of modern VLSI devices, Cambridge University

**E7 211 ( AUG ) 2 : 1****Photonics Integrated Circuits**

Principles: Introduction to Photonics; optical waveguide theory; numerical techniques and simulation tools; photonic waveguide components – couplers, tapers, bends, gratings; electro-optic, acousto-optic, magneto-optic and non-linear optic effects; modulators, switches, polarizers, filters, resonators, optoelectronics integrated circuits; amplifiers, mux/demux, transmit receive modules; Technology: materials – glass, lithium niobate, silicon, compound semiconductors, polymers; fabrication – lithography, ion-exchange, deposition, diffusion; process and device characterization; packaging and environmental issues; Applications: photonic switch matrices; planar lightwave circuits, delay line circuits for antenna arrays, circuits for smart optical sensors; optical signal processing and computing; micro-opto-electro-mechanical systems; photonic bandgap structures; VLSI photonics

**Pre-requisites :** None

**References :** C. R. Pollock and M. Lip Son, Integrated Photonics, Kluwer Pub., 2003. ~T. Tamir, (ed), Guided-wave optoelectronics, (2nd edition), Springer-Verlag, 1990. ~H. Nishihara, M. Haruna, and T. Suhara, Optical Integrated Circuits, McGraw-Hill, 1988. ~E. J. Murphy, (Editor), Integrated Optical Circuits and Components: Design and Applications, Marcel and Dekker, 1999. ~Current literature: Special issues

**E7 221 ( JAN ) 2 : 1****Fiber-Optic Communication**

Introduction to fiber optics; light propagation. Optical fibers; modes, dispersion, low, nonlinear effects; Optical transmitters: LEDs, Semiconductor Lasers, Transmitter design; Optical receivers: Photodetectors, Receiver design, Noise, sensitivity; System design and performance: voice, video, data transmission, analog and digital systems, standards; Broadband local area optical networks and WDM systems; coherent communication systems; long distance telecommunications using optical amplifiers and solitons. Introduction to topics of current interest: all optical networks, integrated optics, MOEMS; microwave photonics. Experiments on characteristics of optical fibers, sources and detectors, analog and digital link, WDM system, tutorial on optical fiber system design, simulation of optical fiber modes.

**Srinivas Talabattula**

**Pre-requisites** : None

**References**

A. Selvarajan, S. Kar and T. Srinivas, Optical Fiber Communications, Principles and Systems, Tata – McGraw Hill

**E8 202 ( AUG ) 2 : 1****Computational Electromagnetics**

Maxwell's equations, Wave equations, scalar and vector potentials, fundamental theorems in EM Method of moments: Greens Functions; Surface equivalence principle; Electrostatic formulation; Magnetostatic formulation; Electric Field Integral Equation; Magnetic Field Integral Equation; Direct and Iterative Solvers; Finite difference time domain methods: 1D wave propagation, yee Algorithm, Numerical dispersion and stability, Perfectly matched absorbing boundary conditions, Dispersive materials. Antenna and scattering problems with FDTD, non-uniform grids, conformal grids, periodic structures, RF circuit Advanced topics in numerical electromagnetics based on recent literature About the course The course will have programming assignments (using Matlab/Fortran/C++).

**Pre-requisites** : None

**References** : A. Taflov and SC Hagness Computational Electrodynamics: The Finite Difference Time Domain Method, 3rd Ed., Artech House. ~Andrew F. Peterson, Scott L. Ray, Raj Mittra: Computational Methods for Electromagnetics, 1st Ed., IEEE Press Series on Electromagnetic Wave Theory. ~Walton C. Gibson: The Method of Moments in Electromagnetics, 1st Ed., Chapman and Hall. ~Roger F.

**E8 242 ( JAN ) 2 : 1****Radio Frequency Integrated Circuits and Systems**

Introduction to wireless systems, personal communication systems, High frequency effects in circuits and systems. Review of EM Fundamentals and Transmission line Theory, terminated transmission lines, smith chart, impedance matching, Microstrip and Coplanar waveguide implementations, microwave network analysis, ABCD parameters, S parameters. Behavior of passive IC components and networks, series and parallel RLC circuits, resonant structures using distributed transmission lines, components and interconnects at high frequencies Basics of high frequency amplifier design, biasing techniques, simultaneous tuning of 2 port circuits, noise and distortion. MEMS technologies and components for RF applications: RF MEMS switches, varactors, inductors and filters. Introduction to microwave antennas, definitions and basic principles of planar antennas. CRLH meta materials for microwave circuits and components. Course will have a Lab component involving design, fabrication and testing of some basic passive circuits and antennas with Industry Standard Softwares.

**Vinoy K J****Pre-requisites** : None

**References** : D M Pozar, Microwave Engineering, John Wiley 2003.~D M Pozar., Microwave and RF Wireless Systems. ~T H Lee, The design of CMOS Radio Frequency Integrated Circuits.~V K Varadan, K. J Vinoy, K.A Jose, RF MEMS and Their Applications.

**E8 311 ( AUG ) 2 : 1****Advanced Topics in Electromagnetics****Pre-requisites** : None**References** : None**E9 203 ( JAN ) 3 : 0****Compressed Sensing and Sparse Signal Processing**

Introduction to Compressed Sensing. Basic theory:  $l_1$  minimization, sparsity property, necessary and sufficient conditions for  $l_0 - l_1$  equivalence. Mutual coherence and the Restricted Isometry property, and their consequences. RIP and random matrices. Johnson-Lindenstrauss Lemma Stable signal recovery and the restricted eigenvalue property. Recovery algorithms and their performance guarantees. Special/advanced topics upon student request.

**Chandra R Murthy****Pre-requisites** : None

**References** : M. Elad, "Sparse and Redundant Representations", Springer, 2010.~H. Rauhut, "Compressive Sensing and Structured Random Matrices," Radon Series Comp. Appl.Math., 2011. ~R. Baranuik, M. A. Davenport, M. F. Duarte, C. Hegde, "An Introduction to Compressive Sensing," Rice University Connexions Course, 2011.

**E9 231 ( JAN ) 3 : 0****MIMO Signal Processing**

In this course, we cover the theory, algorithms, and practical considerations in multiple-antenna adaptive wireless communication systems. The topics covered will include the useful results from information theory, parameter estimation theory, array processing, and wireless communications, all specialized to the case of advanced multiple-antenna adaptive processing. We will also discuss various design issues in ad hoc networks, cognitive radio, and MAC protocols for multiple antenna systems.

**Sundar Rajan B**

**Pre-requisites :** None

**References :** Daniel W. Bliss and Siddharta Govindasamy, "Adaptive Wireless Communications: MIMO Channels and Networks," Cambridge University Press, 2013.~Xiaodong Wang and Vincent Poor, "Wireless Communication Systems: Advanced Techniques for Signal Reception," Prentice Hall Inc., 2004.

**E9 271 ( JAN ) 3 : 0****Space-Time Signal Processing and Coding**

Multiple-Input systems: Space-Time Code construction and decoding algorithms, Distributed space-time coding. Coding and signal processing for multi-way relay systems. Coding and algorithms for broadcast, multicast and interference channels. Simultaneous Wireless Information and Power Transfer (SWIPT) systems. Wireless Network Coding

**Sundar Rajan B**

**Pre-requisites :** None

**References :** A. Paulraj, R. Nabar and D. Gore. Cambridge University Press, 2003. ~Current literature

**E2 242 ( JAN ) 3 : 0****Multiuser Detection**

Direct Sequence spread spectrum, spreading sequences and their correlation functions, near-far effect in DS-CDMA, error probability for DS-CDMA on AWGN channels, Multiuser Detection – MF detector, decorrelating detector, MMSE detector. Successive interference canceller, parallel interference canceller, linear PIC. Performance analysis of multiuser detectors and interference cancellers. Low complexity multiuser detectors for MIMO systems. Multiuser/MIMO detection using belief propagation, probabilistic data association, meta-heuristics, and Markov chain Monte carlo techniques. Spatial modulation index modulation for multiuser systems.

**Chockalingam A**

**Pre-requisites :** None

**References :** S. Verdú, Multiuser Detection, Cambridge Univ. Press, 1998.~A. Chockalingam and B. Sundar Rajan, Large MIMO Systems, Cambridge Univ. Press, February 2014.~H. Wymeersch, Iterative Receiver Design, Cambridge Univ. Press, 2007. ~D. Tse and P. Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005. ~Research Papers in Journals and Conferences

**E9 208 ( AUG ) 3 : 1****Digital Video: Perception and Algorithms**

Frequency response of human visual systems, color perception, video transforms, retinal and cortical filters (center-surround responses, 3D Gabor filter banks), motion detection, optical flow algorithms (Horn Schunck, Black-Anandan, Fleet-Jepson, optical flow in the brain), block motion, supervised and unsupervised deep learning of optical flow, video compression, statistical video models (principal components, independent components, sparse coding), video quality assessment, neural radiance fields, deep generative and prediction models for videos.

**Pre-requisites** : None

**References** : A. C. Bovik, AI Bovik's Lecture Notes on Digital Video, The University of Texas at Austin, 2020M. Tekalp, Digital Video Processing, Prentice Hall, 1995

**MV 299 ( JAN ) 0 : 28****M.Tech Micro & VLSI Dissertation Project**

MTech Microelectronics and VLSI Design Dissertation Project

**Kausik Majumdar**

**Pre-requisites** : None

**References** : None

**E8 204 ( JAN ) 3 : 0****Antenna Theory and Practice**

The objectives of this course are to provide student researchers with: (a) fundamental knowledge regarding functioning of antennas, and (b) application-oriented design concepts for antenna systems. The course will have programming and design assignments using MATLAB Antenna Toolbox for understanding and visualization. Tentative Syllabus is as follows: 1. Definitions & Preliminary topics: Maxwell's Equations and Boundary conditions, Wave Equations, Infinitesimal (Hertzian) Dipoles. 2. Wire Antennas: Finite Length Dipoles from Transmission line approach, Monopoles, Inverted-F Antennas, Loop Antennas, Yagi-Uda and Log-periodic antennas. 3. Antenna Array Theory: Array factors, Linear and planar arrays, Array synthesis approaches, Microstrip patch and printed dipole arrays, Generalized Array factors using Cross-correlation Greens functions. 4. Aperture-type Antennas: Radiation from apertures, aperture distribution, horn and parabolic dish antennas. 5. Microstrip and Dielectric Antenna

**Debdeep Sarkar**

**Pre-requisites**

Presence of preliminary knowledge about vectors, coordinate

**References** : I. D. K. Cheng, Field and Wave Electromagnetics, Pearson Education Asia Ltd, Second Edition, 2006. II. C. A. Balanis, Antenna Theory - Analysis and design, John Wiley, Fourth Edition, 2016. III. W. L. Stutzman and G. A. Thiele, Antenna Theory and Design, John Wiley & Sons Inc, 1981. IV. J.D. Karus, Antennas, McGraw Hill, 1988. V. I.J. Bahl and P. Bhartia, Microstrip antennas, Artech house,



**E2 335 ( JAN ) 3 : 0****Topics in Artificial Intelligence**

The course will cover selected advances in contemporary artificial intelligence research, especially relating to data-driven decision making and control of complex, high-dimensional systems. Topics will be drawn from recent research in reinforcement learning (RL), data-driven control and computation, and other emerging areas in artificial intelligence

**Aditya Gopalan****Pre-requisites**

Random Processes or Stochastic Models and Applications or any course equivalent

**References** : Dynamic Programming and Optimal Control, D.Bertsekas; Assorted lecture notes on reinforcement learning and control

**E1 260 ( JAN ) 3 : 1****Optimization for Machine Learning and Data Science**

The main goal of this course is cover optimization techniques suitable for problems that frequently appear in the areas of data science, machine learning, communications, and signal processing. This course focusses on the computational, algorithmic, and implementation aspects of such optimization techniques. A subset of the following topics are covered. Convexity, canonical problems, gradient methods, accelerated gradient methods, stochastic gradient descent and variants, Frank-Wolfe, alternating direction method of multipliers, nonconvex and submodular optimization.

**Sundeep Prabhakar Chepuri****Pre-requisites**

**References** : 1. A. Beck, First-Order Methods in Optimization, MOS-SIAM Series on Optimization, 2017. 2. S. Bubeck, Convex Optimization: Algorithms and Complexity, Foundations and Trends in Optimization, 2015. 3. F. Bach, "Learning with Submodular Functions: A Convex Optimization Perspective", Foundations and Trends in Machine Learning, Now Publishers Inc.

**E8 304 ( AUG ) 3 : 0****Electromagnetic Metamaterials: Concepts and Applications**

- Background: General Historical perspective and idea of Metamaterials (MTMs), Dispersive model for the dielectric permittivity, Phase velocity and group velocity, Metamaterials and homogenization procedure, Metals and plasmons at optical frequencies, Wire mesh structures as low frequency plasmas, Diamagnetism in a stack of metallic cylinders, Split-ring resonator media, Media with negative permittivity and permeability: theory and properties, Origins of negative refraction and other properties.
- Spatial Metamaterials: Transmission Line Realization (Brillouin's work), Ideal Homogeneous CRLH TLs (Composite Right-Left Handed Transmission Lines), LC Network Implementation and distributed 1D CRLH Structures, Conversion from Transmission Line to constitutive Parameters, Eigenvalue Problem for 2D MTMs.
- Applications of Metamaterials: A. Microwave: Dual-band and enhanced band guided wave components, Negative and Zeroth-Order Resonators, Backfire-to-Endfire (BE) Leaky-Wave (LW) Antennas

**Pre-requisites**

**References** : 1. D. K. Cheng, Field and Wave Electromagnetics, Pearson Education Asia Ltd, Second Edition, 2006. 2. S. A. Ramakrishna and T.M.Grzegorzcyk, Physics and Applications of Negative Refractive Index Materials, CRC Press, Taylor & Francis Group and SPIE Press, 2009. 3. G. V. Eleftheriades and K. G. Balmain, Negative Refraction Metamaterials: Fundamental Principles and Applications

**E3 277 ( AUG ) 2 : 1****Introduction to Integrated Circuit (IC) Design**

1. Devices: Review of Device Characteristics, DC and Small Signal MOS I/V Characteristics, Short-channel effects and device models used in IC design, CMOS Processing and Layout. 2. Analog Circuits: CMOS CS/CG/CD Amplifiers, Cascodes, Current Mirrors, Differential Pairs. 3. Digital Circuits: MOS inverters: Static and Switching Characteristics, Combinational and Sequential MOS Logic Circuits, Low power CMOS logic circuits. 4. Important Design Concepts: Frequency Response, Noise, Feedback, Nonlinearity. 5. Larger Circuits and Sub-systems: Basic operational amplifier design, Stability and Compensation, OTAs. This course will provide hands-on exposure to industry standard VLSI design tools

**Pre-requisites** :

**References** : 1. CMOS Digital Integrated Circuits, Analysis and Design, Kan, Leblebici, Kim, McGraw Hill Education, 4th edition. 2. Analysis and Design of Analog Integrated Circuits, Gray, Hurst, Lewis, Meyer, Wiley, 5th edition. 3. Design of Analog CMOS Integrated Circuits, Razavi, McGraw Hill Education, 2nd edition.

**E2 285 ( JAN ) 1 : 2****MTech ECE Laboratory Course**

Software and hardware experiments on commercial software packages and hardware platforms in digital communications, antennas, networks, signal processing, visible light communications, advanced numerical programming, and machine learning.

**Sudhan Majhi**

**Pre-requisites** :

**References** : None

**EX 299 ( JAN ) 0 : 28****Project (MTech, Electronics and Communication)**

This is the 28-credit MTech project mandatory for all MTech (Electronics and Communication) students, starting from the 2021-23 batch.

**Navin Kashyap**

**Pre-requisites** : None

**References** : Not applicable

**E9 333 ( AUG ) 3 : 1****Advanced Deep Representation Learning**

Reference Material: 1. Understanding Machine Learning: From Theory to Algorithms, Shai Shalev-Shwartz and Shai Ben-David, Cambridge University Press 2. Murphy, Kevin P. Probabilistic Machine Learning: Advanced Topics, MIT Press, 2023 3. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep learning, MIT Press, 2016. 4. Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. Mathematics For Machine Learning. Cambridge University Press, 2020. 5. Machine Learning from Weak Supervision: An Empirical Risk Minimization Approach, By Masashi Sugiyama, Han Bao, Takashi Ishida, Nan Lu, Tomoya Sakai and Gang Niu, MIT Press 6. Deep Generative Modeling, Jakub M. Tomczak, Springer 2022 7. Semi-Supervised Learning, Olivier Chapelle, Bernhard Schölkopf and Alexander Zien, MIT Press 8. Seminal and Survey papers from Machine Learning Conferences such as ICML, Neurips, ICLR, CVPR, AISTATS etc

**Pre-requisites** : 1. A course on probability theory 2. A course on classical machine learning fundamentals 3. Moderate programming skills in Python

**References** : Recap on Fundamentals of Deep Learning: Empirical Risk Minimization, Divergence minimizations and Likelihood maximization Techniques, Deep Learning Architectures (Convolutional and Recurrent Architectures). Deep Generative Models: Introduction to Generative models, Autoregressive and invertible models, Latent variable models, Variational inference and recognition networks

**E2 210 ( JAN ) 3 : 0****Quantum Error-Correcting Codes**

This course is intended to serve as an entry into the field of quantum error-correction. The theory is developed from the basics, assuming the postulates of quantum mechanics. No background in quantum mechanics or quantum information processing will be assumed.

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Syllabus:

Basics of quantum computation: qubits, quantum states, quantum gates, measurement, density matrices, trace, partial trace; the no-cloning theorem

Quantum noise models: bit flips and phase flips, depolarizing channel, amplitude damping, phase damping

Quantum error-correction: quantum codes; the Knill-Laflamme conditions; Pauli error basis; discretization of quantum errors

Constructions: Shor's code, CSS codes, stabilizer codes, topological codes (surface codes, color codes), quantum LDPC codes; encoding/decoding circuits

Bounds: quantum Hamming bound, quantum Singleton bound, quantum Gilbert-Varshamov bound

Entanglement-assisted quantum error-correcting codes

Fault-tolerant quantum computation

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**Navin Kashyap**

**Pre-requisites**

:

**References** : - M.A. Nielsen and I.L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2010 (10th Anniversary Edition)

**E2 217 ( AUG ) 3 : 1****Machine Learning for Wireless Communication**

Introduction to Machine Learning: Overview of supervised semi-supervised and unsupervised. Wireless Communications: AI/ML-based source coding and channel coding, PAPR reduction for the OTFS and OFDM modulation scheme, Autoencoder, Classification of wireless signals, Modulation classification, and deep unfolding methods. Signal Estimation and Detection: AI/ML based Parameter estimation, STO and CFO estimation, Channel estimation, MIMO/OFDM/OTFS detectors. Interference: Interference classification and mitigation for wireless communication, Self interference cancellation for in-band full duplex radios. Spectrum sharing and resource allocation: Resource allocation, Spectrum sharing, Power allocation using reinforcement learning (RL) and deep RL

**Pre-requisites** : Basics of Machine Learning and python

**References** : 1. I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning, MIT Press, 2016. 2. R.-S. He and Z.-G. Ding, Applications of Machine Learning in Wireless Communications, IET, 2019. 3. F.-L. Luo, Machine Learning for Future Wireless Communications, Wiley-IEEE Press, 2020. 4. Y. C. Eldar, A. Goldsmith, D. Gündüz, and H. V. Poor, Machine Learning and Wireless Communications, Cambridge

## Fourier Optics

Analysis of two-dimensional signals and systems: Fourier analysis in two dimensions; Spatial frequency, space-frequency localization; Linear systems; Two-Dimensional Sampling theory; The Discrete Fourier Transform; Projective-Slice Theorem; Phase retrieval from Fourier magnitude  
 Foundations of Scalar Diffraction Theory: Historical introduction; From vector to Scalar Theory; Kirchhoff Diffraction formula; Rayleigh-Sommerfeld Diffraction formula; Generalization to Non-Monochromatic waves; Diffraction at boundaries; The angular spectrum of plane waves  
 Fresnel and Fraunhofer Diffraction: Huygens-Fresnel Principle in rectangular coordinates; Fresnel Approximation; Fraunhofer Approximation; Examples of Fresnel and Fraunhofer Diffraction patterns; Beam Optics.

Wave-Optics Analysis of Coherent Optical systems: A Thin Lens as a Phase Transformation; Fourier Transforming Properties of Lenses; Image Formation: Monochromatic Illumination; Analysis of Complex Coherent Optical Systems.

Frequency Analysis of Optical Imaging Systems: Generalized Treatment of Imaging Systems; Frequency Response for Diffraction-Limited Coherent Imaging; Frequency Response for Diffraction-Limited Incoherent Imaging; Aberrations and Their Effects on Frequency Response; Comparison of Coherent and Incoherent Imaging; Confocal Microscopy

Point-Spread Function and Transfer Function Engineering: Cubic Phase Mask for Increased Depth of Field; Rotating Point-Spread Functions for Depth Resolution; Point-Spread Function Engineering for Exoplanet Discovery; Resolution beyond the Classical Diffraction Limit; Light Field Photography.

Wavefront Modulation: Wavefront Modulation with Photographic Film; Wavefront Modulation with Diffractive Optical Elements; Liquid Crystal Spatial Light Modulators; Deformable Mirror Spatial Light Modulators; Acousto-Optic Spatial Light Modulators; Other Methods of Wavefront Modulation.

Analog Optical Information Processing: Coherent Optical Information Processing Systems; The VanderLugt Filter; The Joint Transform Correlator; Application to Character Recognition; Image Restoration; Acousto-Optic Signal Processing Systems; Discrete Analog Optical Processors

Holography: The Wavefront Reconstruction Problem; The Gabor Hologram; The Leith-Upatnieks Hologram; Image Locations and Magnification; Some Different Types of Holograms; Thick Holograms; Recording Materials; Computer-Generated Holograms; Degradations of Holographic Images; Digital Holography; Holography with Spatially Incoherent Light; Applications of Holography.

Fourier Optics in Optical Communications: Fiber Bragg Gratings; Ultrashort Pulse Shaping and Processing; Spectral Holography; Arrayed Waveguide Gratings

## Balaswamy Velpula

### Pre-requisites

None

**References** : Fourier Optics: Joseph Goodman Latest Edition

**E2 338 ( JAN ) 3 : 0****Mean Field Asymptotics and Applications**

1. Replica methods in statistics physics: Basic concepts in statistical physics, Ising models, statistical decision theory, free energy approach, concentration inequalities in mean field asymptotics, field theory calculations, replica methods, LASSO risk
2. Convergence of mean field limits: Conditions for mean-field convergence, proof using Stein's method, proof using perturbation theory
3. Approximate message passing (AMP) algorithms: Overview of algorithms for Gibbs mean estimators and LASSO, theoretical analysis of AMP, Markov random fields, Belief Propagation (BP) on trees, BP to message passing, MP to LASSO, Derivation of AMP from MP
4. Applications to scheduling, statistical learning, game theory, and control.

**Parimal Parag****Pre-requisites** :

Instructor's approval is required for crediting this course.

- References** : 1. Martin Wainwright, High-dimensional statistics: A non-asymptotic viewpoint, Cambridge University Press, 2019.  
 2. Andrea Montanari, Graphical Models Concepts in Compressed Sensing, <https://arxiv.org/abs/1011.4328>, arXiv, 2011.  
 3. Marc Mezard and Andrea Montanari, Information, Physics, and Computation, Oxford University Press, 2009.

**E2 237 ( AUG ) 3 : 0****Statistical Learning Theory**

The course provides statistical guarantees on the performance of various machine learning algorithms such as classification and regression. The upper bounds are derived from Radmacher complexity and VC dimensions and the lower bounds are derived from the information theoretic methods. We also derive high dimensional asymptotics relating decision theory to statistical physics methods. Course contents: 1.Bias complexity trade off, Rademacher complexity, VC-dimension 2.Multiclass classification, decision trees, nearest neighbours 3.Parameter estimation and nonparametric regression 4.Stochastic gradient descent 5.Statistical decision theory 6.Large-sample asymptotics 7.Mutual information method and lower bound via hypothesis testing 8.Entropic bounds for statistical estimation 9.Strong data processing inequality

**Pre-requisites** : First graduate course in probability theory or equivalent, and instructor's approval.

- References** : 1. Yury Polyanskiy and Yihong Wu, "Information Theory: From Coding to Learning", Cambridge University Press, forthcoming. 2.Yihong Wu, "Information-theoretic Methods for High-dimensional Statistics", lecture notes. <http://www.stat.yale.edu/~yw562/teaching/it-stats.pdf> 3.Martin Wainwright, "High-Dimensional Statistics", Cambridge University Press, 2019. 4.Mehryar Mohri, Afshin

**AI 299A ( JAN ) 0 : 25****Dissertation Project**

Dissertation Project

**Chetan Singh Thakur**

**Pre-requisites** : None

**References** : As suggested by project advisor

## E1 255 ( JAN ) 3 : 0

## Online Optimization and Control

Online convex optimization such as Follow the Regularized Leader and Online Mirror Descent, primal-dual perspective of online learning algorithms, agnostic learning using OCO, non-stochastic control, learning in partially observed systems, linear dynamical systems and their control, spectral state-space models.

We will cover the following topics:

1. Background in control and Reinforcement Learning and online convex optimization.
2. Policy classes for dynamical systems.
3. Online nonstochastic control.
4. Online nonstochastic control for partially observed systems.
5. Online nonstochastic system identification.
6. Learning in linear dynamical systems.
7. Spectral filtering.

## Rahul Singh

## Pre-requisites

E1 245 - Online Prediction and Learning, or instructor's permission

## References

• Elad Hazan, (2016). "Introduction to online convex optimization." Texts Foundations and Trends in Optimization, 2(3-4), 157-325.

# Electrical Engineering

## Preface

### E1 251 ( AUG ) 3 : 0

#### Linear and Nonlinear Optimization

Necessary and sufficient conditions for optima; convex analysis; unconstrained optimization; descent methods; steepest descent, Newton's method, quasi Newton methods, conjugate direction methods; constrained optimization; Kuhn-Tucker conditions, quadratic programming problems; algorithms for constrained optimization; gradient projection method, penalty and barrier function methods, linear programming, simplex methods; duality in optimization, duals of linear and quadratic programming problems

**Pre-requisites** : None

**References** : References: Luenberger D G, Introduction to Linear and Nonlinear Programming, 2nd edition, Addison Wesley, 1984.

### E9 201 ( AUG ) 3 : 0

#### Digital Signal Processing

Discrete-time signals and systems, frequency response, group delay, z-transform, convolution, discrete Fourier transform (DFT), fast Fourier transform (FFT) algorithms, discrete Cosine transform (DCT), discrete Sine transform (DST), relationship between DFT, DCT, and DST; design of FIR and IIR filters, finite word length effects, Hilbert transform, Hilbert transform relations for causal signals, Karhunen-Loève transform. Introduction to linear prediction, bandpass sampling theorem, bandpass signal representation.

**Pre-requisites** : None

**References** : References: Proakis and Manolakis, Digital Signal Processing, Prentice Hall India, Oppenheim A V, Schafer R W, Discrete-time Signal Processing, Prentice Hall, 1998, Sanjit K Mitra, Digital Signal processing : A Computer Based Approach, Tata McGraw-Hill



**E9 213 ( AUG ) 3 : 0****Time-Frequency Analysis**

Time-frequency distributions: temporal and spectral representations of signals, instantaneous frequency, Gabor's analytic signal, the Hilbert and fractional Hilbert transforms, Heisenberg's uncertainty principle, densities and characteristic functions, global averages and local averages, the short-time Fourier transform (STFT), filterbank interpretation of STFT, the Wigner distribution and its derivatives, Cohen's class of distributions (kernel method), bilinear time-frequency distributions, Wigner's theorem, multicomponent signals, instantaneous bandwidth, positive distributions satisfying the marginals, Gabor transform Spaces and bases: Hilbert space, Banach space, orthogonal bases, orthonormal bases, Riesz bases, biorthogonal bases, Frames, shift-invariant spaces, Shannon sampling theorem, B-splines. Wavelets: Wavelet transform, real wavelets, analytic wavelets, dyadic wavelet transform, wavelet bases, multi resolution analysis, two-scale equation, conjugate mirror filters, vanishing

**Pre-requisites** : None

**References** : References: Cohen L, Time Frequency Analysis, Prentice Hall, 1995, Mallat S, A Wavelet Tour of Signal Processing -, The Sparse Way, Elsevier, Third Edition, 2009.

**E9 261 ( JAN ) 3 : 1****Speech Information Processing**

Human speech communication: physiology of speech production, phonetics and phonology. speech perception and illusions. Time- domain features. Time-varying signal analysis: short-time Fourier transform, spectrogram, quasi-stationary analysis: cepstrum, linear-prediction models. Line spectral pair, Mel frequency cepstral coefficients. sinusoidal models. Principles of Speech synthesis, prosody, quality evaluation, pitch and time scale modification. Speech as a sequence of vectors: orthogonal transforms, principal component analysis, vector quantization, Gaussian mixture model and their applications. Dynamic time warping and hidden Markov models. Speaker recognition.

**Prasanta Kumar Ghosh**

**Pre-requisites** : None

**References** : Handbook of Speech Processing, Benesty, Jacob; Sondhi, M. M.; Huang, Yiteng (Eds.), Springer, 2008. Gold B, and Morgan N, Speech and Audio Signal Processing, John Wiley, 2000., Douglas O'shoughnessy, Speech Communication, IEEE Press 2000. Taylor P, Text-to-Speech Synthesis, Cambridge Univ. Press, 2009. Rabiner L R, and Schafer R W, Theory and applications of digital speech

**E1 216 ( JAN ) 3 : 1****Computer Vision**

This course will present a broad, introductory survey intended to develop familiarity with the approaches to modeling and solving problems in computer vision. Mathematical modeling and algorithmic solutions for vision tasks will be emphasised. Image formation: camera geometry, radiometry, colour. Image features: points, lines, edges, contours, texture; Shape: object geometry, stereo, shape from cues; Motion: calibration, registration, multiview geometry, optical flow; approaches to grouping and segmentation; representation and methods for object recognition. Applications;

**Srinivasa Venu Madhav Govindu**

**Pre-requisites** : None

**References** : References: David Forsyth and Jean Ponce , Computer Vision: A Modern Approach, Prentice-Hall India, 2003, Hartley R and Zisserman A, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, 2004., Current literature

**E1 222 ( AUG ) 3 : 0****Stochastic Models and Applications**

Probability spaces, conditional probability, independence, random variables, distribution functions, multiple random variables and joint distributions, moments, characteristic functions and moment generating functions, conditional expectation, sequence of random variables and convergence concepts, law of large numbers, central limit theorem, stochastic processes, Markov chains, Poisson process.

**Pre-requisites** : None

**References** : References: Ross S M, Introduction to Probability Models, (6th Edition), Academic Press and Harcourt Asia, 2000.

**E1 241 ( AUG ) 3 : 0****Dynamics of Linear Systems**

Background material on matrix algebra, differential equations. Representation of dynamic systems, equilibrium points and linearization. Natural and forced response of state equations, state space descriptions, canonical realizations. Observability and controllability, minimal realization. Linear state variable feedback, stabilization, modal controllability, Jordan form, functions of matrices, pole- placement, Lyapunov matrix equations. Asymptotic observers, compensator design, and separation principle. Preliminary quadratic regulator theory.

**Pre-requisites** : None

**References** : Joao P. Hespanha, "Linear systems theory", Princeton University Press, 2009; Panos J. Antsaklis, Anthony N. Michel, "Linear Systems", Birkhauser, 1997; Chi-Tsong Chen, "Linear System Theory and Design", Oxford University Press; Thomas Kailath, "Linear Systems", Pearson, 2016 reprint of 1980 edition; Gilbert Strang, "Linear algebra and its applications"

**E1 242 ( JAN ) 3 : 0****Nonlinear systems and control**

Equilibria and qualitative behavior, Existence and uniqueness of solutions, Lyapunov stability, invariance principle, converse theorems, ultimate boundedness, input-to-state stability, Input-output stability, small-gain theorem, passivity. Selected topics, examples and applications from: Feedback linearization, gain scheduling, sliding mode control, backstepping; Switched and hybrid systems; Applications in networked control systems and distributed control.

**Pavankumar Tallapragada**

**Pre-requisites :** None

**References :** H. K. Khalil. Nonlinear Systems. Prentice Hall, 3 edition, 2002.~S. S. Sastry. Nonlinear Systems: Analysis, Stability and Control. Number 10 in Interdisciplinary Applied Mathematics. Springer, 1999.~Mathukumalli Vidyasagar. Nonlinear systems analysis. Society for Industrial and Applied Mathematics, 2002.~E. D. Sontag. Mathematical Control Theory: Deterministic Finite Dimensional

**E3 252 ( JAN ) 3 : 1****Embedded System Design for Power Application**

Digital Signal Controller (A micro-controller with a DSP engine): Architecture and real time programming in Assembly and Embedded C. Introduction to Fixed Point Arithmetic. Field Programmable Gate Array (FPGA): Architecture and programming of digital circuits including Finite State Machines (FSM) in Verilog HDL. Communication-Chip level: AXI, Board level: SPI, I2C, System level: RS 232, CAN, MODBUS RTU on RS 485. Developing a GUI for supervisory control and monitoring. Introduction to different semiconductor memories: RAM, ROM, NVRAM etc. and their applications. Analog sensing: Anti-aliasing filter design, scaling for fixed point computation, online calibration and biasing. Continuous time feedback controller design and its discrete implementation, D/A and A/D converters, effects of sampling, modeling the Pulse Width Modulator (PWM) etc. Co-design: How to optimally implement an embedded task using a programmable processor (DSC) and a re-configurable hardware (FPGA). Embedded design of a typical Power Conversion System including: process control, protection, monitoring, feedback control etc.

**Kaushik Basu**

**Pre-requisites :** None

**References :** Brown s, and Vranesic Z, Fundamentals of Digital logic with Verilog design, Tata McGraw Hill. Mazidi, Mckinlay and Causey, PIC Micro- controllers and Embedded Systems, Pearson. Franklin G F, Powell J D and Naeini, Feedback Control of Dynamic Systems, Pearson. Erickson R W and Maksimovic D, Fundamentals of Power Electronics, Springer. Proakis J G and Manolakis D K, Digital Signal

**E4 221 ( AUG ) 2 : 1****DSP and AI Techniques in Power System Protection**

Introduction to digital relaying, signal conditioning, sampling and analog to digital conversion, real time considerations, hardware design concepts – microcontroller/DSP based, single/multiprocessor based. Relaying algorithms, software considerations. Digital protection schemes for feeders, transmission lines, generators and transformers, integrated protection scheme – a case study, New relaying principles based on AI techniques, ANN approach and Fuzzy Logic (FL) methods for fault detection and fault location. Software tools for digital simulation of relaying signals, playback simulators for testing of protective relays Laboratory Exercises – Digital techniques for the measurement of phasors, frequency and harmonics, implementation of relaying algorithms and digital protection schemes on hardware platforms. Testing of relays, transient tests based on EMTP data. Design procedures of AI based relays using software tools. Mini-projects.

**Pre-requisites** : None

**References** : References: Warrington A R, and Von C, Protective Relaying: Theory and Practice, Vol. II, Chapman and Hall, 1970.,IEEE Tutorial Course on Microprocessor Relays and Protection Systems, Power Systems Research Group,University of Saskatchewan, 1979 and 1987.,Phadke A G, and Thorp J, Computer Relaying for Power Systems, John Wiley, Inc. 1988.,IEEE Tutorial Course on Advancement

**E4 231 ( AUG ) 3 : 0****Power System Dynamics and Control**

Introduction to system dynamics, concepts of stability, modeling of generator,transmission networks, loads and control equipment, small signal stability-lowfrequency oscillations – methods of analysis for single and multi-machine systems, power system stabilizers.

**Pre-requisites** : None

**References** : References: Padiyar K R,Power System Dynamics,Stability and Control,Interline Publishing,1996.

**E4 233 ( JAN ) 3 : 0****Computer Control of Power Systems**

**Gurunath Gurrala**

**Pre-requisites** : None

**References** : None

**E4 234 ( AUG ) 3 : 0****Advanced Power Systems Analysis**

Introduction to Power System Analysis; Admittance Model of Power System Elements; Kron's Reduction; Power Flow Analysis: Gauss–Seidel, Newton Raphson, Fast Decoupled; Programming Consideration for Large Systems; Balanced and Unbalanced Radial Power Flow, AC-DC Power Flow, Harmonic Power Flow, Continuation Power Flow; Steady-State Voltage Stability; Power Flow Tracing; Loss Allocation Methods; Network Congestions; Available Transfer Capability; Contingency Analysis; Z-Bus Formulations; Fault Analysis using Z-Bus; Structure of Indian Power Systems; Indian Electricity Grid Code.

**Pre-requisites** : None

**References** : References: Kusic G L, Computer Aided Power System Analysis, CRC Press, 2nd edition, 2009., Arilaga J, and Watson N R, Computer Modelling of Electrical Power Systems, Wiley, 2005., Grainger J J, and Stevenson W D, Power System Analysis, McGraw Hill Education (India) Pvt Ltd., 2003., Wang X, Song Y and Irving M, Modern Power Systems Analysis, Springer, 2008, Arilaga J, and Watson N

**E5 201 ( JAN ) 2 : 1****Production, Measurement, and Application of High Voltage**

Generation of HV AC by cascade transformers, resonant circuit, Tesla coil; Generation of HV DC by Cockroft-Walton voltage multipliers; generation of high impulse voltages and currents, Methods of measurement of AC, DC and impulses voltages and currents, basic principles of electric breakdown in gaseous medium; basic aspects of EHV/UHV power transmission, and selected industrial applications of corona. Laboratory: Breakdown experiments on simple air-gaps, Chubb-Fortescue method of AC voltage measurement, Surface discharge demonstration, experiments on insulator strings including pollution flashover, measurement of high impulse voltage, Demonstration of space charge repulsion effect, radio-interference-voltage measurement, Demonstration of Impulse current heating effect.

**Subba Reddy Basappa , Rajanikanth B S**

**Pre-requisites** : None

**References** : References: Kuffel E~Zaengl W S~Kuffel J~High Voltage Engineering- Fundamentals~Newnes

**E5 206 ( AUG ) 3 : 0****HV Power Apparatus**

HV power transformers, equivalent circuit, surge phenomenon, standing and traveling wave theory, ladder network representation, short circuit forces, impulse testing, diagnostics and condition monitoring of transformers, natural frequencies and its measurement, modern techniques. Introduction to HV switching devices, electric arcs, short circuit currents, TRV, CB types, air, oil and SF6 CB, short circuit testing.

**Pre-requisites** : None

**References** : References: Bernard Hochart, Power Transformer Handbook, Butterworth, 1987., The J & P Transformer Book, 12th Edn, MJ Heathcote, Newnes, 1998. Transformers, Bharat Heavy Electricals Limited, Tata McGraw Hill, 2001., Blume L F, and Boya Jian, Transformer Engineering, John Wiley and Sons, 1951. Garzon R D, HV Circuit Breakers – Design and Applications, Marcel and Dekker

**E5 209 ( JAN ) 3 : 0****Over voltages in Power Systems**

Transient phenomena on transmission lines, methods of analysis and calculation, use of PSPICE, principle of EMTP lightning discharges, origin and characteristics of lightning and switching overvoltages, behaviour of apparatus and line insulation under overvoltages. Protection of Apparatus against Overvoltages, Surge arresters, VFTO in GIS, insulation co-ordination.

**Satish L****Pre-requisites** : None**References** : References: Ragaller K (ed.), Surges in High Voltage Networks, Plenum Press, 1980.**E5 212 ( JAN ) 3 : 0****Computational Methods for Electrostatics**

Laplace's and Poisson's equations in insulation design, transient fields due to finite conductivity, method of images, images in two-layer soil, numerical methods, finite difference, finite element and charge simulation methods tutorials and demonstration on PC. Programming assignments.

**Udaya Kumar****Pre-requisites** : None**References** : References: Sadiku M N O, Numerical Techniques in Electromagnetics, Second Edn, CRC Press., Weber E, Electromagnetic Fields, Dover, 1951. Silvester P P and Ferrari R L, Finite Elements for Electrical Engineers, Cambridge University Press, 1996., Selected journal papers.**E5 213 ( AUG ) 3 : 0****EHV/UHV Power Transmission Engineering****Pre-requisites** : None**References** : None

**E5 215 ( JAN ) 2 : 1****Pulsed Power Engineering****Joy Thomas M****Pre-requisites** : None**References** : None**E6 201 ( AUG ) 3 : 1****Power Electronics**

Power switching devices: diode, BJT, MOSFET, IGBT; internal structure, modeling parameters, forward characteristics and switching characteristics of power devices; control and protection of power switching devices; electromagnetic elements and their design; choppers for dc to dc power conversion; single and multi-quadrant operation of choppers; chopper controlled dc drives; closed loop control of dc drives. Hands-on exercises: soldering and desoldering practice, pulse generator circuit, inductor design and fabrication, thermal resistance of heat sink, switching characteristics of MOSFET, dc-dc buck converter, CCM and DCM operation, linear power supply, output voltage feedback for over current protection, dc-dc boost converter, measurement of small-signal transfer functions, closed loop control of boost converter.

**Pre-requisites** : None**References**

References: Mohan, N., Power Electronics; Principles, Analysis and Design, John Wiley, 1989., Robert Ericson, Fundamentals of Power Electronics,

**E6 211 ( JAN ) 3 : 0****Electric Drives**

Closed loop control of DC drives. Static inverters-Voltage source inverters, inverter control; six step and pulse width modulated operation, AC motor operation from inverters. Voltage source drives, closed loop control of AC drives.

**Samir Hazra****Pre-requisites** : None

**References** : References: Ranganathan V T, Electric Drives, Course Notes, IISc, 2005- 06, Fitzgerald A E , Kingsley C Jr. and Umans S D, Electric Machinery, Tata McGraw Hill, 2003. Leonhard W., Control of Electrical Drives, 3rd Edition, Springer, Miller T J E, Brushless Permanent-Magnet and Reluctance Motor Drives, Oxford Science Publications, 1989 Krishnan R, Permanent-Magnet-Synchronous and

**E6 221 ( JAN ) 3 : 1****Switched Mode Power Conversion**

Switched mode power supplies (SMPS): Non-isolated dc-dc converter topologies: continuous conduction mode (CCM) and discontinuous conduction mode (DCM) analysis; non-idealities in the SMPS. Modeling and control of SMPS, duty cycle and current model control, canonical model of the converter under CCM and DCM. Extra element theorem, input filter design. Isolated dc-dc converters: flyback, forward, push-pull, half bridge and full bridge topologies. High frequency output stage in SMPS: voltage doubler and current doubler output rectifiers. Power semiconductor devices for SMPS: static and switching characteristics, power loss evaluation, turn-on and turn-off snubber design. Resonant SMPS: load resonant converters, quasi resonant converters and resonant transition converters. Laboratory exercises on : Opamp circuits for current and voltage sensing in converters, differential amplifiers for sensing in presence of common mode signals, higher order opamp filters, phase shifters, and pulse width modulators, comparator circuits, efficiency modeling and prediction in dc-dc converters, dynamic response and compensator design for dc-dc converters.

**Vinod John , Tapas Roy****Pre-requisites** : None

**References** : References: Robert Ericson, Fundamentals of Power Electronics, Chapman & Hall, 2004., Ramanarayanan V., Switched Mode Power Conversion, 2007 Umanand L, Power Electronics: Essentials and Applications, Wiley India, 2009., Jayant Baliga B, Power Semiconductor Devices, PWS 1996.

**E6 223 ( AUG ) 3 : 0****PWM Converters and Applications**

AC/DC and DC/AC power conversion. Overview of applications of voltage source converters, pulse modulation techniques for 1-phase and 3-phase bridges; bus clamping PWM, space vector based PWM, advanced PWM techniques, practical devices in converter. Calculation of switching and conduction losses. Compensation for dead time and DC voltage regulation; dynamic model of a PWM converter, multilevel converters; constant V/F induction motor drives; estimation of current ripple and torque ripple in inverter fed drives. Line-side converters with power factor compensation.

**Pre-requisites** : None

**References** : References: Mohan, Undeland and Robbins; Power Electronics; Converters, Applications and Design, John Wiley and Sons, 1989., Erickson R W, Fundamentals of Power Electronics, Chapman and Hall, 1997., Vithyathil J, Power Electronics: Principles and Applications; McGraw Hill, 1995. Current Literature.



**E6 224 ( AUG ) 3 : 0****Topics in Power Electronics and Distributed Generation**

Introduction to distribution systems, fault calculations, fault contribution and protection coordination with Distributed Generation (DG), intentional and unintentional islanding, impact on distribution system voltage profile, relaying requirements for DG systems. Power converters for grid interconnection and micro-source-side power converter topologies, inverter modeling, component selection, design for efficiency and reliability, grounding and filtering requirements. Power converter design trade-off considering efficiency and reliability. Control requirements for DG, phase locking, current control, DC bus control, power quality, unbalance, harmonics, surges, voltage and frequency windows.

**Pre-requisites :** None

**References :** V. Ramanarayanan, Switched Mode Power Conversion, 2010. ~Arthur R, Bergen, Vittal, Power Systems Analysis (2nd Ed) Prentice Hall, 1999. ~Ned Mohan, Tore M, Undeland, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley 2002. ~IEEE papers and standards, datasheets, current literature.

**E6 225 ( AUG ) 3 : 0****Advanced Power Electronics**

Rectifiers: Line commutated, unidirectional power factor correction (PFC), bi-directional, rectifiers with isolation. AC to AC power converters: Matrix converters, Multistage conversion: voltage link and current link topology, High frequency link converters. DC to DC converters: Dual active bridge, Resonant converters. Inverters: Multilevel, Inverters for open ended load configurations, Resonant inverters. High frequency magnetics: Modeling and loss estimation, Inductor and transformer design. Thermal design. Emerging power semi-conductor devices.

**Pre-requisites :** None

**References :** Ned Mohan, Tore M Undeland, William P Robbins, Power Electronics: Converters, Applications and Design, Wiley, Third Edition 2007., Erickson R W and Maksimovic D, Fundamentals of Power Electronics, Springer, Second Edition 2005., Umanand L, Power Electronics and Essentials, Wiley, 2009., Ramanarayanan V, Switched Mode Power Conversion, Course Notes, IISc, 2004. Current

**E6 226 ( JAN ) 3 : 0****Switched Reluctance Machines and Drives**

Review of magnetic circuits, energy stored in a magnetic circuit, magnetic circuits with a moving / rotating element in the air gap, force / torque as a partial derivative of stored energy with respect to linear / angular position of the moving / rotating element, effect of magnetic saturation. Constructional features of switched reluctance machines, doubly salient structure, examples of 6/4 and 8/6 machines, basic operating principle, study of motor behaviour from stator terminals, current response to fixed stator voltage with rotor blocked, static flux-linkage characteristics, static torque characteristics, inductance profile at low currents, total and incremental inductances, motoring and generating based on inductance profile, motoring and generating based on flux-linkage characteristics, back-emf response to constant current injection at constant rotor speed, back-emf characteristics. DC-DC converters, asymmetric and symmetric H-bridge converters; current control of DC-DC converters with passive and active loads; current control of DC-AC converters with passive loads, loads with sinusoidal back emf, and loads with non-sinusoidal back emf. Current control of switched reluctance machine, square wave current reference for motoring and generating, current tracking, hysteresis control or delta modulation, PWM control, PI based current control, linearization of nonlinear plant for controller design, equilibrium points for linearization, frequency responses of linearized models, selection of controller parameters, back-emf estimation, back-emf compensation. Phase current, phase torque and total torque; average torque, torque pulsations, current reference waveshapes to reduce torque pulsation; structure for torque control and speed control; torque reference and torque controller design; speed controller design. Reference: T.J.E Miller, "Switched reluctance motors and their control", Magna Physics Publishing, Oxford Science Publications, 1993 T.J.E. Miller, "Electronic control of switched reluctance machines," Newnes Power Engineering Series, 2001 K. Venkataratnam, "Special electric machines," Orient Black Swan, 2008 Krishnan Ramu, "Switched reluctance motor drives: modeling, simulation, analysis, design and application," CRC Press, 2001 Recent research publications

**Narayanan G**

**Pre-requisites** : None

**References** : None

**E8 201 ( AUG ) 3 : 0****Electromagnetism**

Review of basic electrostatics, dielectrics and boundary conditions, systems of charges and conductors, Green's reciprocity theorem, elastance and capacitance co-efficient, energy and forces, electric field due to steady currents, introduction to magnetostatics, vector potential, phenomena of induction, self and mutual inductance, time-varying fields, Maxwell's equations.

**Pre-requisites** : None

**References** : References: Kraus J D, Electromagnetics, McGraw Hill International., Jeans J H, The Mathematical Theory of Electricity and Magnetism, Cambridge University Press., Smythe W R, Static and Dynamic Electricity, McGraw Hill Book Company, New York.

**E9 205 ( JAN ) 3 : 1****Machine Learning for Signal Processing**

Introduction to real world signals - text, speech, image, video. Feature extraction and front-end signal processing - information rich representations, robustness to noise and artifacts, signal enhancement. Basics of pattern recognition, Generative modeling - Gaussian and mixture Gaussian models, hidden Markov models, factor analysis and latent variable models. Discriminative modeling - support vector machines, neural networks and back propagation. Introduction to deep learning - convolutional and recurrent networks, pre-training and practical considerations in deep learning, understanding deep networks. Clustering methods and decision trees. Decoding time sequences with finite state networks. Feature and model adaptation methods. Feature selection methods. Applications in computer vision and speech recognition.

**Sriram Ganapathy**

**Pre-requisites :** None

**References :** "Pattern Recognition and Machine Learning", C.M. Bishop, 2nd Edition, Springer, 2011. ~ "Neural Networks", C.M. Bishop, Oxford Press, 1995. ~ "Deep Learning", I. Goodfellow, Y. Bengio, A. Courville, MIT Press, 2016.

**E9 245 ( AUG ) 3 : 1****Selected Topics in Computer Vision**

This course will develop the use of multiview geometry in computer vision. A theoretical basis and estimation principles for multiview geometry, dense stereo estimation and three-dimensional shape registration will be developed. The use of these ideas for building real-world solutions will be emphasised. Topics Stereo estimation: current methods in depth estimation 3D registration: ICP and other approaches Multiple view geometry: projective geometry. Multilinear relationships in images, estimation.

**Pre-requisites :** None

**References :** None

**E9 246 ( JAN ) 3 : 1****Advanced Image Processing**

Image Features - Scale Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF), Generalized Hough Transform, Texture features, Evaluation  
 Deep Learning of image features - Convolution layers, fully connected layers, back propagation, non-linear activation, batch normalization, network architectures  
 Image Segmentation - Graph-based techniques, Active Shape Models, Active Appearance Models, deep learning based segmentation  
 Image Restoration - Image denoising using statistical priors, order statistics based filters, deep learning methods, deblurring and sharpening, defogging, low light image enhancement  
 Image Compression - Entropy coding, lossless JPEG, quantization, DCT, JPEG  
 Object detection – RCNN and its improved variants like Fast-RCNN, Faster RCNN, SSD  
 Instance Segmentation - Mask-RCNN  
 Image Quality - Natural scene statistics, quality assessment based on structural and statistical approaches, blind quality assessment  
 Generative Models- Generative adversarial networks, variational auto encoders, style transfer, cycle GAN, diffusion models.  
 Vision Transformers

**Soma Biswas , Rajiv Soundararajan**

**Pre-requisites** : None

**References** : David A. Forsyth and Jean Ponce, Computer Vision: A Modern Approach, Pearson Education, 2003, Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010. Simon J.D. Prince,

**SP 299 ( JAN ) 0 : 28****Dissertation Project****Chandra Sekhar Seelamantula**

**Pre-requisites** : None

**References** : None

**E1 246 ( AUG ) 3 : 0****Topics in Networked and Distributed Control**

Core topics: Relevant background topics in control; Estimation and control under communication constraints such as sampling, quantization, packet losses; data rate limited control; Consensus, synchronization, coverage control, multi-agent systems. Selected topics from: Event triggered control, connectivity maintenance, distributed estimation, distributed optimization, distributed hypothesis testing, privacy and security in networked and distributed control systems, social networks, opinion dynamics, epidemic spread, applications in robotics and transportation.

**Pre-requisites** : None

**References** : 1.Bemporad, Alberto, Maurice Heemels, and Mikael Johansson. "Networked control systems". Vol. 406. London: Springer,2010. 2.Yüksel, Serdar, and Tamer Basar. "Stochastic networked control systems: Stabilization and optimization under information constraints". Springer Science & Business Media, 2013. 3.Mesbahi,Mehran, and Magnus Egerstedt. "Graph theoretic methods

**E9 241 ( AUG ) 2 : 1****Digital Image Processing**

Image formation and representation, image histograms, binarization and thresholding, binary morphology, point operations, histogram equalization and matching, spatial filters, 2D Fourier transform, discrete space Fourier transform, discrete Fourier transform, sampling theorem, linear and circular convolution, Wiener filter for restoration, order statistic filters, bilateral filter, image downsampling and upsampling, edge detection, Hough transform, Harris corner detection, scale invariant feature transform, bag of words model, deep learning of image features.

**Pre-requisites** : None

**References** : R. C. Gonzalez and R. E. Woods , Digital image processing, Prentice Hall,2008~Richard Szeliski, Computer Vision: Algorithms and Applications, Springer,2010~A K Jain , Fundamentals of digital image processing, Prentice Hall,1989~A. C. Bovik, AI Bovik's Lecture Notes on Digital Image Processing, The University of Texas at Austin, 2019~David A. Forsyth and Jean Ponce, Computer

**EE 299 ( JAN ) 0 : 24****Project**

MTech EE Project

**Subba Reddy Basappa**

**Pre-requisites** : None

**References** : None

**E0 350 ( JAN ) 3 : 1****Advanced Convex Optimization**

Along with smooth convex analysis, a large part of the course will focus on nonsmooth convex analysis and particularly on subdifferential calculus. A novelty of the course would be to understand the connection between monotone operator theory and convex optimization, and how this can be used to analyze many commonly used iterative algorithms for smooth and nonsmooth optimization. There will be a project component wherein the students would be asked to apply these tools to various engineering problems. Syllabus: convex sets and functions, characterizations of convexity, topological properties, separation theorems, nonsmooth optimization (optimality conditions, constrained optimization, KKT condition), subdifferential calculus (existence, relation to gradient, sum rule, composition rule), proximal operator and Moreau's theorem, first-order algorithms for smooth optimization (gradient descent, projected gradient descent, proximal gradient method, stochastic gradient descent), monotone

**Kunal Narayan Chaudhury****Pre-requisites**

Linear algebra, differential, and multivariate calculus.

**References** : 1. L. Berkovitz, Convexity and Optimization in  $\mathbb{R}^n$ , John Wiley & Sons, 2003. 2. T. Rockafellar, Convex Analysis, Princeton University Press, 2015. 3. Y. Nesterov, Lectures on Convex Optimization, Springer, 2018. 4. E. Ryu and S. Boyd, Primer on Monotone Operator Methods, Appl. Computational Math 15.1: 3-43, 2016. 5. H. Bauschke and P. Combettes, Convex Analysis and Monotone

**E0 298 ( AUG ) 3 : 1****Linear Algebra and Its Applications**

[A] Theory: Solution of linear equations, vector space, linear transformations, matrix representation, inner products and norms, orthogonality, trace and determinant, eigenvalue decomposition, symmetric (Hermitian) matrices and quadratic forms, singular value decomposition. [B] Applications: linear regression and normal equation, linearly constrained optimization, optimal subspace and low-rank approximations, dynamical systems, Markov chains, closest orthogonal transform, graph Laplacian and connectivity

**Pre-requisites** : none.

**References** : [1] S. Axler, Linear Algebra Done Right, Springer, 2015. [2] C. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2000.

**E9 222 ( JAN ) 0 : 3****Signal Processing in Practice**

1. Introduction to Python, Matlab, Latex
2. Effective technical communication, content generation for reports
3. Discrete Fourier transform, cosine transform, Karhunen-Loeve transform
4. Noise types and their power spectra
5. Speech denoising using transform-domain processing
6. Short-time Fourier transform
7. Sampling
8. Linear prediction/autoregressive modeling
9. Basics of 5G and experiments using a network simulator (orthogonal frequency division multiplexing)
10. Image denoising and enhancement, edge-aware filtering, convolutional neural networks for image classification
11. Exercises on image processing and optimization for image recovery
12. Exercises on array signal processing, graph signal processing
13. Exercises on machine learning for a speech/image processing application

**Chandra Sekhar Seelamantula****Pre-requisites** :

**References** : Lab Manual that will be prepared by the M.Tech.(SP) Program Curriculum Committee specifically for this course.

In addition, the instructors will suggest selected reading material from the following references:

**E1 248 ( JAN ) 3 : 0****Sliding mode control and its applications**

Module 1: Preliminaries–  
 1. A brief introduction to state space representation  
 2. Controllability and observability  
 3. Fundamentals of nonlinear systems, linearization of nonlinear systems with examples  
 4. Stability analysis tool: Lyapunov's stability theorem, Lyapunov based control design

Module 2: Sliding mode control–  
 1. Theory of conventional sliding mode: Filippov theory, reaching laws, finite-time stability, equivalent control method, advantages of sliding mode control  
 2. Introduction to second order sliding mode: relative degree, twisting algorithm, super twisting algorithm (as controller, differentiator, and observer)  
 3. Higher order sliding mode (as continuous controller and differentiator)  
 4. Terminal sliding mode control: fast terminal sliding mode control, non singular terminal sliding mode, prescribed convergence law  
 5. Integral sliding mode control  
 6. Discrete-time sliding mode control: Gao's reaching law, Bartoszewicz's reaching law

Module 3: Applications– Inverted pendulum, power convertors and power systems, quadrotors, etc. These will be covered as a part of the course project.

Module 4: Optional topics : sliding mode observers, multi-rate output feedback based control.

**Kiran Kumari**

**Pre-requisites** :

**References** : 1. Sliding mode control and observation (Vol. 10. New York: Springer) by Yuri Shtessel, Christopher Edwards, Leonid Fridman, and Arie Levant, 2014.  
 2. Applications of sliding mode control (Vol. 79. Springer Singapore) by Derbel, Nabil, Jawhar Ghommam, and Quanmin Zhu, 2017.

**E6 228 ( AUG ) 3 : 0****Grid Integration of Inverter-Based Energy Sources**

Synchronous Generator operation, modeling and control, transient behavior modeling; short-circuit and symmetrical components. Three-phase two-level voltage source inverter (VSI), L-C-L filter design, sine and space vector PWM, common-mode voltage and current. Current-controlled grid following inverter, phase-locked loop (PLL), inverter modeling for current control; proportional-resonant controller, synchronous reference frame (d-q) control. Energy sources control, battery – P-Q control, PV – P-Q control, Active front end(AFE)–dc voltage and Q control; startup sequence and protection features of the inverter; LVRT and HVRT. Modeling of grid-connected inverter including PLL dynamics, Stability of operation at higher grid impedance. Voltage-controlled grid-forming model and control, voltage and frequency control; P-Q droop control. Utility-scale battery energy storage system (BESS), inertia and impedance of the power network; inertia emulation

**Pre-requisites** : E6 201 Power Electronics or E6 202 Design of power convertors or E3 252 Embedded System Design for Power Applications or E6 221 Switched Mode Power Conversion

**References** : (a) Grid Converters for Photovoltaic and Wind Power Systems, Remus Teodorescu; Marco Liserre; Pedro Rodriguez (b) Dynamics and Control of Electric Transmission and Microgrids, K. R. Padiyar, Anil M. Kulkarni



**E1 225 ( JAN ) 3 : 0****Introduction to Causality Models**

Intuitive notions of cause and effect, Correlation versus causation, basic ideas behind causation, observational versus interventional distributions, Simpson paradox and causality, basics of Structural Causal Models (SCMs), Review of probability and conditional independence, directed graphical models for capturing independences, Bayesian networks, d-separation, local and global Markov properties in Bayesian networks, Causal Bayesian networks and SCMs, causal minimality and faithfulness in Bayesian networks, inferring causal effects, valid adjustment sets and the back-door adjustment formula, the front-door adjustment formula, Pearl's do-calculus, identification criterion for causal effects, direct and indirect effects, analysis of counterfactual statements with SCM models, learning causal graphical models from data, methods based on checking for independence and methods based on likelihood scores, issues in learning causal models with latent variables.

**Subbayya Sastry P****Pre-requisites**

The students should have done a basic course on probability theory  
**References** : Judea Pearl, Causality: Models, Reasoning and Inference, 2nd edition, Cambridge University Press, 2009

J Peters, D. Janzing and B. Scholkopf, Elements of Causal Inference: Foundations and Learning Algorithms, MIT Press, 2017

**E1 250 ( AUG ) 3 : 0****Mathematics for Electric Power Engineers**

Solving linear equations, row-reduced echelon form and Gauss elimination. Vector space, linear independence, basis, dimension, rank nullity theorem, orthogonality, the four fundamental subspaces, positive definiteness, singular value decomposition, pseudo inverse. Linear programming, simplex method, duality. Linear dynamical systems, eigen decomposition and Jordan form. Stability. Numerical solution of algebraic, root-finding algorithms such as Newton's method. Unconstrained nonlinear optimization, first and second-order necessary conditions, steepest descent, and Newton's algorithm. Constrained optimization, necessary conditions, Lagrange multipliers. Penalty, barrier, and constrained steepest descent algorithms. Sequential linear programming and quadratic programming. Nonlinear dynamical systems, existence and uniqueness of solutions, stability of equilibrium points-Lyapunov's method, gradient and Hamiltonian systems, limit cycles: Poincaré Bendixson theorem. Numerical solution of differential equations, Euler and Runge-Kutta methods. Accuracy, stability, and convergence time

**Pre-requisites** : BTech Engineering Mathematics.

**References** : 1. Linear Algebra and Its Applications by Gilbert Strang. 2. Applied Linear Algebra by Peter J Oliver and, Chehrzad Shakiban. 3. Linear and Nonlinear Programming by David G Luenberger and, Yinyu Ye. 4. Differential Equations, Dynamical Systems, and an Introduction to Chaos by Morris W. Hirsch, Stephen Smale and, Robert L. Devaney. 5. Introductory Methods of Numerical Analysis by SS

**E4 239 ( JAN ) 2 : 1****Multi-converter Power System Analysis**

Overview of wind and solar generations; Grid Connection requirements for large scale Solar and Wind Farms including IEEE 2800 Standard; Basic principles of grid following and grid forming converters with LVRT, HVRT, negative sequence controls; Power Plant Controllers for Solar and Wind Farms; Load flow study in multi-converter power systems; Fault models of grid following and grid forming converters; Short circuit study with multiple converters; Modelling of grid following and grid forming converters for harmonic study; Harmonic analysis in presence of multiple converters; Modelling grid following and grid forming inverters for small signal and transient stability studies; Linear and non-linear stability assessment in presence of multiple converters; Sub-synchronous oscillations in presence of converters; Oscillation source identifications; Simulation assignments on grid following and grid forming inverter modelling for short circuit analysis, stability assessment, harmonic analysis, sub-synchronous oscillations and power flow study will be given as part of the laboratory work. There will be software simulation laboratory every week for 3 hours.

**Sarasij Das****Pre-requisites**

E4 234: Advanced Power System Analysis

**References** : - "Grid converters for photovoltaic and wind power systems". Teodorescu, Remus, Marco Liserre, and Pedro Rodriguez. John Wiley & Sons, 2011.

# Electronic Systems Engineering

## Preface

### E0 284 ( AUG ) 2 : 1

#### Digital VLSI Circuits

Introduction to MOS transistor theory, Circuit characterization & simulation, theory of logical effort, interconnect design and analysis combinational circuit design, sequential circuit design. Design methodology & tools, testing & verification, datapath subsystems, array subsystems, power and clock distribution, introduction to packaging.

**Pre-requisites** : None

**References** : N. Weste and D. Harris, CMOS VLSI Design. A Circuits and Systems Perspective, Addison Wesley, 2005~J. M. Rabaey, A. Chandrakasan, and B. Nikolic, Digital Integrated Circuits~Current literature

### E2 232 ( AUG ) 2 : 1

#### TCP/IP Networking

IP addressing, IP header; subnetting and supernetting, CIDR, routing table, Ethernet, ARP; Serial links, PPP, ICMP, UDP, TCP: header, connection establishment, ISN, half close, delayed acks, header flags, TCP state transitions, sliding window, Slow Start, Congestion Avoidance, Fast Retransmit, Fast Recovery; DNS; multicasting, IGMP; IEEE 802.11 wireless LANs; Bridges, L2 switches, Spanning Tree algorithm, VLANs; Mobile IP; Private IP; NAT; DHCP; http; routing protocols: RIP, OSPF, BGP; IPv6

**Pre-requisites** : None

**References** : W. Richard Stevens, TCP/IP Illustrated, Vol I: The Protocols, Pearson Education Asia, 2000

### E2 243 ( AUG ) 2 : 1

#### Mathematics for Electrical Engineers

Analysis: The Real Number System, Euclidean Spaces, Metric Spaces, Closed and open sets, Numerical sequences and series, Limits, Continuity. Probability Theory: The axioms of probability theory, Independence and conditional probability, Random variables and their distribution, Expectation, Conditional distribution, Convergence of sequences of random variables, Laws of large numbers and Central limit theorem. Linear Algebra: Vector Spaces, Subspaces, Linear independence, Basis and dimension, Orthogonality; Matrices, Determinants, Eigenvalues and Eigenvectors, Positive definite matrices, Singular Value Decomposition.

**Pre-requisites** : None

**References** : Rudin, W., Principles of Mathematical Analysis, McGraw-Hill, 1985~Strang G., Linear Algebra and Applications, Thomson Brooks/Cole, 4th Edition, 2006~D. P. Bertsekas, J. N. Tsitsiklis, Introduction to Probability, Athena Scientific Press, 2nd Edition, 2008

**E3 200 ( AUG ) 1 : 2****Microelectronics Lab**

1. Device TCAD and Device Design Basics using TCAD: Device TCAD Models, Device Simulation Approach, Design of CMOS (nMOS/pMOS) devices using TCAD device simulations, Design of FinFET using device simulations, Analysis of Physical Parameters and Device Physics using TCAD, Parameter extraction from simulation results 2. CMOS Process Technology, Process Development, Integration and Simulation: Processing Steps - Lithography, Etching, Dopant Implantation, Material Deposition, Thermal annealing / Dopant Diffusion and Backend Metallization. TCAD Process simulation - Unit process simulation, process calibration, process integration, simulation of basic CMOS devices. TCAD simulation of standard cell library element, Advance CMOS device design, process simulation and process integration, Basics of 3D process simulation, Layout design for test chips development, Details of Mask writing and device fabrication 3. Semiconductor Device Characterization: Non-destructive and destructive characterization

**Pre-requisites** : None

**References** : None

**E3 204 ( JAN ) 3 : 0****Fundamentals of MOS Analog Integrated Circuits**

Introduction to enhancement mode MOSFETs: MOS capacitor, CV characteristics, MOSFET – Device Physics of the MOSFET, Current voltage characteristics, Linear and saturation operation, MOSFET - Small Signal analysis techniques: transconductance, output impedance due to channel length modulation, small signal resistance, small signal circuit of MOSFETs, MOSFET as a Switch: Operation as a Switch, Switch-capacitor circuits- Dynamics, Time constants, Parasitics - clock feedthrough and charge injection, Charge sharing between capacitors Single Stage MOS Voltage Amplifiers: Voltage amplifiers: Single stage Topologies: Common source, common source with degeneration, common gate, common drain, cascode. CMOS technology and CMOS amplifiers, Small Signal, Low frequency analysis of MOS Single Stage voltage amplifiers, Small Signal, High frequency analysis of MOS Single Stage voltage amplifiers: Miller effect, transit frequency, dominant pole MOS Differential amplifiers: Concept and operation of Differential Amplifiers, Analysis of MOS differential amplifiers: Differential gain, Common mode gain, CMRR, Half circuit method Biasing Circuits: 2 MOSFET Current mirror, Impact of channel length modulation, Cascode current mirror, Self Biasing Circuits, Differential Amplifiers with Active Loads Frequency Response: Transfer function Poles, Zeros, Bode Plots, Stability of Systems, Frequency response of amplifiers, Miller Effect, Transit frequency of the MOSFET Noise: Noise in circuits: Characterization of Noise, Noise spectrum, Types of Noise: thermal noise, flicker noise, shot noise and their noise spectrum, Noise in RC circuits, Noise in MOSFETs: Corner frequency, analysis of noise in MOS voltage amplifiers, calculations of output and input referred noise in MOS circuits, Signal to noise ratio, Effective Noise Bandwidth Feedback: Concepts of Feedback, Analytical methods to calculate loop gain, closed loop gain, Feedback in circuits Operational Amplifiers: OPAMP architectures – Telescopic Cascode, Folded Cascode, Two Stage OPAMPs, Gain Boosted OPAMPs, Stability of OPAMPs - Dominant Pole Compensation, Miller Compensation, Power Supply Rejection Ratio, Slew Rate. System Design: Problem solving and Analysis at the System level – eg. Image sensors, displays, biomedical applications. New technologies: Thin film transistors and Vacuum transistors. Device level challenges and impact on circuit design. Approach to circuit design and impact on system performance.

**Sanjiv Sambandan**

**Pre-requisites** : None

**References** : Design of CMOS Analog Integrated Circuits, B. Razavi, Mc Graw Hill - Analysis and Design of Integrated Circuits, Gray, Hurst, Lewis, Meyer - Research Papers

**E3 230 ( JAN ) 2 : 1****Essential Circuits for System Design****Umanand L****Pre-requisites** : None**References** : None**E3 231 ( JAN ) 2 : 1****Digital Systems Design with FPGAs**

Introduction to Digital design; Hierarchical design, controller (FSM), case study, FSM issues, timing issues, pipelining, resource sharing, metastability, synchronization, MTBF Analysis, setup/hold time of various types of flip-flops, synchronization between multiple clock domains, reset recovery, proper resets. Verilog: different models, simulation cycles, process, concurrent and sequential statements, loops, delay models, library, packages, functions, procedures, coding for synthesis, test bench. FPGA: logic block and routing architecture, design methodology, special resources, Artix - 7 architecture, programming FPGA, constraints, STA, timing closure, case study.

**Debayan Das****Pre-requisites** : None**References** : Digital Design: Principles and Practices By J.F. Wakerly**E3 235 ( AUG ) 2 : 1****Design for Analog Circuits**

Op-amp circuits: single-stage & multi-stage amplifiers; differential & instrumentation amplifiers; FB-topologies; i-v, v-i & impedance converters; current amplifier; Error budgeting: static and dynamic errors in op-amp circuits; Power supplies: precision rectifiers; voltage regulators & protection circuits; Active filters: LPF, HPF, BPF, BRF & APF; 1-pole, 2-pole and Butterworth; Instability: GM, PM, dominant-pole, pole-zero & roc compensation; Nonlinear circuits: hysteresis, schmitt-triggers & exponential circuits; Oscillators: relaxation/phase-shift/wien-bridge/voltage controlled oscillators; waveform generators; Practical designing: sensor amplifiers & damping; AGCs & compressor circuits; ADCs and DACs; photo-resistor & opto-coupler circuits; temperature indicators & PID-controllers; 4-20ma transmitters; ELF/VLF receivers. Lab exercises: understanding datasheets; circuit simulation using LTspice;

**Pre-requisites** : None**References** : Sergio Franco: "Design With Operational Amplifiers and Analog Integrated Circuits" McGraw-Hill Series; Peter D. Hiscocks: "Analog Circuit Design"; Online articles on: "Circuit Simulation with LTSpice"

**E3 245 ( AUG ) 2 : 1****Processor System Design**

Introduction: Basic Processor Architecture, Instruction Set Design, Datapath and Controller, Timing, Pipelining. CISC Processor Design: Architecture, Design. RISC Processor Design: single cycle implementation, multi cycle implementation, pipelined implementation, exception and hazards handling, RISC-V. Memory Hierarchy: Cache, Paging, TLB. Bus: Bus Topologies, AXI, PCIe, Bus Bridges, BFM, Network-on-Chip. Superscalar Processors Design: Superscalar organization, superscalar pipeline overview, VLSI implementation of dynamic pipelines, register renaming, reservation station, reordering buffers, branch predictor, and dynamic instruction scheduler etc.

**Pre-requisites** : None

**References** : Computer Organization and Design: The Hardware/Software Interface, The Morgan Kaufmann, By David A. Patterson and John L. Hennessy~Computer Architecture: A Quantitative Approach, The Morgan Kaufmann By John L. Hennessy and David A. Patterson~Modern Processor Design: Fundamentals of Superscalar Processors, McGraw-Hill By John P. Shen ~Current Literature

**E3 258 ( AUG ) 2 : 1****Design for Internet of Things**

Introduction to IoT, Challenges in IoT - Power, Security, Identification, Location, Low Power Design, Energy harvesting systems, Power management algorithms, Working with ADC, DC-DC and LDO component datasheets, ARM processor low power features, multiprocessor systems, Lifetime estimation, RFID and its applications, Backscattering techniques, Working with protocols such as MQTT, COAP, for low power and energy harvesting sensor nodes, Low power wireless networks - Bluetooth Low Energy (BLE), and IEEE 802.15.4e TSCH. Low Power Wide Area Networks - LORA, NBIoT and power-saving modes, CAT-LTE-M1.

**Pre-requisites** : None

**References** : RFCs, Application notes, Standards, Handbooks, Recent papers on selected topics.

**E3 276 ( AUG ) 2 : 1****Process Technology and System Engineering for Advanced Microsensors and Devices**

Introduction and Overview of Microfabrication Process Technology: Classification of Cleanrooms, Standard Operating Procedures for Working in a Conventional Clean Room Environment: Gowning Procedure, Operating Conditions, Clean Room Protocols, Safety and Contamination Issues in a Cleanroom, Overview of Cleanroom Hazards, Overview of Processes used in the Fabrication of Microsensors and Devices; Silicon Wafers - From Sand to the Laboratory: Silicon Growth Techniques: Czochralski and Float Zone, Wafer Processing from Si Ingot, Wafer Types: Crystallographic Planes, Physics of Silicon as a Semiconductor, Crystal Defects, Silicon Wafer Cleaning Methods: Piranha, RCA-1, RCA-2 using Wet-Benches; Thin Film Growth and Deposition Techniques: Thermal Oxidation, The Deal-Grove Model of Oxidation, Rate coefficients, Wet and Dry Oxidation, Overview of Oxidation Furnaces, Oxide Defects and ways of Mitigating it During Process Run, Contamination Control in the Furnace, Vacuum Systems: Construction and

**Pre-requisites** : None

**References** : None

**E6 212 ( JAN ) 3 : 0****Design and Control of Power Converters and Drives**

Basics of phase controlled converters, Choppers, Front end Ac to DC converter, DC motor speed control, inverters, six step operation, sinusoidal PWM control, current hysteresis PWM and space vector PWM control of three phase inverters. Generation of the three phase PWM signals from sampled reference phase amplitudes and PWM control in overmodulation region, Speed control of induction motor; V/f operation, dynamic equivalent circuit model of induction motor and vector control of induction motor. Current source inverter, Multilevel inverters and its control.

**Umanand L**

**Pre-requisites** : None

**References** : Leonhard W, Control of Electrical Drives, Springer-Verlag, 1985, Mohan N, Undeland T M, Robbins, W P, Power electronics : Converters, Drives and application, John Wiley, NY, USA, Umanand L, Power electronics : Essentials and applications, Wiley India, 2009

**E3 257 ( JAN ) 2 : 1****Embedded System Design**

Development toolchain (Compiler, Linker and Debugger), ARM Cortex processor architecture, Memory subsystem, caching, interfacing and programming peripherals, GPIO, UART, I2C, SPI, interrupts and NVIC architecture, interrupt driven standalone system

**Dagale Haresh Ramji**

**Pre-requisites** : None

**References** : Definitive Guide to Cortex M3 Architecture, Joseph Yiu~Practical Microcontroller Engineering with ARM Technology, Ying Bai, Linkers & Loaders

**E3 260 ( AUG ) 2 : 1****Embedded System Design – II**

Review of an embedded system without OS, Software components: startup code, boot loader, kernel, applications. Realtime concepts for embedded systems, Basic OS constructs Semaphores, Mutex, Queues, Tasks, and Scheduler, Introduction to a real-time kernel, scheduling policies, mutual exclusion, and synchronization, inter-task control flow, inter-task data flow, memory management, interrupt processing. Linux for embedded applications: an overview of Linux kernel architecture; system call interface. Process management; memory management; file system architecture. Linux for micro- controllers and real-time applications. Device driver: character, block and network drivers. Designing a real-time system: development life cycle, modeling a real-time system, Case studies.

**Pre-requisites** : None

**References** : Real Time Concepts for Embedded Systems by Qing Li and Caroline Yao, ELSEVIER~Embedded Systems - Real-Time Operating Systems by Jonathan W. Valvano~Understanding Linux Kernel by Bovet, D., and Cesati, M. O'Reilly Publication

**ED 299 ( JAN ) 0 : 25****MTech ESE Dissertation Project**

MTech ESE Dissertation Project

**Umanand L**

**Pre-requisites** : None

**References** : None

**E6 203 ( AUG ) 1 : 2****Mechatronics System Design**

Mechatronics intro, bond graph modelling of mechatronic systems, sensors and circuits - voltage, current, temperature, pressure, velocity, position, angular velocity, flow, flow rate, torque, stress, strain, etc., electrical actuators and drive - moving iron, solenoids, relays, electric motors, servo motor, stepper motor, motor selection, mechanical actuators - kinematic chains, cam, gears, ratchet, clutches, flexible elements, brakes etc., interfacing microcontrollers with actuators, control of actuators, robotic manipulator, differential dynamic mobile robot

**Pre-requisites** : None

**References** : 1. System dynamics: A unified approach, Dean Karnopp and Ronald Rosenberg, John Wiley and Sons 2. Mechatronics: Principles and Applications, Godfrey C Onwubolu, Elsevier publishers, 2005, 3. Digital control of dynamic systems, Franklin, Powell and Workman, Addison-Wesley, 3ed



**E0 204 ( JAN ) 2 : 1****Neuromorphic Analog VLSI design**

Topic Contents Computational Neuroscience Neuron/Synapse models, Auditory and Visual pathways, Olfaction pathway Neuromorphic Engineering Introduction MOS Transistor, Sub-threshold operation of MOS Analog Circuit Fundamentals DC Analysis, Freq response, Feedback system, Gm/Id Methodology Synaptic devices (Optional) Floating gate, Memristor Static circuits Transconductance Amplifiers, Current Mirror, Differential Pair, Gain Stages DC Operation Current-mode circuits Translinear Principle, Floating-Gate MOS Circuits, Bump Circuit, Current Multipliers Signal-Aggregation Circuit Centroid Circuits, Resistive Networks, Diffusor Circuits, Winner-Take-All Circuits, Delay Lines Basic elements of Neuromorphic electronics Electronic models of neuron, synapse and dendrites Neuromorphic Systems Electronic Cochlea, Auditory Localization, Silicon Retinas, Voltage and Current Mode Neuron Models, Address Event Communication, Motor Pattern Generatio

**Chetan Singh Thakur****Pre-requisites** :

Analog Circuit Design

**References** : • Peter Dayan and L. F. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, The MIT press, 2005. • Carver Mead, Analog VLSI Implementation of Neural Systems, Addison Wesley, 1989 • S.-C. Liu, J. Kramer, G. Indiveri, T. Delbrück, and R. Douglas, Analog VLSI:Circuits and Principles. Cambridge, MA: MIT Press, 2002. • Liu, S.-C., Delbrück, T.,

**E3 203 ( JAN ) 2 : 1****Design of Analog Electronics and Industrial Instru**

1. Sensors and transducers• Active and passive transducers• Transducer characteristics: temperature, pressure,flow,magnetic field, light 2. Sensor and transducer interfacing circuits: amplifiers• Wheatstone bridge• Amplifier characteristics – noise, linearity, supply rejection, impedance, range• Current/voltage/charge sensing circuits Instrumentation, transimpedance amplifiers 3. Analog signal processing: filters• Filter characteristics – magnitude and phase, ripple, group delay• Linear filters – Butterworth, Chebyshev 4. Interfacing circuits: drivers• Load type considerations – resistive and capacitive• Large current drive 5. Interface to digital processors: Analog to Digital Circuits• ADC characteristics – Data rate, ENOB, SFDR, INL, DNL• ADC architectures and choices – Flash, SAR, D-S, Pipeline 6.PIDand Programmable Logic Controllers 7. Digital communication interface– USB, I2C, USART

**Naga Krishna V.**

**Pre-requisites** : None

**References** : Dally, J.W., et al., Instrumentation for Engineering Measurements, John Wiley and Sons, 1984.

**E2 270 ( JAN ) 3 : 0****Quantum Information Theory**

Overview of concepts from classical Shannon theory, noiseless quantum theory, noisy quantum theory and purified quantum theory, distance measures, quantum information and entropy, information of quantum channels, quantum typicality, packing lemma, covering lemma, Schumacher compression, entanglement concentration, noisy quantum Shannon theory, product measurements at the decoder, information-processing task, classical capacity theorem, superadditivity of Holevo information, entanglement-assisted classical communication

**Shayan Garani Srinivasa****Pre-requisites**

some background or familiarity in classical information theory

**References** : • Mark M. Wilde, "Quantum Information Theory", Cambridge University Press  
 • M. Hayashi "Quantum Information Theory: A Mathematical Foundation" Springer-Verlag  
 • John Preskill Notes

**E0 217 ( AUG ) 2 : 1****Efficient and Secure Digital Circuits and Systems**

Circuits: overview of CMOS digital circuit design, logic gates, combinational and sequential logic, finite state machines, arithmetic circuits, memories, timing considerations, power consumption Systems: overview of computer architecture, instruction set, hardware-software interaction, micro-controllers, hardware acceleration, FPGA and ASIC design. Efficiency: gate-level optimization for power-performance-area, low-power versus energy-efficient implementation, pipelining, multi-level memories and caches. Security: introduction to cryptography and security protocols, implementation of multi-precision modular arithmetic, timing and power side-channel attacks and countermeasures

**Pre-requisites** : Basic understanding of digital electronic circuits.

**References** : 1.M.M.Mano and M.D.Ciletti,"Digital Design," Pearson Education,2018. 2. J.M.Rabaey, A.P.Chandrakasan and B.Nikolic,"Digital Integrated Circuits: A Design Perspective," Pearson Education,2016. 3.Journal/Magazine Articles and Conference Papers.

**ET 299 ( JAN ) 0 : 31****MTech EPD Dissertation Project**

MTech EPD Dissertation Project

**Umanand L**

**Pre-requisites** : None

**References** : MTech EPD Dissertation Project

**E3 226 ( JAN ) 2 : 1****Art of Compact Modeling**

Brief description of the course :

Compact modeling, also known as SPICE modeling, acts as a bridge between technology and design community in semiconductor industry. In this course we teach some fundamental techniques to develop compact models for metal-oxide-semiconductor based transistors.

**Syllabus**

Quantum mechanics preliminaries, crystal structure, band theory of solids, carrier transport mechanism, pn junction diode, MOS capacitor theory, C-V characteristics, MOSFET operation, types of compact models, Input Voltage Equation, charge linearization, charge partitioning, quasi-static and non-quasi-static Model, introduction to Verilog-A, Overview of EKV and PSP, small geometry effects, MASTER model. Course aims to teach compact modelling techniques through their implementation in Python/MATLAB.

**Santanu Mahapatra****Pre-requisites** :

Basics of semiconductor device, Python/MATLAB programming skills

**References** : Operation and Modeling of the MOS Transistor, By Yannis Tsividis, Oxford University Press.

**E3 263 ( JAN ) 2 : 1****Applied Security for Cyber-Physical Systems**

Introduction to security concepts - confidentiality, integrity, availability, authentication. Trusted computing base, classic attack methods - stack smashing, code-reuse. Basic mitigation techniques. Security challenges in enterprise networks – web-based attacks and phishing emails. Counter measures to protect email and web services firewalls, WAF, SEG, SPF, DMARC, DKIM, IDS. OT security – ICS networks, industrial networking protocols, security of OT devices – PLC, IED, and Engineering PC (Windows OS). APT attacks, case studies, domain specific security requirements. Security Framework: Purdue model, Cyber Kill Chain and MITRE ATT&CK. Machine learning algorithms and their use in CPS security: Naive Bayes, Multilayer perceptron, Random forest, J48, KNN, Decision Tree, K-Means, Logistic Regression. Lab Content: Static analysis, dynamic analysis, binary analysis. Network Tools – nmap, Kali Linux, Metasploit. Classic network attacks – Denial of Service, port scanning, brute force attacks, Man In the Middle, MAC spoofing, IP spoofing. Web-based attacks – Cross Site Scripting (CSS), Cross site Forgery, code injection. Pen testing: Burp suite, OWASP. IDS: Snort and Suricata.

**Dagale Haresh Ramji , Joy Kuri****Pre-requisites** :

E2-232 TCP/IP Networking

**References** : Security in Computing by Charles Pfleeger, Shari Pfleeger, Lizzie Coles-Kemp Addison-Wesley Professional; 6th edition (25 July 202

Computer Security: Art and Science Hardcover – 12 October 2018 by Matt Bishop (Author) Addison-Wesley; 2nd edition (12 October 2018)

**E2 279 ( JAN ) 2 : 1****Design of Network Security**

Network Security Concepts, Introduction to Number Theory, Symmetric & Asymmetric Cipher Techniques, Finite Fields, DES & AES Block Cipher Function, Data Integrity & MAC, Digital Signatures, Key Management, Transport-Level Security & IP Security. Programming exercises on encryption & decryption techniques & concepts discussed in the theory classes will be assigned to work out in lab sessions possibly with lab based mini projects

**Ramachandran P.****Pre-requisites**

Knowledge of Java or Python programming languages is required

**References**

1. Cryptography Theory and Practice  
 By Douglas R. Stinson and Maura B. Paterson  
 2. Cryptography and Network Security Principles and Practice

# Division of Interdisciplinary Sciences

## Preface

The Division of Interdisciplinary Research consists of the Centre for Biosystems Science & Engineering, Department of Computational and Data Sciences, Centre for Society and Polity, Interdisciplinary Centre for Energy Research, Interdisciplinary Centre for Water Research, Centre for Nano Science and Engineering, Centre for Infrastructure, Sustainable Transportation and Urban Planning, Department of Management Studies, Robert Bosch Centre for Cyber Physical Systems, Supercomputer Education and Research Centre and Interdisciplinary Mathematical Sciences. The courses offered in the different departments of the Division have been reorganized after review and revision, and have been grouped department wise. These are identified by the following codes.

BE Centre for Biosystems Science & Engineering

CP Robert Bosch Centre for Cyber Physical Systems

ER Interdisciplinary Centre for Energy Research

DS Department of Computational and Data Sciences

MG Department of Management Studies

MS Interdisciplinary Mathematical Sciences

NE Centre for Nano Science and Engineering

UP Centre for Infrastructure, Sustainable Transportation and Urban Planning

The first two digits of the course number have the departmental code as the prefix. The Departments/Centres of the Division provide facilities for research work leading to the degrees of M Tech, M Tech (Research) and PhD. There are specific requirements for completing a Research Training Programme for students registered for research at the Institute. For individual requirements, students are advised to consult the Departmental Curriculum Committee. The M Tech Degree Programmes are offered in Centre for Nano Science and Engineering, Department of Computational and Data Sciences and Robert Bosch Centre for Cyber Physical Systems. Department of Civil Engg and CiSTUP jointly offer an M Tech Programme in Transportation Engineering. Department of Management Studies offers a Master of Management Programme. Most of the courses are offered by the faculty members of the Division, but in certain areas, instruction by specialists in the field and experts from industries are also arranged.

Prof. Navakanta Bhat

Dean

Division of Interdisciplinary Sciences

# Society and Policy

## Preface

PS 301 ( JAN ) 3 : 0

### S and T POLICY DISCUSSIONS

Part 1 – Policy dynamics The module will begin with an overview of dynamics of policy formulation, policy process and policy analysis. Further policies from three domains will be discussed, namely, monetary/fiscal, energy and environment, and IP/technology/innovation. Within the domains, the policy instruments, their objectives, implementation, and impacts will be explored with reference to evidence from India and OECD countries. The essay paper will explore global comparison and policy concerns. Part 2 – Telecom policy The module will begin with an overview of the technology and the evolving eco system for which content processing, distribution, and delivery to end users, market structures in various segments, of this eco system, the National Telecom Policy, and the regulatory structure in India. In the second half of the course, we will do a deep dive into specific topics like net neutrality, spectrum management, standardization, Interconnections, economic impact of telecommunication, regulatory issues that may arise in emerging technologies. Part 3 – Data economics and policy The module will provide an introduction to the rapidly emerging area of data policy and economics. It will begin with a study of the privacy and individual rights associated with personal data, including an examination of the upcoming Personal Data Privacy bill, an exploration of how personal data be used in a responsible way to create public good without violating these rights, and several related topics. The course will also examine non-personal data, addressing the issues of data sharing, data ownership rights, fiduciary responsibility for community owned data, and data trusts and data trustees. Also covered will be some models for data monetization, studying some use cases where data has been used to create immense value, while also benefitting society.

**Anjula Gurtoo**

**Pre-requisites** : None

**References** : 1.Understanding Public Policy, 15th Edition – Thomas Dye 2.Readings from various academic papers

**PS 303 ( JAN ) 2 : 0****Communicating science to non-experts****Course**

Content:

- Fundamentals of effective public and professional science communication
- Communication: A two-way street (How to seek and receive feedback for your communication)
- Improvisation exercises
- Role of science communication in science/society dialogue (situational/roleplay exercises)
- Using effective science communication for professional development (Setting up new inter-disciplinary collaborations)
- Narrative structure in communication
- 'Elevator pitches' at poster sessions (1 min, 3 min summary of work at scientific conferences)
- Science communication/outreach/journalism as a career choice

**Learning**

outcomes:

- By the end of the course, students will be able to:
1. Realize the jargon in the description of their research
  2. Learn how to pitch their research in an engaging and exciting manner
  3. Consider the various need of a large and diverse interdisciplinary audience

**Mohit Kumar Jolly****Pre-requisites** : None

- References** :
1. Don't be such a scientist, Island Press, 2009
  2. Am I making myself clear? A Scientist's Guide to talking to the public, Harvard University Press, 2012
  3. The Science of Scientific Writing, American Scientist, 1990

# Bioengineering

## Preface

Educating a new breed of young researchers at the biology-engineering interface is the primary goal of the Interdisciplinary M. Tech and PhD Programme in Bioengineering. It is hoped that the students in this programme are at equal ease with a core area in biology and a core area in engineering.

August	Semester	Courses
BE 203 Bioengineering Practicum I	I	0:1
BE 204 Bioengineering Practicum II	II	0:1
BE 207 Mathematical Methods for Bioengineers		3:0
BE 213 Fundamentals of Bioengineering 1	1	2:0
BE 219 Essentials of Research and Innovation		2:0
BE 206 Biology for Engineers		3:0
BE 210 Drug Delivery: Principles and Applications		3:0

Jan	semester	courses
BE 203 Bioengineering Practicum I	I	0:1
BE 204 Bioengineering Practicum II	II	0:1
BE 214 Fundamentals of Bioengineering 2	2	2:0
BE 215 Chemistry for Bioengineers		3:0
BE 229 Statistics for Bioengineers		1:0
BE 230 Data Science for Bioengineers		2:0
BE 299 MTech Dissertation Project		0:32
BE 211 Cell Mechanics		3:0
BE 216 Dynamical Systems Biology		3:0
BE 218 Computational Epidemiology		3:1
BE 222 Stem Cell Technology		3:0
BE 223 Space Biology and Bioengineering		2:0
BE 224 Diagnostics and Devices		3:0
BE 227 Synthetic Biology and Protein Engineering		2:0
BE 228 Introduction to Mathematical Oncology		3:0

**BE 203 ( AUG ) 0 : 1**

**Bioengineering Practicum 1**

**Ajay Sanjay Tijore**

**Pre-requisites :** None

**References :** None



**BE 204 ( JAN ) 0 : 1****Bioengineering Practicum 2****Ajay Sanjay Tijore**

**Pre-requisites** : None

**References** : None

**BE 206 ( AUG ) 3 : 0****Biology for Engineers**

The course provides an introduction to fundamental concepts in Biology for PhD students with little to no knowledge of Biology past 10th or 12th standard school curriculum. The course will cover the following topics: biomolecules, fundamentals of biochemistry, protein structure and function, basic molecular biology, genetics, and an introduction to the cellular architecture. A combination of theoretical concepts and basic experimental methodologies in biology will be discussed. In addition, an introduction to how cells form tissues will be covered, which includes lectures on classification of tissues. The concepts covered here will aid in the skill development required to study diverse problems in bioengineering.

**Pre-requisites** : None

**References** : Biology: Concepts and Connections, Third Edition. Campbell, Mitchell and Reece. ~Molecular Biology of the Cell, Fourth Edition. B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter

**BE 207 ( AUG ) 3 : 0****Mathematical Methods for Bioengineers**

**Pre-requisites** : None

**References** : None

**BE 210 ( AUG ) 3 : 0****Drug Delivery: Principles and Applications**

The course provides an introduction to fundamental concepts in Biology for PhD students with little to no knowledge of Biology past 10th or 12th standard school curriculum. The course will cover the following topics: biomolecules, fundamentals of biochemistry, protein structure and function, basic molecular biology, genetics, and an introduction to the cellular architecture. A combination of theoretical concepts and basic experimental methodologies in biology will be discussed. In addition, an introduction to how cells form tissues will be covered, which includes lectures on classification of tissues. The concepts covered here will aid in the skill development required to study diverse problems in bioengineering. This course introduces concepts of drug delivery to meet medical challenges. The course is designed to be modular, with each module focusing on the following topics: Diffusion and permeation of drugs in biological systems; Pharmacokinetics and pharmacodynamics; Challenges and stra

**Pre-requisites** : None

**References** : Biology: Concepts and Connections, Third Edition. Campbell, Mitchell and Reece.~Molecular Biology of the Cell, Fourth Edition. B.Alberts,A. Johnson, J.Lewis, M.Raff, K.Roberts and P. Walter Drug Delivery: Engineering Principles for Drug Therapy,W.Mark Saltzman,Oxford University Press, 2001~Drug Delivery:Fundamentals and Applications,Anya M.Hillery and Kinam Park

**BE 211 ( JAN ) 3 : 0****Cell Mechanics**

This course will provide an in-depth understanding of mechanics of the cell including theory of cellular architecture, mechanical forces, deformations, and adhesions, leading up to force generation and interaction of cells with the external environment. Additionally, practical aspects, including measurement of cell mechanics using experimental techniques such as micropipette aspiration, single particle tracking and atomic force microscopy will be presented. The topics covered will culminate in broad applications of cell mechanics in physiology, cell biology and biophysics with the syllabus comprising cell shapes, biomaterials (soft filaments and sheets in cells), forces inside cells, random walks, movement in a viscous fluid, viscoelasticity (background, constitutive models and measurement in cells), complex filaments, rheology of cytoskeletal filaments, biomembrane (bilayers, micelles, vesicle formation), cell-cell and cell-matrix interactions, micropipette aspiration, single particle tr

**Medhavi Vishwakarma**

**Pre-requisites** : None

**References**

David Boal, R. Mechanics of the Cell, Cambridge University Press(2012)  
~Christopher R. Jacobs, Hayden Huang, Ronald Y. Kwon, Introduction to

**BE 213 ( AUG ) 2 : 0****Fundamentals of Bioengineering 1**

This course covers essentials of systems biology and biosensors. It caters to those who want to get first exposure to the topics that lay the foundation for advanced courses in these two topics. Systems biology: Dynamical systems biology, Feedback loops in biological systems, Cellular decision-making and cell differentiation, Mathematical modeling and nonlinear dynamics of biochemical reactions and networks, cell-to-cell variability and stochasticity in biological networks. Biosensors: The recognition-transduction system in a biosensor, chemistries for detection of small molecules, proteins/polypeptides, and nucleic acids; electronic and optical signal detection; microfluidics and its applications in biosensing; fluid dynamics and chemical kinetics of microfluidic biosensors; introduction to point-of-care biosensing; systems engineering approach in designing sample-in-answer-out biosensors

**Pre-requisites :** None

**References :** None

**BE 214 ( JAN ) 2 : 0****Fundamentals of Bioengineering 2**

This course covers essentials of biomaterials and cell and tissue mechanics. It caters to those who want to get first exposure to the topics, which lays the foundation for advanced courses in these two topics.

Part I of the course will cover biomaterials: polymers (synthesis and properties), metals, ceramics, biocompatibility, biodegradability, key properties of biomaterials (mechanical, chemical and physical properties), protein adsorption, host response to biomaterials (innate immune response, blood coagulation and complement response), fibrosis, implant associated infections, drug delivery, tissue engineering

Part II of the course will cover cell and tissue mechanics: Cell and tissue types, Viscoelasticity of cells and tissues, mechanics of cells: cytoskeleton: contractility and movement, molecular motors for transportation within the cells, Signal transduction within the cells to achieve basic mechanics, cellular forces, stiffness sensing of cells, wound healing, mechanics of multi-joint posture and movement control

**Rachit Agarwal , Medhavi Vishwakarma**

**Pre-requisites :** None

**References :** Biomaterials Science, B.D. Ratner et. al., 3rd Edition, Academic Press,2012.  
A Textbook of Biomechanics, S. Pal, Viva Books, New Delhi,India, 2009

**BE 215 ( JAN ) 3 : 0****Chemistry for Bioengineers**

This course aims to provide a fundamental understanding of chemistry to bioengineers so they can harness these concepts to solve bioengineering research challenges. The main topics that will be covered in this course are the following:

1. Bonding models including valence bond theory, molecular orbital theory, chemical forces-types and applications on biological/biochemical reactions. (8 lectures)
2. Quantum chemistry and application to group theory, molecular orbital theory -applications to metals in biology and bioinorganic compounds (hemoglobin) and in molecular spectroscopy. (5lectures).
3. Physical chemistry involving concepts of equilibrium reactions, electrochemistry and chemical kinetics, acid-base chemistry and its subsequent application in biomaterials and disease diagnostics. (6 lectures)
4. Coordination Chemistry-Understanding transition metal chemistry, introductions to crystal field theory to understand reactivity of biologically relevant molecules such as cisplatin, c

**Sanhita Sinharay****Pre-requisites** :

None

**References** :

References

1. Organic chemistry- Clayden, Greeves and Warren

**BE 223 ( JAN ) 2 : 0****Space Biology and Bioengineering**

Human Space programs around the world are moving at a fast-pace and these developments have created a strong need and interest in understanding the effect of outer-space on biological systems. This course is intended to be an introductory course, which will focus aspects of space biology such as extreme microbiology, astrobiology, and understanding of effect of space stressors on biological systems.

Details of course topics:

- Introduction aspects of space biology, extreme microbiology, computational biology for space biology.
- Biological payload design – concepts and design considerations. Use of such payloads to study various systems in available platforms such as PSLV missions.
- Biocementation: Discussion on biocementation capable organisms with a focus on certain biocementation capable microbes that can also tolerate extreme conditions. Biocementation and possible application to extra-terrestrial habitats and terraforming.
- Astrobiology, and understanding of space stressors such as microgravity, radiation, and temperature on biological systems.
- Demonstration of lab-scale simulated microgravity and associated effects.

**Aloke Kumar****Pre-requisites** :

A background in Microbiology is desirable.

**References** : Class Notes

**BE 222 ( JAN ) 3 : 0****Stem Cell Technology**

The course will introduce students to the fundamental principles of stem cell science, stem cell functioning, clinical applications and bioethical issues associated with use of stem cells. Also, students will learn recent techniques to develop scaffolds and platforms to study stem cell differentiation in the context of regenerative medicines. The following topics will be covered: basic overview of stem cells including stem cells from other organisms, history of stem cell research, importance of stem cells, stem cell differentiation and methods to regulate stem cell differentiation, induced pluripotent stem cells (iPSCs) and lab technique to develop iPSCs, methods to use stem cells to study disease, stem cell-based therapies for regenerative medicines and the bioethics of stem cell research. In nutshell, students will learn what has been accomplished, what challenges remain and what potential breakthrough may lie ahead in the field of stem cells. The course lectures will be delivered by experts in each of the topics with occasional guest lectures from colleagues in the academia/industry.

**Ajay Sanjay Tijore**

**Pre-requisites** : None

**References** : 1. Engineering Materials for stem cell regeneration, Faheem Sheikh, Springer Nature, 2021  
2. The Science of Stem Cells, Slack Jonathan M. W  
Course material will include lecture notes (not provided, but taken by students during the lecture), a few slide-handouts (provided), and

**BE 219 ( AUG ) 2 : 0****Essentials of Research and Innovation**

This course aims to provide a fundamental understanding of chemistry to bioengineers so they can harness these concepts to solve bioengineering research challenges. The main topics that will be covered in this course are the following:

1. Bonding models including valence bond theory, molecular orbital theory, chemical forces-types and applications on biological/biochemical reactions. (8 lectures)
2. Quantum chemistry and application to group theory, molecular orbital theory -applications to metals in biology and bioinorganic compounds (hemoglobin) and in molecular spectroscopy. (5lectures).
3. Physical chemistry involving concepts of equilibrium reactions, electrochemistry and chemical kinetics, acid-base chemistry and its subsequent application in biomaterials and disease diagnostics. (6 lectures)
4. Coordination Chemistry-Understanding transition metal chemistry, introductions to crystal field theory to understand reactivity of biologically relevant molecules such as cisplatin, c

**Pre-requisites** :

**References** :

References  
1. Organic chemistry- Clayden, Greeves and Warren

**BE 299 ( JAN ) 0 : 32****MTech Dissertation Project**

Dissertation project for M. Tech. students

**Medhavi Vishwakarma**

**Pre-requisites** : None

**References** : M. Tech. project work

**BE 230 ( JAN ) 2 : 0****Data Science for Bioengineers**

Bioengineering research often generates large amounts of data, analysis of which requires sound technical knowledge of data sciences. The goal of this course is to introduce students to the basic concepts and tools of statistical and machine learning, which may be useful to analyse the data generated by the medical, biological, and bioengineering community. The following topics will be covered: linear regression, analysis of categorical data, logistic regression, linear-discriminant analysis, resampling methods, decision trees, support vector machines, deep learning, unsupervised learning. Problems will be presented and solved using R.

**Narendra M Dixit , Siddharth Jhunjunwala**

**Pre-requisites** :

1. Undergraduate level course in probability and statistics  
**References** : There is no prescribed textbook for this course. But the following reference is suggested:  
 1. An Introduction to Statistical Learning, Gareth James et al.

**BE 229 ( JAN ) 1 : 0****Statistics for Bioengineers**

The goal of this course is to introduce students to the basic concepts and tools of statistics, which is essential to analyse data generated by the medical, biological, and bioengineering community. The following topics will be covered: introduction to descriptive statistics, discrete and continuous probability distributions, estimation, hypothesis testing including students 't' test, ANOVA, and non-parametric tests. Problems will be presented and solved using R.

**Narendra M Dixit , Siddharth Jhunjunwala**

**Pre-requisites** :

1. Undergraduate level course in probability and statistics  
**References** : There is no prescribed textbook for this course. But the following reference texts are suggested:  
 1. Fundamentals of Biostatistics, Bernard Rosner

**BE 227 ( JAN ) 2 : 0****Synthetic Biology and Protein Engineering**

Part I : Concepts and practice of synthetic Biology; genetic engineering; synthetic biology in healthcare; basic research; environment; engineering. Impact of synthetic biology of culture and life. Evidences from Genetically engineered machines development through seminar series.

Part II : Genetic Code Expansion and Protein Engineering: This part of the course explores the principles and applications of genetic code expansion, a powerful tool in synthetic biology and protein engineering. The course will cover the significant aspects of the molecular and cellular mechanisms underlying genetic code expansion, learn about the various methods for incorporating non-natural amino acids into proteins, and explore the diverse applications of this technology in areas such as drug discovery, receptor-ligand interaction, and biotechnology.

**Saravanan Palani**

**Pre-requisites :** None

**References :** "Expanding and reprogramming the genetic code", Nature. 2017 Oct 4;550(7674):53-60. doi: 10.1038/nature24031.  
"Expanding the genetic code", Annu Rev Biophys Biomol Struct. 2006;35:225-49.  
"A chemical toolkit for proteins--an expanded genetic code", Nat Rev Mol Cell Biol. 2006 Oct;7(10):775-82. doi: 10.1038/nrm2005.

# Nanoscience and Engineering

## Preface

### NE 200 ( AUG ) 2 : 0

#### Technical Writing and Presentation

This course is designed to help students learn to write their manuscripts, technical reports, and dissertations in a competent manner. The do's and don'ts of the English language will be dealt with as a part of the course. Assignments will include writing on topics to a student's research interest, so that the course may benefit each student directly.

**Pre-requisites :** None

**References :** The Elements of Style William Strunk Jr. and E.B. White 4th Edition Long man, Academic Writing Stephen Bailey 2nd Edition Routledge, The Elements of Technical Writing Gary Blake and Robert W Bly - Longman

### NE 202 ( AUG ) 0 : 2

#### Micro AND Nano Fabrication

This course is designed to train student in device microfabrication at the cleanroom facility in CeNSE. The course starts with eyes-on demonstration of the process flow of a p-n junction solar cell or MOSFET. Next, the students will execute a microfabrication heavy project which exposes them to design-of-experiment, process development, and troubleshooting

#### Sushobhan Avasthi

**Pre-requisites :** NE203 or NE203A

**References :** None



**NE 203 ( AUG ) 3 : 0****Advanced micro and nanofabrication technology and process**

This is a foundation level optics course which intends to prepare students to pursue advanced topics in more specialized areas of optics such as biophotonics, nanophotonics, non-linear optics etc. Classical and quantum descriptions of light, diffraction, interference, polarization. Fourier optics, holography, imaging, anisotropic materials, optical modulation, waveguides and fiber optics, coherence and lasers, plasmonics. Introduction and overview of micro and nano fabrication technology. Safety and contamination issues in a cleanroom. Overview of cleanroom hazards. Basic process flow structuring. Wafer type selection and cleaning methods. Additive fabrication processes. Material deposition methods. Overview of physical vapour deposition methods (thermal, e-beam, molecular beam evaporation) and chemical vapour deposition methods (PE-CVD, MOCVD, CBE, ALD). Pulsed laser deposition (PLD), pulsed electron deposition (PED). Doping: diffusion and ion implant techniques. Optical lithography

**Pre-requisites** : None

**References** : Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication~Sorab K. Gandhi, VLSI Fabrication Principles: Silicon and Gallium Arsenide~Richard C. Jaeger, Introduction To Microelectronic Fabrication

**NE 213 ( AUG ) 3 : 0****Introduction to Photonics**

This is a foundation level optics course which intends to prepare students to pursue advanced topics in more specialized areas of optics such as biophotonics, nanophotonics, non-linear optics etc. Classical and quantum descriptions of light, diffraction, interference, polarization. Fourier optics, holography, imaging, anisotropic materials, optical modulation, waveguides and fiber optics, coherence and lasers, plasmonics.

**Pre-requisites** : None

**References** : None

**NE 215 ( AUG ) 3 : 0****Applied Solid State Physics**

This course is intended to build a basic understanding of solid state science, on which much of modern device technology is built, and therefore includes elementary quantum mechanics and EM theory. Principle of thermal equilibrium, concept of entropy, Boltzmann factor, Blackbody radiation, H-atom, Wave nature, uncertainty principle, wave equation, application to particle in a box, scattering, different quantum numbers, Dirac notation and application to SHO Idea of operator and commutation Unitary operator, Hilbert space, Time independent perturbation theory, Fermi Golden rule, spin and statistics MB, FD and BE statistics, crystal structure, reciprocal lattice, lattice vibrations, free electrons, electrons in periodic potential, bands, quantization: photon, phonon, excitations, Maxwells equations in vacuum, insulating and conducting media, Fresnel equations Interference, diffraction and polarization quantum description Interaction of light with two level system

**Pre-requisites** : None

**References** : Books for CMP/SSP part: Kittel, Ashcroft & Mermin Books for Quantum Mechanics: Griffiths Books for EMT: Griffiths

**NE 221 ( JAN ) 2 : 1****Advanced MEMS Packaging**

This course intends to prepare students to pursue advanced topics in more specialized areas of MEMS and Electronic packaging for various real time applications such as Aero space, Bio-medical, Automotive, commercial, RF and micro fluidics etc. MEMS – An Overview, Miniaturisation, MEMS and Microelectronics -3 levels of Packaging. Critical Issues viz., Interface, Testing & evaluation. Packaging Technologies like Wafer dicing, Bonding and Sealing. Design aspects and Process Flow, Materials for Packaging, Top down System Approach. Different types of Sealing Technologies like brazing, Electron Beam welding and Laser welding. Vacuum Packaging with Moisture Control. 3D Packaging examples. Bio Chips / Lab-on-a chip and micro fluidics, Various RF Packaging, Optical Packaging, Packaging for Aerospace applications. Advanced and Special Packaging techniques – Monolithic, Hybrid etc., Transduction and Special packaging requirements for Absolute, Gauge and differential Pressure measurements, Temperature measurements, Accelerometer and Gyro packaging techniques, Environmental Protection and safety aspects in MEMS Packaging. Reliability Analysis and FMECA. Media Compatibility Case Studies, Challenges / Opportunities / Research frontier.

**Prosenjit Sen**

**Pre-requisites** : None

**References** : Tai-Ran Hsu, MEMS PACKAGING, INSPEC, The Institution of Electrical Engineers, London, UK, 2004, Tai-Ran Hsu, MEMS & MICRO SYSTEMS Design and Manufacture, Tata McGraw Hill, New Delhi, 2002, John H Lau, Cheng Kuo Lee, C.S. Premchandran, Yu Aibin, Advanced MEMS Packaging, McGraw-Hill, 2010

**NE 222 ( AUG ) 3 : 0****MEMS: Modeling, Design, and Implementation**

This course discusses all aspects of MEMS technology –from modeling, design, fabrication, process integration, and final implementation. Major emphasis will be placed on developing a wholistic view of MEMS and NEMS systems by not only giving consideration to physics of the device but also taking into account fabrication technologies required for manufacturing the device, readout circuits and other electronics and packaging. The course covers device fabrication techniques such as bulk and surface micromachining. Different levels of modelling such as back-of-the envelop calculations to solution of coupled partial differential equations solutions using FEM techniques will be discussed. A wide range of fundamental physics needed to design MEMS devices including, but not limited to, thermal circuits, linear and non-linear spring-mass damper systems, electrostatics, piezoresistivity, piezoelectricity etc. These concepts will be discussed in context of various practical MEMS and NEMS devices such as accelerometers, gyroscopes, micro-bolometers, timing-references, mass spectrometers etc. Finally, integration of micromachined mechanical devices with microelectronics circuits for complete implementation is also discussed.

**Pre-requisites :** None

**References :** 1.Stephen D. Senturia, "Microsystem Design", Kluwer Academic Publishers, 2nd Publishing, 2001. 2.G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat and V.K. Aatre, "Micro and Smart Systems", Wiley India, 2010.

**NE 223 ( JAN ) 2 : 1****Analog Circuits and Embedded System for Sensors**

Basic Circuit Analysis and Passive Components; Introduction to semiconductor devices and circuits involving Diodes, BJT, MOSFET and JFET; Opamp circuits: Transimpedance amplifier, Instrumentation amplifier, Comparator, Precision DMM application; Tradeoffs between power, noise, settling time and cost; Survey of sensors and their datasheets; Filters and Oscillators; State Machines, Digital IO, 555 timer, Latch, Flip-flops, Divide by N; Microcontroller programming; Communication protocols for sensor interfacing. Will include (at least weekly lectures, labs and a final project. Textbooks: Paul Horowitz, Winfield Hill, "Art of Electronics", Cambridge University Press, 3rd Edition, 2015. J. Edward Carryer, Matthew Ohline and Thomas Kenny, "Introduction to Mechatronic Design", Pearson Education India, 1st International edition, 2012. Jeremy Blum, "Exploring Arduino: Tools and Techniques for Engineering Wizardry", Wiley, 2013

**Saurabh Arun Chandorkar**

**Pre-requisites :** None

**References :** None

**NE 231 ( AUG ) 3 : 0****Microfluidics**

This is a foundation course discussing various phenomena related to fluids and fluid-interfaces at micro-nano scale. This is a pre-requisite for advanced courses and research work related to micro-nano fluidics. Transport in fluids, equations of change, flow at micro-scale, hydraulic circuit analysis, passive scalar transport, potential fluid flow, Stokes flow, Electrostatics and electrodynamics, electroosmosis, electrical double layer (EDL), zeta potential, species and charge transport, particle electrophoresis, AC electrokinetics, Surface tension, hysteresis and elasticity of triple line, wetting and long range forces, hydrodynamics of interfaces, surfactants, special interfaces, Suspensions, rheology, nanofluidics, thick-EDL systems, DNA transport and analysis

**Pre-requisites :** None

**References :** Brian J. Kirby, Micro- and Nanoscale Fluid Mechanics, Cambridge University Press, P.-G. de Gennes, F. Brochard-Wyart, and D. Quere, Capillarity and Wetting Phenomena, Springer, R. F. Probstein, Physicochemical Hydrodynamics, Wiley Inter-Science, -,-

**NE 250 ( AUG ) 1 : 0****Entrepreneurship, Ethics and Societal Impact**

This course is intended to give an exposure to issues involved in translating the technologies from lab to the field. Various steps and issues involved in productization and business development will be clarified, drawing from experiences of successful entrepreneurs in high technology areas. The intricate relationship between technology, society and ethics will also be addressed with illustrations from people involved in working with the grass root levels of the society.

**Pre-requisites :** None

**References :** None

**NE 299 ( JAN ) 0 : 27****Dissertation Project****Supradeepa V R**

**Pre-requisites :** None

**References :** None

**NE 310 ( JAN ) 3 : 0****Photonics technology: Materials and Devices**

Optics fundamentals; ray optics, electromagnetic optics and guided wave optics, Light-matter interaction, optical materials; phases, bands and bonds, waveguides, wavelength selective filters, electrons and photons in semiconductors, photons in dielectric, Light-emitting diodes, optical amplifiers and Lasers, non-linear optics, Modulators, Film growth and deposition, defects and strain, III-V semiconductor device technology and processing, silicon photonics technology, photonic integrated circuit in telecommunication and sensors.

**Shankar Kumar Selvaraja**

**Pre-requisites :** None

**References :** Saleh, B. E. A., and M. C. Teich. Fundamentals of Photonics. New York, NY: Wiley, 1991., T. Tamir, Topics in Applied Physics Volume 7: Integrated Optics, Springer-Verlag Berlin., Haus, H. A. Waves and Fields in Optoelectronics. Englewood Cliffs, NJ: Prentice-Hall., Research articles., Handouts and Lecture

**NE 312 ( JAN ) 3 : 0****Nonlinear and Ultrafast Photonics****Supradeepa V R , Varun Raghunathan**

**Pre-requisites :** None

**References :** None

**NE 313 ( AUG ) 3 : 0****Lasers: Principles and Systems**

This is an intermediate level optics course which builds on the background provided in "Introduction to photonics" offered in our department. Owing to the extensive use of lasers in various fields, we believe a good understanding of these principles is essential for students in all science and engineering disciplines.

**Pre-requisites :** None

**References**

Anthony E. Siegman, Lasers, University Science Books (1986),  
 Orazio Svelto, Principles of Lasers, Springer (2010), Miscellaneous

**NE 314 ( AUG ) 3 : 0****Semiconductor Opto-electronics and Photovoltaics**

An advanced graduate level course, NE314 provides a detailed overview of various optoelectronic devices such as LEDs, photodetectors and solar cells. The focus is more on the device physics, though some material and fabrication issues are also discussed. The course is designed for students who have a background in semiconductor device physics. A basic device course, such as NE205, is a strongly suggested prerequisite.

**Pre-requisites** : None

**References** : None

**NE 332 ( JAN ) 3 : 0****Physics and Mathematics of Molecular Sensing**

This course presents a systematic view of the process of sensing molecules with emphasis on bio-sensing using solid state sensors. Molecules that need to be sensed, relevant molecular biology, current technologies for molecular sensing, modeling adsorption-desorption processes, transport of target molecules, noise in molecular recognition, proof-reading schemes, multi- channel sensing, comparison between in-vivo sensing circuits and solid state biosensors

**Manoj Varma**

**Pre-requisites** : None

**References** : None

**NE 241 ( JAN ) 3 : 0****Material Synthesis: Quantum Dots To Bulk Crystals**

All device fabrication is preceded by material synthesis which in turn determines material microstructure, properties and device performance. The aim of this course is to introduce the student to the principles that help control growth. Crystallography ; Surfaces and Interfaces; Thermodynamics, Kinetics, and Mechanisms of Nucleation and Growth of Crystals ; Applications to growth from solutions, melts and vapors (Chemical vapor deposition and Physical vapor deposition methods); Stress effects in film growth

**Pavan Nukala**

**Pre-requisites** : None

**References** : Ivan V. Markov, Crystal growth for Beginners, Fundamentals of Nucleation, Crystal Growth and Epitaxy, World Scientific, 1998. (548.5.N96), ~L.B.Freund, S.Suresh, Thin Film Materials – Stress, Defect Formation and Surface Evolution, Cambridge University Press, 2003. (621.38152 PO36) ~Milton Ohring, Material Science of Thin Films, Academic Press, ~~~~~

**NE 206 ( AUG ) 3 : 0****Semiconductor Device Physics: Basic Devices**

Energy bands in solids; Reciprocal space; Brillouin Zone (BZ); Fermi Dirac distribution; Doping; Density of states; Low-field transport; High-field transport; Carrier flow by Diffusion and Drift; Excess carriers and recombination processes; PN junction at thermal equilibrium; PN junction under bias; Transient behavior of p-n junction; Solar cell and photodetector; Metal-semiconductor (Schottky and Ohmic junctions; Current transport mechanisms; Introduction to compound semiconductors; BJT; MOS capacitor; MOSFET; Short channel effects

**Pre-requisites :** None

**References :** "Introduction to Semiconductor Materials & Devices", by M. S.Tyagi "Physics of semiconductor devices", by S M Sze, Wiley Indi "Semiconductor Device Physics and Design", by Umesh Mishra and Jasprit Singh, Springer "Physical Foundations of Solid State Devices", by E. F. Schubert (e-book available free at [http://nadirpoint.de/Physik\\_Lit\\_PDF/65.pdf](http://nadirpoint.de/Physik_Lit_PDF/65.pdf) )

**NE 311 ( JAN ) 1 : 1****Integrated photonics Lab**

The course envisages giving students hands-on integrated photonic device design and characterization skills. The course covers device design concepts using EDA tools and a custom simulation framework as well. The designs will be fabricated through the CeNSE fabrication facility, and the course students will characterize the devices. The integrated photonic devices that we shall study find applications in optical communication, on-chip photonic sensor, quantum photonic integrated circuit, and neuromorphic photonic circuit. The following are the specific devices that the students will design as a part of their course. 1. Optical waveguides 2. Directional couplers 3. Light-chip coupler 4. Power splitters and combiner 5. Wavelength selective devices 6. Bragg filter 7. Photodetector 8. Light modulator 9. Mach Zehnder interferometers 10. Ring resonator The student will be exposed to design tools, methodology, fabrication and characterization of devices and circuits

**Shankar Kumar Selvaraja , Sreetosh Goswami**

**Pre-requisites :** None

**References :** Fundamentals of Photonics, B.E.A Saleh and M.C. Teich, Wiley, New York, 1991 \*Photonic Devices. Cambridge, J. Liu, Cambridge University Press, 2005. \*Fundamentals of Optoelectronics, Clifford R. Pollock, Irwin, 1995. \*Diode Lasers and Photonic Integrated Circuits, Larry A. Coldren Scott W. Corzine Milan L. Mašanović, Wiley-Interscience.

**NE 281 ( AUG ) 3 : 0****Statistical and probabilistic data analysis techniques**

This course will introduce foundational concepts in statistics and probability from an applied perspective suitable for experimentalists. The learning objectives are the application of stochastic models to aid data analysis, for instance, techniques for parameter estimation and hypothesis testing. Methods to simulate stochastic processes and solve first order stochastic differential equations will be covered. Physical processes such as random walks, chemotaxis, photon counting and single molecule sensing will be used to illustrate the theoretical concepts. Additionally, uncertainty analysis of experiments will also be covered. List of topics: Probability distributions of single r.v, PDF and CDF, Moments, MGF, CGF, joint PDF, conditional distributions, conditional moments, Bayes theorem, PDFs of functions of r.v, Stochastic processes, simulating stochastic processes, Monte-carlo technique, auto-correlation and power spectra of random processes, estimation of PDF and CDF from data, Parameter estimation: estimators such as MLE, MMSE and Bayes, Cramer-Rao bound, Hypothesis testing: statistical significance, Neyman-Pearson approach, p-value, F-distribution, ANOVA, Bayesian inference, Case studies: Uncertainty and error analysis, Random walk and diffusion, Photon counting, Single molecule sensing

**Pre-requisites** : None

**References** : 1. Probability models in engineering and science, Haym Benaroya and Seon Mi Han, Taylor and Francis 2005  
 2. Applied statistical inference, Leonhard Held and Daniel Sabanes Bove, Springer 2014  
 3. Stochastic processes in cell biology, Paul C. Bressloff, Springer 2014

**NE 240 ( AUG ) 3 : 0****Materials design principles for electronic, electromechanical and**

Module 1  
 Structure and symmetry, property predictions from symmetry: piezoelectricity, electrostriction, ferroelectricity, second harmonic generation

Module 2  
 Equilibrium property predictions from thermodynamics, order parameters elementary statistical mechanics of phase transitions, Landau theory, property enhancements near second order phase transitions

Module 3:  
 Dissipative properties, entropy generation, Onsager's formulation, hysteresis, electrical and thermal transport, electrical/thermal resistance, thermoelectric properties

Module 4:  
 Defects, kroger-vink notation, defects as property deteriorating entities, defects as property enhancing entities, Recent findings on designing new properties through defects and their kinetics (revisit of ferroelectricity and electromechanical responses of defective compounds)  
 Tight binding band structure, perturbation by defects, physics of amorphous solids and their electronic properties. Correlations (if time permits), and metal-insulator transitions.

**Pre-requisites** : None

**References** : 1. Physical properties of crystals, J.F. Nye  
 2. Properties of materials, anisotropy, symmetry and structure, R.E.Newnham  
 3. Properties of non-crystalline solids, Mott and Davies



## NE 317 ( JAN ) 3 : 0

**From natural to artificial intelligence**

Artificial intelligence (AI) has been heralded as the flagbearer of the fourth industrial revolution. To implement AI, we need a technological breakthrough in computing hardware. The question is how we design those new generations of devices. This is where the idea of natural intelligence inevitably comes in. The Profuse dendritic-synaptic interconnections among neurons in a brain embed intricate logic structures enabling cognition and sophisticated decision-making that vastly outperforms any artificial electronic analogues. The physical complexity is far beyond existing circuit fabrication technologies: moreover, the network in a brain is dynamically reconfigurable, which provides flexibility and adaptability to changing environments. How about we capture these qualities in a new generation circuit element? That is the whole idea propelling the field of brain-inspired computing which is one of the cutting-edge technologies in development. While there are many courses on AI around the world there is no course where biology is directly correlated to device physics, and circuit design and that is the main idea behind the proposed course. The course will be taught by myself along with Professor Deepak Nair from CNS. Professor Nair will introduce the concepts of natural intelligence and how it is manifested in neuronal networks. The topic to be covered in under this thread are: data processing in neurons and synapses, synaptic plasticity, potentiation, depression, idea of spike time dependent plasticity, 'integrate and fire' response in a neuron, signal transmission through axons, plasticity, reconfigurability and redundancy in a neuronal network and finally, the origin and expression of intelligence in a neuronal circuit. Based on the biological foundation, I will develop the device and circuit design philosophy that is being taken for designing efficient AI hardware platforms. I shall introduce the static and dynamic elements being attempted to make a synapse and a neuron. The material and circuit properties to mimic the features of a neuron and a synapse will be covered. Different approaches such as FET, FTJs, memristors and neuristors will be introduced. We will discuss strategies to operate the circuit elements on the verge of chaos that can enable us to realize intelligence and decision-making ability on a chip. Towards the end of the curriculum, the students will be asked to come up with their own proposals to address specific challenges either at a device or a circuit level. This course could offer cutting-edge exposure and motivate students to take on some of the outstanding, high reward research challenges in this field.

**Sreetosh Goswami**

**Pre-requisites :** None

**References :** 1. Minds Behind the Brain: A History of the Pioneers and Their Discoveries 1st Edition  
 2. Origins of Neuroscience: A History of Explorations into Brain Function Reprint Edition  
 3. Principles of Neural Science (Kandel)

**NE 320 ( JAN ) 3 : 0****Quantum Optics**

Quantum optics is a fundamental subject which describes the behavior of light and light matter interactions at the quantum level. Its only through quantum optics that many deep and often baffling observations with light are resolved. With the advent of quantum computing and quantum communications, quantum optics takes a primary role owing to its foundational contribution to both these applied areas. This course will be an introductory quantum optics course and below listed are some representative topics covered in the course. There will be additional time allocated to specific problems of current interest in the course.

**Topics**

1. Quantization of the electromagnetic field
2. Vacuum fluctuations
3. Wave packet representation
4. Coherent states
5. Density operators and phase space
6. Atom-field interactions
7. Jaynes-Cummins Model
8. Dressed States
9. Von-Neumann Entropy
10. Coherence functions
11. Squeezed States
12. Bunching and Anti-bunching
13. Cat states and other forms of non-classical light
14. Tests of Quantum Mechanics
15. Introduction to cavity QED
16. Advanced topics in quantum measurements

**Supradeepa V R , Baladitya Suri****Pre-requisites** :

- References** : 1. Introductory Quantum Optics by C. C. Gerry and Peter Knight, Cambridge University Press (2012)  
 2. Optical Coherence and Quantum Optics by Leonard Mandel and Emil Wolf, Cambridge University Press (2013)  
 3. Quantum Optics: An Introduction, by Mark Fox, Oxford Master Series in Physics (2007)

**NE 201B ( AUG ) 0 : 2****Lab for structural and functional characterization**

This is a laboratory course designed to train students in various device and material characterization techniques. Following techniques will be covered under the course: XRD, electron diffraction and microscopy such as TEM, SEM, Elastic vs. inelastic Energy loss/spectroscopy/EELS, XPS/XAS. Photoluminescence, Raman Spectroscopy, Confocal and fluorescence microscopy, Optical profilometer/UV-vis/ellipsometer, basics of FTIR, Atomic Force Microscope, including CAFM, KPFM, Basics of electrical measurements including resistivity, 4-probe, Hall, TLM, van der Pauw, Capacitance-Voltage measurement including MOS C-V, theory and working of lock-in amplifier; low frequency highly sensitive measurements, Opto-electronics measurements including measuring detectivity, photo current and noise of photodetector, basics of LED measurements, Basics of high-frequency measurement – needle probe vs CPW, oscilloscope/function generator, basics of VNA and small-signal parameters

**Akshay K Naik , Gayathri Pillai****Pre-requisites** :

**References** : Notes

**NE 352 ( JAN ) 3 : 0****Quantum transport in low dimensional materials**

- a. Basics of solid state physics: Drude theory, counting states, density of states, Fermi energy, Fermi Dirac distribution, conductivity and resistivity tensor
- b. Field-effect transistor, Ohmic and Schottky barrier, Metal semiconductor field effect transistor, Metal oxide semiconductor field effect transistor.
- c. Basics of Nanoscale device fabrication, photo-lithography, electron beam lithography
- d. Why Electron flow, Conductance formula, different transport regime: Diffusive, Ballistic, and hydrodynamic
- e. Conductance fluctuations, phase coherence length, Aharonov-Bohm and weak localization
- f. Quantum hall effect, edge current, Landauer Buttiker formalism, Subnikov de Hass effect, introduction to fractional quantum hall effect
- g. Quantum dot, Coulomb-Blockade, Quantum capacitance
- h. Introduction to Superconductivity and Josephson effect
- i. Introduction to local scanning probes techniques like single electron transistor (SET), superconducting quantum interference devices (SQUID), scanning tunneling microscopy (STM)

**Chandan Kumar****Pre-requisites** :

Exposure to solid state Physics course

- References** :
1. Solid State Physics by Neil Ashcroft, N. David Mermin
  2. Mesoscopic Electronics in Solid State Nanostructures by Thomas Heinzl
  3. Introduction to superconductivity by A.C Rose-innes and E.H Rhoderick

**NE 201A ( AUG ) 3 : 0****Theory of structural and functional characterization**

This course provides theoretical framework for various device and material characterization techniques. Following techniques will be covered under the course: XRD, electron diffraction and microscopy such as TEM, SEM, Elastic vs. inelastic Energy loss/spectroscopy/EELS, XPS/XAS. Photoluminescence, Raman Spectroscopy, Confocal and fluorescence microscopy, Optical profilometer/UV-vis/ellipsometer, basics of FTIR, Atomic Force Microscope, including CAFM, KPFM, Basics of electrical measurements including resistivity, 4-probe, Hall, TLM, van der Pauw, Capacitance-Voltage measurement including MOS C-V, theory and working of lock-in amplifier; low frequency highly sensitive measurements, Opto-electronics measurements including measuring detectivity, photo current and noise of photodetector, basics of LED measurements, Basics of high-frequency measurement – needle probe vs CPW, oscilloscope/function generator, basics of VNA and small-signal parameters

**Akshay K Naik , Pavan Nukala , Gayathri Pillai****Pre-requisites** :

**References** : Lecture notes

**NE 235 ( JAN ) 3 : 0****Microsystem Design and Technology**

This course deals with MEMS transducer design and system development. This course builds on the background provided in “NE222 MEMS: Modelling, Design, and Implementation”. This course covers the following topics (i) Scaling law – Advantages of microsystems (ii) Wave propagation for isotropic and anisotropic materials – Christoffel’s theory, (iii) Elastic waves – Types of waves and their dispersion, (iv) Transducer modelling – Piezoelectric, Piezoresistive and Capacitive, (v) MEMS sensors design and characterization schemes, (vi) MEMS actuator design and characterization schemes, and (vii) RF-switches, resonators, filters, and oscillators. Finite element modelling, layout design and device testing scheme of different MEMS transducers will be covered. The course will be evaluated using quizzes, assignments, and a project. This course will also have basic lab demonstration sessions where microsystems such as ultrasonic transducers, mass sensors, Surface Acoustic Wave resonators, inertial sensors, etc. will be characterized.

**Gayathri Pillai**

**Pre-requisites :** None

**References :** 1) Bhugra, Harmeet, and Gianluca Piazza, eds. Piezoelectric MEMS resonators. New York, NY, USA: Springer International Publishing, 2017.  
2) Stephen D. Senturia, Microsystem Design, Kluwer Academic Publishers, 2000

**NE 303 ( AUG ) 2 : 1****Semiconductor Process Integration**

The course teaches the art and science of semiconductor process integration. The courses will discuss module-level integration issues that come up in complex device fabrication. In the first 4 weeks, we will discuss technologically relevant modules like LOCOS, shallow trench isolation, replacement metal gate, Damascene and dual-Damascene, etc. In the next 9-10 weeks, we will discuss case studies on six advanced devices with complex fabrication flows. The basket of courses will change with time but examples include, leading-node logic, memory, integrated photonics, solar cells, microelectromechanical systems, light emitting device, and heterogenous integration. The course has 1 lecture per week of instructor-led teaching. The lecture will discuss case studies. In parallel, we will have weekly take-home lab-assignment on TCAD software like SEMulator3D. We will organise 1 take-home lab per week. The lab will be in the form of an assignment, where students will be required to submit a report, which will be graded. The lab session, will be supported by 1 tutorial session per week. The tutorial will be organised to help answer questions. It will be primary run by TA(s).

**Pre-requisites :** NE203

**References :** 1. Introduction to Microfabrication by Sami Franssila, Wiley 2. Silicon Devices and Process Integration - Deep Submicron and Nano-Scale Technologies by Badih El-Kareh, Springer 3. Materials & Process Integration for MEMS, Francis E. H. Tay, Springer 4. Handbook of 3D Integration by Christopher Bower, Peter Ramm, Philip Garrou, Wiley Solar Photovoltaics Technology, System Design,

**NE 203A ( AUG ) 3 : 1****Advanced micro and nanofabrication technology and process**

Introduction and overview of micro and nano fabrication technology. Safety and contamination issues in a cleanroom. Overview of cleanroom hazards. Basic process flow structuring. Wafer type selection and cleaning methods. Additive fabrication processes. Material deposition methods. Overview of physical vapour deposition methods (thermal, e-beam, molecular beam evaporation) and chemical vapour deposition methods (PE-CVD, MOCVD, CBE, ALD). Pulsed laser deposition (PLD), pulsed electron deposition (PED). Doping: diffusion and ion implant techniques. Optical lithography fundamentals, contact lithography, stepper/ scanner lithography, holographic lithography, direct-laser writing. Lithography enhancement methods and lithography modelling. Non-optical lithography; E-beam lithography, ion beam patterning, bottom-up patterning techniques. Etching process: dry and wet. Wet etch fundamentals, isotropic, directional and anisotropic processes. Dry etching process fundamentals, plasma assisted etch process, Deep Reactive Ion Etching (DRIE), Through Silicon Vias (TSV). Isotropic release etch. Chemical-mechanical polishing (CMP), lapping and polishing. Packaging and assembly, protective encapsulating materials and their deposition. Wafer dicing, scribing and cleaving. Mechanical scribing and laser scribing, Wafer bonding, die-bonding. Wire bonding, die-bonding. Chip-mounting techniques. Simulation-based assignments on the above topics

**Pre-requisites :** None

**References :** Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication~Sorab K. Gandhi, VLSI Fabrication Principles: Silicon and Gallium Arsenide~Richard C. Jaeger, Introduction To Microelectronic Fabrication

**NE 200A ( AUG ) 3 : 0****Technical Writing and Presentation**

This course is designed to help students learn to write their manuscripts, technical reports, and dissertations in a competent manner. The do's and don'ts of the English language will be dealt with as a part of the course. Assignments will include writing on topics to a student's research interest, so that the course may benefit each student directly. In the current updated version for the updating of the MTech program, we have included the much needed context associated with giving technical talks, seminars and other forms of public dissemination.

**Pre-requisites :** None

**References :** The Elements of Style William Strunk Jr. and E.B. White 4th Edition Longman, Academic Writing Stephen Bailey 2nd Edition Routledge, The Elements of Technical Writing Gary Blake and Robert W Bly - Longman

**NE 241A ( JAN ) 3 : 1****Materials synthesis: from quantum dots to bulk cry**

1. Material thermodynamics: first, second, third laws; solution thermodynamics, phase diagrams, reaction thermodynamics, case studies in materials growth that use these principles
2. Role of surfaces in synthesis
3. Role of elasticity
4. Nucleation and growth, 3D
5. 2D Nucleation and growth
6. Thin film growth modes and techniques

**Manoj Varma , Shankar Kumar Selvaraja , Pavan Nukala**

**Pre-requisites :** None

**References :** 1. Class notes is the most important reference. Please pay attention in the class, take good notes.  
 2. Robert T DeHoff, Thermodynamics in Materials Science, 2nd Ed, Taylor and Francis  
 3. CHP Lupis, Chemical Thermodynamics of Materials, 1983, North Holland publishers

**NE 206A ( AUG ) 3 : 1****Semiconductor Device Physics: Basic Devices**

An graduate level course, NE206 provides an introduction to semiconductor device physics. The focus is on basics like the origin of band-structure, carrier transport, thermal statistics, junctions, defects, and interfaces. Schottky diodes, p-n junction diodes, bipolar junction transistors, and MOS transistors are covered in detail. This is a fundamental course for anyone interested in electronic devices. TThe lab component will use simulation-based assignments to complement the theory part of the course. Topics include, energy bands in solids; Fermi-Dirac distribution; doping; density of states; low-field transport; high-field transport; carrier flow by diffusion and drift; Excess carriers and recombination processes; PN junction at thermal equilibrium & bias; Transient behavior of p-n junction; metal- semiconductor (Schottky and Ohmic junctions; Current transport mechanisms; BJT; MOS capacitor; MOSFET; Short channel effects; advanced CMOS devices Laboratory component based on simulation assignments. Topics similar to above.

**Pre-requisites :** None

**References :** "Introduction to Semiconductor Materials & Devices", by M.S.Tyagi "Physics of semiconductor devices", by S M Sze, Wiley Indi "Semiconductor Device Physics and Design", by Umesh Mishra and Jasprit Singh, Springer "Physical Foundations of Solid State Devices", by E. F. Schubert (e-book available free at [http://nadirpoint.de/Physik\\_Lit\\_PDF/65.pdf](http://nadirpoint.de/Physik_Lit_PDF/65.pdf) )

**NE 242 ( JAN ) 3 : 0****Nanotechnology in Biology and Medicine**

This course introduces students to the fundamental principles of nanotechnology and its advanced applications in diagnostics, drug delivery, imaging, tissue engineering, and disease treatment. It covers an overview of nanotechnology, including its principles, the size and scale of nanomaterials, their unique properties, and the different types of nanomaterials and devices. Key topics include synthesis and fabrication methods, characterization techniques, and the interactions of nanotechnology with biological systems, such as cellular uptake, toxicity, and biocompatibility. The course also delves into the use of nanotechnology in diagnostics, highlighting biosensors and nanoparticles for imaging (MRI, CT, and fluorescence), and in drug delivery, focusing on targeted nanoparticle-based systems with case studies in cancer therapy and gene delivery. Additionally, it explores the role of nanomaterials in tissue engineering and regenerative medicine, including scaffold development, stem cell therapy, and applications in wound healing, bone repair, and organ regeneration. Emerging trends such as nanobots, personalized medicine, and precision therapies are discussed, alongside practical considerations for translating nanomedicine into clinical practice, including safety, ethical concerns, regulatory issues, and patenting.

**Vini Gautam**

**Pre-requisites :** Basic knowledge of concepts in biology, chemistry, and physics (undergraduate level)

**References :**

- o Nanomaterials and Nanotechnology in Medicine (Vishak et al, Wiley)
- o Nanotechnology: Science, Innovations and Opportunity (Foster et al, Person).
- o Research articles from pioneering journals in the field (Nature Nanotechnology, Nanomedicine, Advanced Healthcare Materials etc)

**NE 369 ( JAN ) 2 : 2****Basic to Advanced Spectroscopy Techniques**

This basic-to-advanced-level course would provide a comprehensive exploration of spectroscopy, starting from fundamental principles and advancing to complex applications in material science, chemistry, and physics. The course covers topics such as electronic transitions, UV-Visible spectroscopy, infrared (IR) spectroscopy, Raman spectroscopy, photoluminescence (PL), and advanced techniques like Time-Correlated Single Photon Counting (TCSPC) and Photoluminescence Quantum Yield (PLQY) measurements. The laboratory component provides hands-on experience with material deposition, sample preparation, lifetime measurements, PL mapping, and data analysis. This course equips students with practical skills and theoretical knowledge valuable for research and industry roles involving spectroscopic analysis and material characterization.

**Aditya Sadhanala****Pre-requisites**

Prerequisites

• Basic courses in Physics and Chemistry.

**References**

• Required Textbooks and Materials

- "Principles of Fluorescence Spectroscopy" by Joseph R. Lakowicz
- "Introduction to Spectroscopy" by Donald L. Pavia, Gary M. Lampman, and George S. Kriz

# Computational and Data Sciences

## Preface

### DS 200 ( AUG ) 0 : 1

#### Research Methods

This course will develop the soft skills required for the CDS students. The modules (each spanning 3 hours) that each student needs to complete include: Seminar attendance, literature review, technical writing (reading, writing, reviewing), technical presentation, CV/resume preparation, grant writing, Intellectual property generation (patenting), incubation/start-up opportunities, and academia/industry job search.

**Pre-requisites** : None

**References** : None

### DS 201 ( AUG ) 2 : 0

#### Bioinformatics

Unix utilities, overview of various biological databases (Protein Data Bank, structural classification of proteins, genome database and Cambridge structural database for small molecules), introduction to protein structures, introduction to how to solve macromolecular structure using various biophysical methods, protein structure analysis, visualization of biological macro molecules, data mining techniques using protein sequences and structures. short sequence alignments, multiple sequence alignments, genome alignments, phylogenetic analysis, genome context-based methods, RNA and transcriptome analysis, mass spectrometry applications in proteome and metabolome analysis, molecular modeling, protein docking and dynamics simulation. Algorithms, scaling challenges and order of computing in big biological data.

**Pre-requisites** : None

**References** : C.Branden and J.Tooze (eds) Introduction to Protein Structure, Garland,1991~Mount, D.W., Bioinformatics: Sequence and Genome Analysis, Cold. Spring Harbor Laboratory Press,2001.~Baxevanis, A.D., and Ouellette, B.F.F. (Eds), Bioinformatics: A practical guide to the analysis of the genes and proteins,Wiley-Interscience, 1998



**DS 211 ( JAN ) 3 : 0****Numerical Optimization**

Introduces numerical optimization with emphasis on convergence and numerical analysis of algorithms as well as applying them in problems of practical interest. Topics include: Methods for solving matrix problems and linear systems that arise in the context of optimization algorithms. Major algorithms in unconstrained optimization (e.g., modified Newton, quasi-Newton, steepest descent, nonlinear conjugate gradient, trust-region methods, line search methods), constrained optimization (e.g., simplex, barrier, penalty, sequential gradient, augmented Lagrangian, sequential linear constrained, interior point methods), derivative-free methods (e.g., simulated annealing, Bayesian optimization, Surrogate-assisted optimization), dynamic programming, and optimal control.

**Deepak Narayanan Subramani**

**Pre-requisites :** None

**References :** None

**DS 221 ( AUG ) 3 : 1****Introduction to Scalable Systems**

1) Architecture: computer organization, single-core optimizations including exploiting cache hierarchy and vectorization, parallel architectures including multi-core, shared memory, distributed memory and GPU architectures; 2) Algorithms and Data Structures: algorithmic analysis, overview of trees and graphs, algorithmic strategies, concurrent data structures; 3) Parallelization Principles: motivation, challenges, metrics, parallelization steps, data distribution, PRAM model; Parallel Programming Models and Languages: OpenMP, MPI, CUDA; 4) Big Data Platforms: Spark/MapReduce model, cloud computing. Lab tutorials and programming assignments for above topics.

**Pre-requisites :** None

**References :** None

**DS 256 ( JAN ) 3 : 1****Scalable Systems for Data Science**

This course will teach the fundamental Systems aspects of designing and using Big Data platforms, which are a specialization of scalable systems for data science applications. 1) Design of distributed program models and abstractions, such as MapReduce, Dataflow and Vertex-centric models, for processing volume, velocity and linked datasets, and for storing and querying over NoSQL datasets. 2) Approaches and design patterns to translate existing data-intensive algorithms and analytics into these distributed programming abstractions. 3) Distributed software architectures, runtime and storage strategies used by Big Data platforms such as Apache Hadoop, Spark, Storm, Giraph and Hive to execute applications developed using these models on commodity clusters and Clouds in a scalable manner. Students will work with real, large datasets and commodity clusters, and use scalable algorithms and platforms to develop a Big Data application. See <http://cds.iisc.ac.in/courses/ds256/> for details

**Yogesh L Simmhan**

**Pre-requisites** : None

**References** : None

**DS 260 ( JAN ) 3 : 0****Medical Imaging**

X-ray Physics, interaction of radiation with matter, X-ray production, X-ray tubes, dose, exposure, screen-film radiography, digital radiography, X-ray mammography, X-ray Computed Tomography (CT). Basic principles of CT, single and multi-slice CT. Tomographic image reconstruction, filtering, image quality, contrast resolution, CT artifacts. Magnetic Resonance Imaging (MRI): brief history, MRI major components. Nuclear Magnetic Resonance: basics, localization of MR signal, gradient selection, encoding of MR signal, T1 and T2 relaxation, k-space filling, MR artifacts. Ultrasound basics, interaction of ultrasound with matter, generation and detection of ultrasound, resolution. Doppler ultrasound, nuclear medicine (PET/SPECT), multi-modal imaging, PET/CT, SPECT/CT, oncological imaging, medical image processing and analysis, image fusion, contouring, segmentation, and registration.

**Phaneendra Kumar Yalavarthy**

**Pre-requisites** : None

**References** : None

**DS 265 ( JAN ) 3 : 1****Deep Learning for Computer Vision**

Computer vision – brief overview; Machine Learning – overview of selected topics ; Introduction to Neural Networks, Backpropagation, Multi-layer Perceptrons ; Convolutional Neural Networks ; Training Neural Networks ; Deep Learning Software Frameworks ; Popular CNN Architectures ; Recurrent Neural Networks ; Applications of CNNs Classification, Detection, Segmentation, Visualization, Model compression; Unsupervised learning; Generative Adversarial Networks.

**Venkatesh Babu R****Pre-requisites** : None**References** : Current Literature**DS 284 ( AUG ) 2 : 1****Numerical Linear Algebra**

Introduction: Matrix and vector norms, arithmetic and computational complexity, floating point arithmetic. Matrix factorization and direct methods for solving linear systems: Gaussian elimination, LU factorization, Pivoting, Cholesky decomposition, QR factorization, Gram-Schmidt orthogonalization, Projections, Householder reflectors, Givens rotation, Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, generalized Schur decomposition (QZ decomposition), Least squares and solution of linear systems and pseudoinverse, normal equations. Stability Analysis: conditioning of a problem, forward and backward stability of algorithms, perturbation analysis. Eigenvalue problems: Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations, Power method, Schur decomposition, Jordan canonical form, QR iteration with & without shifts, Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Jacobi method, Divide and Conquer, Iter

**Pre-requisites** : None**References** : None

**DS 288 ( AUG ) 3 : 0****Numerical Methods**

Root finding: Functions and polynomials, zeros of a function, roots of a nonlinear equation, bracketing, bisection, secant, and Newton-Raphson methods. Interpolation, splines, polynomial fits, Chebyshev approximation. Numerical Integration and Differentiation: Evaluation of integrals, elementary analytical methods, trapezoidal and Simpson's rules, Romberg integration, Gaussian quadrature and orthogonal polynomials, multidimensional integrals, summation of series, Euler-Maclaurin summation formula, numerical differentiation and estimation of errors. Optimization: Extremization of functions, simple search, Nelder-Mead simplex method, Powell's method, gradient-based methods, simulated annealing. Complex analysis: Complex numbers, functions of a complex variable, analytic functions, conformal mapping, Cauchy's theorem. Calculus of residues. Fourier and Laplace Transforms, Discrete Fourier Transform, z transform, Fast Fourier Transform (FFT), multidimensional FFT, basics of numerical optimization

**Pre-requisites :** None

**References :** None

**DS 289 ( JAN ) 3 : 1****Numerical Solution of Differential Equations**

Ordinary differential equations: Lipschitz condition, solutions in closed form, power series method. Numerical methods: error analysis, stability and convergence, Euler and Runge-Kutta methods, multistep methods, Adams-Bashforth and Adams-Moulton methods, Gear's open and closed methods, predictor-corrector methods. Sturm-Liouville problem: eigenvalue problems, special functions, Legendre, Bessel and Hermite functions. Partial differential equations: classification, elliptic, parabolic and hyperbolic PDEs, Dirichlet, Neumann and mixed boundary value problems, separation of variables, Green's functions for inhomogeneous problems. Numerical solution of PDEs: relaxation methods for elliptic PDEs, Crank-Nicholson method for parabolic PDEs, Lax-Wendroff method for hyperbolic PDEs. Calculus of variations and variational techniques for PDEs, integral equations. Finite element method and finite difference time domain method, method of weighted residuals, weak and Galerkin forms, ordinary and we

**Konduri Aditya**

**Pre-requisites :** None

**References :** None

**DS 290 ( AUG ) 3 : 0****Modelling and Simulation****Pre-requisites** : None

**References** : P.E Kloeden, Platen, E., Numerical Solution of Stochastic Differential Equations . Springer, Berlin. doi : 10.1007/978 - 3 - 662 - 12616 - 5 . ISBN 978 - 3 - 540 - 54062 - 5 ,1992~Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2013). Discrete-event system simulation: Pearson new international edition. Pearson Higher Ed.~Asmussen, S., & Glynn, P. W. (2007). Stochastic simulation: algorithms

**DS 295 ( JAN ) 3 : 1****Parallel Programming**

1) Architecture: computer organization, single-core optimizations including exploiting cache hierarchy and vectorization, parallel architectures including multi-core, shared memory, distributed memory and GPU architectures; 2)Algorithms and Data Structures: algorithmic analysis, overview of trees and graphs, algorithmic strategies, concurrent data structures; 3) Parallelization Principles: motivation, challenges, metrics, parallelization steps, data distribution, PRAM model; Parallel Programming Models and Languages: OpenMP,MPI, CUDA; 4) Big Data Platforms: Spark/MapReduce model, cloud computing. Lab tutorials and programming assignments for above topics. Parallel Algorithms: MPI collective communication algorithms including prefix computations, sorting, graph algorithms, GPU algorithms; Parallel Matrix computations: dense and sparse linear algebra, GPU matrix computations;Algorithm models: Divide-and-conquer, Mesh-based communications, BSP model;Advanced Parallel Programming Models a

**Sathish S Vadhiyar****Pre-requisites** : None**References** : None

**DS 299 ( JAN ) 0 : 28****Dissertation Project**

This includes the analysis, design of hardware/software construction of an apparatus/instruments and testing and evaluation of its performance. The project work is usually based on a scientific/engineering problem of current interest. Every student has to complete the work in the specified period and should submit the Project Report for final evaluation. The students will be evaluated at the end first year summer for 4 credits. The split of credits term wise is as follows 0:4 Summer, 0:8 AUG, 0:16 JAN.

**Phani Sudheer Motamarri**

**Pre-requisites** : None

**References** : None

**DS 202 ( JAN ) 2 : 1****Algorithmic Foundations of Big Data Biology**

(0) Introduction: basics of biological data, high-throughput DNA/RNA sequencing and associated biotechnological breakthroughs, data structures and algorithms warm-up(1) Exact string pattern matching: Z algorithm, Knuth-Morris-Pratt and Boyer-Moore(2) Genome-scale index structures: suffix tries and suffix trees, Burrows-Wheeler Transform, FM-Index(3) Approximate string pattern matching: Hamming distance, edit distance, dynamic programming, pairwise and multiple sequence alignment (4) Alignment-free sequence comparison: co-linear chaining problem, whole-genome comparison (5)Genome assembly: de Bruijn graphs, overlap graphs, haplotype assembly and phasing (6)Pattern discovery: Hidden Markov models, gene finding(7)Phylogenetics: algorithms for evolutionary tree reconstruction, distance-based phylogeny, neighbour-joining algorithm (8)Trending topics: cancer genomics, deep learning in genomics, transcriptomics, single-cell omics, population genomics

**Chirag Jain****Pre-requisites**

Knowledge of basic data structures, algorithms, programming experience, and DS-221 (or) DS-201 (or) E0-251 (or) E0-225 (or) consent from the

**References** : Gusfield, Dan. "Algorithms on strings, trees, and sequences: Computer science and computational biology." ACM Sigact News 28.4 (1997): 41-60. Durbin, Richard, et al. Biological sequence analysis: probabilistic models of proteins and nucleic acids. Cambridge university press, 1998. Jones, Neil C. and Pavel Pevzner. An introduction to bioinformatics algorithms. MIT press, 2004.

## DS 269 ( JAN ) 2 : 1

## Computational Methods for Reacting Flows

This three-credit course that comprises two parts.

1. Solver design: Governing equations: conservation of mass, momentum, energy and species. Low mach number and fully compressible formulations. Non-dimensional numbers. Discretisation methods: finite difference and finite volume. Introduction to chemical kinetics: global and elementary reactions, Arrhenius equation, chemical time scales, stiffness. Elements of a solver development: initial and boundary conditions, simulation algorithms, verification and validation Dimensionality reduction: principal component analysis, higher order moment tensors. Regression methods for thermo-chemical coefficients

2. Data analytics: DNS database analysis: premixed and non-premixed turbulent flames, modes of combustion, flame structure, turbulence chemistry interactions, chemical explosive mode analysis Machine learning based analysis: flame surface extraction, detection of combustion instabilities

## Konduri Aditya

## Pre-requisites

Basic knowledge in combustion (AE 241 or equivalent), numerical methods for differential equations (DS 289 or equivalent) and machine learning :

## References

1. An Introduction to Combustion, Stephen R. Turns, McGraw Hill, 2011.
2. Theoretical and numerical combustion, Thierry Poinsot and Denis

## DS 215 ( AUG ) 3 : 0

## Introduction to Data Science

## Course

## Description:

This three credit course will be offered every August - December term as a hardcore course in the Dept. of Computational and Data Sciences (CDS). This is designed to be an introductory graduate level course (200-series) with an aim to equip first year graduate students (M.Tech./Ph.D.) with the necessary fundamentals as well as various statistical tools and techniques to analyze, estimate, learn and infer from data. At the end of the course, the students should be able to parse a real-world data analysis problem into one or more computational components learned in this course, apply suitable statistical inference/machine learning techniques and analyze the results obtained to enable optimal decision making. This would also act as a first course in data science and provide necessary prerequisites and knowledge to explore more specialized and involved topics in machine learning, analytics, statistics etc.

## Detailed

## Syllabus:

- Probability and Statistics  
Primer: Fun

## Pre-requisites

Undergraduate level knowledge of linear algebra,  
**References**  
 1. Athanasios Papoulis and S. Unnikrishna Pillai, Probability, Random Variables and Stochastic Processes, McGraw Hill Education, 2017.



**DS 298 ( JAN ) 3 : 1****Random Variates in Computation**

This course is aimed at introducing graduate students to random variate generation, and statistical methods in computation with continuously varying numbers. Basic sets of operations namely linear algebra, integration of functions, and evaluation of statistical parameters are addressed in high-dimensions where a purely numerical approach may either be unviable or significantly less efficient. The following is a brief description of the contents of the coursework.

Topics:

Part I - Random variate generation: Descriptive statistics; probability distributions; convergence of samples; concentration inequalities; operations on random variables and transformations; variates using inverse transform method; numerical stability of inversion; rejection sampling; scaling of rejection sampling with number of dependent variables; acceptance-complement method; linear transformations of multivariate distributions; specialized algorithms. (4 weeks)

Part II - Randomized numerical linear algebra: Background material in NLA; randomized SVD approximations and low-rank projections; matrix norm estimation; approximate matrix multiplication; single-view/streaming approximations of a matrix; randomized solution of linear system of equations and linear regressions. (4 weeks)

Part III - Random sampling and integration/estimation: Monte Carlo sampling; brief note on quasi-Monte Carlo (QMC) and deterministic sampling; Markov Chain Monte Carlo (MCMC) methods - Gibbs sampler, Metropolis type updates, and Hamiltonian dynamics; high-dimensional integration using MCMC; non-convex domains and integration using N-Sphere Monte Carlo (NSMC); stopping and confidence intervals; scaling of methods with number of dimensions; example problems and applications. (4 weeks)

**Murugesan Venkatapathi****Pre-requisites** :

Undergraduate level statistics and graduate level linear algebra.

**References** : 1. Luc Devroye, Non-uniform random variate generation, Springer-Verlag, New York 1986.

2. Martinsson, P. and Tropp, J., Randomized numerical linear algebra: Foundations and algorithms, Acta Numerica 29, 403-572 (2020).

**Artificial Intelligence for Medical Image Analysis**

X-ray Physics, interaction of radiation with matter, X-ray production, X-ray tubes, dose, exposure, screen-film radiography, digital radiography, X-ray mammography, X-ray Computed Tomography (CT). Basic principles of CT, single and multi-slice CT. Tomographic image reconstruction, filtering, image quality, contrast resolution, CT artifacts. Magnetic Resonance Imaging (MRI): brief history, MRI major components. Nuclear Magnetic Resonance: basics, localization of MR signal, gradient selection, encoding of MR signal, T1 and T2 relaxation, k-space filling, MR artifacts. Ultrasound basics, interaction of ultrasound with matter, generation and detection of ultrasound, resolution. Doppler ultrasound, nuclear medicine(PET/SPECT), multi-modal imaging, PET/CT, SPECT/CT, oncological imaging, medical image processing and analysis, image fusion, contouring, segmentation, and registration.

Learning outcomes:  
 On successful completion of the course, the student should be able to:  
 Identify the basic c

**Pre-requisites**

Basic knowledge of Systems and Signals, Proficiency in

**References**

Main Text Books:  
 Kevin Zhou, Medical Image Recognition, Segmentation

**DS 285 ( JAN ) 3 : 1****Tensor Computations for Data Science**

Unit-1: Fundamentals: Basic concepts of matrix properties: norms, rank, trace, inner products, Kronecker product, similarity matrix. Fast Fourier transform, diagonalization of matrices. Toeplitz and circulant matrices with their properties (eigenvalue and eigenvector), block matrix computation, and warm-up algorithms.

Unit-2: Introduction to Tensors: Tensors and tensor operations: Mode-n product of a tensor. Kronecker product of two tensors, tensor element product, tensor trace, tensor convolution, tensor quantitative product, Khatri-Rao product, the outer product. The Einstein product and t-product tensors. The explicit examples include identity tensor, symmetric tensor, orthogonal tensor, tensor rank, and block tensor.

Unit-3: Tensor Decomposition: Block tensor decomposition, Canonical Polyadic (CP) decomposition, the Tucker decomposition, the multilinear singular value (the higher-order SVD or HOSVD) decomposition, the hierarchical Tucker(HT) decomposition, and the tensor-train (TT) decomposition. Eigenvalue decomposition and singular value decomposition via t-product and the Einstein product. Truncated tensor singular value decomposition. Tensor inversion, and Moore-Penrose inverse. power tensor, solving system of multilinear equations.

Unit-4: Applications of Tensor decompositions: Low-rank tensor approximation, background removal with robust principal tensor component analysis, image deblurring, image compression, compressed sensing with robust Regression, higher-order statistical moments for anomaly detection, solving elliptic partial differential equations.

Unit-5: Tensors for Deep Neural Networks: Deep neural networks, Tensor networks and their decompositions, including, CP decomposition, Tucker decomposition, Hierarchical Tucker decomposition, Tensor train and tensor ring decomposition, Transform-based tensor decomposition. Compressing deep neural networks.

**Ratikanta Behera****Pre-requisites**

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**References**

:

**References**

(Books)

(1) Liu, Y. (Ed.). Tensors for Data Processing: Theory, Methods, and Applications.

## DS 207 ( JAN ) 3 : 1

## Introduction to Natural Language Processing

Syllabus:	Specifically,	we	will	cover:
Broad	Introduction	(Week	1):	
-	Why is processing languages hard?			
-	Bird's-eye view of applications and impact of the field			
-	Course			logistics
Text	Classification	(Week	1):	
-	Recap machine learning and deep learning basics			
-	Discriminative vs generative approaches, datasets, evaluation metrics			
Representation	Learning	(Week	2)	
-	Methods of representing words (word2vec, GloVe, etc.), Sentence- and document-level representations			
-	Intrinsic and extrinsic evaluation of learned representations			
Language	Modeling	(Week	3-6):	
-	Simple n-gram language models, smoothing, evaluation (Week 3)			
-	Neural language models with RNNs, LSTMs, etc (Week 4)			
-	Large Language Models (LLMs) (Week 5-6)			
--	Pre-training and emergent capabilities			
--	Prompt engineering and Scaling laws			
--	Applications, benefits and concerns associated with LLMs			
Conditioned	Generation	(Week	7-8)	
-	Basic approaches for conditioning, decoding algorithms (1 class)			
-	Machine translation and evaluation (e.g., BLEU) (2 classes)			
-	Other applications including summarization, chatbots, etc (1 class)			
Multilinguality		(Week	9)	
-	Key approaches (e.g., transfer learning), challenges, and benchmarks			
-	Cross-lingual transfer			
Structured	Prediction	(Week	10-11)	
-	Generative sequence models (Week 10)			
--	HMMs, Viterbi algorithm and applications in named entity recognition, speech transcription, etc.			
-	Discriminative sequence models (Week 11)			
--	CRFs and forward-backward algorithm			
Information	Extraction and Question Answering	(Week	12)	
-	Knowledge graphs and their representations, relation extraction			
-	Probing language models for knowledge			
-	Question answering benchmarks, approaches, evaluation, etc.			
Broader	societal and ethical implications of language technologies	(Week	13)	
-	Issues related to discrimination, (un)fairness and interpretability			
Final	Quiz and Poster Sessions	(Week	14)	

The course also includes three programming assignments that involve building systems for (1) text classification and learning word representations; (2) language modeling; (3) machine translation and/or named entity recognition. The assignments will be implemented using interactive Python notebooks intended to run on Google's Colab infrastructure. This allows students to use GPUs for free and with minimal setup. The notebooks will contain instructions interleaved with code blocks for students to fill in.

## Danish Pruthi

## Pre-requisites

The class is intended for graduate students and senior  
**References** : 1. Speech and Language Processing (3rd ed. draft) by Dan Jurafsky and James H. Martin  
 2. Introduction to Natural Language Processing by Jacob Eisenstein  
 3. Neural Network Methods for Natural Language Processing by Yoav Goldberg

# Management Studies

## Preface

### MG 223 ( JAN ) 3 : 0

#### Applied Operations Research

Introduction to management decision making and operations research. Fundamentals of linear programming. Alternative ways of formulating practical linear programming models. Their advantages and disadvantages. Case studies and applications of linear programming. Solution approaches, implications of sensitivity analysis. Transportation and assignment programming. Sensitivity analysis in transportation programming; integer programming formulations and applications. Basics of heuristic optimization. Dynamic programming. Applications of dynamic programming [Entire course will use real-life business applications].

#### Mathirajan M

**Pre-requisites** : None

**References** : Anderson, Sweeney, and Williams, An Introduction to Management Science: Quantitative Approaches to Decision Making, 11th Edition

### MG 261 ( AUG ) 3 : 0

#### Operations Management

Introduction to Production/Operations Management (P/OM), P/OM strategy, forecasting, process management, facility layout, capacity planning and facility planning, aggregate planning, material requirement planning, scheduling, inventory management, waiting line, project management, management of quality. Introduction to simulation and to supply chain management.

**Pre-requisites** : None

**References** : Stevenson, William, J., Production/Operations Management. 6th Edition. Irwin/McGraw-Hill., Krishnaswamy

### MG 201 ( AUG ) 3 : 0

#### Managerial Economics

Introduction to managerial economics, demand theory and analysis, production theory, cost theory, market structure and product pricing, Pricing of goods and services, pricing and employment of inputs. Micro and macro economics, national income accounting, GDP measurement, inflation and price level, aggregate demand and supply, fiscal and monetary policy.

**Pre-requisites** : None

**References** : Allen, Bruce et al: Managerial Economics: Theory, Applications, and Cases, WW Norton

**MG 202 ( AUG ) 3 : 0****Macroeconomics**

Macroeconomics: Overview, national income accounting, measurement of GDP in India, inflation and its measurement, price indices in India, aggregate demand and aggregate supply. India's macroeconomic crisis: causes and dimensions. Keynesian Theory, money and banking. How banks create money. Monetary Policy: Its instruments and uses, monetary policy in India, monetarism, supply side fiscal policies, Phillip's curve and theory of rational expectations. Case studies on macroeconomic issues.

**Pre-requisites** : None

**References** : Ministry of Finance: Economic Survey, Government of India, Recent Issues., Froyen, Macroeconomics: Theories and Policies

**MG 211 ( JAN ) 3 : 0****Human Resource Management**

Historical development - welfare to HRM in India. Personnel functions of management. Integrated HRPD system, human resource planning, job analysis, recruitment and selection, induction, performance appraisal and counseling, career planning and development, assessment center, wage and salary administration, incentives, benefits and services. Labour legislation - Industrial Disputes Act, Indian Trade Unions Act, Industrial Employment (Standing Orders) Act, dealing with unions, workers participation and consultation, grievance handling, employee relations in a changing environment, occupational health and safety, employee training and management development, need analysis and evaluation, managing organizational change and development. Personnel research, human resource management in the future.

**Parthasarathy Ramachandran**

**Pre-requisites** : None

**References** : DeCenzo and Robbins, Personnel and Human Resource Management, Prentice Hall, 1988. , Werther and Davis

**MG 212 ( AUG ) 2 : 1****Behavioral Science**

Understanding human behaviour; functionalist, cognitive, behaviouristic and social learning theories; perception; learning; personality; emotions; defense mechanisms; attitude; communication; decision making; groups and social behaviour; intra-personal and inter-personal differences; managing conflicts.

**Pre-requisites** : None

**References** : Luthans, F, Organizational Behaviour, McGraw-Hill, 1988. Weiten

**MG 225 ( AUG ) 3 : 0****Decision Models**

Analytical hierarchy process: structuring of a problem into a hierarchy consisting of a goal and subordinate features of the problem, and pairwise comparisons between elements at each level. Goal programming: Pareto optimality, soft constraints, identifying the efficient frontier, duality and sensitivity analysis. Data envelopment analysis: relative efficiency measurements, DEA model and analysis, graphical representation, and dual DEA model. Agent based modeling: complex adaptive systems, emergent structures and dynamic behaviors. Discrete event simulation: random number generators and generating random variates. Selecting input probability distributions and output data analysis. Neural networks: neuron model and network architecture, perceptron learning rule, and back propagation. Support vector machines: Learning methodology, linear learning machines, kernel-induced feature spaces.

**Pre-requisites** : None

**References** : None

**MG 241 ( AUG ) 3 : 0****Marketing Management**

Marketing function, marketing concept, relationship with other functions, relevance, marketing environment, markets. Consumer behavior, market segmentation, marketing planning, marketing mix, Product policy, new products, product life cycle. Pricing, distribution. Advertising and promotion. Marketing organization. Sales forecasting. Management of sales force, marketing control.

**Pre-requisites** : None

**References** : None

**MG 251 ( AUG ) 3 : 0****Finance and Accounts**

Nature and purpose of accounting, financial statements: learning, understanding the basic financial statements. Preparation of P and L account, balance sheet, basic accounts and trial balance. Income measurement, revenue recognition, depreciation accounting. Cash flow statements. Analysis and interpretation of financial statements; concepts and elements of cost, activity based costing. CVP analysis, break-even point, marginal costing, relevant costing. Cost analysis for decision making: opportunity cost concept, dropping a product, pricing a product, make-or-buy and product mix decisions. Joint products, by-products. Process costing. Standard costing, budgeting – flexible budget, master budget, zero based budgeting. Overview of Financial Management, time value of money, fund and cash flow statement, risk and return. Working capital management: estimating working capital, financing working capital, receivables management, inventory management, cash management, money markets in India. Capital Budgeting: appraising long term investment projects, make vs. buy investment decisions, estimating relevant cash flow. Capital Structure: Estimation of cost of debt, cost of equity, overall cost of capital, CAPM. Capital structure planning: Capital structure policy and target debt equity structure, EBIT-EPS analysis. Leasing. Introduction to valuation of firm. Introduction to derivatives.

**Pre-requisites** : None

**References** : None

**MG 258 ( JAN ) 3 : 0****Financial instruments and risk management strategies**

**Shashi Jain**

**Pre-requisites** : None

**References** : None

**MG 265 ( AUG ) 3 : 0****Data Mining**

Introduction to data mining. Data mining process. Association rule mining: Apriori and FP tree. Classification: ID3, C4.5, Bayes classifier. Clustering: K-means, Gaussian mixture model. Bayesian belief networks. Principal component analysis. Outlier detection.

**Pre-requisites** : None

**References** : Jiawei Han and Micheline Kamber, Data Mining: Concepts and Techniques, Morgan Kaufman Publishers 2001., Richard J. Roiger and Michael W Geatz, Data Mining: A Tutorial-Based Primer, Addison-Wesley 2003, Mehmed Kantardzic, Data Mining: Concepts, Models, Methods and Algorithms, Wiley, 2003



**MG 277 ( JAN ) 3 : 0****Public Policy Theory and Process**

Introduction to policy; conceptual foundations; practice of policy making; theories: social, institutional rational choice, punctuated equilibrium, and stages; frameworks and models; government and politics; rationality and governance; role of rules, strategies, culture and resources; member dynamics (institutional and non-institutional); analysis: meta, meso decision and delivery levels.

**Anjula Gurtoo**

**Pre-requisites** : None

**References** : Weimer,D.L.,and Vining A.R.,Policy Analysis: concepts and practice,Prentice Hall

**MG 281 ( JAN ) 3 : 0****Management of Technology for Sustainability**

Concepts of sustainability and sustainable development. Components of sustainability (social, economic, environmental). Linkages between technology and sustainability. Sustainability proofing of technology life cycle. Frameworks for measuring sustainability. Indicators of sustainability. Interactions between energy and technology and their implications for environment and sustainable development. Technological innovations for sustainability. Sustainable innovations – drivers and barriers. Policy and institutional innovations for sustainability transition.

**Balachandra P**

**Pre-requisites** : None

**References** : Dorf,Richard C.,Technology,humans,and society: toward a sustainable world

**MG 298 ( JAN ) 3 : 0****Entrepreneurship for Technology Start-ups****Bala Subrahmanya Mungila Hillemane**

**Pre-requisites** : None

**References** : None

**MG 301 ( JAN ) 3 : 0****Methodology of Management Research****Sumirtha Gandhi****Pre-requisites** : None**References** : None**MG 299 ( JAN ) 0 : 16****Management Project**

The project work is expected to give intensive experience for a student with respect to industrial organizations or institutions in the context of chosen field of specialization. Students are encouraged to carryout individual project works.

**Parthasarathy Ramachandran****Pre-requisites** : None**References** : None**MG 229 ( AUG ) 3 : 0****Regression and Time Series Analysis**

Review of Regression and Best Linear Prediction. Simple and Multiple Linear Regression - Uniformly Minimum Variance Unbiased Estimation, General Linear Hypotheses Testing, Prediction. Correlation Analysis - Simple, Multiple and Partial Correlations. Model Building - Feature Selection, Interactions, Transformations, Dummy Variable Techniques, Residual Analysis. Classical Decomposition of Time Series into Trend, Cyclical, Seasonal and Irregular Components. Stationary Stochastic Processes. Autocorrelation, Partial Autocorrelation, Impulse Response and Forecast Functions of Moving Average, Auto Regressive and ARMA Processes. Fitting ARMA Models. Trend Modeling - Deterministic versus Stochastic Trends, Integrated Processes, Unit Root Tests. Fitting, Interpreting and Forecasting using ARIMA Models. Seasonality Modeling – SARIMA Models.

**Pre-requisites** : MG220 or equivalent

**References** : • Applied Linear Statistical Models by Michael H. Kutner, Christopher J. Nachtsheim, John Neter and William Li., McGraw-Hill, International Edition.  
• Introduction to Time Series and Forecasting by Peter J. Brockwell Richard A. Davis. Second Edition, Springer.

**MG 220 ( JAN ) 3 : 0****Introductory Statistics**

Statistical Inference - Estimation, Hypothesis Testing & Forecasting. Frequentist Sampling Distribution. Point Estimation Criteria - MSE, Unbiasedness, Standard Errors, Consistency, Sufficiency. Exponential Family of Distributions. Uniformly Minimum Variance Unbiased Estimation. Point Estimation Methods - Method of Moments & Method of Maximum Likelihood. Confidence Intervals. Statistical Hypothesis Testing - Type I & Type II Errors, Size and Power of a Test, Neymann-Pearson Lemma, Uniformly Most Powerful Tests, Uniformly Most Powerful Unbiased Tests. Fixed Significance Level Testing versus Observed Significance Level (p-value) Testing. Likelihood Ratio Tests. Sampling Distributions for Normal Populations -  $\chi^2$ , t and F Distributions. Inference for the Mean and Variance of a Normal Population – z, t and  $\chi^2$  Tests and Intervals. Comparison of Means of two Normal Populations – Pooled, Welch and Paired t. Distribution-free Methods – Wilcoxon Rank Sum, Sign and Wilcoxon Signed Rank Tests, Empirical CDF and its Properties. Tests for Normality. Inference for Population Proportions – One Sample, Two Sample and Multi-Sample Problems – z-Tests;  $\chi^2$  Tests for Goodness of Fit, Homogeneity and Independence; Fisher's Exact Test and McNemar's Test.

**Mukhopadhyay C**

**Pre-requisites** : MG219 or equivalent

**References** : • Statistical Inference by George Casella and Roger L. Berger. Second Edition, 2001. Duxbury.  
 • Applied Statistics and Probability for Engineers by Douglas C. Montgomery & George C. Runger. Fifth Edition, 2014. Wiley.  
 • Statistics by David Freedman, Robert Pisani & Roger Purves. Fourth Edition, 2010. Viva Books.

**MG 219 ( AUG ) 3 : 0****Introductory Probability Theory**

Interpretation of Probability. Definition of Probability Space. Combinatorial Probability. Probability Laws - Complement, Addition and Multiplication Law. Conditional Probability. Bayes Theorem. Random Variables – Probability Mass Function, Probability Density Function, Cumulative Distribution Function, Moments & Quantiles. Chebyshev's Inequality. Jointly Distributed Random Variables – Joint, Marginal & Conditional Distributions, Covariance, Correlation & Regression. Properties of Expectation, Variance, Covariance, Correlation and Regression. Probability Generating Function, Moment Generating Function and Characteristic Function. Discrete Probability Models – Bernoulli, Binomial, Hypergeometric, Geometric, Negative Binomial and Poisson Distributions. Poisson Process. Continuous Probability Models – Uniform, Exponential, Gamma, Beta, Weibull and Normal Distributions. Almost Sure, in Probability, in Moment and in Distribution Convergence of Random Variables. Law of Large Numbers. Central Limit Theorem.

**Pre-requisites** : Multivariable Calculus and Linear Algebra

**References** : • A First Course in Probability by Sheldon Ross. Eighth Edition, 2010. Prentice Hall.  
 • Introduction to Probability Theory by Paul G. Hoel, Sidney C. Port and Charles J. Stone. 1971. Houghton Mifflin.  
 • Elementary Probability Theory with Stochastic Processes by Kai Lai Chung. Third Edition, 1974. Narosa Publishing House.

# Energy Research

## Preface

The academic programs (MTech (Res) and PhD) in the Energy Research centre are aimed towards advancing knowledge and skills related to the design of efficient energy conversion and storage processes and devices, utilization of energy resources- conventional fossil fuels to renewable sources such as solar, and waste-energy harvesting, and materials discovery and engineering. The program is open to students with diverse backgrounds in engineering and sciences and focus on equipping and training students to contribute to India's energy transition.

## ER 201 ( AUG ) 3 : 0

### Renewable Energy Technologies

Energy is a critical component in the daily life of mankind. Historically, energy production technologies have shown a continual diversification depending on technological, social, economical, and even political impacts. In recent times, environmental and ecological issues have also significantly affected the energy usage patterns. Hence, renewable energy sources are occupying increasingly important part of the emerging energy mix. This course gives an introduction to key renewable energy technologies. Case studies will be discussed to emphasize the applications of renewable energy technologies. At the end of the course students should be able to identify where, how and why renewable energy technologies can be applied in practice.

**Pre-requisites :** None

**References :** None

## ER 205 ( JAN ) 3 : 0

### Thermal Systems Design and Analysis

Basic equations of fluid mechanics, modified Bernoulli equation, major and minor head losses, pumps and piping systems, piping design problems, fans and air flow system design, heat exchanger design, sizing and rating, LMTD and NTU methods, shell and tube heat exchangers, compact heat exchangers, modelling thermal equipment, waste heat recovery systems, thermal system analysis and optimization methods, energy economics, solar collector and storage system design.

### Pradip Dutta

**Pre-requisites :** None

**References :** Text Books: 1)Thermal Design and Optimization by Bejan, Tsatsaronis & Moran 2)Design of Thermal Systems by W. Stoecker References: 1)F.P. Incropera and D.P. Dewitt, Introduction to Heat Transfer 2)Jaluria, Y., Design and Optimisation of Thermal Systems 3)Burmeister, L.C., Elements of Thermal-Fluid System Design 4)Janna, W.S., Design of Fluid Thermal Systems

**ER 207 ( AUG ) 3 : 0****Optimal design of energy systems**

Thermodynamics and entropy review. Guoy-Stadola theorem, exergy (physical and chemical), component-level 2nd law efficiency. Non-equilibrium thermodynamics, flux and conjugate driving forces, local entropy generation density. Economics of energy systems: CapEx vs. OpEx trade-off, limiting cases and parasitic losses. Power-plant design and optimal resource allocation. Multi-variable optimization, constrained optimization, introduction to calculus of variations. Balancing for energy efficient design. examples from heat exchangers, cryogenic systems, desalination technologies (reverse osmosis, multi-effect distillation, humidification-dehumidification). Control strategies for energy-optimal operation, with examples from air-conditioning.

**Pre-requisites** : None

**References** : Adrian Bejan, George Tsatsaronis, Michael J. Moran, Thermal Design & Optimization (2012), John Wiley & Sons

**ER 208 ( JAN ) 3 : 0****Introduction to Micro Energy Harvesting**

Introduction to micro energy harvesting. Micro energy harvesting using piezoelectric, triboelectric, electrostrictive, flexoelectric, and electrostatic electromechanical couplings. Micro-electromechanical systems (MEMS), nanogenerators, and sensors. Hydrovoltaic energy harvesting from water interaction with materials using water waving, evaporation, moisture, drawing, reverse electrodialysis, and reverse electrowetting processes. Pyroelectric, thermoelectric, magnetoelectric effects-based micro energy harvesting. Radio Frequency (RF) and non-RF micro energy harvesting. Materials in micro energy harvesting, roles of material design in the enhanced energy harvesting performance, basics of micro energy harvesting device fabrication, and applications of micro energy harvesting. Recent developments, renewability, and sustainability in micro energy harvesting.

**Farsa Ram**

**Pre-requisites** : None

**References** : Book:  
1. Micro Energy Harvesting by Danick Briand, Eric Yeatman, Shad Roundy, Link: <https://www.wiley.com/en-us/Micro+Energy+Harvesting-p-9783527672929>

# Water Research

## Preface

### WR 201 ( AUG ) 2 : 1

#### Watershed Modeling

Course description: This course will cover the concepts of watershed modeling. This three-credit course will be offered as an elective every year in the August-December term in the ICWaR. This course is aimed to be an introductory graduate-level (200-series) course, typically with Water Resources Engineering background. In-class lectures include basic and advanced topics related to surface hydrology. Additionally, the basics of computer methods in hydrology will be discussed. Tutorial sessions on MATLAB, MS Excel, and ArcSWAT will be conducted. Calibration and validation of ArcSWAT (distributed model) and HYMOD (lumped model) will be performed during tutorial sessions.

#### Topics

1. Introduction to watershed modeling  
Runoff generation and streamflow. Spatio-temporal scales in watershed modeling. Watershed properties.
2. Pre-processing of model inputs  
Understanding watershed model inputs. Basics of MATLAB computations. Hydrologic data processing in MATLAB.
3. Data-driven watershed models  
Stochastic models (ex: Quantile regression). Neural network models.
4. Different watershed models  
Lumped/ Distributed/ Physical/ Conceptual watershed models. Thornwaite-type water balance model. Thomas model (abcd) model. Data assimilation in abcd model. Introduction to ArcSWAT and HYMOD. Flood forecasting. Performance measures.
5. Predicting the future  
Future hydrologic projections. Impact of climate change on river discharge. Uncertainty in river discharge estimation.

#### Tutorial

Processing of Geospatial and temporal data for watershed modeling. MATLAB tutorials. 'abcd' model set-up in MS Excel. Stochastic and NN model setup in Matlab. Calibration and validation of HYMOD and ArcSWAT. Development of forecast models. Sessions

#### Pre-requisites

Nona

#### References

Dingman, S. P., & L. Frevert, (2015). Physical hydrology. Waveland press.  
Singh, V. P., & D. K. (Eds.). (2010). Watershed models. CRC press. Textbooks:

**WR 202 ( JAN ) 3 : 0****Geodetic signal processing**

A brief introduction to physical and satellite Geodesy, Geodetic data and Earth's surface processes, data from GRACE satellite mission, Introduction to filtering, Kalman filter, Regression, time-series decomposition, moving window averages, introduction to data assimilation, Spherical harmonic analysis and synthesis, GRACE data processing, Global mass change trends, estimating Ice-sheet mass change, estimating groundwater change from satellites, closing the water and sea level budget.

**Bramha Dutt Vishwakarma****Pre-requisites**

MATLAB or Python, ES 220 (would help but not compulsory),

**References**

1. Torge, W., & Müller, J. (2012). Geodesy. In Geodesy. de Gruyter.
- 2.

**WR 203 ( AUG ) 2 : 1****Applied geochemical modeling and Water quality analysis**

Simulation and modelling

- Introduction to the Storm Water Management Model (SWMM) in Urban Catchments (4 hr)
- Tutorial on BRAT (Basic Radar Altimetry Toolbox) (4 hr)
- Tutorial on Remote Sensing (4 hr)
- Introduction to Climate/Earth System Modeling (4 hr)

Basic electronic instrumentation (6 hr)

Measurements of ionic contaminants using an ICPMS and IC (6 hr)

Water Quality (1 hr)

- To assess the alkalinity of a given water sample. (1 hr)
- Determine chloride ion concentration in a water sample. (1 hr)
- To assess the total solids of a given sample of water. (1 hr)
- Measure Total hardness using dye indicators. (1 hr)
- To introduce concepts of total coliforms using the multiple-tube fermentation technique. (2 hr)
- To assess the color of the given water sample. (1 hr)
- Determine the DO content of a given sample. (1 hr)
- To assess the pH value of the given water samples. (1 hr)
- To assess the residual chlorine of the given water sample. (1 hr)

**Pre-requisites** : None

**References** : ITM User's Manual available at the web site <http://web.engr.oregonstate.edu/~leon/ITM.htm>  
 Chavez, P.S., 1996. Image-based atmospheric corrections-revisited and improved. Photogramm. Eng. Remote Sens. 62, 1025-1036.

**WR 204 ( JAN ) 3 : 0****Aqueous Geochemistry**

The focus of this course is to develop an understanding of the chemical compositions of natural waters, emphasizing both physiochemical and biogeochemical processes operating in aqueous systems: equilibrium vs. kinetic controls, redox reactions, aqueous complexes, chemical weathering, solute sources, and mass balances in watersheds, etc. Moreover, the application of stable and radiogenic isotope geochemistry used for fingerprinting processes that control water chemistry (rivers, oceans, groundwater) will be discussed. Simple hydrogeochemical modelling techniques will also be introduced.

1. Introduction to the hydrosphere: water cycle, catchment hydrology mass balance, biogeochemical cycles
2. Aqueous chemical reactions: Equilibrium and kinetic concepts, acids& bases, redox, adsorption-desorption, speciation and complexes, organic reactions and interactions.
3. Isotope geochemistry: stable isotopes (O, H, C and N), stable metal isotope systems (Ca, Mg, Li, Fe, etc.), radiogenic isotopes (Rb-Sr, etc.) applications in natural aquatic systems.
4. Weathering: silicate and carbonate chemistry
5. Composition of natural waters: rivers, oceans, groundwater, global issues
6. Hydrogeochemical modelling techniques: mixing models, source apportionments, etc.

**Praveen Ramamurthy**

**Pre-requisites :** None

- References :**
1. Donald Langmuir (1997), Aqueous Environmental Geochemistry. Prentice Hall.
  2. Carol Kendall and Jeffrey J. McDonnell (Eds) (2006), Isotope Tracers in Catchment hydrology. Elsevier.
  3. William M. White (2013), Geochemistry. Wiley-Blackwell.



# Cyber Physical Systems

## Preface

The Center for Cyber-Physical Systems focuses on interdisciplinary areas including robotics, control and optimization, mobility and urban intelligence, and energy management. The courses are designed to provide good theoretical background and hands-on experience in these areas. The center offers three programs - PhD, MTech (Research) and MTech in Robotics and Autonomous Systems.

## CP 212 ( AUG ) 2 : 1

### Design of Cyber-Physical Systems

This course will be taught jointly with Dr. Ashish Joglekar and Darshak Vasavada. This is an interdisciplinary course on the design of cyber- physical systems, inviting students from all the departments. It provides an in-depth exposure to various elements of a CPS: the microprocessor, interfacing physical devices (analog and digital) and control systems basics. This course uses a practical approach and involves significant programming. Syllabus: 1. Microprocessor system 2. Interfacing physical devices 3. Control system basics 4. EMI/ EMC considerations 5. Network connectivity

**Pre-requisites** : None

**References** : Embedded Systems: a CPS approach: Lee and Seshia~Embedded Systems -Shape the World: Valvano and Yerraballi~Basics of Microprocessor Programming: Darshak Vasavada and S K Sinha

## CP 214 ( AUG ) 3 : 1

### Foundations of Robotics

NOTE: This course is cross-listed with CSA (soft core for CSA) Motivation and objective: As we see an increasing use of industrial and service robots around us, there is a need for development of new skills in the field of robotic systems. More importantly, there is a need for development of new expertise in controllers, systems, sensors and algorithms that are tailored for the domain of robotic systems. Therefore, the objective of this course is to serve as an introductory robotics course for EECS students with little/no background in mechanical systems. The course will first build the necessary mathematical framework in which to understand topics relevant to fundamentals of mechanical systems. Some of the topics are center of gravity and moment of inertia, friction, statics of rigid bodies, principle of virtual work, kinematics of particles and rigid bodies, impacts, Newtonian and Lagrangian mechanics. With these fundamentals, the course will focus on topics like rigid body trans

**Pre-requisites** : None

**References** : Ruina, Andy and Pratap, Rudra, Introduction to Statics and Dynamics, Oxford University Press, 2011.~Murray, Li and Sastry, A Mathematical Introduction to Robot Manipulation, CRC Press, 1994~A. Ghosal, Robotics: Fundamental Concepts and Analysis, Oxford, 2006

**CP 220 ( AUG ) 2 : 1****Mathematical Techniques for Robotics Systems**

Linear Algebra Basics: Matrices, Vector Spaces, Independence, Rank, Mappings Analytic Geometry Basics: Inner products, norms, orthonormal basis, projections, rotations Matrix Decomposition: Determinant & Trace, Eigenvalues and vectors, Cholesky decomposition, Eigen Decomposition, Singular Value decomposition Vector Calculus: Gradients of functions and matrices, Backpropagation and Automatic Differentiation Floating point arithmetic, Optimization Basics: Gradient Descent, Constrained optimization, Convex Optimization. Probability and Stats Basics: Conditional Probability & Independence, Discrete distributions, Continuous distributions, Hypothesis Testing, Computational Techniques: Linear Regression, Density Estimation, Monte Carlo Methods.

**Pre-requisites** : None

**References** : Mathematics for Machine Learning, M P Deisenroth, A Aldo Faisal, Cheng Soon Ong

**CP 316 ( JAN ) 2 : 1****Real-time Embedded Systems**

The course is organized in three parts: standalone (OS less) systems, multi-tasking systems with RTOS and systems with embedded OS. The course involves significant programming in C on embedded platforms running RTOS / embedded Linux. Part 1: Standalone systems: Software architecture: control loop, polling and interrupt driven systems, PID control and finite state machine Experiments: interfacing sensors and actuators to implement a standalone control system on an ARM based hardware platform. Part 2: Multi-tasking systems: Introduction to real-time systems, multitasking, scheduling, inter-task communication, memory management and device drivers. Experiments: build a multitasking system involving multiple simultaneous activities involving computing algorithms, IO processing and a user interface. Part 3: Embedded Linux: Building an embedded Linux system; processes and threads, memory management, file-system, drivers. Real-time limitations and extensions.

**Bharadwaj Amrutur**

**Pre-requisites** :

**References** : Real-time and Embedded Guide, Herman Bruyninckx <https://www.cs.ru.nl/lab/xenomai/RealtimeAndEmbeddedGuide-Bruyninckx.pdf> Embedded Linux Primer: A Practical Real-World Approach, Christopher Hallinan Embedded Systems - Shape the World: Valvano and Yerraballi <http://users.ece.utexas.edu/~valvano/Volume1/E-Book>

**CP 230 ( JAN ) 2 : 1****Motion Planning for Autonomous Systems**

(Theory) Motion planning in discrete space; Logic-based planning methods; Geometric representations; Kinematic chains and rigid and non-rigid transformations; Configuration space; Topological space concepts; Obstacles; Collision detection and avoidance in relative velocity space; Collision cones and velocity obstacles; Artificial potential fields; Flocking; Formation control; Sampling based motion planning; Collision detection, incremental sampling and searching, Rapidly exploring random trees, roadmap methods; Combinatorial motion planning; Complexity. (Laboratory) Path planning infrastructure in software; Planning space representation through vector constructs, Discretization of planning space, sampling the planning space, node-graph representations; Grid search based planning (A\* algorithm); Forward and inverse kinematics, obstacle representations; planning complexity, Various heuristics for A\* algorithm; Sampling based planning (RRT & RRT\* algorithms); Path planning using RRT;

**Pradipta Biswas****Pre-requisites** :

**References** : 1.S.M. LaValle, Planning Algorithms, Cambridge University Press,2006. 2.M.Mesbahi and M.Egerstedt, Graph Theoretic Methods in Multiagent Networks, Princeton Series in Applied Mathematics,2010. 3.J.-C. Latombe, Robot Motion Planning (Vol. 124). Springer Science & Business Media, 2012. 4.Current Literature

**CP 260 ( JAN ) 2 : 1****Robotic Perception**

Module 1: Probabilistic Techniques State Estimation & Bayesian Inference Parametric and Non-parametric Filters for Sensor Signal Processing. Kalman filter and its variants, Use of simple motion models with wheel and IMU odometry in the assignments. Robotic Localization & Perception Laboratory Exercises for each of the above  
 Module 2: Introduction to Deep Learning Techniques Deep feedforward networks Convolutional Neural Networks Recurrent Networks Laboratory Exercises  
 Module 3: Case Studies on Perception for Robotics Basics of Image Processing and Manipulation. Basics of low-level vision, filtering, feature extraction, etc. Object Detection and Segmentation Pose estimation and semantic segmentation. Visual Odometry and Localization Visual SLAM. Introduce fusion of point cloud data and lidar data with RGB. Laboratory Exercises for each of the above.

**Bharadwaj Amrutur****Pre-requisites** :

**References** : Probabilistic Robotics, S. Thrun Deep Learning, I Goodfellow Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010 (For the vision part).

**CP 218 ( JAN ) 2 : 1****Theory and Applications of Bayesian Learning**

Descriptive Statistics, Introduction to Probabilities, Bayes Rules, Probability Distributions, Maximum Likelihood Estimation, Bayesian Regression and Classification, Expectation-Maximization, Frequentist vs Bayesian Learning, Conjugate Priors, Graph Concepts, Bayesian Belief Networks, Probabilistic Graphical Models (PGMs), Probabilistic and Statistical Inferencing, Bayesian Estimation, Structure Learning, Bayesian Optimization, Markov Random Fields, Markov Chain Monte Carlo, PGM examples and applications (including industry and smart cities applications).

**Punit Rathore****Pre-requisites** :

**References** : Probabilistic Graphical Models, Principles and Techniques, 1st edition, Daphne Koller, Cambridge University Press, 2009. Machine learning: A Probabilistic Perspective, Kevin Murphy, MIT Press, 2012. Pattern Recognition and Machine Learning, Christopher Bishop, New York, Springer, 2006. Bayesian Reasoning and Machine Learning, David Barber, Cambridge University Press, 2012

**CP 275 ( JAN ) 2 : 1****Formal Analysis and Control of Autonomous Systems**

This course will provide an end-to-end overview of different topics involved in designing or analyzing autonomous systems. It begins with different formal modeling frameworks used for autonomous systems including state-space representations (difference equations), hybrid automata, and in general labeled transition systems. It also discusses different ways of formally modeling properties of interest for such systems such as stability, invariance, reachability, and temporal logic properties. As a next step, the course will cover different techniques on the verification of such systems including Lyapunov functions, reachability, barrier certificates, and potentially model checking. Finally, the course will introduce students to several techniques for designing controllers enforcing properties of interest over autonomous systems.

**Pushpak Jagtap****Pre-requisites** :

**References** : • E. A. Lee and S. A. Seshia. Introduction to Embedded Systems: A Cyber-Physical Systems Approach. MIT Press, 2017.  
• C. Belta, B. Yordanov, and E. Gözl. Formal Methods for Discrete-Time Dynamical Systems. Springer International Publishing, 2017.  
• C. Baier and J. P. Katoen. Principles of Model Checking. MIT Press, 2008.

**CP 299 ( JAN ) 0 : 26****MTech Project**

Project work under guidance of advisor(s)

**Pushpak Jagtap**

**Pre-requisites** : None

**References** : As per supervisor's recommendation

**CP 320 ( AUG ) 3 : 0****Operations Research for Mobility Management**

This course will introduce operations research (OR) techniques applied to cyber-physical systems (CPS), with an emphasis on decision making for mobility management. Urban mobility is evolving from a fixed supply chain that delivers process-driven travel to a dynamic ecosystem that delivers on-demand services. This new mobility model requires optimization across multiple systems such as transportation, parking, electric vehicle charging and vehicle-to-grid services, etc. The complexity, therefore, arises from the large scale of operations; heterogeneity of system components; dynamic and uncertain operating conditions; and goal-driven decision making and control with time-bounded task completion guarantees.

The focus in this course will be on various classical optimization techniques and learning to optimize approaches that can be applied to solve operational problems at scale in the urban mobility domain. Examples of some decision questions include planning/scheduling charging operations for a fleet of electric vehicles; dynamic pricing for charging demand management; electric vehicle route planning for last-mile delivery of goods and other valued-added services (such as selling energy back to the grid); operations management of mixed fleet of vehicles; etc. Selective operations research topics such as linear programming and combinatorial optimization; dynamic programming; sequential decision making under uncertainty; reinforcement learning; etc.; will be covered to understand the mathematical concepts for problem solving in mobility management.

This course will be relevant to both computer science and electrical engineering students, as well as benefit those specializing in cyber physical systems and sustainable transportation.

**Pre-requisites** :

A preliminary understanding of mathematical programming would  
**References** : • Wayne L. Winston (2003). Operation Research: Applications and Algorithms  
 • Nocedal and Wright (2006). Numerical Optimization (Springer Series in Operations Research)  
 • Norving and Russel (2010). Artificial Intelligence: A Modern Approach (Prentice Hall Series in Artificial Intelligence)

**CP 241 ( AUG ) 2 : 1****Applied Linear and Nonlinear Control**

Linear Systems - Mathematical representation of dynamical systems, State-space and input-output representations, Time response of homogeneous and non-homogeneous systems, Stability, Controllability and observability, State feedback controllers and pole placement, State observers, LQR control, PID control

Nonlinear Systems – Mathematical background for nonlinear systems, Equilibrium points, Essential nonlinear phenomenon like finite escape time, multiple isolated equilibria, limit cycle, chaos etc. Lyapunov and input-state stability, Control Lyapunov functions, Feedback linearization, Model predictive control

Lab - Simulation of linear, nonlinear, and hybrid control systems, Phase-space visualizations, Implementation of different controllers on various robotics and autonomous systems.

**Pre-requisites** :

None  
**References** : 1. A Linear Systems Primer by Antsaklis and Michael, Birkhauser, 2007.  
 2. Linear Systems Theory by Hespanha, Princeton University Press (2nd Edition), 2018.  
 3. Linear System Theory and Design by Chen, Oxford University Press (4th Edition), 2013.

**CP 330 ( JAN ) 2 : 1****Edge AI**

This course provides students with the fundamentals of edge AI and hands-on experience in designing end-to-end AI systems for resource-constrained computing devices, such as microcontrollers. It aims to equip students with knowledge of hardware systems and AI model optimization techniques and tools for IoT edge devices. After completing the course, students will have the skills to implement AI models, such as computer vision, on embedded/edge devices for various real-world applications, including smart cities, sustainability, healthcare, and agriculture. The topics to be covered in this course include:

- Introduction to Edge AI
- ML/AI Algorithms and Computer Vision Fundamentals
- Edge AI Hardware and Accelerators
- Edge AI Software Frameworks and Libraries
- Model Optimization and Pruning Techniques and Tools
- Deployment of Edge AI Systems and Case Studies

**Pandarasamy Arjunan****Pre-requisites**

Proficiency in Python programming is essential, while C

**References** : 1. AI at the Edge: Solving Real-World Problems with Embedded Machine Learning (2022) by Daniel Situnayake and Jenny Plunkett.

2. Deep Learning on Microcontrollers: Learn how to develop embedded AI applications using TinyML (2023) by Atul Krishna Gupta and Dr.

**CP 217 ( AUG ) 3 : 1****Machine Learning for Cyber-Physical Systems**

Frequentist Statistics, Parametric vs Non-parametric models, Linear and Non-Linear Regression, Classification (logistic regression, NB, DT, kNN, SVM), Kernels, Ensemble Models (Bagging, Boosting, Stacking), Clustering (k-means, GMM-EM, Spectral, Hierarchical, DBSCAN), Neural Networks and Deep Learning, Anomaly Detection, Dimensionality reduction, Semi-supervised learning, and Active learning

**Pre-requisites**

Basic knowledge of Linear Algebra, Probability, and Calculus, and Basic Programming knowledge (preferably in Python)

**References** : Pattern Recognition and Machine Learning, Christopher Bishop, New York, Springer, 2006

Machine learning: A Probabilistic Perspective, Kevin Murphy, MIT Press, 2012

**CP 331 ( AUG ) 2 : 1****Energy Data Analytics**

This course teaches the fundamentals of data-driven predictive models to improve the efficiency of various energy systems. It emphasizes practical implementation and real-world energy data analysis through case studies. The main topics covered include:

- Introduction to energy systems, IoT for energy monitoring and smart meters.
- Statistical methods and visual analytics for energy datasets.
- Machine learning (regression, classification, clustering) and data-driven models
- Physics-based models and whole-building energy simulations.
- Case studies: energy forecasting, benchmarking, load profile analysis, consumer segmentation, and anomaly detection.

**Pre-requisites**

Basic knowledge of Linear Algebra, Probability and Statistics, and Programming (preferably in Python).

**References :** - Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow by Aurélien Géron, 3rd Edition, O'Reilly Media, Inc., 2022  
 - Forecasting: principles and practice (2021) By Rob J Hyndman  
 - Applied Data Analysis and Modeling for Energy Engineers and Scientists (2011) by T. Agami Reddy

**CP 321 ( JAN ) 2 : 1****Imitation Learning for Robotics**

Course

Content:

This course delves into the advanced field of imitation learning (IL) as applied to human-robot interaction, encompassing a diverse range of essential topics. It begins with an introduction to the application of machine learning for end users and the integration of IL within interaction pipelines, emphasizing the standardization of terminology to facilitate effective communication and development. Modalities such as reinforcements, preferences, and various teaching methods—absolute and relative—are explored alongside a survey of interfaces including physical contact, teleoperation, video, voice, display, sound, and haptics, highlighting their roles in enhancing interaction quality. Design considerations for IL algorithms encompass pivotal choices like access to reward functions (imitation versus reinforcement learning), system dynamics (model-based versus model-free approaches), and feature sets influencing learning outcomes, such as end-effector manipulation and object interaction. The course offers detailed study into IL techniques for both low-level motion trajectories and high-level task learning, covering trajectory representation methods (keyframe, DMP, probabilistic models, time-invariant dynamical systems) and strategies for generalizing learned behaviors to novel situations. It also addresses compliant control strategies crucial for safe human-robot collaboration, the role of simulators in robotics applications, and methodologies for conducting user studies and evaluating performance metrics. Throughout, students explore the current challenges and future opportunities in applying IL to enhance human-robot interaction across various domains.

**Ravi Prakash****Pre-requisites**

This course assumes that the student has taken a basic course in AI and Robotics and is familiar with the following concepts:

**References :** 1. Celemin, Carlos, Rodrigo Pérez-Dattari, Eugenio Chisari, Giovanni Franzese, Leandro de Souza Rosa, Ravi Prakash, Zlatan Ajanović, Marta Ferraz, Abhinav Valada, and Jens Kober. "Interactive imitation learning in robotics: A survey." Foundations and Trends® in Robotics 10, no. 1-2 (2022): 1-197.

**CP 213 ( JAN ) 2 : 1**

**Hands-on introduction to Robotic Actuators**

Motor basics, Encoder basics and interfaces, Motor driver (h-bridge based), PID closed loop control, Mobile robot frame design and assembly, Soft robotics basics - hyperplastic materials, Material models and FEA, Simple Pneumatic Actuator mold design and fabrication, Gripper pneumatic connections, Air pump, solenoid valve and actuation

- 11. UI (HMI) for teleoperation mode
- 12. Person follower mode through ML models
- 13. Integration of gripper with mobile robot
- 14. Final Demonstration

**Bharadwaj Amrutur**

**Pre-requisites** :  
 Exposure to Embedded Systems, C / C++ or Python Programming,  
 Basic  
**References** :  
 ASME IEEE Transactions  
 Transactions

**CP 290 ( JAN ) 1 : 2**

**Commercializing Innovation: The Science& Strategy**

Unbundling-rebundling journey and the Startup Calculus, Market research (top-down and bottom-up market sizing and competitor analysis), User model definition, User model validation, Value model definition, Value model validation, Business model definition, Business model validation, PMF, Entrepreneurial teams: skill sets needed, how to distribute equity, ESOPs, etc., Funding: how do VCs work? Should you raise capital or not?, Storytelling and creating pitch-deck

**Bharadwaj Amrutur**

**Pre-requisites** :  
 recommended for final year PG,UG students who are interested in  
 understanding what it takes to commercialize innovation and perhaps  
**References** :  
 Crossing the Chasm Harvard Business Review



# Division of Mechanical Sciences

## Preface

The Division of Mechanical Sciences consists of the departments of Aerospace Engineering, Atmospheric and Oceanic Sciences, Civil Engineering, Chemical Engineering, Divecha Centre for Climate Change, Earth Sciences, Mechanical Engineering, Materials Engineering, Product Design and Manufacturing, and Sustainable Technology. It also maintains an Advanced Facility for Microscopy and Microanalysis (AFMM) and manages the Space Technology Cell (STC). The courses offered in different departments of the Division have been reorganized after review and revision. These are identified by the following codes.

AE	Aerospace Engineering
AS	Atmospheric and Oceanic Sciences
CE	Civil Engineering
CH	Chemical Engineering
DC	Divecha Centre of Climate Change
ER	Earth Sciences
ME	Mechanical Engineering
MT	Materials Engineering
PD	Product Design and Manufacturing
ST	Sustainable Technologies

The first two letters of the course number indicate the departmental code. All the departments and centres (except the Space Technology Cell) of the Division provide facilities for research work leading to the degrees of MTech (Research) and PhD. There are specific requirements for completing a Research Training Programme (RTP) for students registered for research at the Institute. For individual requirements, students are advised to consult the Departmental Curriculum Committee (DCC). MTech Degree Programmes are offered in all the above departments except in the Centre for Product Design and Manufacturing, which offers Master of Design (MDes). Most of the courses are offered by the faculty members of the Division, but instruction by specialists in the field and experts from industries is arranged in certain topics. Student feedback is important to maintain quality, breadth, and depth in courses. Hence, students are urged to actively participate in providing feedback after the completion of each course. Written comments are especially encouraged from the students in addition to marking the scores.

Prof. G. K. Ananthasuresh

Dean

Division of Mechanical Sciences

# Aerospace Engineering

## Preface

### AE 202 ( AUG ) 3 : 0

#### Fluid Dynamics

Properties of fluids, kinematics of fluid motion, conservation laws of mass, momentum and energy, potential flows, inviscid flows, vortex dynamics, dimensional analysis, principles of aerodynamics, introduction to laminar viscous flows.

**Pre-requisites :** None

**References :** Kundu, P.K., Cohen, I.M. and Dowling, D.R., Fluid Mechanics, Academic Press, 2016. ~Fay, J.A., Introduction to Fluid Mechanics, Prentice Hall of India, 1996. ~Gupta, V. and Gupta, S.K., Fluid Mechanics and its Applications, Wiley Eastern, 1984 ~Kuethé, A.M. and Chou, S.H., Foundations of Aerodynamics, Wiley, 1972

### AE 203 ( AUG ) 3 : 0

#### Mechanics and Thermodynamics of Propulsion

Classical thermodynamics, conservation equations for systems and control volumes, one dimensional flow of a compressible perfect gas – isentropic and non-isentropic flows. Propulsion system performance, the gas generator Brayton cycle, zero dimensional analysis of ideal ramjet, turbojet and turbofan cycles, non-ideality and isentropic efficiencies. Performance analysis of inlets and nozzles, gas turbine combustors, compressors and turbines and discussion of factors limiting performance. Chemical rockets - thrust equation, specific impulse, distinction between solid and liquid rockets, maximum height gained analysis, multi-staging, characteristics of propellants.

**Pre-requisites :** None

**References :**  
Philip G. Hill and Carl R. Peterson. "Mechanics and thermodynamics of propulsion." Reading, MA, Addison-Wesley Publishing Co., 1992 ~Nicholas

**AE 205 ( AUG ) 3 : 0****Navigation, Guidance and Control**

Navigation: Continuous waves and frequency modulated radars, MTI and Doppler radars; Hyperbolic navigation systems: INS, GPS, SLAM; Guidance: Guided missiles, guidance laws: pursuit, LOS and PN laws, Guidance of UAVs; Control: Linear time invariant systems, transfer functions and state space modeling, analysis and synthesis of linear control systems, applications to aerospace engineering.

**Pre-requisites** : None

**References** : AE NGC Faculty, Lecture Notes.~Skolnik, M. I., Introduction to Radar Systems, 2<sup>nd</sup> edition, McGraw Hill Book Company~Bose A., Bhat, K. N., Kurian T., Fundamentals of Navigation and Inertial Sensors, 1<sup>st</sup> edition, Prentice-Hall India.~Noureldin, A., Karamat, T. B., and Georgy, J., Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration, 1<sup>st</sup> edition ,

**AE 211 ( AUG ) 3 : 0****Mathematical Methods of Aerospace Engineers**

Ordinary differential equations; Elementary numerical methods; Finite differences; Topics in linear algebra; Partial differential equations.

**Pre-requisites** : None

**References** : Erwin Kreysig, Advanced Engineering Mathematics Wiley 2015.

**AE 221 ( JAN ) 3 : 0****Aerodynamics**

Introduction to aerodynamics, potential flows, conformal mapping and Joukowski airfoils, Kutta condition, thin airfoil theory, viscous effects and high-lift flows, lifting line theory, vortex lattice method, delta wings, compressibility effect, supersonic flows, unsteady aerodynamics.

**Sourabh Suhas Diwan , Srisha Rao M V**

**Pre-requisites** : None

**References** : Houghton, E.L. and Carpenter, P.W., Aerodynamics for Engineering Students, Butterworth-Heinemann 2003.~Katz, J. and Plotkin, A., Low-speed Aerodynamics, Cambridge, 2001.~Bertin, J.J. and Smith, M.L., Aerodynamics for Engineers, Prentice-Hall, 1989.

**AE 222 ( JAN ) 3 : 0****Gas Dynamics**

Fundamentals of thermodynamics, propagation of small disturbances in gases, normal and oblique shock relations, nozzle flows, one-dimensional unsteady flow, small disturbance theory of supersonic speeds, generation of supersonic flows in tunnels, supersonic flow diagnostics, supersonic flow over two-dimensional bodies, shock expansion analysis, method of characteristics, one-dimensional rarefaction and compression waves, flow in shock tube.

**Srisha Rao M V**

**Pre-requisites :** None

**References :** Liepmann, H.W. and Roshko, A., Elements of Gas Dynamics, John Wiley, 1957.~Becker, E., Gas Dynamics Academic Press, New York, 1968.~Anderson, J.D., Modern Compressible Flow, McGraw Hill, 1990.~Zucrow, M.J. and Hoffman, J.D., Gas Dynamics, Vols. 1-2, Wiley, 1976.~Zucker, R.D. and Biblarz, O., Fundamentals of Gas Dynamics, Wiley, 2002.

**AE 226 ( JAN ) 3 : 0****Turbulent Shear Flows**

Origin of turbulence, laminar-turbulent transition, vortex dynamics, statistical aspects of turbulence, scales in turbulence, spectrum of turbulence, boundary layers, pipe flow, free shear layers, concepts of equilibrium and similarity, basic ideas of turbulence modeling, measurement techniques.

**Joseph Mathew**

**Pre-requisites :** None

**References :** Tritton, D.J., Physical Fluid Dynamics, Oxford University Press. ~Tennekes, H. and Lumley, J., A First Course in Turbulence, M.I.T. Press. ~Townsend, A.A., The Structure of Turbulent Shear Flow, Cambridge Univ. Press.

**AE 228 ( AUG ) 2 : 1****Computation of Viscous Flows**

Review of schemes for Euler equations, structured and unstructured mesh calculations, reconstruction procedure, convergence acceleration devices, schemes for viscous flow discretization, positivity, turbulence model implementation for unstructured mesh calculations, computation of incompressible flows. Introduction to LES and DNS.

**Pre-requisites :** None

**References :** None

**AE 241 ( JAN ) 3 : 0****Combustion**

Thermodynamics of reacting systems. Chemical kinetics: equilibrium, analysis of simple reactions, steady-state and partial equilibrium approximations. Explosion theories; transport phenomena: molecular and convective transports. Conservation equations of multi-component, reacting systems. Premixed flames: Rankine-Hugoniot relations, theories of laminar premixed flame propagation, quenching and flammability limits. Diffusion flames: Burke-Schumann theory, laminar jet diffusion flame. Droplet combustion, turbulent combustion. Closure problem, premixed and nonpremixed turbulent combustion. Introduction to DNS and LES.

**Irfan Ahmed Mulla**

**Pre-requisites** : None

**References** : Turns, S.R., An Introduction to Combustion, McGraw-Hill, 2000.~Strehlow, R.A., Combustion Fundamentals, McGraw-Hill, 1985.~Kuo, K.K., Principles of Combustion, Wiley, 1986.~Law, C.K., Combustion Physics, Cambridge University Press, 2006.~Williams, F.A., Combustion Theory, 1985.

**AE 242 ( JAN ) 3 : 0****Aircraft Engines**

Description of air breathing engines, propeller theory, engine propeller matching, piston engines, turbofan, turbo-prop, turbojet, component analysis, ramjets, velocity and altitude performance, thrust augmentation starting, principles of component design/selection and matching.

**Sivakumar D**

**Pre-requisites** : None

**References** : Zucrow, M.J., Aircraft and Missile Propulsion, Vols. I and II John Wiley, 1958.~Hill, P.G., and Peterson, C.R., Mechanics and Thermodynamics of Propulsion, Addison Wesley, 1965.~Shepherd, D.G., Aerospace Propulsion, American Elsevier Pub., 1972.

**AE 243 ( JAN ) 3 : 0****Rocket Propulsion**

Introduction to rocket engines, features of chemical rocket propulsion, rocket equation, thrust equation, quasi-one-dimensional nozzle flow, types of nozzles, thrust control and vectoring, aerothermochemistry, propellant chemistry, performance parameters, solid propellant rocket internal ballistics, components and motor design of solid propellant rockets, ignition transients, elements of liquid propellant rocket engines, and spacecraft propulsion.

**Charlie Oommen , Pratikash Prakash Panda**

**Pre-requisites** : None

**References** : Sutton, G.P., Rocket Propulsion Elements, John Wiley and Sons, 2001. ~Barrere, M., et al., Rocket Propulsion, Elsevier Co., 1960.~Huzel, D.K., and Huang, D.K., Modern engineering for design of liquid-propellant rocket engines, AIAA, 1992.

**AE 252 ( JAN ) 3 : 0****Analysis and Design of Composite Structures**

Introduction to composite materials, concepts of isotropy vs. anisotropy, composite micromechanics (effective stiffness/strength predictions, load-transfer mechanisms), Classical Lamination Plate theory (CLPT), failure criteria, hygrothermal stresses, bending of composite plates, analysis of sandwich plates, buckling analysis of laminated composite plates, inter-laminar stresses, First Order Shear Deformation Theory (FSDT), delamination models, composite tailoring and design issues, statics and elastic stability of initially curved and twisted composite beams, design of laminates using carpet and AML plots, preliminary design of composite structures for aerospace and automotive applications. Overview of current research in composites.

**Narayana Naik G**

**Pre-requisites :** None

**References**

Gibson, R.F., Principles of Composite Material Mechanics, CRC Press, 2nd Edition, 2007.~Jones, R.M., Mechanics of Composite Materials, 2nd

**AE 255 ( AUG ) 3 : 0****Aeroelasticity**

Effect of wing flexibility on lift distribution; Torsional wing divergence; Vibration of single, two, and multi-degree of freedom models of wing with control surfaces; Unsteady aerodynamics of oscillating airfoil; Bending-torsion flutter of wing; Gust response of an aeroelastic airplane; Aeroservoelasticity of wing with control surfaces.

**Pre-requisites :** None

**References :** Wright, J.R., and Cooper, J.E., Introduction to Aircraft Aeroelasticity and Loads, John Wiley, 2008.~Hodges, D.H., and Alvin Pierce, G., Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002.~Fung, Y.C., An Introduction to the Theory of Aeroelasticity, Dover edition, 2002.~Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Dover edition, 1996.

**AE 258 ( JAN ) 3 : 0****Non - Destructive Testing and Evaluation**

Fundamentals and basic concepts of NDT & E, Principles and applications of different NDE tools used for testing and evaluation of aerospace structures viz., ultrasonics, radiography, electromagnetic methods, acoustic emission, thermography. Detection and characterization of defects and damage in metallic and composite structural components.

**Ramachandra Bhat M**

**Pre-requisites :** None

**References :** Sharpe, R.A., Research Techniques in NDT, Metals Handbook -Vol.17.

**AE 260 ( JAN ) 3 : 0****Modal Analysis: Theory and Applications**

Introduction to modal testing and applications, Frequency Response Function (FRF) measurement, properties of FRF data for SDOF and MDOF systems, signal and system analysis, modal analysis of rotating structures; exciters, sensors application in modal parameter (natural frequency, damping and mode shape) estimation. Vibration standards for human and machines, calibration and sensitivity analysis in modal testing, modal parameter estimation methods, global modal analysis methods in time and frequency domain, derivation of mathematical models – modal model, response model and spatial models. Coupled and modified structure analysis. Application of modal analysis to practical structures and condition health monitoring.

**Siddanagouda Kandagal**

**Pre-requisites :** None

**References :**

Ewins, D.J., Modal analysis: Theory and Practice, Research Studies Press Ltd., England, 2000.~Clarence W. de Silva, Vibration: Fundamentals and

**AE 261 ( AUG ) 3 : 0****Structural Vibration Control**

Introduction to modal testing and applications, Frequency Response Function (FRF) measurement, properties of FRF data for SDOF and MDOF systems, signal and system analysis, modal analysis of rotating structures; exciters, sensors application in modal parameter (natural frequency, damping and mode shape) estimation. Vibration standards for human and machines, calibration and sensitivity analysis in modal testing, modal parameter estimation methods, global modal analysis methods in time and frequency domain, derivation of mathematical models – modal model, response model and spatial models. Coupled and modified structure analysis. Application of modal analysis to practical structures and condition health monitoring. Introduction to vibration control, passive and active vibration control. Concept of vibration isolation, dynamic vibration absorber, visco-elastic polymers as constrained and unconstrained configuration in passive vibration control. Constitutive modeling of structures with PZ

**Pre-requisites :** None

**References :**

Ewins, D.J., Modal analysis: Theory and Practice, Research Studies Press Ltd., England, 2000.~Clarence W. de Silva, Vibration: Fundamentals and

**AE 264 ( JAN ) 3 : 0****Vibrations**

Concepts from linear system theory; Principles of analytical dynamics; Single-degree-of-freedom systems; Multi-degree-freedom systems, The algebraic eigenvalue problem; Distributed parameter systems and approximate methods for their solution; Parametric and nonlinear vibration.

**Kartik Venkatraman**

**Pre-requisites** : None

**References** : Meirovitch, L. (1997). Principles and Techniques of Vibrations. Upper Saddle River, New Jersey, USA: Prentice-Hall International Inc. Newland, D. E. (2006). Mechanical vibration analysis and computation. Mineola, New York, USA: Dover Publications.

**AE 271 ( JAN ) 3 : 0****Guidance Theory and Applications**

Design process, airworthines, safety, environmental issues, requirements, overall configuration and systems, fuselage layout, wing and tail design, mass and balance, power plant selection, landing gear layout, aircraft performance cost estimation, and initial design and sizing

**Ashwini Ratnoo**

**Pre-requisites** : None

**References** : Zarchan, P., Tactical and Strategic Missile Guidance, AIAA Publications, 4th Edition, 2002.~G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, 2004.~N.A.Sneyhdor, Missile Guidance and Pursuit, Ellis Horwood Publishers, 1998.

**AE 291 ( AUG ) 3 : 0****Special topics in aerospace engineering 1**

This elective will be of an advanced nature on topics of current research being pursued by AE faculty. This course will be open to all students in the Institute.

**Pre-requisites** : None

**References** : None



**AE 296 ( AUG ) 0 : 1****Experimental Techniques in Aerospace Engineering**

Experimental techniques in aerospace engineering is a 0:1 credit course that will include demonstrations of experiments in the major sub-disciplines of aerospace engineering. The intent of this course is to give an overview of the experimental facilities and techniques that are commonly used in research in aerospace.

**Pre-requisites :** None

**References :** None

**AE 299 ( JAN ) 0 : 20****Dissertation Project**

The MTech dissertation project is aimed at training students to analyse independently any problem posed to them. The project may be a purely analytical piece of work, a completely experimental one or a combination of both. In a few cases, the project may also involve a sophisticated design work. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical and/or experimental or design skill.

**Joseph Mathew**

**Pre-requisites :** None

**References :** None

**AE 372 ( AUG ) 3 : 0****Applied optimal Control and State Estimation**

Introduction and Motivation; Review of static optimization; Calculus of variations and Optimal control formulation; Numerical solution of Two- point boundary value problems: Shooting method, Gradient method and Quasi-linearization; Linear Quadratic Regulator (LQR) design: Riccati solution, Stability proof, Extensions of LQR, State Transition Matrix (STM) solution; State Dependent Riccati Equation (SDRE) design; Dynamic programming: HJB theory; Approximate dynamic programming and Adaptive Critic design; MPSP Design and Extensions; Optimal State Estimation: Kalman Filter, Extended Kalman Filter; Robust control design through optimal control and state estimation; Constrained optimal control systems: Pontryagin minimum principle, Control constrained problems, State constrained problems; Neighbouring extremals and Sufficiency conditions; Discrete Time Optimal Control: Generic formulation, Discrete LQR.

**Pre-requisites :** None

**References :** Naidu, D.S., Optimal Control Systems, CRC Press, 2002.~Sinha, A., Linear Systems: Optimal and Robust Control, CRC Press, 2007~Bryson, A.E., and Ho, Y-C, Applied Optimal Control, Taylor and Francis, 1975.~Stengel, R.F., Optimal Control and Estimation, Dover Publications, 1994.~Sage, A.P., and White, C.C. III, Optimum Systems Control, 2nd Ed., Prentice Hall, 1977.~Kirk, D.E.,

**AE 297 ( JAN ) 0 : 1****Aerospace Seminar****Kartik Venkatraman**

**Pre-requisites** : None

**References** : None

**AE 227 ( JAN ) 3 : 0****Numerical Fluid Flow**

Introduction to CFD, equations governing fluid flow, hyperbolic partial differential equations and shocks, finite difference technique and difference equations, implicit difference formula, time discretization and stability, schemes for linear convective equation, analysis of time integration schemes, monotonicity, schemes for Euler equations, finite volume methodology. Introduction to unstructured mesh computations.

**Aravind Balan**

**Pre-requisites** : None

**References** : Charles Hirsch, Numerical Computation of Internal and External Flows, Vols.1-2, Wiley-Interscience publication, 1990.

**AE 292 ( JAN ) 3 : 0****Special topics in Aerospace Engineering 2**

This elective will be of an advanced nature on topics of current research being pursued by AE faculty. This course will be open to all students in the Institute.

**Kartik Venkatraman , Vivekanand Dabade , Rajesh Chaunsali , Rishita Das**

**Pre-requisites** : None

**References** : None

**AE 351A ( JAN ) 3 : 0****Wave propagation in Designed Materials**

Overview of “designed materials”: metamaterials and phononic crystals; Fundamentals of elastic wave propagation in continuum solids; Wave propagation in 1D and 2D periodic structures; Brillouin zones, dispersion curves, bandgaps; Elastic superlattices; Locally resonant metamaterials; Negative effective material properties; Weakly and strongly nonlinear periodic systems; Recent advances in Topological, Non-Hermitian, and time-modulated lattices.

**Rajesh Chaunsali**

**Pre-requisites** : None

**References** : L. Brillouin, “Wave Propagation in Periodic Structures”, Dover Publications Inc. (1953)  
 B. A. Auld, “Acoustic Fields and Waves in Solids”, John Wiley and Sons (1973)  
 K. Graff, “Wave Motion in Elastic Solids”, Oxford University Press (1975)

**AE 204A ( AUG ) 3 : 0****Mechanics of Flight Vehicle Structures**

Solid mechanics: Vector and tensor algebra, kinematics of deformation, balance laws, constitutive equations; Torsion of circular, non-circular, and thin-walled cross-sections; Bending of thin-walled open and closed section beams, Flexural shear flow; Bending of thin plates, bending and twisting of thin plates; bending and in-plane loading of thin plates; Euler buckling of columns, flexure-torsion buckling of columns, buckling of thin plates; Flight vehicle materials; Structural components of flight vehicles and spacecraft; Loads on flight vehicles and V-N diagram.

**Pre-requisites** : None

**References** : Morton E. Gurtin. Introduction to Continuum Mechanics. Academic Press. 1981.  
 P. Chadwick. Continuum Mechanics: Concise Theory and Practise. Dover Publications. 1999.  
 T.H.G. Megson. Aircraft Structures for Engineering Students. Elsevier. 2022.

**AE 201A ( JAN ) 4 : 0****Flight and Space Mechanics**

Flight Mechanics: Atmosphere, Essentials of Aerodynamics and Propulsion, Aircraft Performance, Static Stability, Equations of Motion- 3 DOF and 6 DOF, Attitude representation, Dynamic Stability Essentials, Flight Control Overview, Launch Vehicle Flight Essentials.  
 Space Mechanics: Orbits in 2D and 3D, Orbital Manoeuvres, Docking, Interplanetary trajectories, Planetary Entry, Descent and Landing, Lagrange points and Halo Orbits, Orbital perturbations, Orbits in the Time Domain, Spacecraft attitude dynamics essentials.

**Santosh Hemchandra , Duvvuri Subrahmanyam**

**Pre-requisites** : None

**References** : Introduction to Flight, John D Anderson. Aircraft Performance and Design, John D Anderson. Fundamentals of Airplane Flight Mechanics, David G Hull.

# Atmospheric and Oceanic Sciences

## Preface

### AS 202 ( JAN ) 3 : 0

#### Geophysical Fluid Dynamics

Large-scale, slowly evolving flows on a rotating earth. Vorticity, potential vorticity (pv), consequences of pv conservation. Poincare, Kelvin and Rossby waves. Rotating shallow water equations, effects of stratification and the rotating-stratified Boussinesq equations. Quasi-geostrophic flow and pv, Rossby waves on the mid-latitude beta plane. Basic concepts of tropical dynamics. Waves, jets and undercurrents on the equatorial beta plane. Waves and large-scale flow in the atmosphere and ocean from observations.

#### Jai Suhas Sukhatme

**Pre-requisites** : None

**References** : Pedlosky, J., Geophysical Fluid Dynamics, Springer Verlag, 1977, Gill, A., Atmosphere and Ocean Dynamics, Academic Press Inc., 1982., Holton, J.R., An Introduction to Dynamic Meteorology, Academic Press, 1992. Relevant Journal Articles

### AS 203 ( AUG ) 3 : 0

#### Atmospheric Thermodynamics

Vertical structure and composition of the atmosphere, kinetic theory of gases, first and second principles of thermodynamics, thermodynamics of dry air, concept of saturation vapour pressure, water vapour in the atmosphere, properties of moist air, isobaric and isothermal processes, atmospheric stability, parcel and area methods, nucleation, effect of aerosols, clouds and precipitation, forms of atmospheric convection.

**Pre-requisites** : None

**References** : Iribarne, I.V., and Godson, W.I., Atmospheric Thermodynamics, 2nd Edn, D Reidel Publishing Company, 1971, Rogers, R.R., A Short Course in Cloud Physics, 2nd Edition, Pergamon Press, 1979, Bohren, C.F., and Albrecht, B.A., Atmospheric Thermodynamics, Oxford University Press, 1998, Tsonis, A.A., An Introduction to Atmospheric Thermodynamics, Cambridge University Press, 2002, Wallace,

### AS 205 ( JAN ) 2 : 1

#### Ocean Dynamics

Introduction to physical oceanography, properties of sea water and their distribution, mixed layer, barrier layer, thermocline, stratification and stability, heat budget and air-sea interaction, ocean general circulation, thermohaline circulation, basic concepts and equations of motion, scale analysis, geostrophic currents, wind-driven ocean circulation, Ekman layer in the ocean, Sverdrup flow, vorticity in the ocean, waves in the ocean, surface gravity waves, Rossby and Kelvin waves.

#### Vinayachandran P N

**Pre-requisites** : None

**References** : Talley et al., Descriptive Physical Oceanography, 6th Edition, 2011, B. Cushman-Roising, Introduction to GFD, Introduction to Physical Oceanography, <http://eanworld.tamu.edu> (online book)

**AS 207 ( AUG ) 3 : 0****Introduction to Atmospheric Dynamics****Pre-requisites** : None**References** : None**AS 209 ( JAN ) 3 : 0****Mathematical Methods in Climate Science**

Review of probability and statistics: probability distributions, sample statistics. Confidence intervals. Hypothesis testing; goodness of fit tests,time-series analysis: Fourier transforms, principal component analysis (PCA).

**Venugopal Vuruputur****Pre-requisites** : None

**References** : Papoulis, A., & U. Pillai, Probability, Random Variables and Stochastic Processes, 4th edition, McGraw Hill, 2002., Wilks, D., Statistical Methods in the Atmospheric Sciences, 2nd edition, Academic Press, 2006., O. Brigham, Fast Fourier Transforms, Prentice Hall, First Edition, 1974., Press, W. H., S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, Numerical Recipes in C/Fortran: The Art of Scientific

**AS 210 ( JAN ) 3 : 0****Numerical methods in atmospheric modeling**

Equations used in atmosphere and climate modelling and their scale analysis; numerical discretization (horizontal, vertical, time-discretization) of governing equations (e.g., mass, momentum, energy conservation); solution of discretized equations; finite difference and finite volume schemes; overview of Semi-Lagrangian techniques; various spectral techniques and Galerkin projection; numerical solutions of example problems; modelling of sub-grid scale processes (e.g., cumulus parameterization); special topics (e.g., emerging techniques/architectures, analysis of data driven/hybrid approaches).

**Ashwin K Seshadri****Pre-requisites** : AS-207: Introduction to Atmospheric Dynamics

**References** : P H Lauritzen et al., Numerical Techniques for Global Atmospheric Models, Springer, 2011  
A Chandrasekar, Numerical Methods for Atmospheric and Oceanic Sciences, Cambridge University Press, 2022

**AS 211 ( JAN ) 2 : 1****Observational Techniques**

Principles of measurement and error analysis, fundamentals of field measurements, in situ measurement of atmospheric temperature, humidity, pressure, wind, radiation, precipitation and aerosols. Tower based techniques and automatic measurement systems. Upper air observations, radiosonde techniques. Measurements in the ocean, CTD, ADCP and ARGO. Modern measurement techniques.

**Bhat G S**

**Pre-requisites** : None

**References** : Guide to Meteorological Measurements and Methods of Observation,,World Meteorological Organization Publication No. 8,,7th Edition, WMO, Geneva. radiative transfer, the role of radiation in climate.~Harrison R. G. Meteorological Measurements and Instrumentation Wiley, (2014)~DeFelice, T. P.,An Introduction to Meteorological Instrumentation and Measurement. Prentice Hall, 1998.

**AS 216 ( AUG ) 3 : 0****Introduction to climate system**

Equations of motion for the atmosphere and oceans, observed mean state of the atmosphere and oceans, exchange of momentum, energy and water between the atmosphere and surface, angular momentum cycle, global water cycle, radiation, energetics, entropy in climate system, climate variability, The global carbon cycle, Climate System Feedbacks

**Pre-requisites** : None

**References** : J. Peixoto and A.H. Oort,Physics of Climate,,American Institute of Physics

**AS 299 ( JAN ) 0 : 28****Project****Venugopal Vuruputur**

**Pre-requisites** : None

**References** : None

**AS 313 ( JAN ) 3 : 0****Non-Linear Model in Climate Sciences**

An introduction to nonlinear dynamics: linearization, bifurcation, chaos; Galerkin projection and model reduction; Derivation and analysis of low order models for the atmosphere, ocean, climate dynamics, and geophysics (e.g., Rayleigh-Bénard convection, vorticity, general circulation, ocean thermohaline circulation, planetary dynamos, energy balance and global warming, ice sheets, ENSO, carbon cycle, examples from paleoclimate); Special topics (data driven methods; dynamics on networks)

**Ashwin K Seshadri**

**Pre-requisites** : None

**References** : Primary references:  
 A Provenzale and N Balmforth, Chaos and Structures in Geophysics and Astrophysics

**AS 215 ( AUG ) 3 : 0****Environmental Fluid Dynamics**

An overview of the field of fluid mechanics and description of the physics governing fluid flow. Principles of buoyancy-driven flow: Free-surface flows, gravity currents, stratified flows, gravity waves. Heat transfer and fluid instability: Convection, turbulence, and mixing. The course has four major components: (i) Waves in fluids: interfacial waves and internal gravity waves. (ii) Vertical flows: turbulent plumes, filling box, double-diffusive convection. (iii) Horizontal flows: shallow water approximation, single-layer hydraulics, gravity currents, two-layer flows, and (iv) Turbulent mixing: mixing across very stable interfaces and turbulent convection. The course consists of Lectures, tutorials, and simple laboratory experiments.

**Pre-requisites** : None

**References** : Fluid Mechanics 3rd Edition: Authors: Ira Cohen and Pijush Kundu: Academic Press, Published Date: 2004~Buoyancy Driven Flow: Authors: J. S. Turner: Cambridge University Press, Published Date: 1979~Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics: Authours: J. Pedlosky, Spriger Verlag, Published Date: 2003

**AS 217 ( JAN ) 2 : 1****Modelling and Forecasting****Syllabus**

Overview of Numerical Methods, Hierarchy of Models - global, regional, coupled models, Skill Score Metrics, Downscaling.

Forecasting the weather, Ensemble Forecasting Technique, Dynamical Seasonal Prediction, Decadal Prediction and Climate Projections, Air Quality Modelling, Prediction of South Asian Monsoon. Architecture of Ocean Forecasting System Components, Numerical Ocean Models, Data Preparation, Forcing and IC, Data Assimilation, Forecast Evaluation. Introduction to PDE-constrained optimization, Linearization and Gradient Computation, Lagrange Multipliers; Adjoint-state Method, Seismic Wave Equation and Finite-difference Modeling, Full Waveform Inversion.

**Arindam Chakraborty****Pre-requisites** :

Atmosphere Dynamics/Ocean Dynamics/GFD

**References** : 1. 'Implementing Operational Ocean Monitoring and Forecasting Systems' <https://www.mercator-ocean.eu/wp-content/uploads/2022/10/22-09-26-ETOOFS-BOOK-DOI-UPDATED-AB.pdf>

**AS 298 ( JAN ) 0 : 18****MTech Project**

This is a project course for the Joint MTech programme in Earth and Climate Sciences

**Venugopal Vuruputur**

**Pre-requisites** : None

**References** : Research Papers



# Earth Sciences

## Preface

### ES 201 ( JAN ) 3 : 0

#### Introduction to Earth System

Role of topography and geology during interaction of Earth system processes; composition of Lithosphere, Atmosphere, Hydrosphere and Biosphere; Earth surface processes and its effect on earth systems, earth as a dynamic planet; Early atmosphere, evolution of atmosphere through time, evolution of hydrosphere and general circulation of ocean through time; Long and short term history of cryosphere; fossilization; Geochemical evidences documenting origin of life; extinction events, biosphere on land and ocean, Great oxygenation Event (GOE); Paleobiology; Microfossils; Indian climate present day and past; Global paleoclimatic record; Palaeo-monsoon record and the role of tectonics and green house forcing. Practical: Project on spatial and temporal evolution of earth system

#### Prosenjit Ghosh

**Pre-requisites :** None

#### References

Merritts, D., Dewet, A., and Menking, K., Environmental Geology: An Earth System Science Approach, 1998; Freeman, W.H., ~Jacobson, M.C., Charlson,

### ES 202 ( AUG ) 3 : 0

#### Biogeochemistry

**Pre-requisites :** None

**References :** None

**ES 203 ( JAN ) 3 : 0****Introduction to Petrology**

Theory: Rock forming minerals, textures of Igneous, metamorphic and sedimentary rocks, microtextures and reactions, using petrological datasets, rock types and tectonic settings, geothermometry and geobarometry, isochemical phase diagrams and its interpretations, linking petrology to geochronology, Geology of southern India and applications of petrology.

**Sajeev Krishnan**

**Pre-requisites** : None

**References** : Vernon R.H., A practical guide to Rock Microstructure, Cambridge University Press, 2004.

**ES 204 ( AUG ) 3 : 0****Origin and Evolution of the Earth**

Big Bang; origin of elements; early solar system objects; bulk Earth composition; comparison of Earth and other Solar System objects; core-mantle differentiation; composition of the terrestrial mantle; mantle melting and geochemical variability of magmas; major, trace element and radiogenic isotope geochemistry; redox evolution of the mantle; evolution of the atmosphere and biosphere.

**Pre-requisites** : None

**References**

Charles H. Langmuir and Wally Broecker, How to build a habitable planet, Revised and expanded edition, Princeton University Press, 2012;~A. P. Dickin,

**ES 205 ( AUG ) 3 : 0****Mathematics for Geophysicists**

Vector fields: basic vector algebra, line, surface and volume integrals, potential, conservative fields, gradient, divergence, curl, circulation, Stokes's theorem, Gauss's theorem, applications in fluid mechanics and electromagnetism, Kelvin's theorem, Helmholtz's theorem. Linear algebra: Matrices, operations, eigen components, systems of linear differential equations, examples. Partial differential equations: The diffusion equation, wave equation, Laplace's equation, Poisson's equation, similarity solutions, numerical solutions (simple examples with MATLAB), series solutions, spherical harmonic expansions. Dimensional analysis: Pi theorem, similarity, nondimensional formulation of geophysical problems, examples.

**Pre-requisites** : None

**References** : Riley, K.F., Hobson, M.P., and Bence, S.J., Mathematical methods for physics and engineering, Cambridge University Press, 2006.~Panton, R.L., Incompressible flows, John Wiley & Sons, 2006~Albarede, F., Introduction to geochemical modelling, Cambridge University Press, 1996~Lecture notes

**ES 207 ( AUG ) 0 : 3****Earth Science Laboratory**

This course is designed for students pursuing M.Tech. in Earth Science. Topic covered are: Geochemical techniques; mineral separation; Stable isotope analysis using isotope ratio mass spectrometer, sample preparation and analysis, data reduction, sedimentological techniques; computational techniques.

**Pre-requisites :** None

**References :** Reed, S.J.B., Electron Microprobe Analysis and Scanning Electron Microscopy in Geology, Cambridge University Press, 2010~Handbook of Stable Isotope Analytical Techniques, Pier A. de Groot, ISBN 978-0-444- 51114-0, Elsevier Science 1258, 2004~Techniques in sedimentology edited by Maurice Tucker, Black Scientific Publications, 1988

**ES 208 ( JAN ) 3 : 0****Mantle Convection**

Plate tectonics and mantle convection, Constraining mantle flow from seismic tomography, Maxwell viscoelastic material, Spherical harmonics, Mantle viscosity, Creep mechanisms, Governing equations, Constraints of mantle flow modeling: geoid and dynamic topography, Thermal evolution of the Earth, Convection in other planets.

**Attreyee Ghosh**

**Pre-requisites :** None

**References :** Schubert, G., Turcotte, D., and Olson, P., Mantle convection in the earth and planets, Cambridge University Press, 2001~Turcotte, D., and Schubert, G., Geodynamics. Cambridge University Press, 2nd edition, 2001 ~Fowler, C.M.R., The Solid Earth: An Introduction to Global Geophysics, Cambridge University Press, 2005.

**ES 213 ( JAN ) 3 : 0****Isotope Geochemistry**

Nuclear systematics; decay mode of radionuclides; radioactive decay; Rb- Sr, Sm-Nd, Lu-Hf, Re-Os and U-Th-Pb systematics, U series disequilibrium, stable isotope fractionation, early Solar System processes, crust-mantle processes, aquatic processes, selected mass spectrometry techniques.

**Ramananda Chakrabarti**

**Pre-requisites :** None

**References :** Alan P. Dickin, Radiogenic Isotope Geology, Cambridge University Press, 1995, Gunter Faure and Teresa M. Mensing.

**ES 215 ( AUG ) 3 : 0****Introduction to Chemical Oceanography**

The concentration, isotopic composition, and distribution of the dissolved and particulate components of seawater tells the story of a fascinating and complex interplay between tectonic uplift, chemical and physical weathering, climate, biology, ocean circulation, and intrinsic properties of elements and ions in solution. In this series of lectures we will try to understand what controls the chemistry of seawater from a regional to global scale and what is the interplay between climate and ocean chemistry. The major themes that will be covered are: (a) concentration, spacio-temporal distribution, and the residence time of the dissolved components of seawater; (b) air-sea exchange of gases; (c) steady state and non-steady state oceanic cycle of dissolved components; (d) estimation of oceanic mixing time utilising natural and artificial tracers; (e) influence of biology on ocean chemistry - carbon pumping from surface to deep; (f) the role deep ocean carbon reservoir in controlling clim

**Pre-requisites :** None

**References**

Tracers in the Sea - Broecker and Peng, LDGEO Press, 1983~An Introduction to the Chemistry of the Sea - Michael E. Q. Pilson,

**ES 216 ( JAN ) 3 : 0****Advanced Chemical Oceanography**

This is a course designed to delve in to the application of chemical oceanography, especially that of isotope tracers, to understand the long-term evolution of seawater and climate. The topics covered in the course will broadly include the: (1) the long-term evolution of seawater chemistry from the perspective of strontium, magnesium, osmium, and lithium isotopes; (2) changes in magnesium to calcium ratio of seawater over time; (3) boron isotopes and their application in pH reconstruction; (4) seawater carbonate chemistry – what controls the pH and alkalinity of seawater; (5) proxies and their application in paleoceanography.

**Sambuddha Misra**

**Pre-requisites :** None

**References :** Tracers in the Sea – Broecker and Peng, LDEO Press, 1983~CO<sub>2</sub> in Seawater – Zeebe and Wolf-Gladrow, Elsevier Oceanography Series, 2003~Isotope Geochemistry – William White, Wiley Blackwell, 2015.

**ES 206 ( AUG ) 3 : 0****Solid Earth Geophysics**

Earth's internal structure: composition vs mechanical properties, Geoid, GIA and viscosity, Stress and Strain from seismology perspective, Theory of Elasticity, Wave mechanics, Seismic tomography, Earth's free oscillations, Phase transformations within the Earth, Introduction to mineral physics, Spherical harmonics, Heat: conductive, convective and radioactive heat flow, Heat flow in oceans and continents, Half space vs plate cooling models, Convection within mantle and core, Structure of mid-oceanic ridge system, Strength of continental lithosphere

**Pre-requisites :** None

**References :** Fowler, C.M.R., The Solid Earth: An Introduction to Global Geophysics, 2nd edition, Cambridge University Press, 2005; Turcotte, D., and Schubert, G., Geodynamics, Cambridge University Press, 2002, Turcotte, D., and Schubert, G.

**ES 218 ( AUG ) 3 : 0****Introduction to Seismology**

This course is divided into three parts. It starts with an introduction to the dynamics of diverse seismic sources, e.g., volcanic, tectonic, glacial, fluvial, oceanic, atmospheric and artificial processes, which routinely shake the subsurface. The second part will present the following key topics in elastodynamics that guide the propagation of the waves originating from these seismic sources: types of elastic waves from a point dislocation sources; ray theory, travel-time function in layered media, turning points; plane waves in a homogenous medium and at interfaces; Snell's law; Earth's anisotropy; shear-wave splitting; seismic attenuation; surface-wave propagation and dispersion; free oscillations of the Earth. The final part connects the first two and introduces methods that not only help us infer the Earth's structure but also study the source physics from the seismic measurements. Some motivating examples pertaining to the concepts discussed in this part include: 1. ground-moti

**Pre-requisites :** None

**References :**  
Aki, Keiiti, and Paul G. Richards. Quantitative seismology.  
Chapman,

**ES 220 ( AUG ) 3 : 0****Introduction to satellite Geodesy**

Short history of Geodesy: definition of Geodesy, First attempts at measuring Earth, developments in the 20th century, Modern Geodetic tools Gravitation: Newtons law, potential theory, Laplace's equation Solid Earth: visco-elastic Earth, Loading and deformations, Load love numbers, gravimetry Geodetic sensors in the orbit: GNSS, Altimeters, GRACE Climate change indicators and their relation to Geodesy: sea level rise, ice-sheet mass loss, polar motion.

**Pre-requisites** : None

**References** : 1. Heiskanen, W. A., and Moritz, H., "Physical Geodesy", San Francisco, WH Freeman. 2. William, K. M., Theory of Satellite Geodesy: Applications of Satellites to Geodesy, Dover Earth Science. 3. Torge, W., Geodesy, De Gruyter Textbook.

**ES 222 ( JAN ) 3 : 0****Data Analysis for Earth System Science**

Linear regression, least squares inversion. Statistical Estimation theory and Bayesian methods. Fourier analysis, correlation, convolution. Principal component analysis, dimension reduction and random projections. Optimization algorithms: concept of gradient, Hessian, Jacobian. Unsupervised and supervised learning; deep neural networks for classification and regression. Time series Analysis: Auto-regressive models, AR, MA, ARMA models, Wiener's theory of optimal prediction, estimation in dynamic models, case studies from earth atmospheric sciences.

**Pawan Bharadwaj Pisupati**

**Pre-requisites** : None

**References** : [1] A. Blum, J. Hopcroft, and R. Kannan (2020) Foundations of Data Sciences, Cambridge University Press  
 [2] J. M. Lewis, S. Lakshminarayanan and S. K. Dhall (2006) Dynamic Data Assimilation: a least squares approach, Cambridge University Press  
 [3] Inverse Problem Theory, Albert Tarantola

**ES 221 ( JAN ) 3 : 0****Dynamics of Planetary Interiors**

Overview of planetary interiors: mantle, core, core-mantle interactions, observational constraints.

Dynamics of fluids – equation of motion, vorticity equation, energy and dissipation. Rotation – Coriolis force, linear inertial waves, Taylor columns, geostrophy, quasi-geostrophic approximation. Stratification – Gravity waves, the effect of rotation. Magnetic field – Alfvén waves, Magnetic-Archimedean-Coriolis (MAC) waves, dynamo processes. Dynamics of planetary mantles and cores – convection, dynamical regimes and approximations, simplified solutions.

Turbulence – classical theories, 2D turbulence, turbulence under rotation, MHD turbulence, planetary core turbulence.

**Binod Sreenivasan**

**Pre-requisites** :

Basic mathematics covering vector algebra and PDEs.

**References** : Lowrie, W., Fundamentals of Geophysics, Cambridge University Press, 2007.

Davidson, P.A., Turbulence in rotating, stratified and electrically conducting fluids, Cambridge University Press, 2013.

**ES 225 ( JAN ) 1 : 0****Scientific writing and presentation**

1. Basics of scientific writing
2. What to do and what not to do in science communication
4. Presenting your research work to engage and inspire

**Bramha Dutt Vishwakarma****Pre-requisites** :

None

**References** : 1. "The Sense of Style" by Steven Pinker, ISBN: 978-0-241-95771-

# Sustainable Technologies

## Preface

### ST 203 ( AUG ) 3 : 0

#### Design, Technology and Sustainability

Key concepts and principles of remote sensing, GIS and digital image processing. Tools to address environmental problems. Roles of professionals in managing environment in their respective areas.

**Pre-requisites** : None

**References** : None

### ST 206 ( JAN ) 2 : 1

#### Environmental and Natural Resources Management

Principles of environmental management, principles of ecology, environment and environmental management, policies and legal aspect of environmental management, overview of environmental impact assessment (EIA). Preparation and review of environmental impact assessment report, environmental audit, life cycle assessment as EM Tool. Environmental management systems standards: ISO 14000 (EMS). Related issues in environmental management, environmental design and environmental economics.

#### Ramachandra T V

**Pre-requisites** : None

**References** : Kulkarni, V., and Ramachandra, T.V., Environmental Management, Capital Publishers, New Delhi, 2006,Lo, C.P., and Yeung, A.K.W., Concepts and Techniques of GIS, Prentice Hall of India Private Limited, New Delhi, 2002,. Kanholm, J., EMS Manual, 21 Procedures and Forms, AQA Press, USA, 2000,Holling, C.S., Adaptive Environmental Assessment and Management, John Willey &

### ST 210 ( AUG ) 3 : 1

#### Principles and Applications of GIS and Remote Sensing

Key concepts and principles of remote sensing, GIS and digital image processing. Tools to address environmental problems. Roles of professionals in managing environment in their respective areas.

**Pre-requisites** : None

#### References

Lillesand, T.M., and John Wiley, Kiefer, R.W., Remote Sensing and Image Interpretation, John Wiley & Sons, Inc., New York, Cambell, J.B., :



**ST 214 ( AUG ) 3 : 0****Mathematical Analysis of Experimental Data**

Design of Experiments, Data types and data gathering tools. Errors, systematic & random errors, methods to minimize them, and account for them. Measurement variability. Instrument calibration and corrections at different scales. Significant figures. Uncertainty analysis and curve fitting; Data analysis of data distribution, normal, Chi-squared and t-distribution, confidence interval and hypothesis testing. Design of experiments: replication, randomization, blocking and controls. ANOVA, Single factor experiments, randomized blocks, Latin square designs, factorial and fractional factorial designs. Simple and multiple linear regressions. Mathematical analysis of experimental data from problems in fluid flow, heat transfer and combustion.

**Pre-requisites :** None

**References**

Douglas C. Montgomery, Design and Analysis of Experiments (2012), John Wiley and Sons, Inc.~Box, G. E. P., Hunter, W. G., and Hunter, J. S.

**ST 216 ( AUG ) 3 : 0****Physics in Experiments with Classical Statistics**

Dimensional Analysis: Buckingham pi theorem, non-dimensional groups, physical similarity, functionalities, scaling (with single and multiple independent groups), intermediate asymptotics; Probability: history, gaming, origin of random number, Bernoulli trials, binomial theorem, normal distribution; Curve fitting: regression and theory of splines; Classical Statistics: origin, Galton table-Darwinism; Karl Pearson: large sample studies, Pearson type distribution curves, Chi-square variance and limitations; William Gosset: small sample study, probable error of means, correlation coefficient, z statistics, Barley experiments, Fischer: degree of freedom, z to t statistics for small samples, Rothamsted agricultural experiments, analysis of variance, fundamentals of experimental designs, maximum likelihood, inductive reasoning; Uncertainty Analysis: Moffat's single sample theory in experiments; Engineering and Science problems: (hydrology, hydropower, turbomachinery, biology, chemistry, macroeco

**Pre-requisites :** None

**References**

[1] Barenblatt. G. I, 'Scaling', Cambridge Texts in Applied Mathematics, (2003) [2] Holman J. P., Experimental Methods for Engineers, Mcgraw-Hill

**ST 213 ( JAN ) 3 : 0****Turbo machines in Renewable Energy**

The objectives of the course is to refine turbo machinery designs in challenging operating conditions imposed by renewable energy sources characterized by variability(input/output sides) and low intensity/enthalpy levels. Concepts include Euler theory, velocity triangles, dimensional analysis, meanline/streamline theory, loss models, performance estimation, Cordier/nsds diagrams and others. Practical design approach from theory and experimental modules for incompressible fluids (hydro turbines, wind turbines, and liquid pumps) and compressible fluids (air, steam, and new working fluids for solar thermal and waste heat sources) Radial, diagonal and axial flow turbo machines with impulse and reaction physics. Discussion on innovative and unconventional turbo machines.

**Punit Singh**

**Pre-requisites :** None

**References :** Dixon S.L and Hall C.A, Fluid Mechanics and Thermo Dynamics of Turbomachinery, 6th Edition, Elsevier, publication 2010, ~Neschleba M, Hydraulic turbines-Their design and equipment , Atria Prage, 1957, ~Stepanoff A.J, Centrifugal and Axial Flow Pumps, John Wiley & Sons, Inc., 1957, ~Horlock J.H, Axial Flow Compressors and Axial Flow Turbines, Fluid Mechanics and

**ST 217 ( AUG ) 3 : 1****Field hydrology, river engineering and basin studies**

Dimensional Analysis: Buckingham pi theorem, non-dimensional groups, physical similarity, functionalities, scaling (with single and multiple independent groups), intermediate asymptotics; Probability: history, gaming, origin of random number, Bernoulli trials, binomial theorem, normal distribution; Curve fitting: regression and theory of splines; Classical Statistics: origin, Galton table-Darwinism; Karl Pearson: large sample studies, Pearson type distribution curves, Chi-square variance and limitations; William Gosset: small sample study, probable error of means, correlation coefficient, z statistics, Barley experiments, Fischer: degree of freedom, z to t statistics for small samples, Rothamsted agricultural experiments, analysis of variance, fundamentals of experimental designs, maximum likelihood, inductive reasoning; Uncertainty Analysis: Moffat's single sample theory in experiments; Engineering and Science problems: (hydrology, hydropower, turbomachinery, biology, chemistry, macroeco

**Pre-requisites :** None

**References**

[1] Barenblatt. G. I, 'Scaling', Cambridge Texts in Applied Mathematics, (2003) [2] Holman J. P., Experimental Methods for Engineers, Mcgraw-Hill

## ST 219 ( JAN ) 3 : 0

## Separation Technologies for Sustainable Industrial Processes

Consider any product that you use from the time you wake up till the end of the day - plastics, paper, pharmaceuticals, soaps and detergents, textiles, and many more. In this course, we focus on an important set of steps in the manufacture of such items that are critical in our daily lives, namely the 'chemical separation' steps. Such chemical separations typically account for 40-70% of the total cost of the complete manufacture process of the item. Cumulatively, separations in various industries add up to 15% of the world's energy requirements. However, chemical separations and the concerned separation technologies are responsible for several important processes, such as extracting the final product from the synthesis medium; treating effluent streams before environmental discharge; recovering materials that can be reused for subsequent manufacture cycles; or isolating valuable intermediate products that can be used in a few different industry, or sold. A few examples of chemical separations are:

## Yagnaseni Roy

**Pre-requisites :** None

**References**

[1] De Haan, André B., and Hans Bosch, 'Industrial separation processes: fundamentals.' Walter de Gruyter, 2013.

**ST 218 ( JAN ) 3 : 0****Sustainable Wastewater Management**

This course has been designed to provide its participants knowledge on the fundamentals and practices in wastewater management in both urban and rural contexts. Starting with (i) characteristics of different wastewaters and necessity for their treatment; the course will delve into: (ii) principles of conventional activated sludge process, challenges and sustainability issues; (iii) alternative treatment methods & recent developments with concerns over energy efficiency, nutrient removal/recovery and/or footprint; (iv) need, bottlenecks and options for advanced wastewater treatment and water recycling; and (v) alternative sanitation concepts with emphasis on rural communities. In addition to understanding the fundamentals of different treatment options for wastewater, the participants will learn to see wastewater as a resource and appreciate sustainable practices. The course will be conducted using a combination of interactive lecture & exercise sessions, problem-based learning approach, field visit, and presentation of case studies. Wastewater origin, composition & hazards: parameters and their measurement; domestic wastewater streams; industrial wastewater; stormwater; municipal wastewater and volume flows; agricultural runoff; water & environmental pollution; ecotoxicological impacts; health hazards; water scarcity. Conventional wastewater treatment: centralised vs. decentralised approach; treatment objectives; mechanical treatment; biological treatment; nutrient removal; microbial metabolism & kinetics; introduction to activated sludge model no. 1; wastewater disinfection; sludge treatment & management; energy demands; challenges and sustainability issues. Alternatives to conventional activated sludge process: anaerobic wastewater treatment; energy recovery; membrane bioreactor; biofilm reactors; hybrid technologies; advanced biological nutrient removal; aerobic granular sludge; nutrient recovery; microalgae. Water recycling: micropollutants; environmental concern; water reuse; activated carbon adsorption; ozonation; advanced oxidation processes; membrane technologies. Alternative sanitation approaches: sanitation challenges; low-cost solutions; decentralised treatment; ecological(resource oriented) sanitation; source separation; nutrient recovery; lagooning; anaerobic digestion; terra preta sanitation; composting; greywater treatment; constructed wetlands.

**Sreenivasan Ramaswami**

**Pre-requisites :** None

**References :** Wastewater engineering: Treatment and reuse, 4th edition. Editors: George Tchobanoglous; Franklin L. Burton; H. David Stensel. Publisher: McGraw-Hill. Biological Wastewater Treatment: Principles, Modelling & Design, 2nd edition. Editors: Guang-Hao Chen; Mark C.M. van Loosdrecht; G.A. Ekama; Damir Brdjanovic. Publisher: IWA Publishing.

**ST 221 ( AUG ) 3 : 0****Concrete Technology: fundamentals and sustainable practices**

This module aims to provide students with fundamental knowledge in the area of cement hydration, sustainable mineral admixtures and chemical admixtures, and their influence on fresh and hardened stage of cement-based materials. It also provides students with in-depth knowledge in concrete durability, mechanical properties and time- dependent deformations. The module discusses the basic considerations and design philosophy for performance-based design and production of sustainable concrete. The students will also learn about the progress in concrete technology and the latest development in high-strength, high-performance concrete, lightweight concrete, and self-healing concrete. Sustainable development in construction industry including application of recycled aggregates, bio-based admixtures and low-carbon concrete would be discussed as well. The module would be taught through interactive lecture sessions, exercises, problem-based learning approach and site visits.

**Pre-requisites :** None

**References :** 1. Concrete, by David Darwin, J. Francis Young, and Sidney Mindess. Publisher: Pearson. 2. Properties of concrete, 5th edition, by A.M. Neville. Publisher: Pearson.

**ST 231 ( JAN ) 1 : 0****Seminar**

As per instructors and prospective guide's advice

**Ramachandra T V , Balachandra P , Gali Madhavi Latha , Monto Mani , Punit Singh , Sreenivasan Ramaswami , Yagnaseni Roy , Souradeep Gupta , Navneet Kumar Gupta**

**Pre-requisites** : None

**References** : Peer reviewed journals

**ST 226 ( AUG ) 3 : 0****Sustainable Water Management**

Water cycle, renewable water. Freshwater resources: surface water, ground water. Water usage, stress & scarcity. Water smart agriculture. Rainwater harvesting.

Surface, ground & rainwater quality. Contamination scenarios & need for treatment. Drinking water treatment & requirements. Other remediation techniques. Industrial water treatment & requirements.

Seawater desalination.

Wastewater quantity & quality, parameters. Water pollution, hazards & need for wastewater treatment. Conventional wastewater treatment. Resource recovery options. Recycling of treated wastewater. Options for industrial wastewater treatment.

**Pre-requisites** : None

**References** : Wastewater engineering: Treatment and reuse, 4th edition. Editors: George Tchobanoglous; Franklin L. Burton; H. David Stensel. Publisher: McGraw-Hill.

**ST 229 ( JAN ) 3 : 0****Low-carbon infrastructure**

This module aims to provide students with the state-of-the-art knowledge in areas of low-carbon buildings and infrastructure including the effect of climate change, maintainability, energy efficiency, indoor air quality, implication on health and wellness. This module would involve interactive lectures and assignments. The course covers topics such as Climate change and building design, "Green" building concepts, Indoor air quality and wellness, Sustainable construction and maintainability and Low-carbon materials and processes. Evaluation: 60% (assignments/quiz), 40% final exam

**Souradeep Gupta**

**Pre-requisites** : None

**References** : i. Compressed Earth block and rammed earth structures by B.V. Venkatarama Reddy  
ii. Concrete by David Darwin, J. Francis Young, and Sidney Mindess  
iii. ASHRAE Indoor air quality guide – best practices for design, construction and commissioning (ASHRAE Indoor Air Quality Guide)

**ST 228 ( JAN ) 3 : 0****Data Analysis, Machine Learning and Artificial Int**

This course is designed for graduate students in data analysis, machine learning, and AI. It covers data collection and analysis, integrating physics and mathematics. Students will learn essential concepts, techniques, and tools for data processing, prediction, and AI-driven problem-solving. Hands-on projects and real-world examples will help participants develop practical skills for applying data analysis and machine learning in various domains

**Lakshminarayana Rao M P**

**Pre-requisites :** None

**References :** Wolfgang Ertel, Introduction to Artificial Intelligence  
John Paul Mueller, Machine Learning for Dummies  
Douglas C. Montgomery, Design and Analysis of Experiments (2012), John Wiley and Sons, Inc.

**ST 227 ( JAN ) 2 : 1****Environmental Analytical Chemistry**

Introduction to environmental/water laboratory: fundamental instruments, lab water types and grades of chemicals. Solutions: concentration, dilution factor, preparing solutions. Water quality parameters: pH, electrical conductivity, turbidity & dissolved oxygen. Solids in water: total, suspended, dissolved. Hardness and alkalinity. Spectrophotometric determination: principle, limits, determination of ammonium-nitrogen, phosphate-phosphorous. Nitrogen in water – determination of nitrogen compounds (N-NH<sub>4</sub><sup>+</sup>, N-NO<sub>2</sub><sup>-</sup>, N-NO<sub>3</sub><sup>-</sup> and TN) and material balance. Organic parameters: COD, BOD, TOC. Chromatographic techniques, determination of anions by ion chromatography. Different wastewater sources, water & environmental pollution.

**Sreenivasan Ramaswami**

**Pre-requisites :** None

**References :** APHA, Standard methods for the examination of water and wastewater. American Public Health Association, 23rd edition, Washington DC, (2017).  
ISO standards.

**ST 225 ( AUG ) 3 : 0****Sustainable Materials**

The “Sustainable Materials” course offers a comprehensive understanding of key materials, emphasizing their environmental impact and sustainable practices. It explores eco-friendly material creation using renewable resources, starting with the need for sustainable materials and the environmental issues with current materials. The course covers renewable resources like lignocellulosic biomass, plastic waste, and CO<sub>2</sub>, teaching various conversion and synthesis techniques (biological, chemical, thermal, etc.). Students will learn about the properties and industrial applications of sustainable materials, including carbonaceous materials (graphene, nanotubes, etc.), polymers (new class and dropins), fuel components, surfactants, pharmaceuticals, etc. The aim is to teach students the skills to develop and apply sustainable materials for a greener future.

**Pre-requisites :** None

**References :** V. Popa and I. Volf Biomass as Renewable Raw Material to Obtain Bioproducts of High-Tech Value, Elsevier B.V., 2018.  
<https://doi.org/10.1016/C2015-0-05810-5>

**ST 224 ( AUG ) 3 : 0****Renewable energy**

Renewable energy holds promise for a cleaner future. This module will explore various renewable energy sources such as solar, wind, geothermal, wave, thermo-chemical, and bio-chemical methods, with a specific emphasis on technological advancements. Special attention will be given to the production of hydrogen and high-energy molecules through thermo-chemical conversion.

Additionally, it will cover biomass and municipal solid waste (MSW) as significant carbon/hydrogen resources, examining their transformation into valuable chemicals and fuels using innovative processes such as pyrolysis, gasification, and thermo/bio-chemical conversion. By integrating emerging chemocatalytic methods, these advancements aim to improve energy generation with sustainable alternatives that minimize waste and carbon emissions.

**Pre-requisites :** None

**References :** M. Kanoglu, Y. A. Cengel, J. M. Cimbala Fundamentals and Applications of Renewable Energy 2019 McGraw-Hill Education  
ISBN: 978-1260455304

# Chemical Engineering

## Preface

### CH 201 ( AUG ) 3 : 0

#### Engineering Mathematics

Linear algebraic equations, linear operators, vector and function spaces, metric and normed spaces, existence and uniqueness of solutions. Eigen values and eigen vectors/functions. Similarity transformations, Jordan forms, application to linear ODEs, Sturm-Liouville problems. PDE's and their classification, initial and boundary value problems, separation of variables, similarity solutions. Series solutions of linear ODEs. Elementary perturbation theory. References:

**Pre-requisites** : None

**References** : Linear Algebra and its Applications, Gilbert Strang, Thompson (Indian edition). ~Mathematical Methods for Physicists, J. B. Arfken and H. J. Weber (7th edition, Indian reprint, 2017). ~Mathematical Methods in Chemical Engineering, S. Pushpavanam, Prentice-Hall India (2005). ~Advanced Mathematical Methods for Scientists and Engineers, C. M. Bender and S. A. Orszag, McGraw-Hill/Springer-Verlag

### CH 202 ( AUG ) 3 : 0

#### Numerical Methods

Basics of scientific computing, basics of Matlab programming, solutions of linear algebraic equations, eigenvalues and eigenvectors of matrices, solutions of nonlinear algebraic equations, Newton-Raphson methods, function approximation, interpolation, numerical differentiation and integration, solutions of ordinary differential equations – initial and boundary value problems, solutions of partial differential equations, finite difference methods, orthogonal collocation.

**Pre-requisites** : None

**References** : Gupta S.K., Numerical Methods for Engineers, New Age International Publishers, 3rd edition, 2015 ~Chapra, S.C. and Canale, R.P., Numerical Methods for Engineers, McGraw Hill, NY, 6th edition, 2010 ~Beers, K.J., Numerical Methods for Chemical Engineering, Cambridge Univ. Press, Cambridge, UK 2010

### CH 203 ( AUG ) 3 : 0

#### Transport Processes

Dimensional analysis and empirical correlations. Molecular origins of diffusion. Steady/unsteady shell balances in one/two dimensions. Solution of unsteady diffusion equation by similarity transform and separation of variables. Conservation laws and constitutive relations in three dimensions. Diffusion dominated transport. Fluid flow due to pressure gradients. Boundary layer theory for transport in forced convection. Natural convection. References:

**Pre-requisites** : None

**References** : Bird, R.B, Stewart, W.E. and Lightfoot, E.N., Transport Phenomena, Wiley, 1994. ~L. G. Leal, Laminar Flow and Convective Transport Processes, Butterworth Heineman, 1992.



**CH 204 ( AUG ) 3 : 0****Thermodynamics**

Classical thermodynamics: first and second laws, Legendre transforms, properties of pure substances and mixtures, equilibrium and stability, phase rule, phase diagrams, and equations of state, calculation of VLE and LLE, reaction equilibria, introduction to statistical thermodynamics.

**Pre-requisites :** None

**References :** Tester, J. W., and Modell, M., Thermodynamics and its Applications

**CH 205 ( JAN ) 3 : 0****Chemical Reaction Engineering**

Course Outline Overview of Chemical Reaction Engineering The Attainable Region Theory Analysis of Multiple Reactions -- Chemical Reaction Stoichiometry, Concepts in Catalysis and Microkinetic Modeling Design of Ideal Reactors - Unsteady State, Energy Balance Non-Ideal Reactor Analysis Multiphase Reactor Design CFD for Reactive Flows.

**Venugopal S**

**Pre-requisites :** None

**References :** •Ming, D., Glasser, D., Hildebrandt, D., Glasser, B., and Metzger, M., <http://attainableregions.com/> – An Introduction to Choosing an Optimal Reactor •Levenspiel, O., Chemical Reactor Omnibook •Stewart, W. E., and Caracotsisos, M., Computer-Aided Modeling of Reactive Systems • Mory, M., Fluid Mechanics for Chemical Engineering • Fogler., <http://umich.edu/~elements/5e/index.html>

**CH 206 ( AUG ) 1 : 0****Seminar Course**

The course aims to help students in preparing, presenting and participating in seminars. The students will give seminars on topics chosen in consultation with the faculty.

**Pre-requisites :** None

**References :** None

**CH 207 ( JAN ) 1 : 0****Applied statistics and design of experiments**

Stewart, W. E., and Caracotsisos, M., Computer-Aided Modeling of Reactive Systems

**Venugopal S**

**Pre-requisites** : None

**References** : Overview of statistics; Bayesian Inference applied to solve Chemical Reaction Engineering Problems

**CH 235 ( JAN ) 3 : 0****Modeling in Chemical Engineering**

Modelling of a large variety of example systems to understand modelling of physical processes, four stages of model development; lumped parameter models; rate controlling step in series-parallel resistances; models for batch and continuous systems; distributed parameter n-d models; steady state, unsteady state, and pseudo-steady state models; homogeneous and pseudo homogeneous models; population balance models for birth and death of particles, bubbles, drops, cells, polymers, and residence time distribution; master equation for reversible and irreversible processes stochastic processes: predator - prey model; dispersion of pollutants downstream; moving control volume based models; element models; unit models, and kinetic Monte-Carlo simulations for stochastic systems.

**Sanjeev Kumar Gupta**

**Pre-requisites** : None

**References** : Lecture notes

**CH 236 ( JAN ) 3 : 0****Statistical Thermodynamics**

Introduction to ensembles, partition functions, relation to thermodynamics; imperfect gases; density distribution functions; integral equations and perturbation theories of liquids; lattice gas; Ising magnets; Bragg Williams approximation; Flory Huggins theory; Molecular modeling of intermolecular forces

**Ganapathy Ayappa**

**Pre-requisites** : None

**References**

McQuarrie, D.A., Statistical Mechanics, Viva Books, 2003.~Hill, T. L., An Introduction to Statistical Thermodynamics, Dover Publications, 1986.

**CH 247 ( JAN ) 3 : 0****Introduction to Molecular Simulation**

Introduction to molecular dynamics; conservation laws; integration schemes: verlet, velocity verlet, leapfrog; constraint dynamics; extended Lagrangian dynamics; thermostats and barostats; introduction to Monte Carlo techniques; Metropolis algorithm; NVT, NPT and GCMC simulations; estimation of pressure, chemical potential, radial distribution function, Ewald summation; introduction to density functional theory (DFT); exchange-correlation functionals, basis sets, pseudopotentials, k-point sampling; Hubbard-corrected DFT, hybrid DFT, and dispersion corrections.

**Prabal Kumar Maiti , Sudeep Punnathanam**

**Pre-requisites :** None

**References :** 1.M. P. Allen and D. J. Tildesley, Computer simulation of Liquids, Oxford University Press, New York, 1987 2.D. Frenkel and B. Smit, Understanding Molecular Simulation: From Algorithms to Applications, 2nd Ed., Academic Press, San Diego, 2002 3.D. S. Sholl and J. A. Steckel, Density Functional Theory: A Practical Introduction, John Wiley & Sons, Inc., 2009 4.F. Jensen, Introduction to

**CH 248 ( JAN ) 3 : 0****Molecular Systems Biology**

Various topics highlighting experimental techniques and modeling approaches in systems biology for problems ranging from molecular level to the multi- cellular level will be covered. Topics: Properties of biomolecules, Biomolecular Forces, Single molecule experimental techniques, Molecular motors, Molecular heterogeneity, Self- organization, Enzyme kinetics, Modeling cellular reactions and processes, Fluctuations and noise in biology, Cellular variability, Biological networks, Modeling dynamics of bioprocesses and cellular signaling.

**Rahul Roy**

**Pre-requisites :** None

**References :** Philip Nelson, Biological Physics: Energy, Information, Life, W. H. Freeman, 2007~Edda Klipp, Wolfram Liebermeister, Christoph Wierling, Axel Kowald, HansLehrach, Ralf Herwig, Systems Biology, Wiley-Vch, 2009~Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, Chapman & Hall/CRC Mathematical & Computational Biology, 2006.

**CH 232 ( JAN ) 3 : 0****Physics of Fluids**

**Kumaran V**

**Pre-requisites :** None

**References :** None

**CH 234 ( JAN ) 3 : 0****Rheology of Complex Fluids and Particulate Materials**

Introduction to the kinematics and rheology of complex fluids: Suspensions, Granular materials, and Polymeric fluids; Principles of rheology: Objective tensors, Constitutive models, Material frame indifference; Rheometry in simple flows: Material functions; Plasticity theories for slow granular flows; Kinetic theories for rapid granular flows; Suspension mechanics; Microhydrodynamics; Stress in viscous suspensions; Models for polymeric fluids; Applications to simple flows.

**Prabhu R Nott**

**Pre-requisites** : None

**References** : Rao, K. K. and Nott, P. R., An Introduction to Granular Flow, Cambridge ,2008. E. Guazzelli and J. F. Morris, A Physical Introduction to Suspension Dynamics, Cambridge, 2011 S. Kim and S. J. Karrila, Microhydrodynamics: Principles and Selected Applications, Dover,2005. Larson, R., The Structure and Rheology of Complex Fluids, Oxford,1999.

**CH 299 ( JAN ) 0 : 32****Dissertation Project**

The ME project is aimed at training the students to analyze independently any problem posed to them. The project may be theoretical, experimental, or a combination of the two. In a few cases, the project may also involve sophisticated design work. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature, and analytical, experimental or design skills, and new significant findings in the chosen area.

**Ananth Govind Rajan**

**Pre-requisites** : None

**References** : None

**CH 252 ( AUG ) 3 : 0****Hydroprocessing**

Importance of Hydroprocessing; Catalysis for Hydroprocessing; Hydrogen Management in Refineries; Hydrodesulfurisation; Hydrocracking; Process Integration; Modeling for Hydroprocessing; Design of Trickle Bed Reactor for Hydroprocessing; Process Safety

**Pre-requisites**

Batchelor's level course on Chemical Reaction Engineering

**References** : 1. Verma RP, Bhatnagar AK (ed) "Hydroprocessing in petroleum refining industry – a compendium". Lovraj Kumar memorial trust, Indian oil Institute of Petroleum Management, Gurgaon, India, (2000)  
2. Nigam KDP, Schumpe A (ed) "Three phase sparged reactors", Gordon and Breach Publishers (1996)

**CH 253 ( JAN ) 3 : 0****Quantum-Mechanical Modeling of Nanomaterials**

Introduction to nanotechnology and nanomaterials; overview of classical and quantum mechanics and introduction to phonons, excitons, and polarons; postulates of quantum mechanics, Hartree-Fock method and density functional theory, concepts of basis sets, pseudopotentials, exchange-correlation functionals; quantum confinement, principles of 0D, 1D, and 2D materials, density of states, band structure of materials; force fields and potential energy surfaces, transition state theory, nudged elastic band method; prediction of structural and mechanical properties of nanomaterials; introduction to computational catalysis, thermochemistry calculations of reaction free energies and activation barriers; modeling of nanoscale electrochemical processes, nanomaterial nucleation and growth, and interfacial properties of nanomaterials

**Ananth Govind Rajan**

**Pre-requisites :** None

**References :** 1. K. K. Chittaopadhyay and A. N. Banerjee, Introduction to Nanoscience and Nanotechnology, Prentice Hall of India  
 2. Wolfram Koch and Max C. Holthausen, A Chemist's Guide to Density Functional Theory, John Wiley & Sons, Inc., 2001  
 3. Mark Fox, Optical Properties of Solids, Oxford University Press

**CH 254 ( JAN ) 3 : 0****Heterogeneous Catalysis for Environmental Remediation**

Overview of inorganic and organic contaminants in water, permissible limits and effects; introduction to primary, secondary and tertiary water treatment processes; fundamentals of heterogeneous catalysis; steps of catalytic reactions: rate-determining steps and rate equations, effectiveness factors; overview of advanced oxidation process; homogeneous and heterogenous Fenton processes: photocatalysis, piezo-catalysis, photothermal catalysis, electro-Fenton process; design, preparation, characterization and modulation of heterogeneous catalysts; degradation and transformation of contaminants; effects of various parameters on catalytic contaminant removal; scalability and practical applications of heterogeneous catalysts.

**Debashis Roy**

**Pre-requisites :** None

**References :** 1. Fogler, S. H., Elements of Chemical Reaction Engineering, 4th ed., Pearson Education, 2006.  
 2. Chorkendorff, I., and Niemantsverdriet, J. W., Concepts of Modern Catalysis and Kinetics, 3rd ed., John Wiley and Sons, 2017.  
 3. Thomas, J. M., and Thomas, W. J., Principles and Practice of Heterogeneous Catalysis, 2nd ed., John Wiley and Sons, 2014.

# Civil Engineering

## Preface

### CE 201 ( AUG ) 3 : 0

#### Basic Geo-mechanics

Introduction to genesis of soils, basic clay mineralogy; Principle of effective stress, permeability and flow; Fundamentals of Tensors, Introduction to stresses and deformation measures; Mohr-Coulomb failure criteria, soil laboratory tests; Critical state and stress paths. Shear Strength and Stiffness of Sands; Consolidation, shear strength and stiffness of clays

**Pre-requisites** : None

**References** : Wood,D.M.,Soil Behaviour and Critical State Soil Mechanics,Cambridge University Press,1991.

### CE 202 ( JAN ) 3 : 0

#### Foundation Engineering

Subsurface investigations. Bearing capacity of shallow foundations, penetration tests, plate load tests. Settlement of shallow foundations, elastic and consolidation settlements; settlement, estimates from penetration tests, settlement tolerance. Allowable bearing pressure. Foundations on problematic soils. Principles of foundation design. Introduction of deep foundations. Bearing capacity and settlement of piles and pile groups in soils. Machine foundations.

**Raghuveer Rao Pallepati , Gali Madhavi Latha , Vivek Samu**

**Pre-requisites** : None

**References** : Bowles,J.W.,Foundation Analysis and Design,5th Edn.,McGraw-Hill~Das, M. B.,Principles of Foundation Engineering, Brooks/Cole Engineering Division, 1984.

### CE 202 ( JAN ) 1 : 2

#### Subsurface Exploration and Soil Testing

**Anbazhagan P**

**Pre-requisites** : None

**References** : None

**CE 203 ( JAN ) 3 : 0****Surface Water Hydrology**

Review of basic hydrology, hydrometeorology, infiltration, evapotranspiration, runoff and hydrograph analysis. Flood routing – lumped, distributed and dynamic approaches, hydrologic statistics, frequency analysis and probability, introduction to environmental hydrology, urban hydrology. Design issues in hydrology.

**Srinivas V V**

**Pre-requisites :** None

**References :** Bedient, P. B., and Huber, W. C., Hydrology and Floodplain Analysis, PrenticeHall, 2002.~Chow, V.T., Maidment, D.R. and Mays, L.W., Applied Hydrology, McGraw-Hill 1988~Linsley, R.K., Kohler, M.A. and Paulhus, J.L.H., Hydrology for Engineers, McGraw Hill, 1985.

**CE 204 ( AUG ) 3 : 0****Solid Mechanics**

Introduction to tensor algebra and calculus, indicial notation, matrices of tensor components, change of basis formulae, eigenvalues, Divergence theorem. Elementary measures of strain. Lagrangian and Eulerian description of deformation. Deformation gradient, Polar decomposition theorem, Cauchy-Green and Lagrangian strain tensors. Deformation of lines, areas and volumes. Infinitesimal strains. Infinitesimal strain-displacement relations in cylindrical and spherical coordinates. Compatibility. Traction, body forces, stress at a point, Cauchy's theorem. Piola-Kirchhoff stress tensors. Momentum balance. Symmetry of the Cauchy stress tensor. St. Venant's Principle. Virtual Work. Green's solids, elastic strain energy, generalized Hooke's Law, material symmetry, isotropic linear elasticity in Cartesian, cylindrical and spherical coordinates, elastic moduli, plane stress, plane strain, Navier's formulation. Airy stress functions. Selected problems in elasticity. Kirchhoff's uniqueness theorem

**Pre-requisites :** None

**References**

Fung Y. C. and Pin Tong, Classical and Computational Solid Mechanics, World Scientific, 2001~Boresi, A.P., Chong K., and Lee J., Elasticity in

**CE 205 ( JAN ) 3 : 0****Finite Element Method**

Concepts of the stiffness method. Energy principles. Continuum BVP and their integral formulation. Variational methods: Raleigh-Ritz, weighted residual methods, virtual work and weak formulations. Finite element formulation of one, two and three dimensional problems, Isoparametric formulation. Computational aspects and applications, Introduction to non-linear problems.

**Narayan K Sundaram**

**Pre-requisites** : None

**References** : Zienkiewicz, O.C. and Taylor, R.L., The Finite Element Method: Vol. 1 (The Basis), Butterworth-Heinemann, 2000.~Cook R.D., Malkus, D. S., Plesha and Witt, R.J., Concepts and Applications of Finite Element Analysis, Fourth edition, John Wiley and Sons.~J N Reddy, An Introduction to the Finite Element Method, Second Edition, McGraw Hill Inc, 1993.

**CE 207 ( JAN ) 3 : 0****Geo-environmental Engineering**

Sources, production and classification of wastes, Environmental laws and regulations, physico-chemical properties of soil, ground water flow and contaminant transport, contaminated site characterization, estimation of landfill quantities, landfill site location, design of various landfill components such as liners, covers, leachate collection and removal, gas generation and management, ground water monitoring, end uses of landfill sites, slurry walls and barrier systems, design and construction, stability, compatibility and performance, remediation technologies, stabilization of contaminated soils and risk assessment approaches.

**Sivakumar Babu G L**

**Pre-requisites** : None

**References** : Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.~Rowe, R. Kerry, Quigley, Robert M., Brachman, Richard W. I., and Booker, John R. Barrier Systems for Waste Disposal Facilities , 2nd edn 2004. Spon Press, Taylor & Francis Group,

**CE 208 ( JAN ) 3 : 0****Ground Improvement and Geosynthetics**

Principles of ground improvement, mechanical modification. Properties of compacted soil. Hydraulic modification, dewatering systems, preloading and vertical drains, electro-kinetic dewatering, chemical modification, modification by admixtures, stabilization using industrial wastes, grouting, soil reinforcement principles, properties of geo-synthetics, applications of geo-synthetics in bearing capacity improvement, slope stability, retaining walls, embankments on soft soil, and pavements. filtration, drainage and seepage control with geo-synthetics, geo- synthetics in landfills, soil nailing and other applications of geo- synthetics.

**Gali Madhavi Latha**

**Pre-requisites** : None

**References** : Hausmann, M.R., Engineering Principles of Ground Modification, McGraw- Hill, 1990.~Jones, C.J.E.P., Reinforcement and Soil Structures, Butterworth Publications, 1996.~Koerner, R. M., Designing with Geosynthetics, Prentice Hall Inc. 1998. Dover Publications, New York~



**CE 209 ( JAN ) 3 : 0****Mechanics of Structural Concrete**

Introduction, Limit state design philosophy of reinforced concrete, Stress-strain behavior in multi-axial loading, failure theories, plasticity and fracture, ductility, deflections, creep and shrinkage, Strength of RC elements in axial, flexure, shear and torsion, RC columns under axial and eccentric loading, Beam-column joints, Strut and Tie modelling, Yield line theory of slabs, Seismic resistant design, Methods for predicting the behavior of pre-stressed concrete members and structures.

**Ananth Ramaswamy**

**Pre-requisites :** None

**References :** Nilson, A. H., Darwin, D. and Dolan, C. W., Design of concrete structures, McGraw Hill, 2004~ Lin and Burns, Design of Prestressed concrete structures, John Wiley and Sons, 2006~ Agarwal and Shrikhande- Earthquake resistant design of structures, Prentice-Hall of India Pvt. Ltd. New Delhi, 2006.

**CE 210 ( JAN ) 3 : 0****Structural Dynamics**

Equations of motion. Degrees of freedom. D' Alembert principle. SDOF approximation to vibrating systems. Energy storage elements: mass, stiffness and damper. Undamped free vibration. Natural frequency. Damped free vibration. Critical damping. Forced response under periodic and aperiodic excitations. Support motions. Resonance. Impulse response and complex frequency response functions. Duhamel integral. Vibration isolation: FTR and DTR. Multi-DOF systems. Normal modes and natural frequencies. Orthogonality of normal modes. Natural coordinates. Uncoupling of equations of motion. Repeated natural frequencies. Proportional and non proportional damping. Damped normal modes. Principle of vibration absorber. Continuous systems. Vibration of beams. Forced response analysis by eigenfunction expansion. Moving loads and support motions. Effect of axial loads. Approximate methods for vibration analysis. Rayleigh's quotient. Rayleigh-Ritz method. Method of weighted residual. Method of collocation.

**Chandra Kishen J M**

**Pre-requisites :** None

**References :** Meirovich, L., 1984, Elements of vibration analysis, McGraw-Hill, NY~Clough R W and J Penzien, 1993, Dynamics of structures, McGraw-Hill, NY~Rao, S S 2004, Mechanical Vibrations, 4th Edition, Pearson Education, New Delhi.

**CE 211 ( AUG ) 3 : 0****Mathematics for Engineers**

Revision of ordinary linear ODEs, Formal operators, Adjoint operator, Sturm-Liouville theory, eigenvalue problems, Classification of PDEs, Characteristics / first order PDEs, Laplace equation / potential theory, Separation of variables (cartesian, polar), Eigenfunction expansions, Green's functions, Introduction to boundary value problems Probability space and axioms of probability. Conditional probability. Total probability and Bayes theorems. Scalar and vector random variables. Probability distribution and density functions. Expectation operator. Functions of random variables. Vector spaces and subspaces, solution of linear systems, Linear independence, basis, and dimension, The four fundamental subspaces, Linear transformations, Orthogonal vectors and subspaces, Cosines and projections onto lines, Projections and least squares, The fast Fourier transform, Eigenvalues and eigenvectors, Diagonalization of a matrix, Difference equations and powers of matrices, Similarity transformation

**Pre-requisites** : None

**References** : Michael Stone, Paul Goldbart, 2009, Mathematics for Physics: A Guided Tour for Graduate Students, Cambridge University Press~Probability, Random Variables and Stochastic Processes, A Papoulis and S U Pillai~Linear Algebra and Its Applications by Gilbert Strang

**CE 214 ( JAN ) 3 : 0****Ground Water Hydrology**

Ground water and hydrological cycle. Ground water movement and balance. Ground water monitoring. Equations of flow. Well hydraulics - analysis of aquifer tests and models. Regional groundwater resource evaluation and numerical modeling. Groundwater recharge estimation. Base flow analysis and models. Ground water quality. Mass transport in ground water. Tracer tests and scale effects of dispersion. Solute transport modeling.

**Sekhar M**

**Pre-requisites** : None

**References** : Freeze, A. R. and Cherry, J. A. Groundwater, Prentice Hall, 1979.~Fetter, C. W. Applied Hydrogeology, Prentice Hall, 1988.~Domenico, P. A., and Schwartz, F. W. Physical and Chemical Hydrogeology, John Wiley, 1990. Fetter, C. W. Contaminant Hydrogeology, Prentice Hall, 1993.

**CE 215 ( JAN ) 3 : 0****Stochastic Hydrology**

Introduction to random variables, statistical properties of random variables. Commonly used probability distributions in hydrology. Fitting probability distributions to hydrologic data. Probability plotting and frequency analysis. Data generation. Modeling of hydrologic uncertainty - purely stochastic models, first order Markov processes. Analysis of hydrologic time series - autocorrelation and spectral density functions. Applications to hydrologic forecasting.

**Rajarshi Das Bhowmik**

**Pre-requisites** : None

**References** : Bras, R.L. and Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, New York, USA, 1993.~Hann, C.T., Statistical Methods in Hydrology, First East-West Press Edition, New Delhi, 1995.~Ang, A.H.S. and Tang, W.H., Probabilistic concepts in Engineering Planning Design, Vol. 1, Wiley, New York, 1975.~Clarke, R.T., Statistical Models in Hydrology, John Wiley, Chichester, 1994

**CE 220 ( AUG ) 3 : 0****Design of Substructures**

Design considerations, field tests for bearing capacity and settlement estimates, selection of design parameters. Structural design considerations. Codes of practice. Design of spread footings, combined footings, strap footings, ring footings, rafts, piles and pile caps and piers.

**Pre-requisites** : None

**References** : Bowles, J.E. Foundation analysis and design. 5th Edn., McGraw Hill, 1996 ~Indian Standard Codes

**CE 221 ( AUG ) 3 : 0****Earthquake Geotechnical Engineering**

Introduction to engineering seismology. Plate tectonics. Earthquake magnitude. Ground motion. Effect of local soil conditions on ground motion. Dynamic behaviour of soils. Analysis of seismic site response. Liquefaction phenomena and analysis of pore pressure development. Laboratory and in-situ testing for seismic loading. Analysis and design of slopes, embankments, foundations and earth retaining structures for seismic loading. Case histories. Mitigation techniques and computer-aided analysis

**Pre-requisites** : None

**References**  
Geotechnical Earthquake Engineering By Steven L. Kramer, Pearson  
Education, 2003 ~ Geotechnical Earthquake Engineering Handbook, Robert W.

**CE 227 ( JAN ) 3 : 0****Engineering Seismology**

Introduction to earthquake hazards. Strong ground motions, tsunamis, landslides, liquefaction. Overview of plate tectonics and earthquake source mechanisms. Theory of wave propagation. Body waves and surface waves. Concepts of seismic magnitudes and intensity. Seismic station. Sensors and data loggers, mechanical and digital sensors. Interpretation of seismic records – acceleration, velocity and displacement. Regional seismicity and earthquakes in India. Seismic zonation – scales, macro and micro, attenuation, recurrence relation. Seismic hazard analysis - deterministic and probabilistic. Site characterization – different methods and experiments. Local site effects, ground motion amplifications. Development of response/design spectrum. Liquefaction hazard assessments. Integration of hazards using GIS. risk and vulnerability Studies.

**Anbazhagan P**

**Pre-requisites** : None

**References** : Earthquake Engineering – From Engineering Seismology to Performance Based Engineering, Edited by Bozorgnia, Y. and Bertero, V.V., CRC Press Washington 2004.

**CE 228 ( JAN ) 3 : 0****Continuum Plasticity**

Brief reviews of finite deformation kinematics and constitutive closure; introduction to rational thermodynamics and formulation of constitutive theories; internal variables; dissipation inequality; physics of yielding; plastic flow and hardening; notion of yield surface; classical models for yielding; plastic flow and hardening; additive and multiplicative splitting of kinematic quantities; solutions of simple BVPs; FEM for small deformation plasticity; yield free plasticity models; linearization and computational schemes; introduction to damage mechanics

**Debasish Roy**

**Pre-requisites :** None

**References :** A S Khan, S Huang, 1995, Continuum Theory of Plasticity, John Wiley, NY~J Lubliner, 2008. Plasticity theory. Courier Corporation.~M E Gurtin, L Anand, 2012, The Mechanics and Thermodynamics of Continua, Cambridge University Press, UK~Simo, J.C., & Hughes, T. J., 2006, Computational inelasticity, Springer Science & Business Media.

**CE 229 ( JAN ) 3 : 0****Non-Destructive Evaluation Methods for Concrete Structures**

Planning and interpretation of in-situ testing of concrete structures; Surface hardness methods; Fundamental bases and methodologies of non-destructive evaluation (NDE) techniques related to concrete structures; NDE methods for concrete testing based on sounding: Acoustic emission (AE) testing of concrete structures; NDE methods for concrete testing based on sounding: Ultrasonic pulse velocity (UPV) methods; Partially destructive strength tests related to concrete; cores; Examples of UPV corrections for reinforcement; examples of evaluation of core results

**Remalli Vidya Sagar**

**Pre-requisites :** None

**References :** J. H. Bungey and S. G. Millard (1996) Testing of concrete in structures. Blackie Academic & Professional, 1996, Chapman & Hall publishers.~V. M. Malhotra and N. J. Carino (2005) Handbook on Nondestructive Testing of Concrete Ed. by V.M. Malhotra and N.J. Carino., CRC publishers.~C. V. Subramanian (2016) Practical Ultrasonics., Narosa publishers~C. U. Gross and M. Ohtsu (2008) Acoustic

**CE 235 ( JAN ) 3 : 0****Optimization Methods**

Basic concepts, Kuhn-Tucker conditions, linear and nonlinear programming, treatment of discrete variables, stochastic programming, Genetic algorithm, simulated annealing, Ant Colony and Particle Swarm Optimization, Evolutionary algorithms, Applications to various engineering problems.

**Debraj Ghosh**

**Pre-requisites :** None

**References :** Arora, J.S. Introduction to Optimization, McGraw-Hill (Int. edition) 1989.~Rao, S.S., Optimization: Theory and Applications. Wiley Eastern, 1992 ~Current Literature.

**CE 236 ( AUG ) 3 : 0****Fracture Mechanics**

Introduction; Linear Elastic Fracture Mechanics; Design based on LEFM; Elasto-Plastic Fracture Mechanics; Mixed Mode Crack Propagation; Fatigue Crack Propagation; Finite Elements in Fracture Mechanics.

**Pre-requisites** : None

**References** : T. L. Anderson, Fracture Mechanics, CRC press, Fourth Edition, 2017, Boca Raton, Florida~David Broek, Elementary Fracture Mechanics, Sijthoff and Noordhoff, The Netherlands.~Prashanth Kumar, Elements of Fracture Mechanics, Wheeler Publishing, New Delhi.~J. F. Knott, Fundamentals of Fracture Mechanics, Butterworths, London.

**CE 243 ( AUG ) 3 : 0****Bridge Engineering**

**Pre-requisites** :

Solid Mechanics (CE 204 or equivalent)

**References** : None

**CE 249 ( AUG ) 3 : 0****Water Quality Modeling**

Basic characteristics of water quality, stoichiometry and reaction kinetics. Mathematical models of physical systems, completely and incompletely mixed systems. Movement of contaminants in the environment. Water quality modeling in rivers and estuaries - dissolved oxygen and pathogens. Water quality modeling in lakes and ground water systems.

**Pre-requisites** : None

**References** : Chapra, S.C., Surface Water Quality Modeling, McGraw Hill, 1997. ~Tchobanoglous, G., and Schroeder, E.D., Water Quality, Addison Wesley, 1987.

**CE 262 ( JAN ) 3 : 0****Public Transportation Systems Planning**

Modes of public transportation and application of each to urban travel needs; comparison of transit modes and selection of technology for transit service; transit planning, estimating demand in transit planning studies, demand modeling, development of generalized cost, RP & SP data and analysis techniques; functional design and costing of transit routes, models for planning of transit routes, scheduling; management and operations of transit systems; integrated public transport planning; operational, institutional, and physical integration; models for integrated planning; case studies.

**Ashish Verma****Pre-requisites**

Transportation Systems Modeling course, exposure to UG courses of Transportation Engineering from B-Tech (Civil Engg.)

**References** : A. Verma and T. V. Ramanayya, Public Transport Planning and Management in Developing Countries, CRC Press, 2014~Vuchic Vukan R., Urban Transit: Operations, Planning and Economics, Prentice Hall, 2005~Gray G. E., and Hoel L. A., Public Transportation, Prentice Hall, 1992.

**CE 269 ( AUG ) 3 : 0****Traffic Engineering**

Traffic flow elements and its characterization: vehicle characteristics, human factors, infrastructure elements, capacity and LoS concepts, Highway Capacity Manual (HCM) methods. Uninterrupted Traffic Flow: speed-flow-density relationships, multi-regime models, car-following, lane-changing, simulation framework. Interrupted Traffic Flow: signal design, shock-wave theory, gap-acceptance behavior, delay and queue analysis. Design of traffic facilities: expressways, signalized and un-signalized intersections, interchanges, parking, signs and markings.

**Pre-requisites** : None

**References** : Roess, R.P., Prassas E.S. & McShane, W.R. (2010), Traffic Engineering, Prentice Hall, USA.~May, A. D. (1990), Traffic Flow Fundamentals, Prentice Hall, USA.~Highway Capacity Manual (2010), Transportation Research Board, USA.~Kadiyali, L. R. (2000), Traffic Engineering and Transport Planning, Khanna Publishers, India.~Salter, R J. & Hounsell, N. B. (1996), Highway Traffic Analysis and Design,

**CE 272 ( JAN ) 3 : 0****Traffic Network Equilibrium**

Traffic assignment; Fixed points and Variational inequalities; Fundamentals of convex optimization; Shortest path algorithms; Wardrop user equilibrium; System optimum and Price of Anarchy; Link-based algorithms (Method of successive averages, Frank-Wolfe); Potential games; Variants of the traffic assignment problem (Multiple-classes, Elastic demand); Path-based algorithms; Origin-based methods; Sensitivity analysis.

**Tarun Rambha**

**Pre-requisites** : None

**References** : Sheffi, Y. Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods. Prentice Hall, 1985.~Patriksson, M. The traffic assignment problem: models and methods. Courier Dover Publications, 2015.

**CE 274 ( AUG ) 3 : 0****Seismic Analysis and Design of Structures****Pre-requisites** : None**References** : None**CE 277 ( JAN ) 3 : 0****Remote Sensing in Ecohydrology**

Introduction to ecohydrology, fundamentals of exchange of energy and water in terrestrial ecosystems, soil temperature and moisture, surface energy fluxes, modeling leaf photosynthesis and stomatal conductance, introduction to plant canopies and radiation regime, soil, plant atmosphere continuum, fundamentals of optical remote sensing, remote sensing of vegetation composition, structure and function, applications of remote sensing to coupled water and carbon cycles in terrestrial ecosystems.

**Debsunder Dutta****Pre-requisites** : None

**References** : Ecological Climatology, 3rd Edition, Gordon Bonan, Cambridge University Press. ~An Introduction to Environmental Biophysics, 1998, G.S. Campbell, J. Norman, Springer.

**CE 279 ( JAN ) 3 : 0****Computational Geotechnics**

Introduce governing equations for geotechnical engineering problems, basics of solving governing equations using frequency and time domain numerical methods including finite element and finite difference methods, soil constitutive modeling, examples of coding/solving geotechnical engineering problems using the above methods/tools.

**Swetha Veeraraghavan****Pre-requisites** : None

**References** : Bathe, K.J., Finite Element Procedures in Engineering Analysis, Prentice-Hall, Englewood Cliffs, NJ, 1982. ~Wood, D.M., Soil Behavior and Critical State Soil Mechanics, Cambridge University Press, New York, 1990. ~Hai-Sui Yu, Plasticity and Geotechnics, Springer, 2006 ~Desai, C.S. and Christian, J.T. Eds. Numerical Methods in Geotechnical Engineering, McGraw-Hill, 1977.

**CE 297 ( AUG ) 3 : 0****Problems in the Mathematical Theory of Elasticity**

Introduction: Review of linear elasticity, equilibrium, compatibility, statements of 2D (plane strain / plane stress) and 3D elastic BVPs, Review of Airy stress functions. Functions of a complex variable: Introduction to holomorphic and sectionally holomorphic functions. Laurent series, contour integrals, generalized Cauchy integral formulae. Bi-harmonic equation in the complex plane. Kolosov-Muskhelishvili formulation for planar elasticity. Conformal mapping. The Riemann-Hilbert problem. Analysis of selected problems using complex variable methods: Plate with an elliptic hole. The slit infinite plane. Singular and distributed solutions for halfplanes, disks, and plates with holes. Contact of a rigid punch and halfplane. Multivalued displacements and dislocations. 3D linear elasticity problems: Papkovitch-Neuber formulation. Boussinesq potentials. Kel-vin's problem. The Boussinesq solution. The Hertz contact problem. Galin's theorem. Introduction to micromechanics: Eshelby's ellip

**Pre-requisites** : None

**References**

Current and historic literature

**CE 299 ( JAN ) 0 : 22****Project**

The project work is aimed at training the students to analyze independently problems in geotechnical engineering, water resources engineering, structural engineering and transportation and infrastructural engineering. The nature of the project could be analytical, computational, experimental, or a combination of the three. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature, and analytical, computational, experimental aptitudes of the student.

**Debraj Ghosh**

**Pre-requisites** : None

**References** : None



**CE 217 ( AUG ) 3 : 0****Fluid Mechanics**

Vectors and tensors, divergence theorem, pressure, Archimedes principle, fluid mass conservation, heat and contaminant conservation, momentum conservation and Cauchy equation, stress tensor, constitutive relation for Newtonian fluids, Navier-Stokes equations, vorticity, laminar plane Couette and open channel flow, Euler equations, potential flow approximation, simple solutions of potential flows, laminar flow in pipes and channels, transition to turbulence Reynolds stress and fluxes, laminar boundary layer, laminar bottom dense flows.

**Pre-requisites :** None

**References :** Kundu, Cohen and Dowling Fluid Mechanics, Sixth Ed., Academic Press, 2016. ~White, F.M. Fluid Mechanics, Eighth Edition, McGraw Hill, 2016.

**CE 271 ( JAN ) 3 : 0****Choice Modeling**

Individual choice theories; Binary choice models; Unordered multinomial choice models (multinomial logit and multinomial probit); Ordered response models (ordered logit, ordered probit, generalized ordered response; rank-ordered data models); Maximum likelihood estimation; Sampling based estimation (choice-based samples and sampling of alternatives); Multivariate extreme value models (nested logit, cross-nested logit); Mixture models (mixed logit and latent class models); Mixed multinomial probit; Integrated choice and latent variable models; Discrete-continuous choice models with corner solutions; Alternative estimation methods (EM, analytic approximations, simulation); Applications to travel demand analysis.

**Abdul Rawoof Pinjari**

**Pre-requisites :** None

**References :** F. Koppelman & C.R. Bhat. A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006. ~K. Train. Discrete Choice Methods with Simulation (2nd edition), Cambridge University Press, 2009. ~M. Ben-Akiva & S.R. Lerman. Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, 1985.

**CE 275 ( AUG ) 3 : 0****Transportation Systems Modelling**

Methods – Statistical and econometric methods for transportation data analysis; linear regression for analysis of continuous variable data (assumptions, estimation, specification, interpretation, hypothesis testing, segmentation, non-linear specification, testing of assumptions); discrete outcome models for analysis of categorical data (binary and multinomial choice models, maximum likelihood estimation); entropy methods for analysis of spatial flows; Demand-supply equilibrium; Models of traffic flow; Optimization models to predict traffic volumes. Applications – analysis of user behaviour in infrastructure systems; travel behaviour, travel demand and supply analysis (modelling the generation, spatial and temporal distribution, modal split, and route choice of travel); analysis of vehicular traffic streams; tools for data analysis and transport modelling.

**Pre-requisites :** None

**References :** J. de D. Ortuzar and L.G. Willumsen. Modelling Transport (4th edition), John Wiley and Sons, 2011. ~F. Koppelman and C.R. Bhat. A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.

**CE 250 ( JAN ) 3 : 0****Stability and Design of Steel Structures**

Introduction, Limit state design philosophy of reinforced concrete, Stress-strain behavior in multi-axial loading, failure theories, plasticity and fracture, ductility, deflections, creep and shrinkage, Strength of RC elements in axial, flexure, shear and torsion, RC columns under axial and eccentric loading, Beam-column joints, Strut and Tie modelling, Yield line theory of slabs, Seismic resistant design, Methods for predicting the behavior of pre-stressed concrete members and structures. Concepts and principles of stability of beam-columns- Differential equations for beam-columns, effects of concentrated lateral loads, effects of different end conditions such as built-in or elastic supports; continuous beams and columns with axial loads, torsion in Thin walled sections, Lateral buckling of beams, elastic buckling of rigid frames, arches; influence of material inelasticity and imperfections in the structural stability of member ; application of energy and numerical methods in critica.

**Ananth Ramaswamy****Pre-requisites** :

Solid Mechanics (CE 204 or equivalent)

**References** : Nilson, A. H., Darwin, D. and Dolan, C. W., Design of concrete structures, McGraw Hill, 2004~ Lin and Burns, Design of Prestressed concrete structures, John Wiley and Sons, 2006~ Agarwal and Shrikhande- Earthquake resistant design of structures, Prentice-Hall of India Pvt. Ltd. New Delhi, 2006. 1. Temoshenko, S. and Gere, J., "Theory of Elastic Stability" McGraw Hill. 2. Wai-Fa Chen and Lui,

**CE 260 ( AUG ) 3 : 0****Rock Mechanics**

Physical, mechanical and engineering properties of rocks; rock discontinuities; strike; dip; bedding planes; joints; faults; folds; unconformities; geological exploration by bore holes; methods of drilling; rock strength and rock mass strength; rock failure criteria; rock mass classification; rock mass rating, geophysical methods; geology of dam sites and reservoirs; Importance of geology in dam construction; rock slope stability theory  
Stresses and strains; theory of elasticity; in-situ stresses; numerical and computer methods in rock mechanics and under-ground excavations.

**Pre-requisites** : None

**References** :

1. Engineering Rock Mechanics. John A. Hudson and John P. Harrison.
- 2.

**CE 295 ( JAN ) 3 : 0****Earth Retaining Structures and Earthen Dams**

Earth retaining structures, lateral earth pressure coefficients, Rankine and Coulomb theories, passive earth pressure computation with curved rupture surfaces, stability of gravity and cantilever retaining walls, stability of vertical cuts, braced excavations, cantilever and anchored sheet piles, stability of infinite slopes and finite slopes, different methods of slices for the analysis of finite slopes and embankments, stability analysis of earth and rock dams, forces/loads to be considered, different load cases, factors of safety in different conditions, filters for earthen dams, seepage analysis.

**Jyant Kumar****Pre-requisites** : None

**References** : 1. Terzaghi, K., Theoretical Soil Mechanics, John Wiley, 1965. Taylor, D.W., Fundamentals of Soil Mechanics, John Wiley, 1948. 2. Bowles, J.W., Analysis and Design of Foundations, 4th and 5th Ed., McGraw-Hill, 1988 & 1996. 3. Lambe, T.W. and Whitman, R.V., Soil Mechanics, Wiley Eastern Limited, 1976. 4. Earth and earth-rock dams: Engineering problems of design and

**CE 285 ( JAN ) 3 : 0****Disaster Management for Dams**

Overview of disaster management and flood mapping, Flood risk associated with various types of dams, Dam hazard classification systems, Dam failure modes and assessment of consequences, Dam breach modelling, Hydrologic, Hydraulic and breach outflow routing, Remote Sensing and Geographic Information Systems (GIS) applications for emergency preparedness and flood mapping, Dam hazard classification framework in India, Emergency action plans preparation and implementation.

**Srinivas V V****Pre-requisites** : None

**References** : 1. Guidelines for Developing Emergency Action Plans for Dams, Dam Safety Rehabilitation Directorate (DSRD), Central Water Commission (CWC), 2016. 2. Guidelines for Mapping Flood Risks Associated with Dams, DSRD, CWC, 2018. Heywood, I., Cornelius, S., and Carver, S. 3. An Introduction to Geographical Information Systems, Pearson Education, 1998. Lillesand T.M. and Kiefer

**CE 205A ( AUG ) 3 : 1****Transportation Logistics**

Solution methods for integer programs (Branch and bound, Cutting plane algorithms, Branch and price); Travelling Salesman Problem; Vehicle Routing Problem and variants; Shared ride systems; Crew scheduling; Facility location; Complexity theory; Collaborative logistics; Neighbourhood search; Heuristics

**Pre-requisites** :

Graduate level course on optimization/linear programming.  
**References** : Wolsey, L. A. (2020). Integer programming. John Wiley & Sons.  
 Toth, P., & Vigo, D. (Eds.). (2002). The vehicle routing problem. Society for Industrial and Applied Mathematics (SIAM).  
 Applegate, D. L. (2006). The traveling salesman problem: a computational study. Princeton university press.

**CE 202A ( JAN ) 2 : 1****Integrated Investigation of Dams**

Introductions to Geotechnical field investigations, laboratory experiments and relevant IS codes; Geotechnical and Geophysical investigation of Dams; Theory and demonstration of Ground Penetrating Radar testing; Multichannel Analysis of Surface Testing; Seismic borehole tests, Down/Up and Cross hole testing; Electric Resistivity testing; Planning of Integrated Investigation. Field experimental case studies of Dam investigations.

**Raghuveer Rao Pallepati , Anbazhagan P**

**Pre-requisites :** None

**References :** An-Bin Huang, Paul W Mayne, Geotechnical and Geophysical Site Characterization, CRC Press, 2008. Head, K.H., Manual of Soil Laboratory Testing. Vols. 1 to 3, 1981. Compendium of Indian Standards on Soil Engineering Parts 1 and II, 1987 - 1988.

**CE 201A ( AUG ) 3 : 0****Dam safety surveillance, instrumentation and monitoring**

Dam safety inspection program; Inspecting embankment dams, concrete and masonry dams; Inspecting spillways, outlets and mechanical equipment; Instrumentation and monitoring; Instrumentation types and their uses; Hydro-meteorological instrumentation; Instrumentation data collection and management; Monitoring data organization and analysis.

**Pre-requisites :** None

**References :** 1) Guidelines for safety inspection of dams (2018), Central water Commission, Govt. of India, New Delhi. 2) Guidelines for instrumentation of Large dams (2018), Central water commission, Govt. of India, New Delhi.

**CE 203A ( AUG ) 3 : 0****Hydrologic Safety Evaluation of Dams**

Significance of hydrologic safety evaluation and modeling, uncertainty in hydro-meteorological processes; Standard project storm and Probable maximum precipitation (PMP); Design flood estimation - Hydro-meteorological approach: unit hydrograph construction, design storm depth estimation from PMP Atlas, storm transposition and adjustment, estimation of loss rate, base flow and time distribution coefficients, HEC-HMS model; Flood frequency analysis approach: At-site and regional frequency analysis using commonly used probability distributions in hydrology, Probability plotting and Goodness of fit tests; Reservoir sedimentation, Reservoir rule curve.

**Pre-requisites :** None

**References :** Chow, V.T., Maidment, D.R. and Mays, L.W., Applied Hydrology, McGraw-Hill, 1988. Handbook for Assessing and Managing Reservoir Sedimentation, Dam Safety Rehabilitation Directorate, Central Water Commission, 2019. Hosking, J. R. M., and Wallis, J. R., Regional Frequency Analysis: An Approach Based on L-Moments, Cambridge University Press, 1997.

**CE 204A ( JAN ) 3 : 0****Pavement Engineering**

Introduction to pavement engineering; design of flexible and rigid pavements: selection of pavement design input parameters, traffic loading and volume, material characterization, drainage, failure criteria; pavement design of overlays; pavement performance evaluation; non-destructive tests for pavement; IRC, AASHTO design codes; maintenance and rehabilitation of pavements.

**Satyavati Komaragiri****Pre-requisites** :

None

**References** : 1) Rajib B Mallick and Tahar El-Korchi, Pavement Engineering, Principles and Practice, CRC Press, 2009.  
 2) Y.H. Huang, Pavement Analysis and Design, Prentice-Hall, New Jersey, 1993.  
 3) E. J. Yoder, M. W. Witczak, Principles of Pavement Design, Wiley New York, 1975.

**CE 207A ( AUG ) 3 : 0****Characterization of Bituminous Materials**

Introduction and overview of mixture design; chemical, physical, and rheological properties of asphalt binder; behavior, testing, and selection of aggregates; design of asphalt mixtures, compaction and properties; common distresses and characterization of distresses; additives and surface properties; engineered materials, warm mixtures, RAP, and other special mixtures.

**Pre-requisites** :

None

**References** : 1) F.L. Roberts, P. S. Kandhal, E.R. Brown, D-Y. Lee and T. W. Kennedy, 2nd Edition, NAPA Research and Education Foundation, 19  
 2) Dallas N. Little, David H. Allen, and Amit Bhasin. Modeling and design of flexible pavements and materials, Springer, 2018.  
 3) C. E. G. Justo, S.K. Khanna, and A. Veeraragavan, Highway engineering, Nem Chand & Bros, 2017.

**CE 208A ( AUG ) 3 : 0****Flood Resilient Transport System**

Introduction to principles of resilient transport system and development of resilient plans; Transport network planning and design; Measures/policies for adaptation of transport system to flooding situation; Modelling, simulation, and geospatial analysis methods to design resilient transport system and plans; Integrated macro and micro traffic simulation models for scenario analysis and development of resiliency plans.

**Pre-requisites** :

Transportation Systems Modeling (CE 275)

**References** : 1. M A P Taylor, Climate Change Adaptation for Transportation Systems (1st Edition), Elsevier, 2020.  
 2. Vajjarapu, H., Verma, A., & Hemanthini AR., Evaluating climate change adaptation policies for urban transportation in India, International Journal of Disaster Risk Reduction, 47, 101528. <https://doi.org/10.1016/j.ijdrr.2020.101528>, 2020.

**CE 209A ( AUG ) 3 : 0****Elastic Wave Propagation and Applications in NDE**

Introduction to elastic wave propagation and its role in Nondestructive evaluations. 1D nondispersive wave propagation, 1D dispersive wave propagation, introduction to Spectral Finite Element Method (SFEM). Two-dimensional scalar wave propagation (acoustic waves): scalar waves in free field, material interface, analysis of layered system using dynamic stiffness method, introduction to lamb waves (SH waves), love waves, cylindrical and spherical waves. Elastic wave propagation: Elastodynamic formulation, Helmholtz decomposition, elastic wave on a plane, P waves, SV waves, Rayleigh waves, and guided waves in layered media. NDE applications, Practical aspects of implementation including instrumentation, signal processing and interpretation of results.

**Pre-requisites :** None

**References :** 1. Wave propagation in Elastic Solids, J.D. Achenbach (1973).  
2. Ultrasonic Guided Waves in Solid Media, J.L. Rose, Cambridge University Press, 2014.  
3. Wave Propagation in Structures, James F. Doyle, Second Edition, Springer, 1997.

**CE 210A ( AUG ) 3 : 0****Thermodynamic Modelling of Cementitious Systems**

A brief recap of cement chemistry, cement hydration and concrete technology (influence of binder chemistry on reaction products, concrete microstructure, mineral and chemical admixtures, microstructure and pore structure; concrete mechanics and durability); A brief recap of thermodynamics (zeroth law, first law, second law, activity); Law of mass action; Mass Balance calculations; Determination of Reactivity; Fundamentals of thermodynamic modelling; Predicting reaction products; Predicting pore solution compositions; Predicting pore volumes; Kinetic modelling; Structure-property relations in concrete.

**Pre-requisites :** Prerequisites: The participants are expected to have basic knowledge of cement hydration and concrete durability. Undergraduate level courses on Concrete Technology and Civil Engineering Materials are recommended. Registration will only be permitted after an initial discussion with the instructor.

**References :** 1. "Concrete: Microstructure, Properties, and Materials" by P.K. Mehta and Paulo J. M. Monteiro, 4th Edition (2014), McGraw Hill Education (India), New Delhi, India.

**CE 211A ( JAN ) 3 : 0****Concrete Durability and Repair**

Introduction to concrete; Concrete constituents and manufacture; Introduction to cement and concrete microstructure; Transport through cement microstructure - physics and measurement; Dimensional Changes in Concrete - shrinkage and creep; Corrosion of steel and repair, role of chlorides; Carbonation; Aggregates and durability of concrete; Freeze-thaw and salt-scaling; Sulphate attack and delayed ettringite formation, physical salt attack; Effect of fire, acid attack, abrasion and cavitation; Concrete quality control, workmanship and choice of materials; Biological processes and mic; Non-destructive and laboratory test-methods; Inspection, repair and protection of structures; Durability based design of structures.

**Keshav Bharadwaj Ravi**

**Pre-requisites :** Undergraduate level courses on Concrete Technology and Civil Engineering Materials are recommended.

**References :** I will be combining information from several books in this course and will also include information from recent literature.

Reference Books:  
1. Mehta P.K. and Monteiro P.J.M., Concrete Microstructure Properties and Materials, Fourth Edition, Tata McGraw Hill, 2014

# Climate Change

## Preface

# Materials Engineering

## Preface

### MT 201 ( JAN ) 3 : 0

#### Phase Transformations

Overview of phase transformations, nucleation and growth theories, coarsening, precipitation, spinodal decomposition, eutectoid, massive, disorder-to-order, martensitic transformations. crystal interfaces and microstructure. topics in the theory of phase transformations: linear stability analysis, elastic stress effects, sharp interface and diffuse interface models of microstructural evolution.

#### Chandan Srivastava

**Pre-requisites** : None

**References** : None

### MT 202 ( AUG ) 3 : 0

#### Thermodynamics and Kinetics

Classical and statistical thermodynamics, Interstitial and substitutional solid solutions, solution models, phase diagrams, stability criteria, critical phenomena, disorder-to-order transformations and ordered alloys, ternary alloys and phase diagrams, Thermodynamics of point defects, surfaces and interfaces. Diffusion, fluid flow and heat transfer.

**Pre-requisites** : None

**References** : C.H.P. Lupis: Chemical Thermodynamics of Materials, Elsevier Science, 1982~P.Shewmon: Diffusion in Solids, 2nd Edition, Wiley, 1989.~A.W. Adamson and A.P.Gast: Physical Chemistry of Surfaces (Sixth Edition), John Wiley, 1997.

### MT 206 ( AUG ) 3 : 0

#### Texture and Grain Boundary Engineering

Concepts of texture in materials, their representation by pole figure and orientation distribution functions. Texture measurement by different techniques. Origin and development of texture during material processing stages: solidification, deformation, annealing, phase transformation, coating processes, and thin film deposition. Influence of texture on mechanical and physical properties. Texture control in aluminum industry, automotive grade and electrical steels, magnetic and electronic materials. Introduction to grain boundary engineering and its applications.

**Pre-requisites** : None

**References** : M. Hatherly and W. B. Hutchinson, An Introduction to Texture in Metals (Monograph No. 5), The Institute of Metals, London~V. Randle, and O. Engler, Introduction to Texture Analysis: Macrotecture, Microtexture and Orientation mapping, Gordon and Breach Science Publishers~F. J. Humphreys and M. Hatherly, Recrystallization and Related Phenomenon, Pergamon Press~P. E. J.



**MT 208 ( JAN ) 3 : 0****Diffusion in Solids****Pikee Priya****Pre-requisites** : None**References** : Paul G. Shewmon, Diffusion in Solids, A. Paul, T. Laurila, V. Vuorinen, S. Divinski, Thermodynamics, Diffusion and The Kirkendall effect in Solids, A. Paul, S. Divinski, Handbook of Solid State Diffusion**MT 209 ( JAN ) 3 : 0****Defects in Materials**

Review of defect classification and concept of defect equilibrium. Review of point defects in metallic, ionic and covalent crystals. Dislocation theory - continuum and atomistic. Dislocations in different lattices. Role of anisotropy. Dislocation kinetics. Interface thermodynamics and structure. Overview of grain boundaries, interphase boundaries, stacking faults and special boundaries. Interface kinetics: migration and sliding. Defect interactions: point defect-dislocation interaction, dislocation-interface interactions, segregation, etc.. Overview of methods for studying defects including computational techniques

**Karthikeyan Subramanian****Pre-requisites** : None**References** : W.D. Kingery, H.K. Bowen and D.R. Uhlmann: Introduction to Ceramics, 2nd ed., John Wiley and Sons, 1976~D. Hull and D. J. Bacon: Introduction to dislocations, 4th ed., Butterworth-Heinemann, 2001.~D.A. Porter and K.E. Easterling: Phase Transformation in Metals and Alloys, 2nd ed. Chapman and Hall, 1992.~R.W. Balluffi, S.M. Allen, W.C. Carter: Kinetics of Materials, 1st ed. Wiley-**MT 213 ( JAN ) 3 : 0****Electronic Properties of Materials**

Introduction to electronic properties; Drude model, its success and failure; energy bands in crystals; density of states; electrical conduction in metals; semiconductors; semiconductor devices; p-n junctions, LEDs, transistors; electrical properties of polymers, ceramics, metal oxides, amorphous semiconductors; dielectric and ferroelectrics; polarization theories; optical, magnetic and thermal properties of materials; application of electronic materials: microelectronics, optoelectronics and magnetoelectrics.

**Bhagwati Prasad****Pre-requisites** : None**References** : R. E. Hummel, Electronic Properties of Materials, S. O. Kasap, Principles of Electronic Materials and Devices, S. M. Sze, Semiconductor devices: Physics and Technology, D. Jiles, Introduction to the electronic properties of materials

**MT 218 ( JAN ) 2 : 1****Modeling and Simulation in Materials Engineering**

Importance of modeling and simulation in Materials Engineering. and numerical approaches. Numerical solution of ODEs and PDEs, explicit and implicit methods, Concept of diffusion, phase field technique, modelling of diffusive coupled phase transformations, spinodal decomposition. Level Set methods, Cellular Automata, simple models for simulating microstructure, Finite element modelling, Examples in 1D, variational approach, interpolation functions for simple geometries, (rectangular and triangular elements); Atomistic modelling techniques, Molecular and Monte-Carlo Methods.

**Govind S Gupta , Suryasarathi Bose , Abhik N Choudhury**

**Pre-requisites :** None

**References :** A.B. Shiflet and G.W. Shiflet: Introduction to Computational Science: Modeling and Simulation for the Sciences, Princeton University Press, 2006.~D.C.Rapaport: The Art of Molecular Dynamics Simulation, Cambridge Univ. Press,1995.~K. Binder, D. W. Heermann: Monte Carlo Simulation in Statistical Physics, Springer, 1997.~K.G.F Janssens, D. Raabe, E. Kozeschnik, M.A. Miodownik,

**MT 220 ( AUG ) 3 : 0****Microstructural Engineering of Structural Materials**

Review of crystal defects: dislocation theory, grain boundaries and heterophase boundaries, defect kinetics and defect interactions; Role of microstructure on mechanical properties: strengthening mechanisms, ductilizing mechanisms, toughening mechanisms, effect of microstructure on creep, fatigue and impact resistance; Methods of controlling microstructures: phase transformations (L $\rightarrow$ S, V $\rightarrow$ S, S $\rightarrow$ S), heat treatments, solidification, mechanical processing, texture control, recovery and recrystallization, sintering, etc;Case studies of microstructural control of engineering metals, alloys and ceramics (Ni- base superalloys, YSZ, ceramic-matrix composites, Ti-alloys,steels, etc)

**Pre-requisites :** None

**References :** None

**MT 243 ( JAN ) 0 : 2****Laboratory Experiments in Materials Engineering**

Experiments in Metallographic techniques, heat treatment, diffraction mineral beneficiation, chemical and process metallurgy, and mechanical metallurgy.

**Rajeev Ranjan**

**Pre-requisites :** None

**References :** None

**MT 248 ( JAN ) 3 : 0****Modelling and Computational Methods in Metallurgy**

Basic principles of physical and mathematical modelling. Similarity criteria and dimensional analysis. Detailed study of modelling of various metallurgical processes such as blast furnace, induction furnace, ladle steelmaking, rolling, carburizing and drying. Finite difference method. Solution of differential equations using various numerical techniques. Convergence and stability criteria. Assignments will be based on developing computer code to solve the given problem. Prerequisite: Knowledge of transport phenomena, program language

**Govind S Gupta**

**Pre-requisites :** None

**References :** Govind S Gupta, J. Szekely and N. J. Themelis: Rate Phenomena in Process Metallurgy, Wiley, New York, 1971, B. Carnahan, H. A. Luther, and J. O. Wikes: Applied Numerical Methods, John Wiley, NY 1969.

**MT 250 ( AUG ) 3 : 0****Introduction to Materials Science and Engineering**

**Pre-requisites :** None

**References :** None

**MT 253 ( AUG ) 3 : 0****Mechanical Behaviour of Materials**

Theory of Elasticity. Theory of Plasticity. Review of elementary dislocation theory. Deformation of single and polycrystals. Temperature and Strain rate effects in plastic flow. Strain hardening, grain size strengthening, solid solution strengthening, precipitation strengthening, dispersion strengthening, martensitic strengthening. Creep, fatigue and fracture.

**Pre-requisites :** None

**References :** Thomas H. Courtney, Mechanical Behaviour of Materials, Waveland Press. ~George E. Dieter, Mechanical Metallurgy, McGraw-Hill Book Company.

**MT 255 ( JAN ) 3 : 0****Solidification Processing**

Advantage of solidification route to manufacturing, the basics of solidification including fluid dynamics, solidification dynamics and the influence of mould in the process of casting. Origin of shrinkage, linear contraction and casting defects in the design and manufacturing of casting, continuous casting, Semi-solid processing including pressure casting, stir casting and thixo casting. Welding as a special form of manufacturing process involving solidification. Modern techniques of welding, the classification of different weld zones, their origin and the influence on properties and weld design. Physical and computer modeling of solidification processes and development of expert systems. New developments and their possible impact on the manufacturing technology in the future with particular reference to the processes adaptable to the flexible manufacturing system.

**Abhik N Choudhury**

**Pre-requisites** : None

**References** : Abhik N Choudhury, J. Campbell: Casting, Butterworth - Haneman, London, 1993, M.C. Flemings: Solidification Processing, McGraw Hill, 1974.

**MT 260 ( AUG ) 3 : 0****Polymer Science and Engineering**

Fundamentals of polymer science. Polymer nomenclature and classification. Current theories for describing molecular weight, molecular weight distributions. Synthesis of monomers and polymers. Mechanisms of polymerization reactions. Introduction to polymer processing (thermoplastic and thermoset). Structure, property relationships of polymers: crystalline and amorphous states, the degree of crystallinity, cross-linking, and branching. Stereochemistry of polymers. Instrumental methods for the elucidation of polymer structure and properties; basic principles and unique problems encountered when techniques such as thermal (DSC, TGA, DMA, TMA, TOA), electrical, and spectroscopic (IR, Raman, NMR, ESCA, SIMS) analysis GPC, GC-MS, applied to polymeric materials. Polymer Processing - Injection Molding, Extrusion, Compression Molding, Blow Molding, Casting and Spin Coat, Calendaring.

**Pre-requisites** : None

**References** : None

**MT 261 ( AUG ) 3 : 0****Organic Electronics**

Fundamentals of polymers. Device and materials physics. Polymer electronics materials, processing, and applications. Chemistry of device fabrication, materials characterization. Electroactive polymers. Device physics: Crystal structure, Energy band diagram, Charge carriers, Heterojunctions, Diode characteristics. Device fabrication techniques: Solution, Evaporation, electrospinning. Devices: Organic photovoltaic device, Organic light emitting device, Polymer based sensors. Stability of organic devices.

**Pre-requisites :** None

**References :** T. A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers: Theory, Synthesis, Properties and Characterization, CRC Press. ~T.A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers: Processing and Applications Edited by Terje A. Skotheim and John R. Reynolds, CRC

**MT 262 ( JAN ) 3 : 0****Concepts in Polymer Blends and Nanocomposites**

Introduction to polymer blends and composites, nanostructured materials and nanocomposites, Polymer-polymer miscibility, factors governing miscibility, immiscible systems and phase separation, Importance of interface on the property development, compatibilizers and compatibilization, Blends of amorphous & semi-crystalline polymers, rubber toughened polymers, particulate, fiber reinforced composites. Nanostructured materials like nano clay, carbon nanotubes, graphene etc. and polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites nanocomposites. Various processing techniques like solution mixing, melt processing. Unique properties of blends, composites nanocomposites in rheological, mechanical, and physical properties and applications

**Suryasarathi Bose**

**Pre-requisites :** None

**References :** D.R. Paul and S. Newman: Polymer Blends, Vol 1&2 , Academic Press, 2000, L.A. Utracki: Polymer Alloys and Blends, Hanser, 2000, C. Chung: Introduction to Composites, Technomic, Lancaster, PA. 1998., J. Summerscales and D. Short: Fiber Reinforced Polymers, Technomic. 1988, T.J. Pinnavia and G.W. Beall (Editors): Polymer-Clay Nanocomposites, Wiley, New York 2000. P.M. Ajayan,

**MT 271 ( AUG ) 3 : 0****Introduction to Biomaterials Science and Engineering**

This course will introduce basic concepts of biomaterials research and development including discussion on different types of materials used for biomedical applications and their relevant properties. Content: Surface engineering for biocompatibility; Protein adsorption to materials surfaces; Blood compatibility of materials; Immune response to materials; Corrosion and wear of implanted medical devices; Scaffolds for tissue engineering and regenerative medicine; Concepts in drug delivery;

**Pre-requisites :** None

**References :** Ratner et al: Biomaterials science: An introduction to materials in medicine, Lecture notes, Literature

**MT 299 ( JAN ) 0 : 32****Dissertation Project**

The M.E. Project is aimed at training the students to analyse independently any problem posed to them. The project may be a purely analytical piece of work, a completely experimental one or a combination of both. In a few cases, the project can also involve a sophisticated design work. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical and/or experimental or design skill.

**Govind S Gupta**

**Pre-requisites** : None

**References** : None

**MT 245 ( AUG ) 3 : 0****Transport Processes in Process Metallurgy**

Basic and advanced idea of fluid flow, heat and mass transfer. Integral mass, momentum and energy balances. The equations of continuity and motion and its solutions. Concepts of laminar and turbulent flows. Concept of packed and fluidized bed. Non-wetting flow, Natural and forced convection. Unit processes in process metallurgy. Application of the above principles in process metallurgy.

**Pre-requisites** : None

**References** : J. Szekely and N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley, New York, 1971~G.H. Geiger and D R Poirier: Transport Phenomena in Metallurgy, Addison-Wesley, 1980.~D.R. Gaskell: Introduction to Transport Phenomena in Materials Processing, 1991.~R.B. Bird, W.E. Stewart and E.N. Lightfoot: Transport Phenomena, John Wiley International Edition, 1960~F.M. White: Fluid

**MT 240 ( AUG ) 3 : 0****Principles of Electrochemistry and Corrosion**

Introduction to electrochemical systems, including batteries, fuel cells and capacitors. Designing electrochemical systems with emphasis on thermodynamics, kinetic, and mass transport limitations. Measuring electrochemical properties with various measurement techniques. Basic electrochemical principles governing corrosion. Types and mechanisms of corrosion. Advances in corrosion engineering and control.

**Pre-requisites** : Basic knowledge in materials thermodynamics

**References** : 1. A.J. Bard and L.R. Faulkner, Electrochemical Methods: Fundamentals and Application, 2nd Edition, Wiley India 2006. ISBN:812650  
2. M.G. Fontana, Corrosion Engineering, 3rd Edition, McGraw-Hill, N.Y., 1978.

**MT 211 ( AUG ) 3 : 0****Magnetism, Magnetic Materials, and Devices**

Fundamentals: Classical and quantum mechanical pictures of magnetism; spin orbit coupling, crystal field environments, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, dipolar and exchange interactions, magnetic domains, magnetic anisotropy, magnetostriction, superparamagnetism, biomagnetism, and spin glass Bulk magnetic Materials: Transition and rare earth metals and alloys. Oxide based magnetic materials. Hard, soft and magnetostrictive materials, Magnetic shape memory alloys, Structure-microstructure-magnetic property correlations. Low dimensional Magnetic systems and devices: Magnetic nanostructures, thin films, and epitaxial heterostructures; exchange bias and exchange coupling, and magneto-optical materials and devices, AMR, GMR, TMR, spin-transfer torque, spin-orbit torque and spin-Hall effect; Multiferroics, magnetoelectric and magnetoionics; nonvolatile magnetic memory, synaptic and neuromorphic computing devices; Experimental techniques: VSM, SQUID, Mossbauer, MFM, Magneto-transport, Magneto-optical Kerr-effect, XMLD and XMCD

**Pre-requisites** : None

**References** : S. O. Kasap, Principles of Electronic Materials and Devices; Stephen Blundell, Magnetism in Condensed Matter; J.M.D. Coey, Magnetism and Magnetic Materials; B. D. Cullity and C.D. Graham, Introduction to Magnetic Materials; K. M. Krishnan, Fundamental and Application of Magnetic Material

**MT 217 ( AUG ) 3 : 0****Computational Mathematics for Materials Engineers**

Vector and tensor algebra; Basics of linear algebra and matrix inversion methods; Coordinate transformations methods; Optimization methods, Probability and statistics; Numerical methods: Concepts of discretization in space/time, implicit, explicit; Solution to ODEs(Euler, Heun, Runge-Kutta methods), PDEs (Elliptic, Parabolic, Hyperbolic), solutions to Laplace equation and applications, transient diffusion and wave equation; Discretization methods (FDM, FVM, FEM); iterative solution schemes Jacobi, Gauss-Seidel, ADI, Multigrid, Fourier-spectral schemes; Root finding methods, interpolation, curve-fitting, regression; Special functions: Bessel, Legendre, Fourier, Laguerre, etc;

Computational tools for the solution to all the above problems will be discussed along with canonical examples from materials problems. Software tools, based on python and/or MATLAB, will also be introduced in the course.

Instructor: A N Choudhury and S. Gautam G

**Pre-requisites** : None

**References** : Books: Advanced Engineering Mathematics; Erwin Kreyzig  
Mathematical Numerical methods for Engineers(Steven C. Chapra (V. and Paymond P. Balakrishnan) Canale)

**MT 309 ( JAN ) 3 : 0****Introduction to Manufacturing Science**

- Introduction to casting processes: Mechanism of solidification, Gravity die casting; Pressure assisted casting processes: Pressure die casting, Squeeze casting etc.; Compcasting; Semi-solid casting processes: Rheocasting, Thixocasting, Rheo and Thixo-moulding etc.; Centrifugal casting; Vacuum assisted casting. (6 hrs)
- Introduction to metal forming processes: Mechanics of metal working, friction, temperature and strain rate effects, processing maps. Forging, Rolling, Extrusion, Wire and tube drawing, Hot and Cold Working, Rolls and Roll Pass Design, Extrusion Processes, Extrusion Defects, Experimental methods to assess formability of sheet materials, Defects in sheet metal forming. (18 hrs)
- Introduction to Welding processes: Insight of weld metallurgy; Weld mechanics, Filler and base material interaction; Quality control of weld; Weld & HAZ microstructure; Effects of process parameters on weld quality in welding processes.

**Prosenjit Das**

**Pre-requisites :** None

**References :** Rao, P.N., Manufacturing Technology Volume 1 (Foundry, Forming and Welding), McGraw Hill Education (India) Pvt. Ltd.  
 Rao, P.N., Manufacturing Technology Volume 2 (Metal Cutting and Machine Tools), McGraw Hill Education (India) Pvt. Ltd.  
 Ghosh, A., Malik, A.K., Manufacturing Science, East-West Press Pvt. Ltd.

**MT 307 ( JAN ) 3 : 0****Materials in Extreme environments**

Overview of engineering systems under extreme environment

Background review: Materials response under low and high temperature: Microstructure and atomic structure, defects, Materials response under quasistatic loadings (tensile, fracture and fatigue), strengthening mechanisms, Effect of temperature on microstructure and properties, Creep, high-temperature fatigue

Materials response under mechanical extremes: Loading states, Elastic waves in solids, Shock loading, Distance-time diagrams, Static high-pressure devices, Platforms for loading at intermediate strain rates, Platforms for shock and quasi-isentropic loading, Shock compression of FCC, BCC and HCP metals, Amorphous metals, Phase transformations, Plasticity in compression, Ramp loading, Release, Spallation and Failure, Adiabatic shear, Response of Ceramics

Materials response under Irradiation: Irradiation basics, Irradiation-Processes Leading to Extreme Situations, Irradiation Using Different Incident Beams, Defect Dynamics in Materials Under Irradiation, Irradiation-Enhanced Diffusion, Irradiation-Induced Segregation, Radiation-Induced/Enhanced Phase Transformation, Influence of Radiation-induced Microstructure on Mechanical Properties

Materials in Hostile corrosive environment: Introduction, Corrosion by Liquid Sodium, Materials for the Hostile Corrosive Environments in Steam Water Environments, Materials in Seawater Environment

**Ankur Chauhan**

**Pre-requisites :** None

**References :** George Dieter, Mechanical Metallurgy; Neil Bourne, Materials response under mechanical extreme; Gary was, Fundamentals of Radiation Materials Science



**MT 205 ( JAN ) 3 : 0****Structural characterization of Materials**

(A) Diffraction  
Fourier transforms, Reciprocal lattice, Ewald construction, Kinematical and dynamical theory of diffraction, Howie-Whelan relations, , neutron and electron diffraction, Kikuchi patterns, X-Ray Diffraction (XRD), Basics of x-rays, generation, Experimental methods in x-ray diffraction (Laue, Oscillation/rotation, powder diffraction) and applications

(B) Imaging  
Interaction volume, Concepts of resolution, magnification and depth of field, Electron optics, Lenses and lens aberrations

1. Light Microscopy (LM)  
Working principle of an optical microscope, Modes of contrast, applications

2. Scanning electron microscopy (SEM)  
Working principle of an SEM, Imaging modes, Electron Back Scattered Diffraction, applications

3. Transmission electron microscopy (TEM)  
Working principle of a TEM, Modes of operation, Imaging using diffraction contrast, phase contrast and Z-contrast, applications

4. Scanning probe microscopy (SPM)  
Different types of SPMs, Working principle of an Atomic Force Microscope (AFM), Modes of operation, Applications

(C) Spectroscopy:  
XPS, Raman, FTIR (working principle) and their applications.

(D) Field Ion Microscopy (FIM) and 3D-atomprobe tomography (3DAPT)  
Working principle of FIM and 3DAPT and their applications.

**Rajeev Ranjan , Surendra Kumar Makineni**

**Pre-requisites :** None

**References :** 1. C Barry Carter and David Williams, Transmission Electron Microscopy  
2. James Howe, Transmission Electron Microscopy and Diffraction of Materials  
3. Baptiste Gault, Atom Probe Microscopy

**MT 204 ( AUG ) 3 : 0****Structure and Properties of Materials**

Bonding and crystal structures Bonding in solids, Cohesive energy for ionic and van der Waals solids, simple crystal structures of compounds, metals and alloys. Geometrical crystallography Crystal symmetry and Bravais Lattices, Stereographic projection, Point groups, Space groups, Description of crystal structures with space group. Tensor properties of crystals, Neumann's principle and related concepts. Heckmann diagram and multifunctionality, Thermodynamics of equilibrium properties of crystals. Point Defects Types of point defects, Equilibrium point defect concentration, Defect chemistry, Effects on diffusion, ionic conductivity, electronic and optical properties Line Defects Continuum and atomistic models, stress fields and energy of dislocations, forces on dislocations, dislocation motion and slip, dislocations in FCC, BCC and HCP metals, Effects on mechanical properties and phase transformations Planar Defects Types of interfaces: heterophase interfaces (S-V, S-L, S S) and homophase interfaces (grain boundaries and stacking faults), Interface thermodynamics and Gibbs-Thompson effect, Anisotropy of interface energy, Effect of interfaces on properties including mechanical behavior, phase transformations, magnetic, optical, etc.

**Pre-requisites :** This is a foundational course which aims to introduce basics of crystallography, defects and properties. It is meant for Masters, UG (4th Sem) and PhD students.

**References :** • Structure of Materials, M. D. Graef and M. E. Henry, Cambridge 2007 • Fundamentals of Ceramics, M. W. Barsoum, IOP publishing Ltd. 2003 • Physical Properties of Crystals, J. F. Nye, Oxford University Press, 2006 • Richard J D Tilley, Defects in Solids, Wiley 2008 • P.G.Shewmon: Diffusion in Solids, 2nd ed., TMS, 1989 • D. Hull and D. J.Bacon: Introduction to dislocations, 4th ed.,

**MT 273 ( AUG ) 3 : 0****Semiconductor Films: Deposition and Spectroscopic Characterization**

MT 273 (AUG) 3:0 Semiconductor Films: Deposition and Spectroscopic Characterization This course focuses on the imparting fundamental understanding of the working principles of advanced high vacuum deposition techniques used for the fabrication of semiconductor thin films and devices. The necessary theoretical background, important mechanisms associated with growth of films, and the working principles of various optical spectroscopic techniques will be covered. Semiconductor fundamentals: Common semiconducting materials and their crystal structures; Intrinsic and extrinsic point defects in semiconductors; Electronic band structure; Defect states and their influence on semiconducting properties. Thin film growth processes: Nucleation and growth mechanisms; uncorrelated or random deposition; surface diffusion-controlled growth; ballistic deposition; shadowing effects, etc. Thin film deposition techniques: Hot-wire chemical vapor deposition (HW CVD); plasma-enhanced chemical vapor deposition (PE-CVD); atomic layer deposition (ALD); pulse laser deposition (PLD); RF sputtering, physical vapor deposition (PVD); DC sputtering; Molecular Beam Epitaxy (MBE); thermal evaporation; etc. Spectroscopic characterization of semiconductors: Ultraviolet-visible- near infrared spectroscopy (UV-Vis-NIR); photoluminescence spectroscopy (PL); time-resolved photoluminescence spectroscopy (TRPL); transient spectroscopy (TAS); etc. Hands-on laboratory sessions: Hands-on laboratory sessions and practical demonstrations will be conducted for a few high vacuum deposition techniques and spectroscopic measurements for a few semiconductors' thin films

**Pre-requisites** : None

**References** : References 1. Thin Film Deposition: Principles and Practice by Donald L. Smith 2. Spectroscopic Methods in Organic Chemistry by Dudley H. Williams and Ian Fleming 3. Principles of Instrumental Analysis by Douglas A. Skoog, F. James Holler, and Stanley R. Crouch 4. Introduction to Spectroscopy by Donald L. Pavia, Gary M. Lampman, George S. Kriz, and James R. Vyvyan 5. Handbook of

**MT 303 ( JAN ) 2 : 1****Materials Informatics**

The course will be structured into three modules, with learnings from one module transferred into others. Each module will have lecture sessions followed by hands-on/tutorial sessions where students have to learn new tools and execute them, via jupyter-notebooks (or similar) frameworks. Module 1 will focus on basic aspects of computations and machine learning. Module 2 will work on statistical mechanics, lattice models, and coarse graining techniques commonly used. Module 3 will describe the construction and validation of machine-learned interatomic potentials, and other advanced machine learning topics relevant for materials science.

**Sai Gautam Gopalakrishnan**

**Pre-requisites** : Students should have preferably taken the "MT 202: Thermodynamics and Kinetics of Materials" and "MT 217: Computational Mathematics for Materials Engineers" courses. Students should preferably have a laptop where they can install necessary libraries/codes and execute them.

**References** : There are no text books for this course. Suggested are some books for additional reading.

- "Computational Materials Science", June Gunn Lee, Second Edition 2016
- "Understanding molecular simulation: from algorithms to applications", Daan Frenkel and Berend Smit, Second Edition, 2002

# Mechanical Engineering

## Preface

### ME 201 ( AUG ) 3 : 0

#### Fluid Mechanics

Fluid as a continuum, mechanics of viscosity, momentum and energy theorems and their applications, compressible flows, kinematics, vorticity, Kelvin's and Helmholtz's theorems, Euler's equation and integration, potential flows, Kutta-Joukowski theorem, Navier-Stokes equations, boundary layer concept, introduction to turbulence, pipe flows.

**Pre-requisites :** None

**References :** None

### ME 225 ( AUG ) 1 : 0

#### Introduction to Soft Matter

Introductory course on soft matter/complex fluids. A review of preliminaries of continuum mechanics, which are required for dealing with soft matter. General concepts of viscous and elastic deformations and relevant models. Experimental approaches to soft materials such as creep response and stress relaxation.

**Pre-requisites :** None

**References :** Bird, R.B., Armstrong, R.C., Hassager, O., Dynamics of Polymeric Fluids, John Wiley and Sons~Joseph, D.D, Fluid Dynamics of Viscoelastic Liquids, Spinger-Verlag, 1990~Gurtin, M.E., Fried, E., Anand, L. The Mechanics and Thermodynamics of Continua, Cambridge University Press 2011~R.C.~Hassager

### ME 228 ( JAN ) 3 : 0

#### Materials and Structure Property Correlations

This course introduces incoming students to the basic ideas of modern materials science, beginning from the smallest scale of electrons all the way to materials selection for mechanical design. We will build on preliminary undergraduate level understanding of materials structure and their implications. We will first undertake basic considerations of atomic bonding and discuss coherent structures that can form as a result. This will be followed by a review of materials thermodynamics, phases and transformations and their consequences for material structure. We will then attempt to understand how material structure can affect, and is in turn altered by, external mechanical loading. Finally, the lessons we've learnt by looking at structure will be summarized in the form of selection maps that are of value to engineering practice.

#### Koushik Viswanathan

**Pre-requisites :** None

**References :** We will not follow a single textbook, but periodic lecture notes and reading material will be provided. Some texts that can serve as reference are: 1) LH van Vlack, Elements of Materials Science and Engineering 2) C Kittel, Introduction to Solid State Physics 3) DR Gaskell, Introduction to the Thermodynamics of Materials 4) WD Callister, Fundamentals of Materials Science and Engineering

**ME 240 ( JAN ) 3 : 0****Dynamics and Control of Mechanical Systems**

Representation of translation and rotation of rigid bodies, degrees of freedom and generalized coordinates, motion of a rigid body and multi-body systems, Lagrangian and equations of motion, small vibrations, computer generation and solution of equations of motion, review of feedback control, PID control, root locus, Bode diagrams, state space method, control system design and computer simulation.

**Jayanth G R , Jishnu Keshavan**

**Pre-requisites** : None

**References**

Greenwood, D.T., Principles of Dynamics, Second Edn., Prentice Hall

**ME 242 ( AUG ) 3 : 0****Solid Mechanics**

Analysis of stress, analysis of strain, stress-strain relations, two-dimensional elasticity problems, airy stress functions in rectangular and polar coordinates, axisymmetric problems, energy methods, St. Venant torsion, elastic wave propagation, elastic instability and thermal stresses.

**Pre-requisites** : None

**References** : None

**ME 243 ( AUG ) 3 : 0****Continuum Mechanics**

Analysis of stress, analysis of strain, stress-strain relations, two-dimensional elasticity problems, airy stress functions in rectangular and polar coordinates, axisymmetric problems, energy methods, St. Venant torsion, elastic wave propagation, elastic instability and thermal stresses.

Introduction to vectors and tensors, finite strain and deformation-Eulerian and Lagrangian formulations, relative deformation gradient, rate of deformation and spin tensors, compatibility conditions, Cauchy's stress principle, stress tensor, conservation laws for mass, linear and angular momentum, and energy. Entropy and the second law, constitutive laws for solids and fluids, principle of material frame indifference, discussion of isotropy, linearized elasticity, fluid mechanics.

**Pre-requisites :** None

**References**

Malvern, L.E., Introduction to the Mechanics of a continuous medium, Prentice Hall, 1969. Gurtin

**ME 246 ( AUG ) 3 : 0****Introduction to Robotics**

Robot manipulators: representation of translation, rotation, links and joints, direct and inverse kinematics and workspace of serial and parallel manipulators, dynamic equations of motion, position and force control and simulation.

**Pre-requisites :** None

**References :** Ghosal, A., Robotics: Fundamental Concepts and Analysis, Oxford University Press, 2006, Notes and recent research papers.

**ME 251 ( JAN ) 3 : 0****Biomechanics**

Bone and cartilage, joint contact analysis, structure and composition of biological tissues. Continuum mechanics, constitutive equations, nonlinear elasticity, rubber elasticity, arterial mechanics. Introduction to cell mechanics.

**Namrata Gundiah**

**Pre-requisites** : None

**References** :

Humphrey, J.D., Cardiovascular Solid Mechanics, Springer-Verlag,

**ME 255 ( AUG ) 3 : 0****Principles of Tribology**

Surfaces, theories of friction and wear, friction and wear considerations in design, viscosity, hydrodynamic lubrication, Reynolds equation, coupling of elastic and thermal equations with Reynolds equation. Elasto-hydrodynamic lubrication. Mechanics of rolling motion, hydrostatic lubrication, lubricants, tribometry, selection of tribological solutions.

**Pre-requisites** : None

**References** : None

**ME 257 ( JAN ) 3 : 0****Finite Element Methods**

Linear finite elements procedures in solid mechanics, convergence, isoparametric mapping and numerical integration. Application of finite element method to Poisson equation, calculus of variations, weighted residual methods, introduction of constraint equations by Lagrange multipliers and penalty method, solution of linear algebraic equations, finite element programming.

**Chandrashekhar S Jog**

**Pre-requisites** : None

**References** : Cook, R.D., Malkus, D.S., and Plesha, M.E., Concepts and Applications of Finite Element Analysis, Third Edn, John Wiley, 1989., Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1982.

**ME 260 ( AUG ) 3 : 0****Topology Optimization**

A quick overview of finite-variable optimization and calculus of variations. Analytical size optimization of bars and beams for stiffness, flexibility, strength, and stability criteria in the framework of variational calculus. Gradient-based computational optimization of trusses, frames, and continuum structures. Sensitivity analysis for parameter, shape, and topology variables. Shape optimization. Topology optimization. Design parameterization for topology optimization of coupled structural problems involving thermal, electro-thermal, electrostatic, fluid, and other multiphysics domains.

**Pre-requisites** : None

**References**

NPTEL MOOC: <https://nptel.ac.in/courses/112/108/112108201/~Haftka>, R. T. and Gurdal, Z., "Elements of Structural Optimization," Kluwer Academic

**ME 261 ( AUG ) 3 : 0****Engineering Mathematics**

Vector and tensor algebra: Sets, groups, rings and fields, vector spaces, basis, inner products, linear transformations, spectral decomposition, tensor algebra, similarity transformations, singular value decomposition, QR and LU decomposition of matrices, vector and tensor calculus, system of linear equations (Krylov solvers, Gauss-Seidel), curvilinear coordinate transformations. Ordinary and partial differential equations: Characterization of ODEs and PDEs, methods of solution, general solutions of linear ODEs, special ODEs, Euler-Cauchy, Bessel's and Legendre's equations, Sturm-Liouville theory, critical points and their stability. Complex analysis: Analytic functions, Cauchy-Riemann conditions and conformal mapping. Special series and transforms: Laplace and Fourier transforms, Fourier series, FFT algorithms, wavelet transforms.

**Pre-requisites** : None

**References** : None

**ME 271 ( JAN ) 3 : 0****Thermodynamics**

Concepts of thermodynamics, zeroth law, first law, properties of pure substances and mixtures, first order phase transitions, thermophysical properties, energy storage; second law; energy analysis of process and cycle; calculation of entropy and entropy diagrams; availability analysis, chemical equilibrium, non-equilibrium thermodynamics, multi-phase-multi component systems, transport properties; third law

**Ravikrishna R V , Susmita Dash**

**Pre-requisites** : None

**References** : None

**ME 273 ( JAN ) 3 : 0****Solid and Fluid Phenomena at Small Scales**

Intermolecular forces, surfaces, defects. Size-dependent strength, micro - mechanics of interfaces and thin films. Solvation forces, double layer forces, effect of physico-chemical forces on fluid flow at micron-scales. Slip boundary condition, friction and nano tribology. Nanoindentation, atomic force microscopy, micro-PIV and other characterizing techniques. MEMS, micro fluidics, microscopic heat pipes and other applications.

**Raghuraman N Govardhan , Bobji M S**

**Pre-requisites** : None

**References** : Israelachvili, J.N., Intermolecular and Surface Forces, Elsevier Publishing Company, 2003.

**ME 274 ( AUG ) 3 : 0****Convective Heat Transfer**

Energy equation, laminar external convection, similarity solution, integral method, laminar internal convection, concept of full development heat transfer in developing flow, turbulent forced convection, free convection from vertical surface, Rayleigh-Benard convection.

**Pre-requisites** : None

**References** : None



**ME 283 ( AUG ) 3 : 0****Two Phase Flows and Boiling Heat Transfer**

Characterization of two phase flow patterns (bubbly, slug, annular, mist, stratified, etc), homogeneous and heterogeneous flow models, suspension of particles in fluids, particulate fluidization, Bubble dynamics, Rayleigh-Plesset Equation, Boiling and Condensation Heat Transfer, Homogeneous and heterogeneous nucleation, Hydrodynamic stability of stratified fluids, molecular theory of surface tension, contact line dynamics, dewetting pathways.

**Pre-requisites :** None

**References :** None

**ME 285 ( AUG ) 3 : 0****Turbomachine Theory**

Introduction to turbo-machines, mixing losses, review of vorticity, profile changes in contracting and expanding ducts. Brief review of diffusers, rotating co-ordinate system, total enthalpy, rothalpy, Euler turbine equation, velocity triangles. Specific speed and Cordier diagram, cascade aerodynamics. Elemental compressor stage, reaction work and flow coefficients. Equations of motion in axisymmetric flow, simple and extended radial equilibrium. Elemental axial turbine stage, radial and mixed flow machines, work done by Coriolis forces and by aerofoil action, the centrifugal compressor, vaned and vaneless diffusers.

**Pre-requisites :** None

**References**

Sabersky, R.H., and Acosta, A., Fluid Flow: A First Course in Fluid Mechanics

**ME 289 ( AUG ) 3 : 0****Principles of Solar Thermal Engineering**

Introduction, solar radiation – fundamentals, fluid mechanics and heat transfer, methods of collection and thermal conversion, solar thermal energy storage, solar heating systems, solar refrigeration, solar thermal elective conversion. Other applications.

**Pre-requisites :** None

**References :** Kreith, F., and Kreider, J.F., Principles of Solar Thermal Engineering

**ME 297 ( AUG ) 1 : 0****Departmental Seminar**

The student is expected to attend and actively take part in ME departmental seminars for one semester during his/her stay.

**Pre-requisites** : None

**References** : None

**ME 299 ( JAN ) 0 : 27****Dissertation Project**

The M. E. Project is aimed at training students to analyse independently any problem posed to them. The project may be a purely analytical piece of work, a completely experimental one, or a combination of both. In a few cases, the project may also involve sophisticated design work. The project report is expected to show clarity of thought and expression critical appreciation of the existing literature and analytical and/or experimental or design skill.

**Gaurav Tomar**

**Pre-requisites** : None

**References** : None

**ME 303 ( JAN ) 3 : 0****Partial Differential Equations with Applications**

Fundamentals of vibration, vibrations of continuous systems (strings and rods), 1-D acoustic wave equation, sound waves in ducts, standing waves and travelling waves, resonances, complex notation, harmonic solutions, concept of impedance. Kirchoff-Helmholtz Integral Equation, spherical coordinates, spherical harmonics, Green function (Dirichlet and Neumann), Sommerfeld radiation condition, sound radiation from simple sources, piston in a baffle, pulsating sphere, piston in a sphere, vibrating free disc, scattering from a rigid sphere. Near field and far field, directivity of sources, wave guides (phase speed and group speed), lumped parameter modeling of acoustic systems, sound in enclosures (rectangular box and cylinders), Laplace Transforms and PDEs, 1-D Green Function, octave bands, sound power, decibels. Brief introduction to diffraction, scattering, reflection, refraction. Shell coordinates, infinitesimal distances in curved shells, equations of motion for general shell structure.

**Gaurav Tomar , Koushik Viswanathan**

**Pre-requisites** : None

**References** : Introduction to Partial Differential Equations with Applications by Zachmanoglou and Thoe; An Introduction to Partial Differential Equations by Renardy and Rogers; Applied Partial Differential Equations by R. Haberman; Elements of Partial Differential Equations by Ian N. Sneddon; Introduction to Partial Differential Equations by L.C. Evans

**ME 254 ( JAN ) 3 : 0****Compliant Mechanisms**

Systematics and mobility analysis of compliant mechanism. Discrete and distribute compliance. Methods of elastostatic and elastodynamic analysis including multi-axial stiffness, pseudo-rigid-body, and spring- mass-lever models. Non-dimensional analysis of compliant topologies. Energetics including mechanical advantage and efficiency; static and dynamic balancing; and bistability and multistability. Synthesis and design methods including rigid-body replacement, topology optimization, building blocks, constraint theory, and selection maps. Applications in automotive, aerospace, biomedical, consumer products, and microelectromechanical systems.

**Ananthasuresh G K**

**Pre-requisites :** None

**References :** NPTEL MOOC: [https://nptel.ac.in/courses/112/108/112108211/~Instructor's notes. ~L. L. Howell, Compliant Mechanisms, Wiley, 2001](https://nptel.ac.in/courses/112/108/112108211/~Instructor's%20notes.%20~L.%20L.%20Howell,%20Compliant%20Mechanisms,%20Wiley,%202001)

**ME 260 ( AUG ) 3 : 0****Structural Optimization: Size, Shape, and Topology**

A quick overview of finite-variable optimization and calculus of variations. Analytical size optimization of bars and beams for stiffness, flexibility, strength, and stability criteria in the framework of variational calculus. Gradient-based computational optimization of trusses, frames, and continuum structures. Sensitivity analysis for parameter, shape, and topology variables. Shape optimization. Topology optimization. Design parameterization for topology optimization of coupled structural problems involving thermal, electro-thermal, electrostatic, fluid, and other multiphysics domains.

**Pre-requisites :** None

**References**

NPTEL MOOC: [https://nptel.ac.in/courses/112/108/112108201/~Haftka, R. T. Gurdal, Z., "Elements of Structural Optimization," Kluwer Academic](https://nptel.ac.in/courses/112/108/112108201/~Haftka,%20R.%20T.%20Gurdal,%20Z.,%20\)

**ME 280 ( AUG ) 3 : 0****Fundamentals of nanoscale conduction heat transport**

General introduction to the basic rules of quantum mechanics; crystal lattice definitions; reciprocal lattice; harmonic and anharmonic potential energy of the crystal; phonons as normal modes/eigenmodes of the crystal lattice vibrations; harmonic properties of the phonons - wavelength, wavevector, dispersions, group velocities and heat capacity; Einstein and Debye models; anharmonic phonon-phonon interactions; Fermi's golden rule and applications to phonons; anharmonic properties of phonons - phonon scattering rates, phonon lifetimes and phonon mean free paths; properties of the phonon-phonon collision matrix; momentum- conserving and momentum-dissipating scattering processes; Boltzmann equation for phonon transport; thermal conductivity; diffusive and non- diffusive heat transport.

**Pre-requisites :** None

**References :** Electrons and Phonons: The Theory of Transport Phenomena in Solids, by J. M. Ziman, Oxford University Press.~Nanoscale Energy Transport and Conversion: A Parallel Treatment of Electrons, Molecules, Phonons, and Photons, by Gang Chen, Oxford University Press.

**ME 281 ( JAN ) 3 : 0****Thermodynamics of crystalline solids**

A brief introduction to classical and quantum mechanics, operators, bra- ket notation, the crystal potential and lattice dynamics, harmonic phonons, second quantization, renormalized and self-consistent phonon theory, anharmonic perturbation expansion - free energy, phonon frequency shift and width, pressure-volume and stress-strain variables, volume correction and wave propagation, band structure theory, adiabatic approximation, electron-phonon interaction and pseudopotential perturbation theory.

**Navaneetha Krishnan Ravichandran**

**Pre-requisites :** None

**References :** "Thermodynamics of Crystals" by Duane C. Wallace

**ME 223 ( JAN ) 3 : 0****Nonlinear Dynamics of Physical Systems**

Introduction to nonlinear physical, biological, and chemical systems.

Low-dimensional systems: Continuous and discrete dynamical systems, primary solutions, linear stability analysis, bifurcation theory, numerical solutions to nonlinear equations (integration, root finding methods, pseudo-arclength continuation, multi-stability), phase-space description, oscillatory solutions, Poincare/first-return map, Floquet exponents and their numerical estimation

Chaos: Lorenz equation and its historical origins, chaos and its characterization (leading Lyapunov exponent, fractal dimension), routes to chaos, strange attractors, universality in chaos

Spatially extended nonlinear systems: Pattern forming systems, linear stability analysis, instabilities of a uniform state, 1D models for pattern forming systems (Swift–Hohenberg, reaction diffusion, Kuramoto-Sivashinsky models), nonlinear saturation, amplitude equations

**Balachandra Suri****Pre-requisites** :

Basics of linear algebra and programming experience (MATLAB/python)

**References** : Steven H. Strogatz: Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering

Michael Cross and Henry Greenside: Pattern Formation and Dynamics in Nonequilibrium Systems

**ME 278 ( AUG ) 3 : 0****A practical introduction to data analysis**

- Matrix computations and visualization using python, matrix manipulations, solutions of linear equations - LU/QR/SVD/Krylov methods
- Introduction to machine learning - getting started with TensorFlow/PyTorch
- Supervised learning - Regressions, classifications, overfitting and generalization
- Unsupervised learning - Clustering, dimensionality reduction, Self-supervised learning
- Introduction to optimization problems - gradient descent, matrix-free methods like CG - getting started with `scipy.optimize` and `scipy.sparse.linalg` modules
  - Constrained and unconstrained optimization problems - Lagrange multipliers, linear programming, quadratic programming,
  - Convex sets, functions and types of convex optimization problems - getting started with `CVX_OPT/ CVX_PY`
  - Discrete and continuous random variables. Bayes' rule, Gibbs sampling, Bayesian inference - getting started with `pymc`

**Pre-requisites** : None

**References** : 1. Probabilistic Machine Learning: An introduction, Kevin P Murphy, The MIT Press [<https://probml.github.io/pml-book/book1.html>]  
2. Linear Algebra and Learning from Data, Gilbert Strang [<https://math.mit.edu/~gs/learningfromdata/>]

**ME 204 ( JAN ) 3 : 0**

**Mechanics of the Elastica**

The proposed course is a graduate-level elective emphasizing the interplay between geometry and elasticity. It adopts the one-dimensional Elastica model as a prototype to reveal the intricacies of geometric nonlinearity. The course will expose students to modern and exciting new structural mechanics applications, without compromising on a hands-on problem-solving experience.

The subject and applications covered in the elective complement existing courses on solid, continuum, and structural mechanics in the Mechanical Sciences division. The material covered and assessment procedure will particularly benefit students engaged in research and projects related to elastic buckling, shape optimization, structural design, etc.

Module 1: Linearized beam theories  
 A relook at Euler-Bernoulli & Timoshenko beam theories  
 - Kinematic assumptions  
 - Constitutive assumptions  
 - Underlying variational principles and energy minimization  
 - Interpretation of moments and shear forces  
 - Comparisons with linear elasticity solutions  
 - Influence of slenderness ratios  
 Ref: Chapter 4 of [SD]

Module 2: Geometry of curves  
 Self-contained, with emphasis on developing intuition  
 - Parametric curves and arc length parameterization  
 - Tangents, normal and curvature  
 - Fundamental theorem of plane curves and its relation to beam theory  
 Ref: Chapter 1 of [dC]

Module 3: The Elastica model  
 Sources of geometric nonlinearity and contrast with classical models  
 - Kinematics of the centerline solution  
 - Parameterization of the equilibrium equations  
 - Elliptic integral solutions and related special functions  
 - Phase portraits and the Kirchhoff analogy with the pendulum  
 Ref: Chap 1 of [FF]

Module 4: Special and graphical problems  
 Amenable to closed-form solutions and point loads  
 - Transverse Follower buckling, and post-buckled loads  
 - Axial loading, Distributed edge supports  
 - Knife Elastic farthest-reach foundations  
 - Designing the the tallest problem  
 - The Circular elastic catapult arches  
 Ref: Chap 2-5 of [FF]

Module 5: Stability and Energy minimization  
 Self-contained introduction, starting from multi-dof systems  
 - Directional derivatives, first and second variations  
 - Bifurcations points, stable and unstable branches  
 - Stability of Elastica solutions  
 - Vainberg's theorem on energy functionals  
 Ref: Chap 9-10 of [KD]

Module 6: Numerical continuation  
 Self-contained introduction to computing post buckled solutions  
 - Newton's method for nonlinear systems  
 - Path following with Rik's method  
 - Modal perturbations

# Dept. of Design and Manufacturing

## Preface

### MN 201 ( AUG ) 3 : 0

#### Materials and Processes

Engineering materials: crystal structure and bonding, elastic and plastic deformation, strengthening, fatigue, fracture, creep, wear Design considerations: bending, compression, tension, shapes and sections, multiple constraints, ecological and sustainability Processes: Broad classification of processes - casting, forming, cutting and joining – with simple analyses.

**Pre-requisites** : None

**References** : Materials Selection in Mechanical Design, 4th edition, M.F.Ashby, Elsevier (2011) Introduction to Manufacturing Processes, J. A.Schey, McGraw-Hill, NY (1987) CES EduPack software package for materials design and selection (2019)

### MN 202 ( AUG ) 3 : 0

#### Digital Manufacturing

Product modelling, Process Modelling, Intelligent machines, Autonomous devices in manufacturing, Interoperability of digital models in manufacturing, computer aided inspection and verification, Digital Thread and applications of digital models in maintenance and operations

**Pre-requisites** : None

**References** : None

### MN 203 ( JAN ) 3 : 0

#### Design for Additive Manufacturing

Geometry processing pipeline in AM, considerations of shape representation – smooth vs. discrete; material choices in the design for additive manufacturing; material representation for AM Process planning; manufacturability constraints – design to minimize supports; Adapting extant designs for AM; Design Principles - Unitisation of structures; Basics of finite element analysis in the context of structural design for additive manufacturing; overview of size, shape, and topology optimization methods for structures; sensitivity analysis; lattice structures; hierarchy and economy; Standards

**Gurumoorthy B , Ananthasuresh G K**

**Pre-requisites** : None

**References** : None

**MN 205 ( AUG ) 1 : 2****Makers' Project**

Each maker's project will be offered to be carried out in groups of 4-5 students. The course will involve two components: a common primer on metrology of mechanical, electrical, optical, contact and non-contact measurements (about 4 weeks, to be taught by appropriate faculty from the programme), followed by carrying out a single project by each group (8 weeks). The project will be allotted from a list of 'assemble- program-characterize' projects to be shared with students each year.

**Pre-requisites** : None

**References** : None

**PD 201 ( AUG ) 2 : 1****Elements of Design**

Visual language, visual elements, visual perception, visual deception. Universal principles of design. Theory of colour, studies in form, graphic compositions, grid structure, spatial analysis and organization. Visual expressions in nature.

**Pre-requisites** : None

**References** : Young, F.M., Visual Studies, Prentice-Hall, USA., Lidwell, W., Holden, K., and Butler, J., Universal Principles of Design, Rockport, USA., Evans, P., and Thomas, M., Exploring the Elements of Design, Thomson, USA.

**PD 202 ( AUG ) 2 : 1****Elements of Solid and Fluid Mechanics**

Analysis of stress and strain, failure criteria, dynamics and vibrations. Control of engineering systems, elements of fluid mechanics drag and losses, thermal analysis, problems in structural and thermal design.

**Pre-requisites** : None

**References** : Shigley, J.E., Mechanical Engineering Design, McGraw Hill., White, F.M., Fluid Mechanics, Tata McGraw Hill., Gupta, V., Elements and Heat and Mass Transfer, Sage Publishers.



**PD 203 ( AUG ) 2 : 1****Creative Engineering Design**

Design: definitions, history and modern practice. Design and society, design and the product life cycle. Methodology for problem solving in engineering design: recognition, definition, analysis, synthesis, communication and presentation. Hands-on projects.

**Pre-requisites** : None

**References** : Jones, J.C., Design Methods, John Wiley, 1981.,Cross, N., Engineering Design Methods, John Wiley, 1994.,Pahl, G., and Beitz, W., Engineering Design, Design Council, 1984.,Brezet and van Hammel, ECODESIGN – A promising approach to sustainable production and consumption, UNEP Manual

**PD 205 ( JAN ) 2 : 1****Materials, Manufacturing and Design**

Material usage and sustainability issues, concept or closed and open loop.Engineering materials, metals and their properties, uses, processing methods,design data and applications, material selection criteria, manufacturing and processing of materials. Plastics and composites, types, classification,properties, processing techniques and limitations, basics of reliability,failure and failure analysis.

**Anindya Deb**

**Pre-requisites** : None

**References** : Dieter, G.E., Engineering Design – A Materials and processing approach, McGraw Hill, 1991.,Ashby, M.F., Materials selection in Mechanical Design, Pergamon press, 1992.,Patton, W.J., Plastics Technology, Theory, Design and Manufacture, Lenton Publishing Co.

**PD 207 ( AUG ) 1 : 2****Product Visualization, Communication and Presentation**

Object drawing fundamentals, theory of perspectives, exploded views, sectional views. Fundamentals of lighting, idea representation and communication methods and pitfalls. Materials, tools and techniques of representation in various media like pencil, ink, colour etc. Rendering techniques, air brush illustration. Idea documentation. Fundamentals of photography, video-graphy and digital media. Dark room techniques. Studio assignments in all the above topics. Mock-up modeling and simulation in various materials.

**Pre-requisites** : None

**References** : Geometry of design: Studies in proportion and composition, ISBN: 1568982496,Foundation of Art & Design 1856693759,Earle,J.E.,Engineering Design Graphics, Addison Wesley, ISBN 020111318x

**PD 209 ( JAN ) 2 : 1****New Product Development: Concepts and Tools**

Technology-based products, business context, front-end of innovation, opportunity identification, target markets, integrated teams, product features, differentiation from competition, business cases, product architecture, designing and prototyping products, planning for manufacturing capabilities, marketing and sales programs

**Gurumoorthy B**

**Pre-requisites** : None

**References** : (1) Ulrich, K.T., and Eppinger, S.D., Product Design and Development, 2nd edition, (2) Philip Kotler, Kevin Lane Keller, Marketing Management, 15th edition, (3) Douglas Smith and Jon Katzenbach, The Wisdom of Teams: Creating the High-Performance Organization, 2015 edition.

**PD 211 ( JAN ) 2 : 1****Product Design**

Semiotic studies – product semantics, syntactics, and pragmatics. Study of expressions, metaphors, feelings, themes. Study of product evolution, problem identification, design methods, design process, design brief, concept generation, concept selection, design and development, product detailing, prototyping, design evaluation.

**Vishal Singh**

**Pre-requisites** : None

**References** : Papanek, V., Design for the Real World, Thames & Hudson, London., Ulrich, K.T., and Eppinger, S.D., Product Design and Development, Tata McGraw Hill, India.

**PD 217 ( AUG ) 2 : 1****CAE in Product Design**

Product development driven by concurrent engineering, role of Computer- Aided Engineering (CAE) in product design. Mathematical abstractions of products for functionality verification; lumped mass, finite element, boundary element, and statistical modeling procedures. Use of commercial finite element-based packages for design analysis and optimization.

**Pre-requisites** : None

**References** : Bathe, K.J., Finite Element Procedures, Prentice Hall, 1995., Robert Cook, Finite Element Modeling for Stress Analysis, 1995., Banerjee, P.K., Boundary Element Methods in Engineering Science, McGraw Hill.

**PD 231 ( AUG ) 2 : 1****Applied Ergonomics**

Introduction to ergonomics. Elements of anthropometry, physiology, anatomy, biomechanics and CTDs. Workspace, seating, hand tool design, manual material handling. Man-machine system interface, human information processing, displays and controls, compatibility. Environmental factors, cognitive ergonomics, principles of graphic user interface design, human error, product safety, product liability.

**Pre-requisites** : None

**References** : Sanders and McCormick, Human Factors in Engineering and Design, Seventh Edn, McGraw Hill

**PD 233 ( AUG ) 2 : 1****Design of Biomedical Devices and Systems**

Medical Device Classification, Bioethics and Privacy, Biocompatibility and Sterilization Techniques, Design of Clinical Trials, Design Control & Regulatory Requirements, Introduction to specific medical technologies: Biopotentials measurement (EMG, EOG, ECG, EEG), Medical Diagnostics (In vitro diagnostics), Medical diagnostics (Imaging), Minimally Invasive Devices, Surgical Tools and Implants, Medical Records and Telemedicine. The course will include guest lectures by healthcare professionals giving exposure to current needs in the healthcare technologies and systems.

**Pre-requisites** : None

**References** : Paul H king, Richard C. Fries, Arthur T. Johnson, Design of Biomedical Devices and Systems. Third edition, ISBN 9781466569133, Peter J. Ogorodnik, Medical Device Design: Innovation from Concept to Market, Academic Press Inc; 1st edition (2012), ISBN-10:0123919428, Stefanos Zenios, Josh Makower, Paul Yock, Todd J. Brinton, Uday N. Kumar, Lyn Denend, Thomas

**PD 236 ( JAN ) 2 : 1****Embodiment Design**

Introduction to design research, a methodology for design research and its components, types of design research, selecting criteria and its research methods, understanding factors influencing design and its research methods, developing design support and its research methods, evaluating design support and its research methods, associated exercises and tests. Embodiment methodology, basic components and interfaces, design for performance including strength, usability, maintenance and reliability, Design for manufacturing, assembly, packaging, distribution, services, cost and environmental impact. Dimensioning, tolerance and standards.

**Amaresh Chakrabarti , Abhijit Biswas**

**Pre-requisites** : None

**References** : Blessing, L.T.M., Chakrabarti, A., and Wallace, K.M., An Overview of Design Studies in Relation to a Design Research Methodology. , Frankengerger and Badke-Schaub (Eds), Designers: The Key to Successful Product Development, Springer Verlag, 1998., Current Literature including papers from Proceedings of the International Conference in Engineering Design, Prague, 1995 Pahl, G

**PD 239 ( AUG ) 0 : 3****Design and Society**

Independent study/research on a chosen topic by students under the supervision of faculty members. Presentation of seminar on work done. The course also includes invited seminars on various aspects of product design and marketing issues. The focus is on real life situations from practicing professionals.

**Pre-requisites :** None

**References :** None

**PD 299 ( JAN ) 0 : 16****Dissertation Project**

Spread over 15 months, commencing immediately after the second semester. It involves complete design and prototype fabrication with full documentation.

**Vishal Singh**

**Pre-requisites :** None

**References :** None

**PD 216 ( AUG ) 2 : 1****Design of Automotive Systems**

Classification of automotive systems, interfacing of marketing, design and manufacturing, converting customer's needs into technical targets, vehicle design process milestones with a systems engineering approach, trade-off studies, manufacturing cost and economic feasibility analysis. Design tools such as reverse engineering, rapid prototyping, CAD/CAE, Taguchi methods, and FMEA. Styling concepts and features, ergonomics, packaging and aerodynamics. Review of vehicle attributes (NVH, durability, vehicle dynamics, crash safety, etc.). Overview of automotive technology (body, power train, suspension systems, etc.).

**Pre-requisites :** None

**References :** Ulrich, K.T., and Eppinger, S.D., Product Design and Development, Second Edn, Irwin McGraw Hill, Gillespie, T.D., Fundamentals of Vehicle Dynamics, SAE Inc., Schwaller, A.E., Motor Automotive Technology, Third Edn, Delman Publishers

**PD 230 ( JAN ) 3 : 0****Haptic Systems Design****Abhijit Biswas****Pre-requisites** : None**References** : None**PD 204 ( AUG ) 2 : 1****Basics of Electronics for Product Design and Manufacturing**

Introduction to sensors and actuators, Static vs. current electricity, Passive and active components of electrical systems, Type of electrical sources, Introduction to linear and non-linear electrical components, Basic circuit theory and analysis of DC circuits, Basics of AC circuit, Basics of power distribution, domestic and industrial electrical wiring and safety, AC-AC and AD-DC conversion, Voltage regulator, Constant current source, Sensor biasing (voltage vs. current biasing) and transduction, Transistors: Type and application as amplifier and switch, Basic op-amp circuit, Introduction to digital logic, Combinational and sequential circuit, Discrete signals: Number systems and binary arithmetic, Logic gates, Flip-Flops, Sampling theory, Sampling and hold circuit, anti-aliasing filter, Digital to Analog (DAC) and Analog to Digital (ADC) Conversions, Different types of ADC and DAC with their benefits and limitations, Basics of Microprocessors and microcontrollers.

Introduction to sens

**Pre-requisites**

Students without electrical or electronics or instrumentation  
**References**  
 • Roy Choudhury, D. (1988). Networks and Systems. India:Wiley Eastern.

**PD 206 ( AUG ) 2 : 1****Basics of Computing, AI and Data Science for Design and Manufacturing**

Introduction to sensors and actuators, Static vs. current electricity, Passive and active components of electrical systems, Type of electrical sources, Introduction to linear and non-linear electrical components, Basic circuit theory and analysis of DC circuits, Basics of AC circuit, Basics of power distribution, domestic and industrial electrical wiring and safety, AC-AC and AD-DC conversion, Voltage regulator, Constant current source, Sensor biasing (voltage vs. current biasing) and transduction, Transistors: Type and application as amplifier and switch, Basic op-amp circuit, Introduction to digital logic, Combinational and sequential circuit, Discrete signals: Number systems and binary arithmetic, Logic gates, Flip-Flops, Sampling theory, Sampling and hold circuit, anti-aliasing filter, Digital to Analog (DAC) and Analog to Digital (ADC) Conversions, Different types of ADC and DAC with their benefits and limitations, Basics of Microprocessors and microcontrollers.

**Pre-requisites**

Students without computer science or data science or

**References**

• Roy Choudhury, D. (1988). Networks and Systems. India: Wiley Eastern.

**MN 207 ( AUG ) 2 : 1****Intelligent Mobile Robots: Perception, Action and Control**

Introduction to Mobile Robotics Locomotion Principles Kinematic Modelling Perception Control System Design Localization Motion Planning Multi-robot systems ROS and Matlab for Robotics Autonomy in Mobile Robot

**Pre-requisites**

**References** : • H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion: Theory, Algorithms and Implementations, PHI Ltd., 2005. • R. Siegwart, I. R. Nourbakhsh, Introduction to Autonomous Mobile Robots, MIT Press, 2011 • G. Dudek and M. Jenkin, Computational Principles of Mobile Robotics, Cambridge University Press, 2010 • H. Asama, T.

**MN 299 ( JAN ) 0 : 24****Dissertation Project**

Each project will be offered to be carried out in groups of 2-3 students. The project will involve an indepth development or in-depth study in an area in smart manufacturing

**Vishal Singh**

**Pre-requisites** : None

**References** : -

**PD 298 ( JAN ) 0 : 22****Dissertation Project**

Spread over 15 months, commencing immediately after the second semester. It involves complete design, prototype fabrication, demonstration of requirement satisfaction along with full documentation.

**Vishal Singh**

**Pre-requisites :** None

**References :** Gerhard Pahl , Wolfgang Beitz , Jörg Feldhusen , Karl-Heinrich Grote, Engineering Design A Systematic Approach, Springer, ISBN:978-1-84628-318-5

# Mobility Engineering

## Preface

### MO 201 ( AUG ) 3 : 0

#### Introduction to Hybrid Electric Vehicles

- Introduction to Conventional IC Engines
- Description of various types of hybrid powertrains
- Pros and cons of various hybrid powertrains and their effect on performance and complexity
- Sizing of powertrains in micro, mild, full hybrids, as well as plug-in hybrids
- Energy Management System and control of various hybrid powertrain modes
- Simulation of Hybrid Electric Vehicles on various drive cycles in MATLAB Simulink

**Pre-requisites** : None

**References** : 1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, CRC Press, 2005.

### MO 210 ( AUG ) 1 : 0

#### Seminar

Exposure to latest topics in research and industry

**Pre-requisites** : None

**References** : Not applicable

### MO 299 ( JAN ) 0 : 30

#### Dissertation Project

Dissertation Project

#### Ravikrishna R V

**Pre-requisites** : None

**References** : Not applicable



# Division of Physical and Math. Sciences

## Preface

The Division of Physical and Mathematical Sciences comprises the Department of Mathematics, Department of Instrumentation and Applied Physics, Department of Physics, Centre for Cryogenic Technology and Centre for High Energy Physics (formerly Theoretical Studies). The Joint Astronomy and Astrophysics Programme also comes under its purview.

The courses offered in the Division have been grouped into six broad areas. These areas have been identified by code letters as follows:

IN Instrumentation and Applied Physics

MA Mathematics

PH Physics

AA Astronomy & Astrophysics

HE High Energy Physics

The course numbers have the prefix of the code letter followed by the numbers. The first digit indicates the level of the course.

There are specific requirements for completing a Research Training Programme for students registering for research conferments at the Institute. For specific individual requirements, the students are advised to approach the Departmental Curriculum Committee.

The Department of Physics and the Centre for High Energy Physics offer an Integrated PhD Programme to which BSc graduates with an adequate background of Physics and Mathematics are admitted.

The Integrated PhD programme in the Mathematical Sciences is offered by the Department of Mathematics to which BSc graduates with an adequate knowledge of Mathematics are admitted.

An M Tech programme in Instrument Technology is offered in the Department of Instrumentation and Applied Physics. For all these programmes, most of the courses are offered by the faculty members of the Division, but in certain special areas, courses offered in other Divisions may also be chosen.

Prof. Kaushal Verma

Dean

Division of Physical & Mathematical Sciences

# Cryogenic Technology

## Preface

### CCT 303 ( AUG ) 3 : 0

#### Cryoelectronics for Space Science

Cryogenics in space science and the need for cryoelectronics; Cryocoolers for space applications; Developments in cryoelectronics: superconductivity and its occurrence, survey of superconducting materials, Meissner Effect, BCS theory of superconductivity, Type I and Type II superconductors, Flux quantization, Josephson tunnelling, AC and DC Josephson effects, HTS superconductors, SQUIDs and their applications; Cold Electronics: Electronics based on semiconductors at cryogenic temperatures, improvements in their performance through material related properties such as mobility, thermal and electrical conductivities, associated problems due to thermal contraction mismatch and thermal cycling; Electronics for space exploration missions – performance of conventional transistors, oscillators, A/D converters, DC/DC converters, PWM controllers, components and systems at cryogenic temperatures; Cryocoolers for space missions: Development of different cryocoolers and their electronics for Space missions for specific use under European Space Agency; Cryoelectronics for miscellaneous applications: IR detectors in space missions, memory technology and readout electronics, SC Qubit control and readout.

#### Pre-requisites

Nil :

**References** : 1. E. A. Gutierrez, J. Deen and C. Claeys, Low temperature electronics: Physics, devices, circuits and applications, Elsevier Publishing

### CCT 302 ( AUG ) 2 : 1

#### Single Molecule Imaging and Cryoelectron Microscopy

Light Sources, Monochromators, Optical Filters, Photomultiplier Tubes, Polarizers, Beer-Lambert Law, Paraxial Ray Optics and System Designing, Wave Optics, Electromagnetic Theory, Fluorescence Microscopy Systems, Molecular Physics, Photophysics and Stern-Volmer Equation, Jablonski Diagram, Emission Spectra, Fluorescence Lifetime and Quantum Yield, Time-Domain Lifetime Measurements, Fluorescence Correlation Spectroscopy, Total Internal Reflection Fluorescence Microscopy, Electric Field Effects, Point Spread Function, Single- and Multi- Photon Fluorescence Microscopy, Advanced Super Resolution Microscopy, Aperture Engineering Techniques, 3D Image Reconstruction, Markov Random Field, Maximum Likelihood Algorithm, Bayes Theorem. Cryoelectron Microscope Instrumentation, Electron Gun, Electron Lenses, Vacuum Systems, Sample Chamber, Energy Filters, Electron Detectors, Electron Scattering, Point Spread Function, Fourier Transform, Image formation. Dedicated Lab Sessions & Practical on Fluorescence, Light Sheet, Cryoelectron and Single Molecule Super-resolution Microscopy.

#### Pre-requisites

Nil :

**References** : 1. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, Springer Publisher, 2006.  
2. Partha Pratim Mondal, Fundamental of Fluorescence Microscopy, Springer Publisher, 2014.  
3. T. Gonen and B. L. Nannenga, CryoEM: Methods and Protocols, Humana Press, 2021.

**CCT 201 ( AUG ) 3 : 0****Cryogenic Technology: Fundamentals and Applications**

Introduction and fundamentals of cryogenic technology; Properties of cryogenic fluids: nitrogen, oxygen, argon, neon, fluorine, methane; Low temperature properties of materials: mechanical, thermal, electrical and magnetic properties; Physics of liquefaction and liquefaction systems; Cryogenic fluid storage and transfer systems: cryogenic fluid storage vessels design and insulations, cryogenic fluid transfer systems; Gas liquefaction systems: thermodynamically ideal system, production of low temperatures, liquefaction systems for gases other than neon, hydrogen and helium, liquefaction systems for neon, hydrogen and helium; Cryogenic refrigeration systems: ideal refrigeration systems, refrigeration for temperature above 2 K, refrigerators for temperature below 2 K; Introduction to cryocoolers; Cryogenic safety; Cryogenic instrumentation: temperature, pressure, flow and liquid level measurements; Vacuum technology: Importance of vacuum in cryogenics, flow regimes in vacuum systems, conductance in vacuum systems, calculation of pump down time, basic components of vacuum systems, basics of vacuum pumps, gauges and valves; Application of cryogenics: space, medical, biological, food preservation and industrial applications.

**Pre-requisites**

Nil :

**References** : 1. T. Bradshaw, B. Evans and J. Vandore, Cryogenics: Fundamentals, foundations and applications, IOP Publishing, 2022.  
 2. R. F. Barron, Cryogenic Systems, Oxford University Press, 2nd Edition. 1985.  
 3. G. G. Haselden, Cryogenic fundamentals, Academic Press, New York. 1972.

# High Energy Physics

## Preface

HE 386 ( AUG ) 3 : 0

### Experimental High Energy Physics

Particles and interactions in the standard model. Strong, weak and electromagnetic interactions. Kinematics of particle interactions. Concepts of accelerators, linear and circular Accelerators. Introduction to particle detectors, interaction of particles with matter. Gaseous detectors, scintillator detectors, solid state detector. Readout electronics, vertex detection and tracking. Calorimetry for electrons, photons, charged hadrons and neutrons. Particle identification and detector systems. Experimental tests of the building blocks of matter and their fundamental interactions. Examples of QCD tests, top quark, Z and W bosons, Higgs boson, new particle searches. Review of some particle physics experiments, concepts of collider physics, basic phenomenology of a hard scattering process. Data analysis techniques in collider physics, statistical analysis in particle physics.

**Pre-requisites** : None

**References** : None

HE 395 ( AUG ) 3 : 0

### Quantum Field Theory - I

Scalar, spinor and vector fields. Canonical quantisation, propagators. Symmetries and Noether theorem. Path integrals for bosonic and fermionic fields, generating functionals. Feynman diagrams. Klein-Gordon and Dirac equations. Discrete symmetries: P, C, T. S-matrix, LSZ reduction formula. Interacting scalar and Yukawa theories. Scattering cross-sections, optical theorem, decay rates. Loop diagrams, power counting, divergences. Renormalization, fixed point classification. One loop calculations. Callan-Symanzik equations, beta functions. Effective field theory.

**Pre-requisites** : None

#### References

Zee A., Quantum Field Theory in a Nutshell (Second edition), Princeton University Press, 2010~Srednicki M., Quantum Field Theory, Cambridge

**HE 397 ( JAN ) 3 : 0****The Standard Model of Particle Physics**

Fermions coupled to gauge fields. Tree-level QED processes. Weak interactions before gauge theory. V-A theory, massive vector bosons. Spontaneous symmetry breaking, Goldstone bosons, Higgs mechanism. Charged and neutral currents, gauge symmetries and  $SU(2) \times U(1)$  Lagrangian. Flavour mixing, GIM mechanism. CP violation, K/B systems. Neutrinos. Electroweak precision measurements.

**Ananthanarayan B**

**Pre-requisites** : None

**References** : Halzen F. and Martin A.D., Quarks and Leptons: An Introductory Course in Modern Particle Physics, John Wiley & Sons, 1984~Georgi H., Weak Interactions and Modern Particle Theory, Benjamin/Cummings, 1984~Pokorski S., Gauge Field Theories (Second edition), Cambridge University Press, 2000~Peskin M.E. and Schroeder D.V., An Introduction to Quantum Field Theory, Addison Wesley,

**HE 398 ( JAN ) 3 : 0****General Relativity**

Review of tensor calculus and properties of the Riemann tensor. Killing vectors, symmetric spaces. Geodesics. Equivalence principle and its applications. Scalars, fermions and gauge fields in curved space-time. Einstein's equations and black hole solutions. Schwarzschild solution, Motion of a particle in the Schwarzschild metric. Kruskal extension and Penrose diagrams. Reissner-Nordstrom solution, Kerr solution. Laws of black hole physics. Gravitational collapse. Oppenheimer-Volkoff and Oppenheimer-Snyder solutions, Chandrasekhar limit. Cosmological models, Friedmann-Robertson-Walker metric. Open, closed and flat universes. Introduction to quantizing fields in curved spaces and Hawking radiation.

**Sachindeo Vaidya**

**Pre-requisites** : None

**References** : Landau L.D. and Lifshitz E.M., The Classical Theory of Fields, Pergamon Press, 1975~Weinberg S., Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, John Wiley & Sons, 1972~Wald R.M., General Relativity, Overseas Press, 2006~'t Hooft G., Introduction to General Relativity, Introduction to the theory of Black Holes, <http://www.phys.uu.nl/thoof~>

**HE 315 ( JAN ) 3 : 0****Advanced Mathematical Physics**

Introduction to differential geometry, Calculus on manifolds. Tensor analysis. Connection and covariant derivative. Riemannian geometry, curvature and torsion. Introduction to topology, Manifolds and homotopy. Fibre bundles, Gauge theories. Applications of the above to physics.

**Justin Raj David**

**Pre-requisites** :

PH209 or equivalent

**References** : 1. Modern Geometry - Methods and Applications Parts I & II, by B. A. Dubrovin, A. T. Fomenko and S. P. Novikov. 2. Lectures on Advanced Mathematical Methods for Physicists, by S. Mukhi and N. Mukunda.

**HE 396 ( JAN ) 3 : 0****Quantum Field Theory II**

Abelian gauge theories. QED processes and symmetries. Gauge invariance, covariant derivatives, massless photons, Ward identity. Loop diagrams and 1- loop renormalization. Lamb shift and anomalous magnetic moments. Nonabelian gauge theories. Faddeev-Popov ghosts. BRST quantization. QCD beta function, asymptotic freedom. Spinor helicity formalism for gauge theories. Composite operators, operator product expansion. Anomalies. Lattice gauge theory, strong coupling expansion. Confinement and chiral symmetry breaking.

**Chethan Krishnan**

**Pre-requisites** : None

**References** : Schwartz M.D., Quantum field theory and the standard model, Cambridge University Press, 2014.~Srednicki M., Quantum Field Theory, Cambridge University Press, 2007.~Weinberg S., The Quantum Theory of Fields, Vol. I: Foundations, Vol. II: Modern Applications, Cambridge University Press, 1996. ~Peskin M.E. and Schroeder D.V., An Introduction to Quantum Field Theory, Addison

**HE 379 ( JAN ) 3 : 0****Physics Beyond Standard Model**

Higgs discovery and its implications, effective field theories, supersymmetry and supergravity, extra dimensions and its variants, composite Higgs models, Cosmological solutions like relaxions and its variants, neutrino masses and GUTS, axions, and modern probes of new physics.

**Sudhir Kumar Vempati****Pre-requisites** :

Advanced graduate students, all qft courses and the Standard Model course.

**References** :

Csaki's lecture notes, original papers.

**HE 380 ( AUG ) 3 : 0****3D Quantum Gravity and 2D Conformal Field Theory**

3D gravity, Chern-Simons formulation, BTZ black hole as a quotient, Brown-Henneaux, Virasoro algebra, central charge, 2D CFT (basics, state-operator map, OPE, bootstrap, Virasoro blocks, modular invariance), BTZ entropy from Cardy, large-c and AdS3/CFT2, HLLH 4-point functions, semi-classical Virasoro blocks and information loss.

**Pre-requisites** :

General Relativity HE398 and Quantum Field Theory II HE396 are useful as prerequisites. Get permission of instructor if you have not taken

**References** : 1. Di Francesco et al. for 2D Conformal Field Theory.  
2. Carlip for 3D quantum gravity, but more up to date references will be suggested in class

# Instrumentation and Applied Physics

## Preface

### IN 201 ( AUG ) 3 : 0

#### Analytical Instrumentation

Principles, instrumentation, design and application of UV, visible and IR spectroscopy, mass spectrometry, Mossbauer and NMR spectroscopy, X- ray methods of analysis including powder diffraction, wavelength and energy dispersive x-ray fluorescence. Electron microscopy and microprobe. ESCA and AUGer techniques, photo electron spectroscopic methods, scanning tunneling and atomic force microscopy. Chromatography, thermal analysis including DTA, DSC and TGA. Thermal wave spectroscopic techniques such as photo-acoustic, photo-thermal deflection and photopyro-electric methods.

**Pre-requisites** : None

**References** : Willard,H.W.,Merritt,L.L.,Dean

### IN 214 ( AUG ) 3 : 0

#### Semiconductor Devices and Circuits

Quantum Mechanics Fundamentals, Schrodinger Equation, Particle in a Box, Harmonic Oscillator, Bonding, Crystals, Winger Seitz Cell, Bragg's Law, Lattice Waves and Phonons, Reciprocal Lattice Brillouin Zones, Kronig Penny Model, Formation of Energy Bands, Metals, Semiconductors- Density of States,Fermi Function, Carrier Concentrations and Mass Action Law, Doping,Recombination and Generation, Continuity Equation, Metal Semiconductor Junctions, PN Junctions, BJT, JFET, MESFET, MOS Capacitor, MOSFETs, Small Signal Models, Single Stage Amplifiers Basics, Organic Semiconductors, amorphous silicon, metal oxides.

**Pre-requisites** : None

**References** : Advanced Semiconductor Fundamentals,Robert F Pierret,Modular series on Solid State Devices,Robert F Pierret and Gerold W Neudeck Pearson Education Inc,Semiconductor Devices: Physics and Technology.

**IN 221 ( AUG ) 3 : 0****Sensors and Transducers**

Electromagnetics, Electromagnetic Sensors, Electrical Machines, Semiconductor fundamentals, MOS capacitor based sensors, FET based sensors, Mechatronics, Microelectromechanical system, Mechanical Transducers, Photonics, Imaging Sensors, Fiber optics, interferometry, Measurements on the Micro and Nanoscale, Fundamental limits on amplifiers, Fabrication of sensors, Photolithography

**Pre-requisites** : None

**References**

W. Bolton, Mechatronics, Longman, 2015~B.E.A. Saleh and M.C.Teich, Fundamentals of Photonics, John Wiley and Sons, 2007~D. Pozar, Microwave

**IN 227 ( AUG ) 3 : 0****Control Systems Design**

Dynamics of linear systems, Laplace transforms, analysis of feedback controlsystems using Nyquist plots, Bode plots and Root Locus, design of controlsystems in single-degree of-freedom configuration using direct design,proportional-integral-derivative control, lead-lag ompensation, design ofcontrol systems in two-degree of-freedom configuration to achieve robustness,Quantitative feedback theory control of non-minimum phase systems, Bodesensitivity integrals, use of describing functions to analyze and compensatenonlinearities.

**Pre-requisites** : None

**References** : Horowitz I.M.,Synthesis of Feedback Systems,Academic Press,1963.,Goodwin G. C.

**IN 232 ( AUG ) 3 : 0****Concepts in solid state physics**

Vibrations in solids; Electrons in Metals; Phonons; Tight binding chain; Chemical bonding in solids; Crystal structure; Real and Reciprocal Space; Scattering experiments; Waves in reciprocal space; Band structure and optical properties; Fermi surfaces; Introduction to semiconductors; Magnetism; Practical examples and review.

**Pre-requisites** : None

**References**

H. Ibach and H. Luth, Solid State Physics: An Introduction to Principles of Materials Science, Springer, 4th Edition 2009~Steven H. Simon, The Oxford



**IN 234 ( JAN ) 3 : 0****Biomedical Optics and Spectroscopy**

Mathematical Preliminaries: Signal Processing, Probability and Linear Algebra. A brief introduction to medical imaging, basic principles of imaging modalities such as x-ray, CT, SPECT, PET, MRI, Ultrasound. Basics of Spectroscopy: Infrared Spectroscopy, Raman Spectroscopy, Fluorescence Spectroscopy and Optoacoustic spectroscopy. Introduction to biomedical optics, single-scatterer theories, Monte Carlo modelling of photon transport, convolution for broad-beam responses, radiative transfer equation and diffusion theory, hybrid model of Monte Carlo and diffusion theory, sensing of optical properties and spectroscopy, optical coherence tomography basics, diffuse optical tomography, optoacoustic tomography, and ultrasound modulated optical tomography. Spectroscopy in the context of imaging.

**Jaya Prakash**

**Pre-requisites** : None

**References** : Lihong V. Wang and Hsin-i Wu, Biomedical Optics: Principles and Imaging, Wiley, (2007). ISBN: 978-0-471-74304-0. ~Valery Tuchin, Tissue Optics: Light Scattering Methods and Instruments for Medical Diagnosis, SPIE Press (2007). ~Jerry L. Prince and Jonathan M. Links, Medical Imaging Signals and Systems, Prentice Hall, (2005).

**IN 270 ( AUG ) 3 : 0****Digital Signal Processing**

Signals and Systems Review, Time scaling and shifting, Amplitude scaling and shifting, LTI Systems, Properties of Signals and Systems, CTFS, CTFT, Nyquist Sampling Theorem, Reconstruction of Bandlimited Signals, DTFS, DTFT, Discrete Fourier Transform, Properties of Fourier Transform, existence of Fourier Transform. Laplace transform and its properties, z-transform and its properties. Signal Flow graphs, FIR and IIR filter realization. Impulse invariance method, and Bilinear transformation. Low-Pass Filtering, Filter design - Chebyshev Filter, Butterworth Filter and linear-phase filters. Windowing and Parks-McClellan Algorithm. Multi-resolution analysis, Filter Banks, Short-time Fourier Transform, Wavelets. 1D & 2D signals and its property, Sub-Nyquist Sampling, Reconstruction with uniform and non-uniform sampling (prior constraints): Pseudo-inverse, Truncated SVD, Minimum Norm Solution, Tikhonov Regularization, Iterative Methods, Majorization-Minimization, and Compressive Sampling.

**Pre-requisites**

Signals and Systems & consent from the instructor

**References**

Textbooks:

**IN 222 ( JAN ) 2 : 1****Sensors and Transducers Laboratory**

Sensor development and signal processing, temperature sensor, hall sensor, noise analysis, Dynamic modeling and system identification, DC motor, Induction motor, water bath, Actuation, piezo-actuation, bimetallic strip, magnetic actuation, Control systems, One degree of freedom control, two degree of freedom control, PID control, Lead-lag compensation

**Atanu Kumar Mohanty**

**Pre-requisites** : None

**References** : 1. W. Bolton, Mechatronics, Longman, 2015

**IN 252 ( JAN ) 3 : 0****Optical materials and devices**

Introduction, Fundamentals of semiconductors and optoelectronic devices, photodetector, LED, LASER, optical properties of thin films and noble metals, Fabrication methods- chemical and physical techniques, Surface Plasmon Polariton, Metasurface, Metasurface applications in sensing and non-linear light generation, Optical fibers and Waveguides, Fiber drawing process, Fiber materials, multi-material micro-structured fibers, multi-material fibers for electronic and photonic applications, Integrated photonics-material choice and applications.

**Tapajyoti Das Gupta**

**Pre-requisites** : None

**References** : 1- Solid State Physics; Ashcroft, Neil W., and N. David Mermin; Belmont, CA 2-Introduction to Solid State Physics; Kittel, Charles; Hoboken, NJ: Wiley 3- Elements of Photonics; For Fiber and Integrated Optics, Vol. 2; Keigo Iizuka; Wiley-Interscience 4- Flat optics with designer metasurfaces, Nature Materials volume 13, pages 139–150 (2014).

**IN 203 ( AUG ) 3 : 0****Micro to Quantum Supercapacitor Devices**

Fundamentals of supercapacitor, Supercapacitor Fabrication, State-of-art supercapacitor design, Supercapacitor materials, Macro supercapacitor, Planar micro supercapacitor, Self-powered supercapacitor, Design of planar supercapacitor electrodes, Differences in macro-supercapacitor and planar supercapacitors, Mechanism of electrochemical interactions, Energy density and power density, Fundamentals of electromagnetic interaction in device design, Optically active devices and circuit design, Instrumentation of supercapacitor, Flexible electronics of supercapacitor, Ultra small planar devices, Device design parameters, Quantum Supercapacitors, Current technological advancements and future roadmap, Future Applications

**Pre-requisites** :

**References** : 1- Electrochemical Supercapacitors, Author: B E Conway. 2- Semiconductor Devices and Circuits (Oxford Higher Education), by Alok Dutta 3- Physics of Optoelectronics, by Michael A. Parker

**IN 277 ( AUG ) 2 : 1****Instrumentation Electronics Laboratory**

Applications of operational amplifiers, active filters, oscillators, A/D and D/A converters, phase-locked loops, mixers, lock-in amplifiers, switched mode power supplies, speed control of motors using PWM, introduction to microcontrollers and microprocessors. (There will be lectures and laboratory sessions on each of the topics mentioned here.)

**Pre-requisites** :

**References** : \* Paul Horowitz and Winfield Hill, The Art of Electronics, Cambridge University Press, 2015

**IN 299A ( JAN ) 0 : 20****M Tech Project**

Research project for fulfillment of M Tech degree requirements

**Baladitya Suri**

**Pre-requisites** : None

**References** : Project-specific references

**IN 280 ( AUG ) 2 : 1****Optical Instrumentation**

Building-Blocks of Optical Instrumentation: Properties of Light and Physical Principles (Refraction, Diffraction, Scattering and Interference), Optical Components (such as Elements, Sources and Detectors) and Modules (such as Optical Fibers and Imaging Systems), Optical Sensors and Transducers.

Design & Characterization of Optical Systems: Signals, Systems, Analysis, Measurement, Characterization and Calibration. Point-Spread Function, Optical Transfer Function. Specific Tutorials and Case-Studies on Optical Microscopy and Spectroscopy Techniques.

Simulations with MATLAB / Python: Signal Processing and Image Processing Tools, Hardware Interfacing, Data Acquisition and Analysis, Signal-to-Noise Ratio, Digital Image Correlation, Fourier Transform based Analysis.

Experiments in Optics Laboratory: Hands-on training on Optical Alignments, building Pulse-oximeter / Hemoglobinometer, Michelson Interferometer, and Digital Brightfield Microscope. This lab component of the course will combine the learnings from different modules of the course: Basic Concepts, Applied Theory and Computational Tools.

**Pre-requisites**

No Prerequisites. This is an introductory level course suitable

**References** : "Handbook of Optical Sensors" José Luís Santos , Faramarz Farahi; CRC Press; ISBN: 9781439866856

"Optical Sensors: Basics and Applications" by Jörg Haus; Wiley-VCH, ISBN: 978-3527408603

**IN 278 ( JAN ) 2 : 1****Introduction to Embedded Systems**

Introduction to the embedded systems landscape and the importance of programming, operating systems, middleware, interfacing, design, debugging and testing.  
 B) Role of the microcontroller. Introduction to modern computing architecture. Highlights of microcontroller architecture, GPIO, UART, and hardware protocols such as SPI and I2C.  
 C) Representative sensors and actuators and interfacing these to microcontrollers.  
 D) Representative tasks – sensing, actuating, processing  
 E) Interconnecting microcontrollers and protocols.  
 F) Designing and debugging embedded systems.  
 G) Emerging topics and issues related to embedded systems.  
 H) Laboratory activities will be designed to provide training and practice for students to design and deploy a range of embedded systems without using a real-time operating system.

**Baladitya Suri****Pre-requisites**

Basic Knowledge of C programming

**References** : 1. Hennessey and Patterson, Computer Organization  
 2. E.A. Lee and S.A. Seshia, Introduction to Embedded Systems  
 3. P. Marwedel, Embedded Systems Design, Springer 2006

**IN 332 ( JAN ) 3 : 0****2D MATERIALS**

Introduction to low dimensional materials - 0D, 1D, 2D; properties of conventional 2D electron gases; introduction to layered 2D materials, atomic structure of graphene and other layered materials, electronic band structures of single and bilayer graphene, production of 2D materials; Raman spectroscopy and other characterization techniques; device fabrication and measurement techniques; quantum Hall effect in graphene-based systems; electronic and electromechanical properties; optical properties; sensors; membranes; van der Waals heterostructures; moiré physics

**Chandni U****Pre-requisites**

UG level Quantum Mechanics and Solid State Physics or (PH 203)

**References** : 1. 2D Materials: Properties and Devices, edited by Avouris, Heinz and Low, Cambridge University Press  
 2. The Physics of Low Dimensional Semiconductors, John M. Davies, Cambridge University Press  
 3. Solid State Physics, N. Ashcroft and N. D. Mermin, Saunders College Publishing

### Concepts of Terahertz Communication

1. Maxwell's Equations, Poynting's Theorem, Boundary Conditions (4 hours)  
 In this section, the course will introduce and discuss the fundamental laws governing electromagnetism, starting with Maxwell's equations. The Maxwell's equations are pivotal in governing and describing how electric and magnetic fields generate, interact and propagate in medium and in free space. We then explore Poynting's theorem, which provides a framework for understanding energy transfer in electromagnetic fields, and the flow of electromagnetic power through space. The boundary conditions will be discussed, which are essential for solving Maxwell's equations in different media, ensuring the continuity of tangential components of electric and magnetic fields across interfaces.

2. Wave Equations, Plane Waves, Polarization, Conduction and Polarization Currents, Diffraction and Scattering (6 hours)  
 This part introduces the wave equation, derived from Maxwell's equations, which describes the propagation of electromagnetic waves. We will investigate plane waves, their characteristics, and significance in the signal propagation. Polarization, a critical property of transverse waves indicating the orientation of the electric field, will be discussed in detail. Furthermore, we will examine conduction and polarization currents, essential concepts in understanding the movement of charges and dipoles in materials. Finally, we will cover the diffraction and scattering phenomena, which describe the behavior of waves in a scattering media, crucial for applications in optics and telecommunications.

3. EM Waves Propagation in Waveguides and Resonant Cavities, Eigen Modes, Phase and Group Velocity (6 hours)  
 Here, we will focus on the propagation of electromagnetic waves within waveguides and resonant cavities, structures that confine and direct waves. We will analyze eigenmodes, the natural resonant modes of these systems, which are vital for understanding the operational characteristics of the communication/resonant devices. The concepts of phase and group velocity, describing the speed at which individual wave fronts and wave packets travel, will be thoroughly examined to provide insights into signal transmission and dispersion in guided wave systems.

4. Dipole Radiation, Antennas, Multiplexers, Beam Steering and Beam Forming (8 hours)  
 In this section, we will explore the principles of dipole radiation, the fundamental mechanism of how antennas emit electromagnetic waves. We will cover various types of antennas, their design, and operational principles. Multiplexers, devices that combine multiple signals into one for transmission and then separate them at the receiver, will be discussed. The concepts of beam steering and beam forming, techniques used to direct the radiation pattern of antennas to enhance signal strength and quality in desired directions, are crucial for modern communication systems.

5. Hybrid Electronic-Photonic Systems, High Frequency Diodes, Sources, and Detectors

### Manukumara Manjappa

#### Pre-requisites

Waves and Optics, Basic electronics; Semiconductors/Solid state physics

**References** : 1. Classical Electrodynamics, John David Jackson, 1999 (3rd Edn).  
 2. Introduction to Terahertz Electronics, Jae-Sung Rieh, Springer Nature Switzerland AG 2021 Edn.  
 3. High-frequency Electrodynamics, Boris Z. Katsenelenbaum, Wiley-VCH 2006 Edn.

## IN 279 ( JAN ) 2 : 1

**RF networks and Systems**

The course will cover the following topics -- Review of Transmission line theory, Lumped versus Distributed elements concept, lossless and lossy lines, line impedance, concept of reflection, transmission. General solutions for TEM, TE and TM waves. Introduction to stripline and microstripline, Wheeler charts, Graphical design technique using Smith chart. Network Synthesis: N-port RF networks, impedance, admittance, transmission and scattering matrix representations, reciprocal and lossless networks, network matrices transformations, Impedance matching and tuning: L-section impedance matching, Quarter wave transformer, Distributed matching: single and double stub matching. Practical application scenarios, Microwave passive circuits: Waveguide cavity resonators. Principles of power dividers, splitters, 90 degree hybrid directional couplers, 180 rat race couplers, Design of Wilkinson power divider, Filter design: Figure of Merit, Design of High Pass, Low pass, BPF using Chebyshev, butterworth and maximally flat response types. Lumped and distributed realizations will be covered.

In the second part of the course we will also discuss RF transceiver systems and subsystems. Under this the following topics will be covered -- Noise: Noise representation as a noise voltage, types of noise in typical RF systems, Noise Figure concept, Signal to noise ratio, and methods to measure system noise such as Y factor method, Active devices basics: Review of diodes, BJTs and MOSFETs, Amplifiers, concept of gain compression, non-linearities, Dynamic Range and third order intercept point, Amplifier design: Stability concept, gain circles, choice of device, design of input and output matching stages. Amplifier characterization using VNA , Low Noise amplifier design: Choice of device, noise circles, design of matching networks with trade-off

**Baladitya Suri****Pre-requisites**

RLC circuits, Analog electronics, EM wave theory, Time and Frequency Domain analysis, Probability Theory and Random Processes, Linear

**References** : Microwave Engineering, David M. Pozar, 4th Edition, Wiley 2012  
 RF circuit design, Christopher Bowick, 2nd edition, Elsevier 2011  
 Fundamentals of Microwave and RF design, Michael Steer, 3rd edition, NC State University , 2019

# Mathematics

## Preface

**MA 201 ( JAN ) 7 : 0**

### Project

**Mahesh Ramesh Kakde**

**Pre-requisites** : None

**References** : None

**MA 215 ( AUG ) 3 : 0**

### Introduction to Modular Forms

**Pre-requisites** : None

**References** : None

**MA 216 ( JAN ) 3 : 0**

### Introduction to Graph Theory

Graphs, subgraphs, Eulerian tours, trees, matrix tree theorem and Cayley's formula, connectedness and Menger's theorem, planarity and Kuratowski's theorem, chromatic number and chromatic polynomial, Tutte polynomial, the five-colour theorem, matchings, Hall's theorem, Tutte's theorem, perfect matchings and Kasteleyn's theorem, the probabilistic method, basics of algebraic graph theory.

**Apoorva Khare**

**Pre-requisites** : None

**References** : Adrian Bondy and U.S.R. Murty, Graph Theory, Graduate Texts in Mathematics, 244. Springer, New York, 2008, ISBN: 978-1846289699. ~Reinhard Diestel, Graph theory (Third edition), Graduate Texts in Mathematics, 173. Springer-Verlag, Berlin, 2005. ISBN: 978-3540261827. ~Douglas B. West, Introduction to graph theory, Prentice Hall, Inc., Upper Saddle River, NJ, 1996. ISBN:



**MA 218 ( JAN ) 3 : 0****Number Theory****Radhika Ganapathy****Pre-requisites** : None**References** : None**MA 219 ( AUG ) 3 : 1****Linear Algebra**

ector spaces: definition, basis and dimension, direct sums. Linear transformations: definition, the Rank-ity Theorem, the algebra of linear transformations. Dual spaces. Matrices. Systems of linear equations: elementary theory of determinants, Cramer's rule. Eigenvalues and eigenvectors, the characteristic polynomial, the Cayley-Hamilton Theorem, the minimal polynomial, algebraic and geometric multiplicities. Diagonalization. The Jordan canonical form. Symmetry: group of motions of the plane, discrete groups of motion, finite subgroups of  $SO(3)$ . Bilinear forms: symmetric, skew-symmetric and Hermitian forms, Sylvester's law of inertia, Spectral theorem for Hermitian and normal operators on finite-dimensional vector spaces.

**Pre-requisites** : None

**References** : Hoffman K. and Kunze R. Linear Algebra (2nd Ed.) Prentice-Hall of India. 1992. ~Artin M. Algebra. Prentice-Hall of India. 1994.~Halmos P. Finite dimensional vector spaces. Springer-Verlag (UTM). 1987.~Lang S. Linear Algebra (3rd Ed.) Springer-Verlag (UTM). 1989.

**MA 220 ( JAN ) 3 : 0****Representation theory of Finite groups**

Representation of finite groups, irreducible representations, complete reducibility, Schur's lemma, characters, orthogonality, class functions, regular representations and induced representation, the group algebra. Linear groups: Representation of the group  $SU_2$  Books Artin, M., Algebra, Prentice Hall of India, 1994. Fulton W., and Harris, J., Representation Theory, Springer-Verlag, 1991. Serre, J.P., Linear Representations of Finite Groups, Springer-Verlag, 1977.

**Soumya Das****Pre-requisites** : None

**References** : Etingof Pavel, Golberg Oleg, Hensel Sebastian, Liu Tiankai, Schwendner Alex, Vaintrob Dmitry, Yudovina Elena., Introduction to representation theory. With historical interludes by Slava Gerovitch, Student Mathematical Library 59. American Mathematical Society. 2011.~J. P. Serre. Graduate Texts in Mathematics. Vol. 42. Springer-Verlag. New York-Heidelberg, 1977.

**MA 222 ( JAN ) 3 : 1****Analysis - II**

Sigma-algebras, outer measures and measures. Construction of Lebesgue measure. Measurable functions. Lebesgue integration and integration with abstract measures. Monotone convergence theorem, Fatou's lemma and the dominated convergence theorem. Comparison of Riemann integration and Lebesgue integration. Product sigma-algebras, product measures, Fubini's theorem. Signed measures and the Radon-Nikodym theorem.  $L^p$  spaces, characterization of continuous linear functionals on  $L^p$  spaces. Complex measures, the Riesz representation theorem.

**Arka Mallick**

**Pre-requisites** : None

**References** : Stein E. M. and Shakarchi R. Real analysis: measure theory. integration and Hilbert spaces. Princeton university press (2005).~Folland G.B. Real Analysis:Modern Techniques and their Applications (2nd Ed.) .Wiley. ~Royden H. L. Real Analysis .Macmillan. 1988.~Hewitt E. and Stromberg. K. Real and Abstract Analysis. Springer. 1969.

**MA 224 ( MAY ) 3 : 1****Complex Analysis**

Complex numbers, complex-analytic functions, and the Cauchy-Riemann condition. Cauchy's integral formula, power series. Liouville's theorem and applications. The maximum-modulus principle. Morera's theorem, Schwartz reflection principle. Isolated singularities and the residue theorem. Contour integration. Möbius transformations, conformal mappings. Normal families and Montel's theorem. The Riemann Mapping Theorem. The Schwarz Lemma: proof, applications, automorphisms of the unit disc. Basics of analytic continuation (time permitting).

**Narayanan E K**

**Pre-requisites** : None

**References** : None

**MA 231 ( AUG ) 3 : 1****Topology**

Point-set topology: Open and closed sets, Continuous functions, Metric topology, Product topology, Connectedness and path-connectedness, Compactness, Countability axioms, Separation axioms, Complete metric spaces, Quotient topology, Topological groups, Orbit spaces. The fundamental group: Homotopic maps, Construction of the fundamental group, Fundamental group of the circle, Homotopy type, Brouwer's fixed-point theorem, Separation of the plane.

**Pre-requisites** : None

**References**

Armstrong, M. A., Basic Topology, Springer (India), 2004., Functional Analysis (2nd Ed.), McGraw-Hill, 2006.~Munkres, K. R., Topology, Pearson :

**MA 232 ( AUG ) 3 : 0****Introduction to Algebraic Topology**

The fundamental group: Homotopy of maps, multiplication of paths, the fundamental group, induced homomorphisms, the fundamental group of the circle, covering spaces, lifting theorems, the universal covering space, Seifert-van Kampen theorem, applications. Simplicial and singular homology: Simplicial complexes, chain complexes, definitions of the simplicial and singular homology groups, properties of homology groups, applications.

**Pre-requisites** : None

**References** : Allen Hatcher Algebraic topology. Cambridge University Press. Cambridge. 2002. ~Armstrong, M.A., Basic Topology, Springer (India), 2004.~William S. Massey A basic course in algebraic topology. Graduate Texts in Mathematics. 127. Springer-Verlag. New York. 1991.

**MA 241 ( JAN ) 3 : 1****Ordinary Differential Equations**

Basics concepts: Introduction and examples through physical models, First and second order equations, general and particular solutions, linear and nonlinear systems, linear independence, solution techniques. Existence and Uniqueness Theorems : Peano's and Picard's theorems, Gronwall's inequality, Dependence on initial conditions and associated flows. Linear system: The fundamental matrix, stability of equilibrium points, Phase- plane analysis, Sturm-Liouville theory . Nonlinear system and their stability: Lyapunov's method, Non-linear Perturbation of linear systems, Periodic solutions and Poincare- Bendixson theorem

**Vamsi Pritham Pingali**

**Pre-requisites** : None

**References** : 221, Coddington, E. A. and Levinson, N., Theory of Ordinary Differential Equations , Tata McGraw-Hill, 1972, Perko, L., Differential Equations and Dynamical Systems , Springer-Verlag, 1991.

**MA 242 ( AUG ) 3 : 0****Partial Differential Equations**

**Pre-requisites** : None

**References**  
Garabedian, P. R., Partial Differential Equations, John Wiley and Sons, 1964. ~Fritz John, Partial Differential Equations, Springer

**MA 261 ( AUG ) 3 : 0****Probability Models**

Sample spaces, events, probability, discrete and continuous random variables, Conditioning and independence, Bayes' formula, moments and moment generating function, characteristic function, laws of large numbers, central limit theorem, theory of estimation, testing of hypotheses, linear models.

**Pre-requisites** : None

**References**

Ross, S.M., Introduction to Probability Models, Academic Press, 1993.,  
 Taylor~Taylor, H.M., and Karlin, S., An Introduction to Stochastic

**MA 305 ( JAN ) 3 : 0****Analysis on Lie Groups****Muna Naik**

**Pre-requisites** : None

**References** : None

**MA 310 ( JAN ) 3 : 0****Algebraic Geometry I**

Refresher on Commutative Algebra: localization, local rings, integral closure, Krull dimension. Zariski topology, Hochster's characterization of Zariski topology, spectral spaces. Zariski spectrum as a frame  
 Refresher on categories : Categories, functors, Yoneda Lemma, equivalence of categories, adjoints. Grothendieck sites : Zariski, étale and Nisnevich sites. Presheaves and Sheaves Locally ringed spaces and schemes Separated schemes, proper schemes, irreducible schemes, reduced schemes, integral schemes, noetherian schemes. Morphisms : separated, proper, finite morphisms, finite type morphisms, affine morphisms Sheaves of algebras : affine morphisms as sheaves of algebras Sheaves of modules over a scheme, Quasi-coherent and coherent sheaves Divisors and Line Bundles, Weil divisors, Cartier divisors, Line bundles on Projective spaces, Serre sheaves. Projective morphisms, ample and very ample line bundles Formal schemes

**Abhishek Banerjee**

**Pre-requisites** : None

**References** : None

**MA 312 ( AUG ) 3 : 0****Commutative Algebra**

Noetherian rings and Modules, Localisations, Exact Sequences, Hom, Tensor Products, Hilbert's -stellensatz, Integral dependence, Going-up and Going down theorems, Noether's normalization lemma , Discrete valuation rings and Dedekind domains.

**Pre-requisites** : None

**References** : None

**MA 313 ( AUG ) 3 : 0****Algebraic Number Theory**

Number fields and rings of integers, Dedekind domains; prime factorization, ideal class group, finiteness of class number, Dirichlet's unit theorem, cyclotomic fields, theory of valuations, local fields.

**Pre-requisites** : None

**References**

Jurgen Neukirch, Algebraic Number theory, Springer, 1999~Daniel A. Marcus, Number fields, Springer Universitext, 2018~J.P Serre, Local

**MA 326 ( JAN ) 3 : 0****Fourier Analysis**

Introduction to Fourier Series; Plancherel theorem, basis approximation theorems, Dini's Condition etc. Introduction to Fourier transform; Plancherel theorem, Wiener-Tauberian theorems, Interpolation of operators, Maximal functions, Lebesgue differentiation theorem, Poisson representation of harmonic functions, introduction to singular integral operators.

**Narayanan E K**

**Pre-requisites** : None

**References** : None

**MA 328 ( AUG ) 3 : 0****Introduction to Several Complex Variables**

Preliminaries: Holomorphic functions in  $C^n$  : definition, the generalized Cauchy integral formula, holomorphic functions: power series development (s), circular and Reinhardt domains, analytic continuation : basic theory and comparisons with the one- variable theory. Convexity theory: Analytic continuation: the role of convexity, holomorphic convexity, plurisub-harmonic functions, the Levi problem and the role of the d-bar equation. The d-bar equation: Review of distribution theory, Hormander's solution and estimates for the d-bar operator.

**Pre-requisites** : None

**References** : Lars Hormander, An Introduction to Complex Analysis in Several Variables, 3rd edition, North-Holland Mathematical Library, North- Holland, 1989.~Function Theory of Several Complex Variables, 2nd edition, Wadsworth & Brooks/Cole,1992.~Raghavan Narasimhan, Several Complex Variables, Chicago Lectures in Mathematics Series, The University of Chicago Press, 1971.

**MA 333 ( AUG ) 3 : 0****Riemannian Geometry**

Review of differentiable manifolds and tensors, Riemannian metrics, Levi-Civita connection, geodesics, exponential map, curvature tensor, first and second variation formulas, Jacobi fields, conjugate points and cut locus, Cartan-Hadamard and Bonnet Myers theorems. Special topics - Comparison geometry (theorems of Rauch, Toponogov, Bishop-Gromov), and Bochner techniques.

**Pre-requisites** : None

**References** : Sylvestre Gallot, Dominique Hulin, Jacques Lafontaine, Riemannian geometry,Third edition., Universitext. Springer-Verlag, Berlin, 2004. ~Peter Petersen,Riemannian geometry, Graduate Texts in Mathematics, 171. Springer-Verlag, New York, 1998.~John Lee, Riemannian Geometry - An introduction to curvature,Graduate Texts in Mathematics, 176. Springer - Verlag, New York, 1997.

**MA 361 ( AUG ) 3 : 0****Probability theory**

Discrete parameter martingales: Conditional expectation. Optional sampling theorems. Doob's inequalities. Martingale convergence theorems. Applications.Brownian motion. Construction. Continuity properties. Markov and strong Markov property and applications. Donsker's invariance principle. Further sample path properties. Ergodic theory (if time permits) Probability measures and random variables, pi and lambda systems, expectation,the moment generating function, the characteristic function, laws of large numbers, limit theorems, conditional contribution and expectation, martingales, infinitely divisible laws and stable laws.

**Pre-requisites** : None

**References** : Rick Durrett, Probability: theory and examples., Cambridge University Press,2010~David Williams, Probability with Martingales, Cambridge

**MA 368 ( JAN ) 3 : 0****Topics in Probability and Stochastic Processes**

Discrete parameter martingales: Conditional expectation. Optional  
 sampling theorems. Doob's inequalities. Martingale convergence theorems.  
 Applications. Brownian motion. Construction. Continuity properties.  
 Markov and strong Markov property and applications. Donsker's invariance  
 principle. Further sample path properties. Ergodic theory (if time  
 permits)

**Manjunath Krishnapur**

**Pre-requisites** : None

**References**

Rick Durrett, Probability: theory and examples., Cambridge University  
 Press, 2010~David Williams, Probability with Martingales, Cambridge

**MA 372 ( JAN ) 3 : 0****Harmonic Analysis****Narayanan E K**

**Pre-requisites** : None

**References** : None

**MA 200 ( AUG ) 3 : 1****Multivariable Calculus**

Functions on  $\mathbb{R}^n$ , directional derivatives, total derivative, higher order derivatives and Taylor series. The inverse and implicit function theorem, Integration on  $\mathbb{R}^n$ , differential forms on  $\mathbb{R}^n$ , closed and exact forms. Green's theorem, Stokes' theorem and the Divergence theorem.

**Pre-requisites** : None

**References** : Rudin, Principles of Mathematical Analysis, McGraw-Hill, 1986.~B. V. Limaye and S. Ghorpade, A course in Calculus and Real Analysis, Springer~Spivak, M., Calculus on Manifolds, W.A. Benjamin, co., 1965

**MA 212 ( AUG ) 3 : 0****Algebra I**

Part A 1. Groups: definitions & basic examples; 2. Normal subgroups, quotients; 3. Three isomorphism theorems; 4. Centralizer and normalizer of a subset, centre of a group; 5. Permutations, symmetric groups and Cayley's Theorem; 6. Group actions and their applications, Sylow's theorems. Part B 1. Rings and ideals: basic definitions, quotient rings; 2. The Chinese Remainder Theorem; 3. Maximal and prime ideals; 4. Unique factorization, unique factorization domains, principal ideal domains, Euclidean domains, polynomial rings; 5. Modules: basic definitions and examples, Hom and tensor products, the Structure Theorem for finitely generated modules over PIDs; 6. Fields: basic definitions and examples, algebraic & transcendental numbers; 7. Finite fields, characteristic, the order of a finite field.

**Pre-requisites** : None

**References** : Artin M. Algebra. Prentice-Hall of India. 1994.~Dummit. D. S. and Foote R. M. Abstract Algebra. McGraw-Hill. 1986.~Herstein I. N. Topics in Algebra. John Wiley and Sons. 1995.~Lang S. Algebra. (3rd Ed.) Springer. 2002.

**MA 213 ( JAN ) 3 : 1****Algebra II**

Part A: Field theory (1) Theory of symmetric polynomials – Newton's theorem (2) Basic theory of field extensions (3) Algebraic and transcendental extensions (and transcendence degree) (4) Construction with straight edge and compass; Gauss-Wantzel theorem (5) Algebraic closure – Steinitz's theorem (6) Splitting fields, normal extensions (7) Separable extensions (8) Finite fields: construction, subfields, Frobenius (9) Primitive element theorem (10) Dedekind-Artin linear independence of (semi)group characters Part B: Galois theory (1) Fundamental theorem of Galois theory (including Normal Basis Theorem) (2) Composite extensions and Galois group (3) Galois group of cyclotomic extensions, finite fields (4) Galois groups of polynomials, Fundamental theorem of Algebra (5) Solvable and radical extensions, insolvability of a quintic

**Shaunak Vilas Deo**

**Pre-requisites** : None

**References** : Artin, M., Algebra, Prentice\_Hall of India, 1994.~Dummit, D. S. and Foote, R.M., Abstract Algebra, McGraw-Hill, 1986.~Lang, S., Algebra (3rd Ed.), Springer, 2002~Jonathan Alperin and Rowen Bell, Groups and Representations, Graduate Texts in Mathematics 162, Springer Verlag, 1995.~Hungerford, Algebra, Graduate Texts in Mathematics 73, Springer Verlag, 1974.~Galois Theory, Artin, E., University



**MA 221 ( AUG ) 3 : 0****Analysis I**

Construction of the field of real numbers and the least upper-bound property. Review of sets, countable & uncountable sets. Metric Spaces: topological properties, the topology of Euclidean space. Sequences and series. Continuity: definition and basic theorems, uniform continuity, the Intermediate Value Theorem. Differentiability on the real line: definition, the Mean Value Theorem. The Riemann-Stieltjes integral: definition and examples, the Fundamental Theorem of Calculus. Sequences and series of functions, uniform convergence, the Weierstrass Approximation Theorem. Differentiability in higher dimensions: motivations, the total derivative, and basic theorems. Partial derivatives, characterization of continuously-differentiable functions. The Inverse and Implicit Function Theorems. Higher-order derivatives.

**Pre-requisites** : None

**References** : Rudin W. Principles of Mathematical Analysis. 3rd edition. McGraw-Hill International Edition. ~Tao T. Analysis I. 3rd edition. TRIM series. Hindustan Book Agency. 2014. ~Tao T. Analysis II. 3rd edition. TRIM series. Hindustan Book Agency. 2014. ~Apostol T. M. Mathematical Analysis. Narosa. 1987.

**MA 291 ( JAN ) 3 : 0****Masters project B**

Optional project for undergraduate students in their fifth year

**Vamsi Pritham Pingali**

**Pre-requisites** : None

**References** : None

**MA 307 ( AUG ) 3 : 0****Riemann surfaces**

Riemann surfaces are one-dimensional complex manifolds, obtained by gluing together pieces of the complex plane by holomorphic maps. This course will be an introduction to the theory of Riemann surfaces, with an emphasis on analytical and topological aspects. After describing examples and constructions of Riemann surfaces, the topics covered would include branched coverings and the Riemann-Hurwitz formula, holomorphic 1-forms and periods, the Weyl's Lemma and existence theorems, the Hodge decomposition theorem, Riemann's bilinear relations, Divisors, the Riemann-Roch theorem, theorems of Abel and Jacobi, the Uniformization theorem, Fuchsian groups and hyperbolic surfaces.

**Pre-requisites** : None

**References** : H.M. Farkas and I. Kra, Riemann surfaces, Springer GTM 1992. ~R. Miranda, Algebraic Curves and Riemann Surfaces, AMS Graduate Studies in Mathematics, 1995. ~W. Schlag, A Course in Complex Analysis and Riemann surfaces, AMS Graduate Studies in Mathematics, 2014.

**MA 315 ( AUG ) 3 : 0****Lie Algebra and their representations**

Finite dimensional Lie algebras, Ideals, Homomorphisms, Solvable and Nilpotent Lie algebras, Semisimple Lie algebras, Jordan decomposition, Killing form, root space decomposition, root systems, classification of complex semisimple Lie algebras Representations Complete reducibility, weight spaces, Weyl character formula, Kostant, Steinberg and Freudenthal formulas

**Pre-requisites** : None

**References** : J E Humphreys Introduction to Lie algebras and Representation theory Springer-Verlag, 1972~J P Serre Complex Semisimple Lie Algebras, Springer, 2001~Fulton.W., and Harris J. Representation theory, Springer- Verlag. 1991

**MA 321 ( JAN ) 3 : 0****Analysis III**

Theory of Distributions: Introduction, Topology of test functions, Convolutions, Schwartz Space, Tempered distributions. Fourier transform and Sobolev-spaces:Definitions, Extension operators, Continuum and Compact imbeddings, Trace results. Elliptic boundary value problems: Variational formulation, Weak solutions, Maximum Principle, Regularity results.

**Swarnendu Sil**

**Pre-requisites** : None

**References** : Barros-Nato, An Introduction to the Theory of Distributions, Marcel Dekker Inc. , New York, 1973.~Kesavan, S., Topics in Functional Analysis and Applications, Wiley Eastern Ltd., 1989.~Evans, L. C., Partial Differential Equations, Univ. of California, Berkeley, 1998.~Schwartz, L. Hermann, Theorie des Distributions, 1966.

**MA 365 ( JAN ) 3 : 0****Topics in Gaussian Processes**

A course in Gaussian processes. At first we shall study basic facts about Gaussian processes - isoperimetric inequality and concentration, comparison inequalities, boundedness and continuity of Gaussian processes, Gaussian series of functions, etc. Later we specialize to smooth Gaussian processes and their nodal sets , in particular expected length and number of nodal sets,persistence probability and other such results from recent papers of many authors.

**Manjunath Krishnapur**

**Pre-requisites** : None

**References** : Robert Adler and Jonathan Taylor, Gaussian Random Fields, Springer, New York,2007.~A. I. Bogachev, Gaussian Measures, American Mathematical Society,Providence, RI, 1998~Svante Janson, Gaussian Hilbert Spaces, Cambridge University Press, Cambridge, 1997.

**MA 223 ( AUG ) 3 : 0****Functional Analysis****Pre-requisites** : None**References** : None**MA 235 ( JAN ) 3 : 0****Introduction to differentiable manifolds**

A review of continuity and differentiability in more than one variable. The inverse, implicit, and constant rank theorems. Definitions and examples of manifolds, maps between manifolds, regular and critical values, partition of unity, Sard's theorem and applications. Tangent spaces and the tangent/cotangent bundles, definition of general vector bundles, vector fields and flows, Frobenius' theorem. Tensors, differential forms, Lie derivative and the exterior derivative, integration on manifolds, Stokes' theorem. Introduction to de Rham cohomology.

**Ved V Datar****Pre-requisites** :

**References** : 1. Tu, Loren An Introduction to Manifolds, Universitext, Springer-Verlag 2011. 2. John Lee, Introduction to Smooth Manifolds, Graduate Texts in Mathematics 218, Springer-Verlag 2012. 3. Barden, Dennis and Thomas, Charles, An Introduction to Differential Manifolds, World Scientific 2003. 4. Spivak, Michael Comprehensive Introduction to Differential Geometry, Vol 1, Publish or Perish, 2005.

MA 356 ( JAN ) 3 : 0

Class field theory, a course in arithmetic geometry

1. Review of Dedekind domains and rings of integers in number fields.
2. Topology of discrete valuation fields.
3. Group cohomology
4. and Galois cohomology.
5. Brauer group of local fields.
6. Hasse principle for Brauer group.
7. Norm subgroups and their openess.
8. Class field theory for local and global fields.
9. Class field theory for compact curves over finite fields.
10. field theory for open curves over finite fields.

**Mahesh Ramesh Kakde**

**Pre-requistes**

Basic algebra, commutative rings, Noetherian rings, basic number

**References**

1. Local fields by J.-P. Serre.
2. Lecture notes on class field theory

**MA 388 ( AUG ) 3 : 0****Topics in Non-linear Functional Analysis**

In this course, our main aim is to develop abstract variational techniques which can be employed to study the existence of solutions of various Semi-linear elliptic Partial Differential Equations. The main fundamental results, that will be covered in this course, are functional analytic in nature and can be used in many other situations. A basic outline of the course is as follows:

1. Pohozaev identity and non-existence of solutions.
2. Calculus in normed linear space: Fréchet and Gâteaux differentiability, Notion of integral, Existence and uniqueness theorem for ODE in Banach space.
3. Dirichlet's principle, Basics of Sobolev spaces, Connection between critical points and solutions of PDE
4. Direct Methods in Calculus of Variations: Existence of extrema, Ekeland's Variational Principle, Constrained critical points (method of Lagrange Multiplier).
5. Deformation and the Palais-Smale condition, Saddle points and min-max methods: The mountain pass theorem and its application, The

**Pre-requisites**

MA 222, MA 223

**References**

1. Ambrosetti, A., and Malchiodi, A. (2007). Nonlinear Analysis and Semilinear Elliptic Problems (Cambridge Studies in Advanced

**MA 262 ( JAN ) 3 : 0****Introduction to Stochastic Processes**

Discrete parameter Markov Chains: Chapman-Kolmogorov equations, Classification of states, Limit Theorems, Examples: Random Walks, Gambler's Ruin, Branching processes. Time reversible Markov chains. Simulations and MCMC; Poisson processes: Definitions, and properties: interarrival and waiting time distributions, superposition and thinning, Nonhomogeneous Poisson process, Compound Poisson process. Simulation; Continuous time Markov Chains: Definition, Birth-Death processes, Kolmogorov backward and forward equations, Limiting probabilities, Time reversibility. Queueing Theory, Simulation; Renewal Theory; Brownian Motion.

**Sanchayan Sen****Pre-requisites**

**References** : Samuel Karlin and Howard M. Taylor: A first course in Stochastic Processes, 2nd edition, Academic Press, 1975. Sheldon M. Ross: Stochastic Processes, 2nd edition, John Wiley and Sons, 2008. Rabi N. Bhattacharya and Edward C. Waymire: Stochastic Processes and Applications, Siam, 2009.

**MA 208 ( JAN ) 3 : 1**

**Proofs and Programs**

This course introduces various aspects of Computer Proofs, both interactive and fully automated. We will consider proofs of mathematical results as well as of correctness of programs. We will primarily use the Lean Theorem Prover 4, which is a formal proof system as well as a programming language. The foundations on which the lean prover is based, Dependent Type Theory, allow a seamless integration of mathematical objects, theorems, proofs and algorithms.

Topics covered will be among the following.

- \* Interactively proving mathematical results in the lean theorem prover.
- \* Programming in lean - functional programming with dependent types.
- \* Mathematical proofs of correctness of programs.
- \* Foundations of Mathematics and Computation using Dependent Type Theory
- \* First-order logic
- \* Fully automated theorem proving: SAT Solvers, Resolution Theorem Proving etc.
- \* Use of Machine Learning in Automated and Interactive Theorem Proving.

**Siddhartha Gadgil**

**Pre-requisites** :

Familiarity with mathematical proofs and some basic mathematics

**References** : 1. Jeremy Avigad, Leonardo de Moura, Soonho Kong and Sebastian Ullrich, Theorem Proving in Lean 4, available online at [https://leanprover.github.io/theorem\\_proving\\_in\\_lean4/](https://leanprover.github.io/theorem_proving_in_lean4/)

**MA 345 ( JAN ) 3 : 0**

**Complex Manifolds**

Introduction to the local theory: holomorphic functions of several variables, the definition and examples of complex manifolds and holomorphic vector bundles, sheaves and cohomology, complex vector bundles: Hermitian metrics, connections and curvature, Kahler manifolds, Hodge theorem, the Kodaira embedding theorem

**Purvi Gupta**

**Pre-requisites** : MA 235 : MA 224 : Complex Analysis  
manifolds : Introduction to Differentiable

**References** : 1) Huybrechts, Daniel. Complex geometry. An introduction. Universitext. Springer-Verlag, Berlin, 2005. xii+309 pp.  
2) Lee, John M. Introduction to Complex Manifolds. Vol. 244. American Mathematical Society, 2024

**MA 389A ( AUG ) 1 : 0****Seminar on topics in mathematics I**

The students must commit to attending a seminar series (algebra, eigenfunctions, etc) of their choice and attend all the talks during the semester.

**Pre-requisites** : None

**References** : No references.

**MA 267 ( JAN ) 3 : 1****Introduction to Statistical Learning with Applica**

Exploratory Data Analysis and Descriptive Statistics, with basic introductory programming in R using tidyverse for data visualisation. Sampling Distribution and Limit Theorems: Order Statistics, Chi<sup>2</sup>, F, Student's t. Sampling statistics from Normal Population, Law of Large numbers, Central Limit Theorem, Variance Stabilising transformation. Proofs via simulation in R. Estimation: Method of Moments, Maximum Likelihood Estimate and Confidence intervals. Hypothesis Testing: Binomial Test for proportion, Normal Test for mean when variance is known/unknown, two sample t-test for equality of means when variance is known. Linear Models, Normal Equations, Gauss Markov Theorem, Testing of linear hypotheses. One-way and two-way classification models: ANOVA, Random effects. Emphasis on Numerical evaluation. Regularisation and Subset Selection methods. Basics of Decision trees: Regression Tress, Classification trees and comparison with Linear Models. Computational Optimal transport. Applications from Epidemiology, Networks and Optimal transport.

**Srikanth Krishnan Iyer****Pre-requisites**

UM 201, MA 261 or equivalent, basic Linear Algebra.

**References** : 1. Probability and Statistics with Examples Using R by Siva Athreya, Deepayan Sarkar and Steve Tanner. Publisher: Institute of Mathematical Statistics, Hayward, CA.  
2. Applied Linear Regression by Sanford Weisberg. Publisher: John Wiley and Sons, New York.

**MA 389B ( JAN ) 1 : 0****Seminar on topics in mathematics II**

The students must commit to attending a seminar series (algebra, eigenfunctions, etc) of their choice and attend all the talks during the semester.

**Vamsi Pritham Pingali**

**Pre-requisites** : None

**References** : No references.

**MA 237 ( JAN ) 3 : 0****Introduction to Tilings**

This course will be an introduction to the mathematical theory of tilings. The first part of the course will concern tilings of the Euclidean plane, and topics covered will include tilings by regular Euclidean polygons, Archimedean tilings, symmetry groups of planar tilings, substitution tilings, aperiodic tilings including the Penrose tiles and the hat tile. The second part of the course will concern tilings of the hyperbolic plane, including triangle groups, existence of weakly aperiodic tiles and semi-regular tilings. In the final part of the course, topics related to tilings on surfaces, conformal tilings, and higher-dimensional tilings (in Euclidean  $n$ -space and hyperbolic 3-space) will be discussed. Along the way, the course will cover the basic notions needed from Euclidean and hyperbolic geometry, group theory, topology, and the theory of Riemann surfaces.

**Subhojoy Gupta****Pre-requisites** :

Prerequisites for undergraduates: MA 231 (Topology)

**References** :

Suggested books:  
 "The Tiling Book" by Colin Adams, published by the American Mathematical Society (2022).

**MA 376 ( JAN ) 3 : 0****Extremal Combinatorics**

1. Double counting, pigeonhole principle, Erdos-Szekeres theorem, Mantel's theorem, Turan's theorem, Dirichlet's theorem. (5-6 lectures)
2. Ramsey theorem for graphs: bounds on Ramsey numbers. (2-3 lectures)
3. Extremal set theory: intersecting families, Erdos-Ko-Rado theorem, maximal intersecting families, Furedi's theorem. (3-4 lectures)
4. Chains and antichains: Dilworth's theorem, Sperner's theorem, Bollobas' theorem. (3-4 lectures)
5. Algebraic Methods: Even-odd town problem, Fisher's inequality, 2-distance sets in  $\mathbb{R}^n$ , bounds on the number of sets with restricted pairwise intersections. (3-4 lectures)
6. Probabilistic methods: Lower bounds for Ramsey numbers, tournaments, dominating sets, sum-free sets of integers. (4-5 lectures)

**Arvind Ayyer****Pre-requisites** :

This course will explain ideas for solving the problem of determining or estimating the maximum or minimum possible cardinality of a

- References** :
1. Extremal Combinatorics by Stasys Jukna
  2. A Course in Combinatorics by J. H. Van Lint and R. M. Wilson
  3. Lecture notes by Benny Sudakov and Jan Vondrak, available at



**MA 368A ( AUG ) 3 : 0****Exclusion processes**

Review of discrete and continuous time Markov chains, review of equilibrium and nonequilibrium statistical mechanics, Ising model in one dimension, Glauber dynamics, Bethe ansatz, Yang-Baxter equation, asymmetric simple exclusion processes with periodic and open boundary conditions, multispecies exclusion processes, Zero range processes, Schur and Macdonald processes

**Pre-requisites**

MA 261 or equivalent

**References** : R. J. Baxter, Exactly solved models in statistical mechanics, Academic Press, London, 1982.

B. Derrida, An exactly soluble non-equilibrium system: The asymmetric simple exclusion process, Physics Reports 301 (1998), 65–83.

**MA 346A ( JAN ) 3 : 0****Homogeneous dynamics**

The course is about the ergodic theory of actions by (subgroups of) semisimple Lie groups which arise as groups of isometries of non-compact symmetric spaces. Some of the main topics include Howe-Moore's theorem on vanishing of matrix coefficients at infinity for unitary actions on Hilbert spaces, Moore's ergodicity theorem, ergodic aspects of the geodesic flow, the horocycle flow and classification of ergodic invariant measures of the horocycle flow. Dani-Margulis' proof of a stronger version of Oppenheim's conjecture will be discussed at the end of the course as an application of topics covered.

Topics from the theory of non-compact semisimple Lie groups including Cartan involution, restricted root spaces, Weyl chambers, Iwasawa decomposition, Cartan decomposition and Bruhat decomposition will be discussed in some detail. Basic topics from ergodic theory like ergodicity, strong mixing and the pointwise ergodic theorem will also be recalled.

**Manjunath Krishnapur****Pre-requisites**

Measure theory (equivalent to MA222) will be assumed. Familiarity with basic notions of differential geometry (covered)

**References** : 1. Ergodic Theory and Topological Dynamics of Group Actions on Homogeneous Spaces, Bekka-Mayer (Cambridge University Press)

2. Homogeneous dynamics and applications, Einsiedler-Ward

**MA 346 ( JAN ) 3 : 0****Ergodic theory**

Measure preserving systems, Poincare recurrence, von Neumann ergodic theorem, Khintchine's theorem, spectral theorem and applications to combinatorics, ergodicity, Birkhoff ergodic theorem, mixing, unique ergodicity, disintegration of measures, Furstenberg correspondence principle, Furstenberg-Sarkozy theorem, Jacobs-de Leeuw-Glicksberg decomposition theorem and application to Roth's theorem, The Kronecker Factor. (Additional material: Bhattacharya's proof of the periodic tiling conjecture in  $\mathbb{Z}^2$ )

**Manjunath Krishnapur****Pre-requisites**

Measure theory and elements of Functional analysis. It would help to have some familiarity with Fourier analysis and some probability

**References** : 1) Peter Walters, An Introduction to Ergodic Theory, Springer-Verlag (1982)

2) Manfred Einsiedler and Thomas Ward, Ergodic Theory with a view Towards Number Theory, Springer-Verlag (2012)

# Physics

## Preface

HE 215 ( AUG ) 3 : 0

### Nuclear and Particle Physics

Radioactive decay, subnuclear particles. Binding energies. Nuclear forces, pion exchange, Yukawa potential. Isospin, neutron and proton. Deuteron. Shell model, magic numbers. Nuclear transitions, selection rules. Liquid drop model, collective excitations. Nuclear fission and fusion. Beta decay. Neutrinos. Fermi theory, parity violation, V-A theory. Mesons and baryons. Lifetimes and decay processes. Discrete symmetries, C, P, T and G. Weak interaction transition rules. Strangeness, K mesons and hyperons. Hadron multiplets, composition of mesons and baryons. Quark model and quantum chromodynamics.

**Pre-requisites :** None

### References

Povh B., Rith K., Scholz C. and Zetsche F., Particles and Nuclei: An Introduction to Physical Concepts (Second edition), Springer, 1999–Krane :

**PH 201 ( AUG ) 3 : 0****Classical Mechanics**

Newton's laws, generalized co-ordinates. Lagrange's principle of least action and symmetry. Integrable problems, scattering. Small oscillations including freedom, rigid body Hamilton's Hamilton Jacobi theory. Canonical special relativity. Lorentz mechanics.

and equations. elastic collisions and systems with many degrees of motion. brackets. Poisson elements of relativistic

perturbation theory, chaos,

transformations,

**Pre-requisites** : None

**References** :

**PH 202 ( JAN ) 3 : 0****Statistical Mechanics**

Basic principles of statistical mechanics and its application to simple systems. Probability theory, fundamental postulate, phase space, Liouville's theorem, ergodicity, micro-canonical ensemble, connection with thermodynamics, canonical ensemble, classical ideal gas, harmonic oscillators, paramagnetism, Ising model, physical applications to polymers, biophysics. Grand canonical ensemble, thermodynamic potentials, Maxwell relations, Legendre transformation. Introduction to quantum statistical mechanics, Fermi, Bose and Boltzmann distribution, Bose condensation, photons and phonons, Fermi gas, classical gases with internal degrees of freedom, fluctuation, dissipation and linear response, Monte Carlo and molecular dynamics methods.

**Aveek Bid , Shibananda Das**

**Pre-requisites** : None

**References** : Pathria, R.K., Statistical Mechanics, Butterworth Heinemann, Second Edn, 1996, Reif, F., Fundamentals of Statistical and Thermal Physics, McGraw Hill, 1965., Landau, L.D., and Lifshitz E.M., Statistical Physics, Pergamon, 1980.

## PH 203 ( AUG ) 3 : 0

## Quantum Mechanics-I

Historical foundations. Wave function for a single particle. Hamiltonian. Schrodinger equation. Probability current. Wave packets. One-dimensional problems: step, barrier and delta-function potentials. Tunnelling, scattering and bound states. Harmonic oscillator, approach. Matrix Hermitian formulation of quantum mechanics. operators. Orthonormal unitary basis. Momentum relations. Postulates of Uncertainty quantum mechanics. Heisenberg representation. theorem. Ehrenfest's problems. Rotations, angular momentum commutation relations. Spherical harmonics. Hydrogen atom, and wave functions. Symmetries and degeneracies. Spin angular momentum. Spin-1/2 and two-level systems. Addition of angular momentum. Spin-orbit and hyperfine interactions. Time-independent perturbation theory. Stark and Zeeman effects. Variational methods, ground helium atom. state of

**Pre-requisites :** None

**References :** None

**PH 204 ( JAN ) 3 : 0****Quantum Mechanics II**

Time dependent perturbation theory. Fermi golden rule. Transitions caused by a periodic external field. Dipole transitions and selection rules. Decay of an unstable state. Born cross section for weak potential scattering. Adiabatic and sudden approximations. WKB method for bound states and tunneling. Scattering theory: partial wave analysis, low energy scattering, scattering length, Born approximation, optical theorem, Levinson's theorem, resonances, elements of formal scattering theory. Minimal coupling between radiation and matter, diamagnetism and paramagnetism of atoms, Landau levels and Aharonov-Bohm effect. Addition of angular momenta, Clebsch Gordon series, Wigner Eckart theorem, Lande's g factor. Many particle systems: identity of particles, Pauli principle, exchange interaction, bosons and fermions. Second quantization, multielectron atoms, Hund's rules. Binding of diatomic molecules. Introduction to Klein Gordon and Dirac equations, and their nonrelativistic reduction.

**Biplob Bhattacharjee**

**Pre-requisites** : None

**References** : Schwabl, F., Quantum Mechanics. Landau, L.D., and Lifshitz E.M., Quantum Mechanics. Cohen-Tannoudji, C., Diu, B., and Laloe, F., Quantum Mechanics (2 Vols.). Bethe, H. and Jackiw, R., Intermediate Quantum Mechanics.

**PH 205 ( AUG ) 3 : 0****Math Methods of Physics**

**Pre-requisites** : None

**References**

Linear vector spaces, linear operators and matrices, systems of

**PH 206 ( JAN ) 3 : 0****Electromagnetic Theory**

Laws of electrostatics and methods of solving boundary value problems. Multi-pole expansion of electrostatic potentials, spherical harmonics. Electrostatics in material media, dielectrics. BiotSavart Law, magnetic field and the vector potential. Faraday's Law and time varying fields. Maxwell's equations, energy and momentum of the electromagnetic field, Poynting vector, conservation laws. Propagation of plane electromagnetic waves. Radiation from an accelerated charge, retarded and advanced potentials, Lienard-Wiechert potentials, radiation multi-poles. Special theory of relativity and its application in electromagnetic theory. Maxwell's equations in covariant form: four – potentials, electromagnetic field tensor, field Lagrangian. Elements of classical field theory, gauge invariance in electromagnetic theory.

**Rajeev Kumar Jain**

**Pre-requisites** : None

**References** : Jackson, J.D., Classical Electrodynamics, Third Edn, John Wiley., Panofsky, W.K.H., and Phillips, M., Classical Electricity and Magnetism, Second Edn, Dover, Jackson, J.D., Classical Electrodynamics, Third Edn, John Wiley.

**PH 207 ( JAN ) 1 : 2****Electronics I**

Basic diode and transistor circuits, operational amplifier and applications, active filters, voltage regulators, oscillators, digital electronics, logic gates, Boolean algebra, flip-flops, multiplexers, counters, displays, decoders, D/A, A/D. Introduction to microprocessors.

**Atanu Kumar Mohanty**

**Pre-requisites** : None

**References** : Horowitz and Hill, The Art of Electronics, Second Edn., Millman and Halkias, Integrated Electronics, McGraw Hill., Horowitz and Hill, The Art of Electronics, Second Edn.

**PH 208 ( JAN ) 3 : 0****Condensed Matter Physics-I**

Drude model, Sommerfeld model, crystal lattices, reciprocal lattice, X-ray diffraction, Brillouin zones and Fermi surfaces, Bloch's theorem, nearly free electrons, tight binding model, selected band structures, semi-classical dynamics of electrons, measuring Fermi surfaces, cohesive energy, classical harmonic crystal, quantum harmonic crystal, phonons in metals, semiconductors, diamagnetism and paramagnetism, magnetic interactions.

**Anindya Das**

**Pre-requisites** : None

**References** : Ashcroft, N.W., and Mermin, N.D., Solid State Physics

**PH 211 ( AUG ) 0 : 3****General Physics Laboratory**

Diffraction of light by high frequency sound waves,  
 Michelson interferometer, Hall effect, band gap of semiconductors,  
 diode as a conductivity sensor, thermal conductivity of a Pirani gauge,  
 normal modes of vibration in a box, Newton's of cooling, constant selenate, random medium. measurements of dielectric triglycine walk in porous

**Pre-requisites** : None

**References** : None

**PH 212 ( JAN ) 0 : 3****Experiments in Condensed Matter Physics**

Stirling Engine  
 Thinfilm deposition by thermal evaporation technique  
 Low temperature measurement (using closed cycle Helium cryostat)  
 Scanning Tunneling Force Microscopy  
 Atomic Force Microscopy  
 Franck-Hertz Experiment  
 Laue Pattern of Single Crystal  
 Semiconductor Thermogenerator (Peltier and Seebeck effect)  
 Alpha Scattering  
 Lock-in Amplifier

**Vibhor Singh**

**Pre-requisites** : None

**References** : None



**PH 217 ( AUG ) 3 : 0****Fundamentals of Astrophysics**

Overview of the major contents of the universe. Basics of radiative transfer and radiative processes. Stellar interiors. HR diagram. Nuclear energy generation. White dwarfs and neutron stars. Shape, size and contents of our galaxy. Basics of stellar dynamics. Normal and active galaxies. High energy and plasma processes. Newtonian cosmology. Microwave background. Early universe.

**Pre-requisites** : None

**References** : None

**PH 250A ( JAN ) 0 : 6****Project I**

This two part project starts in the fourth semester of the Integrated Ph.D Programme (PH 250 A) and ends in the summer before the beginning of the 5th semester

**Prateek Sharma**

**Pre-requisites** : None

**References** : None

**PH 320 ( AUG ) 3 : 0****Condensed Matter Physics - II**

Review of one-electron band theory. Effects of electron-electron interaction: Hartree – Fock approximation, exchange and correlation effects, density functional theory, Fermi liquid theory, elementary excitations, quasiparticles. Dielectric function of electron systems, screening, plasma oscillation. Optical properties of metals and insulators, excitons. The Hubbard model, spin-and charge-density wave states, metal-insulator transition. Review of harmonic theory of lattice vibrations. Anharmonic effects. Electron-phonon interaction – phonons in metals, mass renormalization, effective interaction between electrons, polarons. Transport phenomena, Boltzmann equation, electrical and thermal conductivities, thermo-electric effects. Superconductivity–phenomenology, Cooper instability, BCS theory, Ginzburg-Landau theory

**Pre-requisites** : None

**References** : None

**PH 322 ( JAN ) 3 : 0****Molecular Simulation**

Introduction to molecular dynamics, various schemes for integration, inter-and intra-molecular forces, introduction to various force fields, methods for partial atomic charges, various ensembles(NVE, NVT, NPT, NPH), hard sphere simulations, water simulations, computing long-range interactions. Various schemes for minimization: conjugate gradient, steepest descents. Monte Carlo simulations, the Ising model, various sampling methods, particle-based MC simulations, biased Monte Carlo. Density functional theory, free energy calculations, umbrella sampling, smart Monte Carlo, liquid crystal simulations, introduction to biomolecule simulations

**Prabal Kumar Maiti , Sudeep Punnathanam**

**Pre-requisites** : None

**References** : None

**PH 325 ( AUG ) 3 : 0****Advanced Statistical Physics**

Systems and phenomena. Equilibrium and non-equilibrium models. Techniques for equilibrium statistical mechanics with examples, exact solution, mean field theory, perturbation expansion, Ginzburg Landau theory, scaling, numerical methods. Critical phenomena, classical and quantum. Disordered systems including percolation and spin glasses. A brief survey of non-equilibrium phenomena including transport, hydrodynamics and non-equilibrium steady states.

**Pre-requisites** : None

**References** : None

**PH 350 ( JAN ) 3 : 0****Physics of Soft Condensed Matter**

Phases of soft condensed matter, colloidal fluids and crystals, polymer solutions, gels and melts. Micelles, vesicles, surfactant mesophases, polymer colloids, microgels and star polymers-particles with tunable soft repulsive interaction, surfactant and phospholipid membranes. Lyotropic liquid crystals. Structure and dynamics of soft matter, electrostatics in soft matter, dynamics at equilibrium. Glass formation and jamming, dynamical heterogeneity. Soft glassy rheology. Shear flow, linear and nonlinear rheology, visco-elastic models, Introductory biological physics. Active matter. Experimental methods, Small angle scattering and diffraction, Dynamic light scattering and diffusive wave spectroscopy, dynamics of soft matter using synchrotron X-ray and neutron scattering, rheometry. Confocal microscopy.

**Sriram Ramaswamy**

**Pre-requisites** : None

**References** : None

**PH 351 ( AUG ) 3 : 0****Crystal Growth, Thin films and Characterization**

Basic concepts and experimental methods of crystal growth: nucleation phenomena, mechanisms of growth, dislocations and crystal growth, crystal dissolutions, phase equilibria, phase diagrams and material preparation, growth from liquid-solid equilibria, vapour- solid equilibria, monocomponent and multi-component techniques. Thin film growth and characterization: concepts of ultra high vacuum, nucleation and growth mechanisms, deposition techniques such as sputtering, evaporation, LPE, MOCVD, MBE, PLD, etc., thickness measurements and characterization such as RHEED, LEED thin-film XRD, etc.

**Pre-requisites** : None

**References** : None

**PH 352 ( JAN ) 3 : 0****Semiconductor Physics**

Semiconductor fundamentals: band structure, electron and hole statistics, intrinsic and extrinsic semiconductors, energy band diagrams, drift-diffusion transport, generation - recombination, optical absorption and emission. Basic semiconductor devices: pn junctions, bipolar transistors, MOS capacitors, field-effect devices, optical detectors and emitters. Semiconductor technology: fundamentals of semiconductor processing techniques; introduction to planar technology for integrated circuits.

**Ramesh Chandra Mallik**

**Pre-requisites** : None

**References** : Seeger, K., Semiconductor Physics, Springer-Verlag, 1990.; Sze, S.M., Physics of Semiconductor Devices, Wiley, 1980.; Muller, K., and Kamins, T., Device Electronics for Integrated Circuits, John Wiley, 1977.

**PH 353 ( AUG ) 3 : 0****Principles of Magnetism**

**Pre-requisites** : None

**References** : None

**PH 354 ( JAN ) 3 : 0****Computational physics**

Introduction to computational physics; Machine representation, precision and errors; Roots of equations; Quadrature; Random numbers and Monte- Carlo Fourier methods Ordinary differential equations Numerical Linear algebra.

**Prateek Sharma**

**Pre-requisites** : None

**References** : Mark Newman, Computational Physics, Createspace Independent Publishing (2015).,Rubin H. Landau, Manuel J. Paez and Cristian Bordeianu, Computational Physics,3rd Ed Problem Solving with Python, Wiley (2015).,A. Klein and A. Godunov,Introductory Computational Physics, Cambridge University Press (2006),Forman Acton,Real computing made real: Preventing Errors in Scientific and

**PH 359 ( JAN ) 3 : 0****Physics at the Nanoscale**

Introduction to different nanosystems and their realization, electronic properties of quantum confined systems: quantum wells, wires, nanotubes and dots. Optical properties of nanosystems: excitons and plasmons, photoluminescence, absorption spectra, vibrational and thermal properties of nanosystems, Zone folding. Raman characterization.

**Arindam Ghosh**

**Pre-requisites** : None

**References** : Delerue,C and Lannoo,M.,Nanostructures: Theory and Modelling,Springer

**PH 364 ( JAN ) 3 : 0****Topological Phases of Matter (Theory and experiment)**

The course is designed to teach the concepts and methods of various forms of topological phases of matter to mainly physics students. Some related concepts and their extensions such as Aharonov-Bohm effect, Berry phase, graphene, Majorana, Weyl fermions will also be taught. This is a combined theory and experimental course (no experiment will however be performed). Students are expected to have taken condensed matter I, but no prior knowledge of group theory is required.

**Subroto Mukerjee**

**Pre-requisites** : None

**References** : None

**PH 365 ( JAN ) 3 : 0****Galaxies and Interstellar Medium**

Galactic structure: local and large scale distribution of stars and interstellar matter, the spiral structure, the galactic centre. Galactic dynamics, stellar relaxation, dynamical friction, star clusters, density wave theory of galactic spiral structure, chemical evolution in the galaxy, stellar populations. Galaxies, morphological classification of galaxies, active galaxies, clusters of galaxies, interactions of galaxies, dark matter, evolution of galaxies.

**Nirupam Roy**

**Pre-requisites** : None

**References** : Mihalas, D. and Binney, J.: Galactic Astronomy., Binney, J. and Tremaine, S.: Galactic Dynamics, Spitzer, L.: Physical Process in the Interstellar Medium.

**PH 366 ( JAN ) 3 : 0****Physics of Advanced Optical Materials**

Syllabus: Introduction to novel optical materials; Quantum dots, plasmonic nanoparticles, two dimensional materials, metamaterials, photonic crystals; Fundamental excitations in optical materials and their interactions; weak (Purcell) and strong coupling (Rabi) – classical and quantum treatments; wave optics; Fourier optics and microscopy; Maxwell's electromagnetic waves; resonators; quantum theory of photons; light-matter interaction; optical and optofluidic forces in colloidal materials; Advanced experimental techniques to probe optical materials – steady state and time resolved measurements; super-resolution techniques; optical tweezers; anti-bunching and photon correlations.

**Jaydeep Kumar Basu**

**Pre-requisites** : None

**References**

Recommended Books: 1. Principles of Nano Optics, Lukas Novotny and Bert Hecht 2. Optical Metamaterials: Fundamentals and Applications, Wenshan Cai and Vladimir

**PH 371 ( JAN ) 3 : 0****General Relativity & Cosmology**

Foundations of general relativity. Elements of tensor analysis. Schwarzschild and Kerr spacetimes. Black hole physics. Gravitational radiation. Cosmological models. Observational tests. The early universe. The microwave background. Formation of structures.

**Nirupam Roy**

**Pre-requisites** : None

**References** : Landau, L.D., and Lifshitz, E.M.: The Classical Theory of Fields., Weinberg, S.: Gravitation and Cosmology., Peebles, P.J.E.: Physical Cosmology.

**PH 377 ( JAN ) 0 : 2****Astronomical Techniques (Seminar Course)**

Radio: coordinate system, detection principles, resolution and sensitivity, interferometry and aperturesynthesis. IR/Optical/UV: CCD fundamentals, imaging systems, point-spread-function, sensitivity, photometry and spectroscopy, speckle techniques, adaptive optics. X-ray/Gamma-ray astrophysics: detection principles, detectors and imaging systems, resolution and sensitivity, detector response, data analysis methods for spectroscopic and timing studies. Coordinated laboratory / data analysis exercises in each of the three areas.

**Nirupam Roy**

**Pre-requisites** : None

**References**  
Christianson, W.N., & Hogbohm, J.A.: Radio and Telescopes Roy, A.E., & Clarke, D.: Astronomy Principles and Practice., Kitchin, C.R.:

**PH 375 ( JAN ) 3 : 0****Symmetry, Topology, and Entanglement in Condensed Matter**

Group theory and group representations with applications to the quantum field theory of condensed matter systems. Linear and projective representations. Application to fermionic systems and the tenfold way. Homotopy groups and applications in condensed matter. Topological terms in nonlinear sigma models. Application to spin systems, Dirac fermion systems (such as graphene) and disordered fermionic systems. Entanglement and its characterization. Area law. Short-range entangled phases of matter, including topological insulators. Entanglement in gapless phases. Long-range entangled phases with introduction of topological order. Applications to the quantum Hall effect. Critical phenomena. Conformal symmetry and conformal field theory. Entanglement structure of quantum field theories.

Topological quantum field theory. Chern-Simons theories. Anyons: Abelian and Non-Abelian. Examples from fractional Hall effect and other topologically ordered phases. Ideas of topological quantum computation. A survey of recent developments in the classification of phases.

**Vijay B Shenoy****Pre-requisites**

Advanced Condensed Matter, Quantum Statistical Field Theory :

**References**

A. Zee, Group Theory in a Nutshell, Princeton University Press, 2016.  
M. Nakahara, Geometry, Topology and Physics, CRC Press, 2003.

**PH 380 ( AUG ) 3 : 0****Non-equilibrium Quantum Many-Body Dynamics**

Basic notions of quantum dynamics. Thermalization and quantum statistical mechanics – eigenstate thermalization hypothesis (ETH), entanglement and quantum information, transport, and quantum chaos. Analytical and numerical methods of many-body quantum dynamics – Schwinger-Keldysh field theory for closed and open systems in out-of-equilibrium and non-equilibrium steady states, quantum kinetic equations, Wigner function, and semiclassical approximations, effective field theories, exact diagonalization, matrix-product state methods. Topics in quantum many-body dynamics – dynamical phase transitions, many-body localization, entanglement transitions, dynamics of integrable and non-integrable systems, quantum quenches, Floquet theory, and time crystals.

**Pre-requisites**

Quantum Mechanics I & II, Statistical Mechanics, Condensed Matter Physics :

**References** : 1. A. Kamenev, Field Theory of Non-Equilibrium Systems (Second Edition), Cambridge, 2023.  
2. A. Altland and B. Simons, Condensed Matter Field Theory (Second Edition), Cambridge, 2010.

**PH 367 ( JAN ) 3 : 0****Plasma Physics and Applications**

What is a plasma? Plasma Parameters; approaches to Plasma Physics [3 hours]  
Debye length, the plasma parameter, Saha Ionization equation  
Magnetohydrodynamics, two-fluid, (anisotropic) transport coefficients, kinetic approach (qualitative)

Single particle dynamics: [3 hours]  
Uniform E and B Fields:  $E=0$ , Finite E, Gravitational Field  
Nonuniform B Field: Grad B drift, Curvature drift, Magnetic Mirrors  
Nonuniform Field : Nonuniform E field, Time-Varying E and B Field  
Adiabatic Invariants: The first adiabatic invariant, Second Adiabatic invariant and Third adiabatic invariant  
Examples from fusion (mirror machines), space (van Allen belts, particle drifts)

Waves in plasmas: [9 hours]  
Representation of Waves, Plasma Oscillation, Electron Plasma Waves, Sound waves, Electrostatic ion and electron oscillation perpendicular to B, electromagnetic waves perpendicular to B, cut-off and resonances, hydromagnetic and magnetosonic waves. Application examples: Faraday rotation, pulsar dispersion

Diffusion and resistivity: [5 hours]  
Diffusion and Mobility in Weakly Ionized Gases, Decay of a Plasma by Diffusion, Diffusion Across a Magnetic Field, Collisions in Fully Ionized Plasmas, Bohm Diffusion and Neoclassical Diffusion.

Kinetic theory of plasma: [9 hours]  
The Vlasov-Maxwell equation, The evolution of distribution function, Integrating along the unperturbed orbits, The dielectric tensor, The hot plasma dispersion relation, and Electrostatic waves. Landau damping.

Nonlinear effects in plasmas: [6 hours]  
Ponderomotive force, parametric instabilities, instability threshold, nonlinear Landau damping. Turbulence.

Basic paradigms & applications: [4 hours]

plasma sheath, turbulence reconnection, dynamo, cosmic ray acceleration

Fusion energy: [6 hours]

Magnetic fusion, tokamak, stellarator, Inertial fusion.

**Animesh Kuley****Pre-requisites** :

PH202 (Statistical Mechanics), PH 206 (Electromagnetic Theory)

**References** : 1. Fundamentals of Plasma Physics, by J. A. Bittencourt  
2. Introduction to Plasma Physics and Controlled Fusion, by F F Chen  
3. Plasma Kinetic Theory, by Donald Gary Swanson

**PH 373 ( AUG ) 3 : 0****Introduction to Fluid Mechanics and Plasma Physics**

Boltzmann equation. Derivation of fluid equations. An introduction to stellar dynamics. Important properties of ideal and viscous fluid flows. Gas dynamics. Waves in fluids. Hydrodynamics stability. Turbulence. Plasma orbit theory. Debye shielding and collective behaviour. Waves and oscillations in plasmas. From the Vlasov equation to MHD equations. Flux freezing. MHD waves. Reconnection and relaxation. Dynamo theory.

**Pre-requisites** : None

**References** : [1] Acheson: Elementary Fluid Dynamics  
[2] R. Blandford & K. Thorne: Application of Classical Physics  
[3] F. F. Chen: Introduction to Plasma Physics and Controlled Fusion



**PH 372 ( AUG ) 3 : 0****Radiative Processes in Astrophysics**

Elements of radiative transfer and stellar atmospheres. Theory of grey atmospheres. Covariant formulation of classical electrodynamics. Radiation from accelerated charges. Cyclotron and synchrotron radiation. Bremsstrahlung. Thomson and Compton scattering. Plasma effects. Atomic and molecular spectra. Transition rates and selection rules. Opacity calculations. Line formation in stellar atmospheres.

**Pre-requisites**

None

:

**References** : G. Rybicki & A. Lightman: Radiative Processes in Astrophysics

**PH 301 ( AUG ) 2 : 0****Seminar Course**

We wish to enhance the credit for the seminar course. Under the updated seminar course, we will make it compulsory for all the students taking this course to attend all department colloquia and to give a presentation and a write-up based on one of the topics covered in the colloquia. Also, we plan to include a few lectures on topics such as Research Ethics and Tools for Research. With changes the removal of the workshop course, the total credits in compulsory courses for IPhD students remain the same.

**Pre-requisites** : None

**References** : None

# Instrumentation and Applied Physics\_QT

## Preface

### QT 207 ( AUG ) 3 : 0

#### Introduction to Quantum Computation

Axiomatic quantum theory; Quantum states, observables, measurement and evolution; Qubits versus classical bits; Spin-half systems and photon polarizations; Pure and mixed states; Density matrices; Quantum correlations; Entanglement and Bell's theorems; Turing machines and computational complexity; Reversible computation; Universal quantum logic gates and circuits; Quantum algorithms; Database search; Fast Fourier Transform and prime factorisation.

**Pre-requisites :** None

#### References

Nielsen, M.A. and Chuang, I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2000. Peres, A., Quantum Theory:

### QT 201 ( AUG ) 1 : 0

#### Survey of Quantum Technologies

Introductory lectures by IISc faculty on the variety of developments in quantum technology. Augmented by seminars from leading researchers around the world.

**Pre-requisites**

None

#### References

Online talks.

**QT 209 ( AUG ) 3 : 0****Introduction to Quantum Communications and Cryptography**

Digital and entropy; coding and capacity; General and error and one-time key distribution; optics; Quantisation states; Coherent states; Squeezing and beam-splitters.

communication; Shannon's teleportation; quantum correction pad; Quantum of the

Communication theorems; von Neumann evolution codes; Stabilizer and private key cryptography.

channels; Quantum communication, and quantum superoperators; formalism; cryptography; Geometrical and wave field; Photon number

Information dense channel Errors Cryptography Quantum wave number

**Pre-requisites** : None

**References**

Nielsen M.A. and Chuang I.L., Quantum Computation and

**QT 211 ( AUG ) 1 : 2****Basic Quantum Technology Laboratory**

Intro to RF equipment – VNA, signal generators, AWGs, Oscilloscopes, Basics of Microwave Engineering – Impedance, S-parameters, Characterisation of passive RF components – Cables, terminations, attenuators, directional couplers, RF mixer, filters, circulators and isolators, Python packages from Quantum Optics and Quantum computation – QISKIT and QuTiP, Simulating basic quantum Hamiltonians, Dissipative systems, Quantum circuit simulations.

**Pre-requisites** : None

**References**

1. David Pozar, Microwave Engineering

2. QISKIT and QuTiP programming manual

**QT 204 ( JAN ) 3 : 0****Introduction to Materials for Quantum Technologies**

Recap of basic solid-state physics: Electronic band structure; Phonon- band structure, electron-phonon interactions, electron transport and modeling in nanoscopic devices Topology and Quantum Devices: Semiconductor heterostructures, Two dimensional electron systems, Topological materials, Introduction to Superconductivity Correlations and disorder: Electron-electron interactions, Peierls distortion and transition, Disorder physics, Anderson's localization, Quantum devices through correlations, Magnetic materials, Dielectric materials and ferroelectrics, phase transitions Optics and optical materials: Light-Matter Interaction, introduction to nonlinear optical materials, Optical properties of semiconductors and metals, properties of nanostructured materials, plasmonics.

**Dhavala Suri****Pre-requisites** :

**References** : Solid State Physics by N. Aschcroft and N. D. Mermin Electrons and Phonons: The Theory of Transport Phenomena in Solids by J.Ziman Electronic Processes in Non-Crystalline Materials by N. F.Mott and E. A. Davi.

**QT 299 ( JAN ) 0 : 20****Project**

Introduction to Classical Measurement, Introduction to quantum mechanics through measurement, the quantum measurement postulate and its consequences, standard quantum limits (SQL), types of measurements – direct and indirect measurements, orthogonal, non-orthogonal, quantum non-demolition measurements, linear measurements and amplification, beyond the SQL - parametric amplification. Case studies of measurement – quantized charge measurement, single photon detection, non-demolition method for photon quadrature measurements etc. Control of single quantum systems, introduction to decoherence – decoherence as measurement by environment, characterizing decoherence in qubits, openloop control and stabilization of qubit states. Project

**Baladitya Suri**

**Pre-requisites** : None

**References** : Quantum Measurement by Braginsky and Khalili Quantum measurement by Wiseman and Milburn Mechanics by Landau-Lifshitz.

**QT 202 ( JAN ) 3 : 0****Introduction to Quantum Measurement**

Introduction to Classical Measurement, Introduction to quantum mechanics through measurement, the quantum measurement postulate and its consequences, standard quantum limits (SQL), types of measurements – direct and indirect measurements, orthogonal, non-orthogonal, quantum non-demolition measurements, linear measurements and amplification, beyond the SQL - parametric amplification. Case studies of measurement – quantized charge measurement, single photon detection, non-demolition method for photon quadrature measurements etc. Control of single quantum systems, introduction to decoherence – decoherence as measurement by environment, characterizing decoherence in qubits, openloop control and stabilization of qubit states.

**Baladitya Suri****Pre-requisites**

:

**References** : Quantum Measurement by Braginsky and Khalili Quantum measurement by Wiseman and Milburn Mechanics by Landau-Lifshitz.

**QT 203 ( AUG ) 3 : 0****Physics and Engineering Foundations for Quantum Te**

Introductory lectures by IISc faculty on the variety of developments in quantum technology. Augmented by seminars from leading researchers around the world. Basics of Quantum Mechanics -- Postulates of quantum mechanics, harmonic oscillator, time dependent perturbation theory, Rabi problem, Unitary transformations and Qubit Gates, basics of quantum optics, Coherent states, Wigner distribution, Basics of Electrostatics and of Electrodynamics -- Maxwells equations, light-matter interaction, Dipole approximation, Radiation, circuit lagrangians, transmission line equations. Basics of Solid state physics -- Drude model, Periodic potential and Bloch Theory, Hartree-Fock approximation, Solid state devices.

**Pre-requisites**

:

None

**References**

:

Online

J J Sakurai -- Modern Quantum Mechanics (any edition) talks.

# Mathematical Science\_Int PhD

## Preface

# IISc's Knowledge and E-Learning Network

## Preface

IISc's Knowledge and E-Learning Network

# Artificial Intelligence Stream

## Preface

**E0 270o ( JAN ) 3 : 1**

**Machine Learning**

**Ambedkar Dukkupati**

**Pre-requisites** : None

**References** : None

**E9 241o ( AUG ) 3 : 1**

**Digital Image Processing**

**Pre-requisites** : None

**References** : None

**E0 251o ( JAN ) 3 : 1**

**Data Structures and Graph Analytics**

**Chandramani Kishore Singh**

**Pre-requisites** : None

**References** : None



**E1 277o ( AUG ) 3 : 1****Reinforcement Learning**

Introduction to Reinforcement Learning, Multi-armed bandits, Markov decision processes, Dynamic Programming - Value and Policy Iteration Methods, Model-Free Learning Approaches, Monte-Carlo Methods, Temporal Difference Learning, Q-learning, SARSA, Double Q-learning, Value Function Approximation Methods - TD Learning with Linear Function Approximation, Neural Network Architectures, Deep Q-Network Algorithm, Policy Gradient Methods, Actor-Critic Algorithms.

**Pre-requisites** :

**References** : 1. R. Sutton and A. Barto, Reinforcement Learning, MIT Press, 2'nd Ed., 2018 2. D.Bertsekas, Reinforcement Learning and Optimal Control, Athena Scientific, 2019 3. Selected Recent Papers

**DS 265o ( AUG ) 3 : 1****Deep Learning for Visual Analytics**

Basics of machine learning and computer vision, CNN basics, Loss function and back propagation, Object Recognition, Detection and Segmentation. Recurrent Neural Networks, LSTM, Generative Adversarial Networks (GANs), Self-supervised learning, Transformers, Explainable AI, Adversarial Robustness of Deep models.

**Pre-requisites** :

Basics knowledge of Machine learning and Image processing.

**References** : 1. Dive into Deep learning, Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola (Online) 2. Recent Research papers.

**AI 299o ( AUG ) 0 : 27****MTech Dissertation Project****Chandramani Kishore Singh**

**Pre-requisites** : None

**References** : None

**E1 252o ( JAN ) 3 : 1**

**Linear and Nonlinear Optimization**

**Chandramani Kishore Singh**

**Pre-requisites** : None

**References** : None

**E0 295o ( AUG ) 4 : 0**

**Introduction to Cryptography (Online)**

**Pre-requisites** : None

**References** : None

**E1 294o ( JAN ) 3 : 1**

**Edge and Cloud Systems for Machine Learning Algori**

**Sumit Kumar Mandal**

**Pre-requisites** : None

**References** : None

**E1 286o ( AUG ) 3 : 1**

**Deep Generative Models**

**Pre-requisites :** None

**References :** None

# Data Science & Business Analytics Stream

## Preface

**DA 231o ( AUG ) 3 : 1**

**Data Engineering at Scale**

**Pre-requisites** : None

**References** : None

**DA 226o ( AUG ) 3 : 1**

**Financial Analytics**

**Pre-requisites** : None

**References** : None

**DA 227o ( AUG ) 3 : 1**

**Data Mining**

**Pre-requisites** : None

**References** : None

**DS 261o ( AUG ) 3 : 1**

**Artificial Intelligence for Medical Image Analysis**

**Phaneendra Kumar Yalavarthy**

**Pre-requisites** : None

**References** : None

**DA 218o ( JAN ) 3 : 1**

**Probabilistic Machine Learning: Theory and Applica**

**Punit Rathore**

**Pre-requisites** : None

**References** : None

**DA 299o ( MAY ) 0 : 32**

**DSBA Stream Project**

**Deepak Narayanan Subramani**

**Pre-requisites** : None

**References** : None

**DA 216o ( JAN ) 3 : 1**

**Applied Artificial Intelligence in Healthcare**

**Vaanathi Sundaresan**

**Pre-requisites** : None

**References** : None

**DS 285o ( JAN ) 3 : 1**

**Tensor Computations for Data Science**

**Ratikanta Behera**

**Pre-requisites** : None

**References** : None

**DA 219o ( JAN ) 3 : 1**

**Quantum Computing Methods: Theory and Applications**

**Phani Sudheer Motamarri**

**Pre-requisites** : None

**References** : None

**DA 204o ( AUG ) 3 : 1**

**Data Science in Practice**

**Pre-requisites** : None

**References** : None

**DA 245o ( JAN ) 3 : 1**

**Linear Optimization and Network Science**

**Tarun Rambha**

**Pre-requisites** : None

**References** : None

# Electronics & Communication Engg. Stream

## Preface

**E2 202o ( AUG ) 3 : 1**

**Random Process**

**Pre-requisites** : None

**References** : None

**E2 201o ( JAN ) 3 : 1**

**Digital Communications**

**Chandra R Murthy , Sundeep Prabhakar Chepuri**

**Pre-requisites** : None

**References** : None

**E2 251o ( MAY ) 3 : 1**

**Communication Systems Design**

**Pre-requisites** : None

**References** : None



**E1 245o ( JAN ) 3 : 1**

**Statistical Inference for Engineers and Data Scientists**

**Vaibhav Katewa**

**Pre-requisites** : None

**References** : None

**E1 220o ( AUG ) 3 : 1**

**Linear Algebra**

**Pre-requisites** : None

**References** : None

**E2 299o ( MAY ) 0 : 28**

**MTech(Online) ECE Stream Project**

**Sundeep Prabhakar Chepuri**

**Pre-requisites** : None

**References** : None

**E2 217o ( JAN ) 3 : 1**

**Machine Learning for Wireless Communication**

**Sudhan Majhi**

**Pre-requisites** : None

**References** : None

**E9 246o ( AUG ) 3 : 1**

**Advanced Topics in Image Processing**

**Pre-requisites** : None

**References** : None

**E8 205o ( JAN ) 3 : 1**

**Antennas and Circuits for Emerging Communication a**

**Debdeep Sarkar**

**Pre-requisites** : None

**References** : None