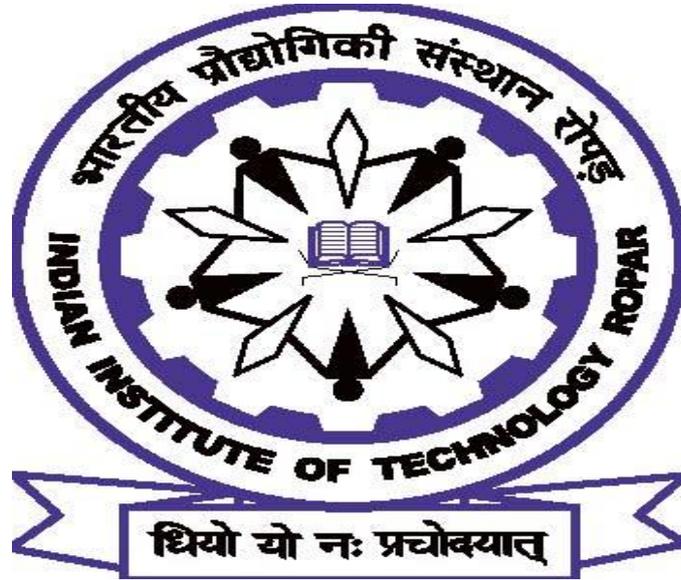


# COURSE BOOKLET

POSTGRADUATE PROGRAMME

2017-18



## COURSE BOOKLET

POSTGRADUATE PROGRAMME 2017-18  
INDIAN INSTITUTE OF TECHNOLOGY ROPAR

# COURSE DESCRIPTION

## 1. Center for Biomedical Engineering

### **BML601 Fundamentals of Human Physiology, 4 (3-0-2)**

*Pre-requisites: NIL*

Introduction to Human Physiology; Homeostasis , Skeletal and Muscular System , Membrane Physiology, Gastro –intestinal system and metabolism , Respiratory Membrane Physiology, Gastro-intestinal system and metabolism, Respiratory system, Circulatory system, Nervous system (includes special sensory mechanisms), Excretory system (Emphasis on Urinary), Endocrine system of the body. LAB: Study of anatomical organ models, Study and identification of stained tissue sections of different mammalian organs, hematological experiments: Preparation and staining of blood film with Leishman's stain, Total blood count , Different count of WBC, Blood grouping (ABO and RH) measurements of lung function test by Spirometer. Check the heart electrical activity by ECG, measurement of electrical activity in response to a nerve's stimulation of the muscle with Electromyography (EMG).

### **BML602 Drug Delivery, 3 (3-0-0)**

*Pre-requisites :A general understanding of organic chemistry and biochemistry principles.*

An overview of pharmacokinetics(PK) and pharmacodynamics (PD);Routes of drug administration including barriers; Membrane transport and BCS classification; Drug targeting and controlled drug delivery; Traditional and novel drug delivery system ; and Biopharmaceutics delivery (assessment of pharmacokinetic parameters).

### **BML603 Fluorescence Spectroscopy in Biomedical Application, 3 (3-0-0)**

*Pre-requisites :NIL*

Basic Concepts, Instrumentation, Time And Frequency domain Life Time measurements, Protein Fluorescence, Energy transfer, Multi-Photon excitation and microscopy, Molecular imaging, Mechanism: Photo induced electron transfer, internal charge transfer, molecular rigidity, quenching, excited state proton transfer, excimer, Solvatochromism, Fluorophores: synthetic design, NIR dyes, Green Fluorescent proteins, Sensing in cellular environment.

### **BML604 Introduction to Advanced Biology, 4 (3-0-2)**

*Pre-requisites :NIL*

#### **Theory:**

**Modern Biology:** An interdisciplinary approach, Organization of life: Simple to complex , The chemistry of cell , Cell biology: Prokaryotes and eukaryotes, Cell division: Replication, mitosis and, meiosis, Fundamentals of gene expression and regulation, Cell signaling, Fundamentals of genetic engineering , Stem cell technology, Introduction to translational medicine: Trends and challenges, Introduction to experimental biology, introduction to data mining and handling of biological databases.

**LAB:** Introduction to safe laboratory practices- Handling of biological materials, Mammalian cell culture , isolation of RNA and proteins from cells and Quantitation, Gene expression analysis using Western blotting , Gene expression analysis using qPCR, Molecular biology: Molecular cloning and analysis.

### **BML606 Biomaterial Tissue Interaction, 3 (2-0-2)**

*Pre-requisites :NIL*

**Theory:** An overview of biomaterials used for fabricating medical devices for hard and soft tissue replacements and drug delivery, biodegradation, and biocompatibility; protein adsorption on device surface; Blood –biomaterial interaction and coagulation ; inflammation and infection; immune system and hypersensitivity ; wound healing; Biomaterial surfaces and the physiological environment ; case studies

**Lab:** basic laboratory skills ; Fabrication of polymeric hydrogels /gels; Characterization of hydrogels /gels ; Drug delivery studies in vitro; Introduction to cell culture; evaluation of cytotoxicity and adhesion; cell encapsulation in hydrogels /gels.

### **BML608 Biomechanics, 4 (3-0-2)**

*Pre-requisites :NIL*

**Module1:** Terrestrial locomotion : jumping , walking, running, gait analysis.

**Module 2:** Skeletal biomechanics: Composition and structure of bone, biomechanical properties of bone, bone fracture, fracture mechanics, functional adaptation, mechanobiology, structure of collagen, ligament, tendon and cartilage, biomechanical properties of ligament, tendon, and cartilage.

**Module3:** muscle and movements: skeletal muscle morphology and physiology, muscle constitutive modeling, whole muscle mechanics, muscle/bone interactions.

**Module4:** cellular biomechanics: introduction to eukaryotic cell, architecture, cytoskeletons, cell – matrix interaction, methods to measure the mechanical properties of cell and biomolecules, methods of cellular biomechanical behavior, mechanotransduction, technique for mechanical stimulation of cells, mechanobiology.

**Module 5:** hemodynamics: blood rheology, large artery hemodynamics, blood flow in small vessels.

**Module6:** the circulatory system : anatomy of vasculature , arterial pulse propagation, the capillaries , the veins, scaling of hemodynamic variables.

### **BML609 Physics of medical imaging, 4 (3-0-2)**

*Pre-requisites: NIL*

The course provides the necessary physics background that underpins day-to-day medical imaging physics activities. It is aimed primarily at new entrants to the profession, but should be of benefit to post-graduate students or post-doctoral research workers, wishing to deepen or re-establish their understanding of the physics of medical imaging.

This course introduces the physics behind most of the common medical imaging modalities including x-ray, ultrasound, CT, PET, SPECT, optical imaging and MRI. There is emphasis on the physics of MR in this course as this is an active area of research in the field. Some math is required, Fourier Transform theory is helpful, but it will be reviewed in the course. The course will provide the student with a good understanding of the strengths and weaknesses of the different imaging modalities, what areas are still being developed, and the key applications of each modality.

### **BML610 Research Ethics and Professional/Scientific Communication, 2 (2-0-0)**

*Pre-requisites :NIL*

Introduction and history of research Ethics; Animal and human experimentation; Data management; Case studies in biomedical research; Ethics for biomedical engineers; Conflict of interest; Collaborative research; Authorship and publication , including intellectual property rights; General principals of communication in formal contexts; Strategies for writing effectively; Guidelines for using formal language; and project writing.

### **BML612 Tissue Engineering and Regenerative Medicine, 3 (3-0-0)**

*Pre-requisites :NIL*

**THEORY:** Principle of tissue engineering and Regenerative medicine; Tissue dynamics and Cell sources: Stem cells; Cell matrix and cell-cell interaction; Tissue Fabrication: Scaffolds/Biopolymers; Bioreactors-Bone& cartilage Tissue engineering; Biomaterials for wound healing; vascular tissue engineering; Brain tissue engineering ; Biomimetics engineering: Organoids; Clinical application.

## 2. DEPARTMENT OF CHEMICAL ENGINEERING

### **CHL601: CHEMICAL ENGINEERING THERMODYNAMICS, 3 (3-0-0)**

*Pre-requisites: NIL*

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 dynamics.

### **CHL602: Advanced Transport Phenomena, 4 (3-1-0)**

*Pre-requisites: NIL*

Introduction to the field of transport phenomena including molecular mechanisms of momentum transport (viscous flow); energy transport (heat conduction); mass transport (diffusion); Vector and tensor; Constitutive relations for heat, mass and momentum transfer; Conservation equations of heat and mass transfer; Scaling and Approximation techniques; Reynolds' transport theorem; Derivation of equations of motion; Lubrication approximation; Creeping flow; Laminar flow at high Reynolds number, Boundary layer separation, flow past bluff bodies; Forced convection heat and mass transfer in unconfined laminar flow; Transport in buoyancy driven flow.

### **CHL603: Engineering Applications of Rheology, 4 (3-0-2)**

*Pre-requisites: NIL*

Classification of fluids, Time-dependent, time-independent and visco-elastic fluid behaviours Rheometry for non-Newtonian fluids: various approaches for rheological measurements and their applications; Laminar flow of non-Newtonian fluids in pipes and non-circular cross-sections, Criteria for transition from laminar to turbulent flow, Friction factors for transitional and turbulent flows; Particulate flow: Drag force and terminal falling velocity on a sphere in non-Newtonian fluids, particle shape and wall effects, Heat transfer characteristics of non-Newtonian fluid flow in pipe (isothermal and isoflux), Effect of viscous energy dissipation; Laminar boundary layer flow of non-Newtonian fluids over a plate, Transition criteria for laminar to turbulent boundary layer flow, Heat transfer in boundary layer flow; Mixing and agitation.

### **CHL604: Chemical Reactor Analysis and design, 4 (3-1-0)**

*Pre-requisites: Basic Knowledge of Chemical Reaction Engineering*

**Introduction and Basic concepts:** Review of Kinetics of homogeneous and heterogeneous chemical and biochemical reactions, single and multiple reactions, order & molecularity, rate constant, elementary and non elementary reactions, Reaction equilibrium, equilibrium constant and equilibrium compositions.

**Isothermal reactor design:** Design of single and multiple reactions in batch reactor, plug flow reactor, Continuous Stirrer Tank Reactor (C.S.T.R), and semi batch reactor, packed bed reactors and fluidized bed reactors.

**Non isothermal reactor design:** General design procedure, optimum temperature progression, adiabatic operation, non adiabatic operation, semi batch reactors. Steady state and unsteady state operations in C.S.T.R and Plug flow reactors, Stability of steady state, linearized stability analysis, Reactor stability (with special reference to C.S.T.R), parametric sensitivity and runaway behaviour, optimization of chemical reactors.

**Non Ideal Flow:** Residence time distribution of fluid in vessel, E, F & C Curve, Mean residence time, Reactor modelling using RTD, Dispersion model, N Tanks in series model, micromixing and macromixing.

**Reactors:** Fixed Bed Catalytic Reactor, Single and multibed adiabatic reactors, Multitubular fixed bed reactor, Monolith reactors.

### **CHL605 Heterogeneous Catalysis And Catalytic Reactors, 4 (3-0-2)**

*Pre-requisites: Basic Knowledge of Chemical Reaction Engineering*

Introduction and Basic concepts in heterogeneous catalysis, Classification of catalysts, Application of

catalyst functionality concepts for control of reaction selectivity and kinetic models.

Steps in catalytic reaction, Effect of heat and mass transfer on reaction rate and its role in heterogeneous catalysis, Diffusion in Porous Catalyst, Concept of effective diffusivity and thermal conductivity of porous catalysts, Thiele modulus and effectiveness factor, falsified kinetics, Mechanism and kinetics of heterogeneous reactions.

Selection, Preparation and Characterization of catalysts, Acid base catalysts, Supported metal catalysts and Zeolites, their Application, Promoter and inhibitors, Catalysts Deactivation/Poisoning, various deactivation models.

Catalysis Reactors: Commercial Reactors (Fixed bed, fluidized bed, trickle bed, slurry etc.), Reactor Modeling.

Industrially important Green catalysts and processes such as oxidation, processing of petroleum and hydrocarbons, synthesis gas and related process, Chemistry and engineering aspects of catalytic processes along with problems arising in industry.

## 3. Department of Chemistry

M.Sc.

### Core courses

#### **CYL411 Concise Inorganic Chemistry, 3 (3-0-0)**

Representative Chemistry of Main-Group Elements: Chemistry of Boron: boranes, bonding and topology of boranes, synthesis and reactivity, carboranes and metallocarboranes. Chemistry of Silicon: organosilicon compounds, silicates and aluminosilicates; Chemistry of halogens and noble gases: recent trends, CFC's and ozone layer. Theories of bonding. Crystal-field and Molecular orbital, effects of ligand-field (Spectrochemical series, consequences of d-orbital splitting). Absorption spectra of metal complexes and magnetochemistry, Reaction mechanism of transition metal complexes and electron-transfer. Unusual Compounds of Main-Group Elements and Transitional metal complexes. Organometallic Chemistry and applications of organometallics in organic synthesis; Role of metal complexes in biology and environment; Introduction of bio-inorganic chemistry: heme, non-heme, Fe-S proteins.

#### **CYL412 CONCISE ORGANIC CHEMISTRY, 3(3-0-0)**

Introduction to organic molecules:

Nature of bonding in aliphatic, alicyclic, aromatic and heterocyclic compounds; Aromaticity in benzenoid and non-benzenoid compounds. Alternant and non-alternant hydrocarbons; Nomenclature of polycyclic compounds including bridged, spiro and other special structures.

Oxidation: With Cr and Mn compounds; with peracids and other peroxides; with periodic acid,  $\text{Pb}(\text{OAc})_4$ ,  $\text{Hg}(\text{OAc})_2$  and  $\text{SeO}_2$ .

Reduction: Catalytic hydrogenation; metal hydride, dissolving metal and hydrazine based reductions. Cram-Felkin-Anh model.

C-C Bond Formation: Acyloin, Aldol, Stobbe, Claisen, Knoevenagel and Benzoin condensations, Darzen's glycidic ester synthesis; Dieckmann reactions, Wittig reaction, Reformatsky reaction. Acetoacetic ester and malonic ester synthesis. Acylation reactions. Enamine reactions. Gattermann aldehyde synthesis. Michael and Mannich reactions.

Carbohydrate Chemistry: Introduction, Structural elucidation and some typical reactions of mono and discharides

Heterocyclic Chemistry: Furan, Pyrrole, Thiophene, Pyridine, Indole, quinolines etc.

Photo and pericyclic chemistry:

Brief introduction, Norrish type I and type II cleavage, photoreduction, Paterno-Buchi reaction, cis-trans isomerisation, Chemistry of vision.

Electrocyclic, Diels-Alder, Sigmatropic and Ene reactions.

Problems: Based on multistep reactions involving C-C bond formation, oxidation and Reduction (to be solved in the class and supplemented by home assignments).

#### **CYL414 An Introduction to Biochemistry ,3(3-0-0)**

*Pre-requisites : Basic understanding of organic reactions, and structure and function of lipids, carbohydrates, proteins, enzymes, and nucleic acids.*

Cellular, chemical, physical, and genetic foundations of life; Role of water and buffers in biological systems; Role of biomolecules, like lipids, carbohydrates, nucleic acids, and proteins, in sustaining life processes; Enzymes and catalysis of biochemical reactions; Vitamins as coenzymes; and Common metabolic pathways and ATP synthesis.

#### **CYL415 Numerical Methods for Chemists 3(3-0-0)**

Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient; Data fitting by least square; Truncation and round-off errors, Step-size dilemma, Difference table (Pascal's triangle)

Numerical Integration: Quadrature rule, Interpolating polynomials (Lagrange's), Weights, Mid-point, Trapezoidal, Simpson's rule of integration, Adams' Predictor-Corrector method. Roots of equations-

Newton-Raphson and Secant methods, Bisection and False-point methods, Bracketing method. Numerical solution of ordinary differential equations- Initial value problems, Euler's method, Taylor and Runge-Kutta methods, Modified Euler method, Error estimates. Curve fitting- Least square fit algorithm, Cubic Splines.

Matrices and Linear systems of equations: Forward, Backward substitution, LU- factorization, pivoting, Gaussian Elimination, Gauss-Jordan Elimination, Jacobi and Gauss-Seidel methods. Eigenvalue problems. Statistical analysis of data.

Vectors and vector spaces, matrices and determinants, eigen values and eigen vectors, similarity transformations, ordinary differential equations- first and second order. Solution of differential equations by power series method: solutions of Hermite, Legendre and Laguerre differential equations, Orthogonality properties and recurrence relations among special functions: associated Legendre functions and Spherical Harmonics. Introduction to Fourier series and Fourier transforms, convolution theorem.

### **CYL416 Reaction Rates and Classical Thermodynamics, 3(3-0-0)**

Reaction Rates: Rates of chemical reactions, rate expressions. Methods of determining rates and orders of reactions. Theories of reactions rates and their application in photochemistry, solution kinetics, etc. Kinetics involves in complex reactions, heterogeneous catalysis, enzyme kinetics etc. Potential energy surfaces and reaction dynamics.

Classical Thermodynamics: Concepts involve in thermodynamics, laws of thermodynamics, energy, entropy, availability, partial molar properties, activity, fugacity etc. Thermodynamics involves in chemical/ionic equilibrium, and ideal/non-ideal solutions, and combustion process. Science and engineering applications including thermal analytical techniques based on thermodynamics.

### **CYL417 Quantum Chemistry & Group Theory, 3(3-0-0)**

*Pre-requisites :NIL*

Review of old quantum theory. Postulates of quantum mechanics, wave functions and probabilities, operators, matrix representations, commutation relationships. Solution of the Schrödinger equation for exactly solvable problems such as particle-in-a- box, particle-in-a-ring, harmonic oscillator, rigid rotor and the hydrogen atom, including shapes of atomic orbitals; orbital and spin angular momenta; Tunneling. Valence bond and Molecular orbital theories, Hückel approximation; approximate techniques: Variational and Perturbation. Applications to Spectroscopy - atomic and molecular structure, molecular spectroscopy. Chemical applications of group theory, symmetry elements, point groups, character tables, selection rules, Woodward-Hoffman rules.

### **CYP401 Practical – I, 3(0-0-6)**

*Pre-requisites :NIL*

Experiments in thermodynamics, kinetics, phase rule, electrochemistry and exposure to various spectroscopic and analytical characterization techniques.

### **CYP402 Practical -2, 3(0-0-6)**

*Pre-requisites :NIL*

Experiments in kinetics, catalysis, electrochemistry, receptors, spectroscopy, quantum chemistry, organometallic chemistry, complex organic reactions and biochemistry. Exposure to various spectroscopic characterization techniques.

Synthesis and characterization of organic compounds, isolation and estimation of proteins and DNA; and Gram staining of bacterial cultures

### **CYL403 Practical -3, 3(0-0-6)**

Experiments in inorganic, organometallic chemistry and solid-state materials synthesis, spectroscopic characterization, evaluation of absorption and emission properties of materials, solvent extractions, qualitative and quantitative inorganic analysis.

### **CYL404 Practical -4, 3(0-0-6)**

*Pre-requisites :NIL*

Computational methods involving structure optimization, property calculation, orbital energies, potential energy surface computation and data analysis with error minimization followed by curve fitting.

### **CYL421 Advanced Organic Chemistry 3, (3-0-0)**

*Pre-requisites: CYL412*

Stereochemistry: Brief Introduction, Dynamic stereochemistry: Conformation and Reactivity. Various chemo, regio and stereoselective reactions.

Reactive Intermediates :

Carbenes and carbenoids

Radicals: Structure, reactivity, selectivity and mechanisms of radicals and radical based reactions, involving various functional groups. Radical cations and radical anions.

Carbocations: Nonclassical carbocation. Sigma and pi-participation.

Mechanistic and Stereochemical Aspects of: Baeyer-Villiger, Claisen (including Johnson-Claisen, Ireland-Claisen, Eschenomser, Overman

modifications) Cope, and oxy-Cope, Wittig rearrangements (both 1,2 and 2,3 Wittig rearrangements); ene and metalloene reactions; (2+2), (3+2) and (4+2) cycloadditions; Barton reaction.

Organometallic Chemistry: Mechanism and stereochemistry of various reactions. Palladium based reactions such as Heck, Stille, Suzuki, Sonogashira, Buchwald-Hartwig couplings; Tsuji-Trost C-C bond formations; Ni and Sn-catalysed reactions.

Enzymatic Reactions: Mechanistic and stereochemical aspects of hydrolases (including esterases and lipases), oxidoreductases.

Green Chemistry: Concepts and applications Amino Acids and Peptides: Physical properties of amino acids, Synthesis of  $\alpha$ -amino Acids and peptides, End group analysis of peptides. Classification and Structures of some natural products such as terpenoids, steroids, alkaloids and prostaglandins.

### **CYL423 Solid State Chemistry 3(3-0-0)**

Crystalline and amorphous solids; crystal systems, point groups, space groups: methods of characterizing crystal structure, types of close packing -hcp and ccp, packing efficiency, radius ratios; polyhedral description of solids; representative structure types. Preparative methods: Solid state reaction, chemical precursor method, co-precipitation, sol-gel, metathesis, self-propagating high temperature synthesis, ion exchange reactions, intercalation reactions; hydro/solvothermal and high pressure synthesis. Characterization: Thermal analysis: TGA, DTA, DSC. Properties; electrical: Band theory of solids -metals and their properties; semiconductors - extrinsic and intrinsic, Hall effect; thermoelectric effects, insulators - dielectric, ferroelectric, pyroelectric, piezoelectric and multiferroic properties. Magnetic properties: Dia, para, ferro, ferri, and antiferro magnetic types; soft and hard magnetic materials; selected magnetic materials such as spinels, garnets, perovskites, and transition metal- lanthanide compounds; magnetoresistance. Optical properties: Luminescence of d- and f- block ions; structural probes; up and down conversion materials and also, including other important properties of solids.

### **CYL424 Electrochemistry and Statistical Thermodynamics, 3(3-0-0)**

Electrode Kinetics: Electrode/Electrolyte interface- Thermodynamics of Electrified Interfaces, The structure of Electrified interfaces, Electron transfer under an interfacial electric field -Reaction rate on over potentials Derivation of Butler-Volmer Equation and its implications, Tafel plot, Electrode kinetics involving the semiconductor/solution interface, Techniques of electrode kinetics, Multi step reactions.

Statistical Thermodynamics: The statistical method, probability of distribution, Molecular partition functions- Translational, rotational and vibrational partition functions. Internal energy and statistical entropy, Concept of ensembles, Canonical ensemble, Boltzmann distribution, Thermodynamic quantities and canonical partition function. Grand canonical ensemble, Fermi-Dirac and Bose-Einstein distributions. Partition function and their evaluation and relation with thermodynamic properties, evaluation of entropy of gases by statistical method. Real gases, intermolecular potential and virial coefficients. Debye and Einstein theory of heat capacity of solids. Structure and thermal properties of liquids, Pair correlation functions.

### **CYL426 Coordination Chemistry , 3(3-0-0)**

*Pre-requisites :NIL*

Basic concepts, periodic properties, molecular symmetry, isomerism, HSAB concept, acid and bases, thermodynamic stability, step-wise and overall binding constant, chelate and macrocyclic effect. Structure, bonding and properties of: transition metal complexes, lanthanides and actinides. Theories of Bonding: VBT, CFT and their limitations; splitting of d-orbitals, CFSE of d1 to d10 system. Charge transfer transitions, colors, origin of spectra, term symbols, selection rules for electronic transitions, Orgel diagram, calculations of Dq, B and Nephelauxetic effect. Inorganic reaction mechanism: substitution reactions, trans effect, water exchange, hydrolysis, inner and outer sphere electron transfer mechanism, magnetochemistry. pi acceptor ligands, details of transition metal ions, role of metal complexes in biology and environment.

### **CYL427 Interpretative Molecular Spectroscopy, 3(3-0-0)**

*Pre-requisites :NIL*

Electronic spectroscopy (UV-visible, fluorescence and phosphorescence): Simple chromophoric groups, conjugated and aromatic systems. Characteristic absorption of organic and inorganic compounds. Infrared spectroscopy: Characteristic group frequencies of organic and inorganic molecules. Mass spectrometry, the production and analysis of positive ions, molecular ions, application of isotopic abundance measurements, fragmentation modes and rearrangement of ions. Mass spectra of certain chemical classes. Nuclear magnetic resonance spectroscopy of compounds containing <sup>1</sup>H, <sup>13</sup>C, <sup>19</sup>F and <sup>31</sup>P nuclei. Identification of organic and inorganic compounds using combination of spectral data.

### **CYL511 Instrumental Analysis , 3(3-0-0)**

Principle, Instrumentation, Applications, Analysis and Interpretation of the data for the following techniques: AAS, XRD, Thermoanalytical techniques: Differential Scanning Calorimetry (DSC), Thermogravimetry (TG), Thermo mechanical analysis (TMA): Principles instrumentation and applications Microscopy: SEM, TEM, Cryomicroscopy, AFM, confocal microscopy.

Electron Spectroscopy: X-ray photoelectron (XPS) and Auger electron spectroscopy (AES), secondary ion mass spectrometry.

### **CYL513 Polymer Chemistry, 3(3-0-0)**

*Pre-requisites: CYL412, Concise Organic Chemistry*

Introduction and applications of polymers, molecular weight distributions, various experimental methods (GPC/SEC, solution viscosity, VPO, light scattering) to determine relative and absolute molecular weight distributions, chain growth and step growth mechanisms and kinetics, ionic polymerization, living polymerization, stereochemistry of polymers, free radical copolymerization (random, block, alternate and graft copolymers), kinetics and mechanisms of free radical copolymerization, polymerization conditions and polymer reactions, thermal, mechanical and solution properties of polymers, thermoplastics, thermosets and elastomers, conducting polymers, branched polymers (star, dendritic and hyperbranched polymers).

### **CYL514 Environmental Chemistry, 3(3-0-0)**

Concepts and terms, segments of environment, cyclic pathways in the environment, the chemistry of natural water and determination of its major parameters, pollution and purification of water, chemosensors and biosensors, concepts of water treatment: toxic heavy metals, anions, surfactants, detergents, pesticides, DDT and other toxic compounds of environmental concern. Air pollution classification, Biochemical effects of hazardous air pollutant, Ways to reduce exposure, exhaust emission control, Air pollution control method, Control device and equipments, Particulate control, Vehicular emissions and control, Air pollution triggered by the conventional energy production and environment friendly method for the energy production. Meteorology transport and dispersion of air pollution: Adiabatic Lapse rate and its mathematical derivation, Atmospheric stability, Introduction to hazardous waste management and resource conservation, Atmospheric Chemistry, Solid, Liquid, other waste management.

### **CYL515 Bio-organic Chemistry, 3(3-0-0)**

*Pre-requisites :NIL*

A comparison of organic reactions carried out in laboratory and in biological systems; nature of biomolecular interactions; amino acid, peptide and protein synthesis and properties; enzyme mechanisms, catalytic side chains and cofactors; stereospecificity and rate enhancement in enzyme catalysed reactions; nucleoside, nucleotide, and nucleic acid; nucleosides as therapeutic agent and target of therapeutic agent.

### **CYT530 Project – I, 10(0-0-20)**

Methodology in research, original work of acceptable standard. Dissertation with presentation.

### **CYS500 Seminar 2 CREDITS**

Current topics in chemistry including related topics in project work undertaken.

### **CYT540 Project – II, 15(0-0-30)**

*Pre-requisites: Nil*

Methodology in research, original work of acceptable standard. Dissertation with presentation.

### **CYT599 MS Thesis, 40 (40(0-0-40)**

Methodology in research, original work of acceptable standard. Thesis with presentation will be evaluated by the committee.

### **Elective Courses (MSc/PhD)**

#### **CYL601 Concepts in Physical Chemistry: (3-0-0) 3 Credits**

Theory of reaction rates, Kinetics of complex reactions, Reaction kinetics in solution and surfaces, Different types of reactor system, and selection of reactor based on reactions. Thermodynamics and its usefulness, Laws of thermodynamics, Maxwell relation, Gibbs-Helmholtz equation, Van't Hoff isotherm, Clapeyron-Clausius equation, Chemical Potential, Thermodynamics of Mixing, Fugacity. Electrolytic conductance and transference, EMF of reversible cells, concentration cells, liquid junction potential, potentiometric titrations, overvoltage, and polarography. Ideal and Real solutions, Raoult's law, Colligative properties of Solution, Nernst Distribution Law, Ionic Equilibrium, Concept of pH and Solubility product. Failures of classical mechanics and introduction to quantum principles, Schrödinger equations for hydrogen atom, approximate methods. Concepts involved in solid state chemistry, Crystalline and non-crystalline materials, Metallic crystal structures of cubic and hexagonal types, Polymorphism and allotropy, Ceramic crystal structures of AX, AX<sub>2</sub>, ABX<sub>2</sub> and AB<sub>2</sub>X<sub>4</sub> types, Silicate ceramics, Defect in crystal structures.

#### **CYL602 Concepts of Organic Chemistry: (3-0-0) 3 Credits**

C-C bond formation: Alkylation of enolates, enamines and hydrazones, organometallic reagents; Grignard, organo lithium, cuprates, Umpolung, heteroatom stabilized anions, rearrangements; sigmatropic, ene reaction.

C=C bond formation: Aldol Condensation, Wittig Reaction, Peterson Olefination, Julia-Lythgoe Olefination, Carbonyl Coupling Reactions (McMurry Reaction), Tebbe Reagent, Shapiro and Related Reaction, Elimination and Dehydration, From Diols and Epoxides, From Other Alkenes-Transition Metal Catalyzed Cross-Coupling and Olefin Metathesis.

Oxidations: Metal Based Reagents; Chromium Reagents, Manganese Rgts., Silver, Ruthenium, other metals, Non-Metal Based Reagents; Activated DMSO, Peroxides and Peracids, Oxygen/ ozone, others. Reductions: Hydrogenation, Boron Reagents, Aluminium Reagents, Tin Hydrides, Silanes, Dissolving Metal Reductions.

Functional Group Interconversions: sulfonates, halides, nitriles, azides, amines, esters and lactones, amides and lactams.

Protecting Groups: Hydroxyl groups, Ketones and aldehydes, Amines, Carboxylic Acids

### **CYL603 Concepts of Inorganic Chemistry: (3-0-0) 3 Credits**

Use of electrochemistry in inorganic chemistry; some useful aspects of main group chemistry; Coordination Chemistry:- Bonding, Spectra, Magnetism, Structure and Reaction Mechanism, Supramolecular Chemistry, Molecular Magnetism; Organometallic Chemistry, Introduction to catalysis, Inorganic Chemistry of Biological systems

### **CYL604 Electronic Structure Calculation: (2-0-2) 3 Credits**

Review of the basics of quantum chemistry. The Born-Oppenheimer approximation. Semi-empirical and Ab initio methods. Molecular dynamics. Variational methods. Hartree-Fock approximations. Self-consistent field method. Restricted and unrestricted Hartree-Fock. Gaussian- and Slater basis functions. Hartree-Fock-Roothaan method. Correlations: Many-body perturbation theory, Configuration interaction and Coupled-Cluster methods. Density-functional theory: Local density approximation (LDA). Beyond LDA. Hybrid methods. The Mulliken charges, Orbital population. Vibration analysis. Plane wave formalism. Potential energy surfaces and Quantum dynamics. Review of commercial and non-commercial codes for ab initio electronic structure calculations.

### **CYL605 Quantum Molecular Reaction Dynamics: (3-0-0) 3 Credits**

Macroscopic and microscopic processes - Cross section and impact parameter, Relationship between rate constants and cross sections, Attractive interaction potentials in bimolecular reactions, Determination of cross sections.

Potential energy surfaces - Two dimensional representations, Features on potential energy surfaces, Experimental probing of potential energy surfaces and reaction mechanisms, Molecular dynamics calculations.

Transition state theory - Partition functions and chemical equilibrium, Transition state theory (TST), Application of TST to unimolecular decomposition, RRKM theory

### **CYL611 Advances In Catalysis, 3(3-0-0)**

*Pre-requisites: Instructor decides*

Basic principles involves in homogenous catalysis, heterogeneous catalysis, phase transfer catalysis, ionic liquids, electrocatalysis etc. Principles of Green chemistry. Application of catalysts in petrochemical industry, reforming and refining, value added chemicals, environmental protection, autoexhaust catalysts, fuel Cell, biodiesel production etc.; Catalysts poisoning and regeneration. Some selected category of homogenous and heterogeneous catalysts from recent literature. Mechanistic investigations using in-situ spectroscopic techniques. Analytical techniques to monitor the progress of catalytic reactions.

### **CYL612 Molecular Recognition, 3(3-0-0)**

Supramolecular Chemistry, EDTA – a classical supramolecular host (crown ethers, lariat ethers, podands, cryptands, spherands, calyx[n]arenes), nature of non-covalent interactions, co-operativity, chelate effect, pre-organization, receptor design, synthetic strategies for receptor development cation and anion recognitions and receptors for ionpair recognition, Membrane Transport, Solvent extraction, Factors effecting the solvent extraction and membrane transport.

### **CYL613 The Chemistry of Metal Carbon Bond, 3 (3-0-0)**

Bonding models in compounds with M-C and M-M bonds, Applications of these compounds in catalysis and organic synthesis, organometallic polymers. Organometallic chemistry of transition metals – Introduction-donor/acceptor ligands, organometallic catalysis –Oxidative Addition and reductive elimination, Hydrogenation, Cross coupling reaction, C-H activation, Olefin Metathesis – olefin isomerization.

### **CYL614 Principals of Biochemistry: (3-0-0) 3 Credits**

Cellular, chemical, physical, and genetic foundations of life; Role of water and buffers in biological systems; Carbohydrates and glycoconjugates on cell surfaces; Lipids, biological membrane and transport, and biosignaling; Nucleic acids and recombinant DNA; Protein structure and function, and enzymes; Carbohydrate metabolism, electron transport, oxidative phosphorylation, photophosphorylation, lipid, amino acid, and nucleotide metabolism; Hormonal regulation and integration of metabolic pathways and metabolic disorders; Genes and chromosomes, DNA metabolism (replication, repair, and recombination), RNA metabolism (transcription), protein metabolism (translation), and regulation of gene expression.

### **CYL621 ADVANCED QUANTUM CHEMISTRY, 3(3-0-0)**

*Pre-requisites: CYL425 Quantum Chemistry and Group Theory*

Time-independent perturbation theory, degenerate states, variational method, Hellmann-Feynman theorem. Spectra and structure of helium atom, term symbols for atoms, Hartree-Fock equations, self-consistent field method and coupling schemes. Born-Oppenheimer approximation, hydrogen molecule ion, hydrogen molecule: valence bond and molecular orbital methods, polyatomic molecules and hybridisation. Conjugated p-systems and Huckel theory, frontier orbital theory, semi-empirical CNDO and ab initio methods, configuration interaction. The concept of groups, symmetry operations and symmetry elements in molecules, matrix representations of symmetry operations, point groups, irreducible representations and character tables.

### **CYL622 Applied Electrochemistry, 3(3-0-0)**

Conversion and Storage of Electrochemical Energy: Fuel Cells and Batteries

Corrosion: Introduction to corrosion, Forms of Corrosion, Corrosion monitoring and prevention methods

Controlled Potential techniques: Polarography, Pulse voltammetry, Stripping analysis, Flow analysis

Environmentally Oriented Electrochemistry: The environmental Situation, Electrochemical Advantage, photoelectrochemical cells, The fixing of CO<sub>2</sub>, Removal of Wastes.

### **CYL623 Heterogeneous Catalysis And Interfacial Phenomena, 3(3-0-0)**

*Pre-requisites: Instructor decides*

General aspect of catalysis at surfaces, adsorption process at solid surfaces, thermodynamics and kinetics of surface catalyzed reactions, essential steps in heterogeneous catalysis, adsorption isotherms. Introduction to solid state chemistry with respect to heterogeneous catalysis. Creation of catalytic surfaces. Destructive and non-destructive techniques for surface investigations. Catalysts deactivation and regeneration. Some well known catalytic applications of heterogeneous catalysts in petrochemical industry and fine chemical synthesis including metal mediated organic transformations.

### **CYL624 Chemistry Of Natural Products, 3(3-0-0)**

*Pre-requisites: CYL412, CYL421*

Biosynthetic aspects and Synthesis of selected natural products of biological and structural importance: Discussions on synthetic methods, strategies towards these natural products mostly in chiral forms will be discussed in detail. The natural products include carbocycles and heterocyclic moieties containing structures ranging from 3-membered to macrocycles, and complex natural products such as Taxol, rapamycin, lejimailde B etc.

### **CYL625 Inorganic Material Chemistry, 3(3-0-0)**

*Pre-requisites: CYL411 for MSc students: Concise Inorganic Chemistry*

Synthesis, structure, properties, structure-property correlations and potential applications of inorganic solid state materials. Inorganic clusters, organic-inorganic hybrid materials, molecular clusters to materials. Inorganic materials for energy storage and sustainability including nanostructured materials. Porous materials: Hydrogen economy, CO<sub>2</sub> sequestration applications. Magnetic materials: single molecule magnets, photo-luminescent materials based on lanthanide compounds, thermoelectric materials, ferroic and multiferroic compounds. Other relevant examples from the recent literature.

## **CYL626 Synthetic Organic Chemistry, 3(3-0-0)**

*Pre-requisites: CYL412, CYL421*

Asymmetric Synthesis, Organo Catalysts, Metathesis and Application. Principles of retrosynthetic analysis: Linear and convergent synthesis, Synthesis under steric control, Regio- and stereoselective synthesis, Basic synthetic methods. Methodologies for the construction of 3-7 membered homo- and hetero-cyclic rings, medium and large rings. Application in natural product synthesis.

## **CYL701 Molecular Spectroscopy: (3-0-0) 3 Credits**

**Infrared Spectroscopy:** Vibrational spectra and rotational spectra-selection rule and energy calculation, Instrumentation, Examining IR spectra, Characteristic functional group IR analysis, In-situ IR spectroscopy for the identification of reaction intermediates etc.

**UV-Vis:** Instrumentation, Electronic transitions, Woodward-Fisher-Scott rules, application to various organic functional groups, differentiation of position isomers, stereo-chemical factors effecting electronic spectra.

**Fluorescence spectroscopy:** Instrumentation, Excitation and relaxation processes, Mechanism of PET, ICT, FRET; stacking, Keto-enol tautomerism, applications.

**NMR:** Instrumentation, Chemical and magnetic non-equivalence – chemical shift (factors effecting) – coupling constant – spin splitting – spin decoupling or rapidly exchangeable protons – relaxation process – NOE, 2D NMR.

**X-Ray Diffraction:** X-rays, Diffraction, Types of solid and order, Brief-introduction of crystal structure, Diffraction from crystalline materials-Braggs law, Practical aspect of X-ray diffraction, Crystal structure determination of cubic and hexagonal structure, Determination of Crystallite size etc.

**Mass Spectroscopy:** Ionization methods, Mass Analyzer, Fragmentation and Interpretation, Hyphenated MS Techniques.

## **CYL702 Chemistry of Novel Heterogeneous Catalytic Materials: (3-0-0) 3 Credits**

Conventional synthesis methodology: precipitation and co-precipitation, sol-gel process, soft template method, hard template method etc. Concept of synthesis of zeolite, ordered mesoporous materials, pillared clays, nanoporous carbon materials and metal oxides. Synthetic methodology for supported catalysts: deposition-precipitation, ion-exchange and impregnation, grafting and anchoring of transition metal complexes to inorganic oxides, immobilization in porous matrix. Spectroscopic techniques for the physico-chemical characterizations of materials. Selected catalytic and sensing applications of these novel materials.

## **CYL703 Strategies in Supramolecular Chemistry: (3-0-0) 3 Credits**

Molecular Devices, Molecule- Based Electronics, Molecular Analogues of Mechanical Machines, Crystal Engineering, Biological Inspiration for Supramolecular Chemistry, Semiochemistry in the Natural World, Biochemical Self-Assembly, Solid-State Inclusion Compounds, Network Solids, Self-Assembly, Zeolites, Metal-Organic Frameworks, Molecular Knots and Nanochemistry.

## **CYL704 Chemical Synthetic Strategy of Organic Reactions: (3-0-0) 3 Credits**

Cycloaddition Reactions – Principles, Mechanism (metal mediated and catalytic version), Applications, Catalytic cycles, Ligand designing for catalytic cycloaddition reaction, Click chemistry, Pauson-Khand reaction and their applications. Asymmetric catalysis, Macromolecules synthesis, Organo catalysts, Metathesis and their applications, Photon induced electron transfer reactions. Strategic application towards natural products synthesis.

## **CYL705 Bioconjugates: Techniques and Applications (3-0-0) 3 Credits**

Bioconjugates, rationale for bioconjugate synthesis, comparison with prodrugs, influence of bioconjugation on pharmacokinetic properties with emphasis on drug targeting, and an overview on general use of bioconjugates in diagnostics, therapeutics, and prophylaxis

Solid-phase and solution-phase bioconjugation, chemoselectivity, role of non-degradable and degradable linkers, and chemical linkages used in bioconjugation

Biophysical techniques used for bioconjugate purification and characterization

Antibody and enzyme, protein, nucleic acid, carbohydrate and lipid, polymer conjugates, and their applications

Evaluation of bioconjugate activity in vitro and in vivo Biofunctionalization of surfaces.

### **CYL706 Advances in AB INITIO METHODS, 3(3-0-0)**

*Pre-requisites: Instructor decides*

Ab initio methods covering areas such as the correlation technique, Perturbation theory, the Generalized Valence Bond method, Many electron wavefunctions, Hartree-Fock Approximation, Multi-Configurations Self Consistent Field, Configuration Interaction, Coupled Cluster theory, Pair and Coupled Pair Theories, Many body Green Function.

### **CYL707 Non-adiabatic effects in chemical dynamics, 3(3-0-0)**

*Pre-requisites: Instructor decides*

Mathematical framework to treat electronic NACTs and their conical intersections, concepts of adiabatic and diabatic frameworks. Non-adiabatic transition: Landau-Zener-Stueckelberg Theory, Rosen-Zener-Demkov Theory, Coriolis Coupling and Dynamical state representation, Solution of linear curve crossing problem, Non-adiabatic Tunneling, Non Curve-crossing, Two-state theory for Time-dependent processes, Multi-dimensional problems, Conical Intersection, Semiclassical Methods including Trajectory Hopping method, Bound states in Continuum.

## 4. Department of Civil Engineering

### Ph.D Courses

#### **CEL601 Modeling, Simulation and Optimization (3-1-0)4 Credits**

*Pre-requisites :NIL*

**System and Models:** System and system modeling; Classification of models: physically based and black box, linear and non-linear , time invariant and time –variant ,lumped , state space and distributed; model parameters; Direct and inverse problems; Role of optimization.

**Optimization:** Linear , Non linear and Dynamic programming ; Analytical , gradient based and soft computing algorithms

Regression Analysis: linear and multiple , tests of goodness of fit, parsimony criterion

**Model building:** Choice of model Structure : A prior considerations, selection based upon preliminary data analysis , balance concept , comparing model structures ,parsimony criterion ; Model calibration :Role of historical/experimental data, direct and indirect methods, validation

**Simulation:** Random variables: Discrete and continuous, probability density and distribution function , expectation and standard deviation , covariance and correlation , stochastic and Markov processes, commonly used theoretical probability distributions , fitting distributions to raw data , Chi –square and kolmogrov – smimov’s tests of the goodness of fit, central limit theorem , algorithms for generation of realization of random variables and stochastic processes:

Monte Carlo simulation : Basic concepts, generation of realization of forcing function , simulation of output realizations and their statistical interpretation , evaluation of definite integrals, examples

#### **CEL602 Earthquake Resistant Design of Structures, 3 (2-1-0)**

*Pre-requisites : Knowledge of Design of Structure*

Basic Concepts: Seismic performance of structure and structural components during earthquakes; Ground motion parameters; Response spectrum, design spectrum

Seismic Design Philosophy: Concept of strength , Overstrength and ductility, Concept of equal displacement and equal energy principles, Capacity design; seismic design consideration in buildings with irregularities

Seismic Analysis of Buildings: Equivalent static analysis, response spectrum analysis,modeling concept of reinforced building .

Seismic Design of Building Components: seismic resistant properties of reinforced concrete; Seismic behavior and design of linear reinforced concrete elements; codal provision.

#### **CEL603 Geotechnical Earthquake Engineering, 3 (3-0-0)**

*Pre-requisites :Soil Mechanics and Foundations*

**Introduction:** Scope and objective; Nature and types of earthquake loading ; importance of geotechnical earthquake engineering,

**Engineering Seismology:** Basic Seismology, Earthquake, List of major earthquakes, Causes of earthquakes , Sources of earthquakes data , Elastic rebound Theory, faults , Plate tectonics, Seismography and Seismogram , Prediction of Earthquakes , Protection against earthquake damage , Origin of Universe, Layers of Earth , Theory of Continental Drift , Hazards due to Earthquakes.

**Size of Earthquake:** Magnitude and Intensity of Earthquake, Modified Mercalli Intensity scale, Measuring of Earthquake, Earthquake Magnitude-Local (Richter)magnitude, surface wave magnitude, Moment magnitude, Seismic energy, Correlations. Spectral Parameters: Peak Acceleration, Peak Velocity, Peak Displacement, Frequency Content and duration, Spatial Variability of Ground Motion, Attenuation Relationships, Fourier Amplitude Spectra Arias Intensity.

**Introduction to Wave Propagation:** Elastic response of continua (one, two and three-dimensional wave equations).

**Seismic Hazard Analysis:** Magnitude Indicator, Segmentation, Deterministic Seismic Hazard Analysis(DSHA), Probabilistic Seismic Hazard Analysis (PSHA),Earthquake Source characterization, Gutenberg- Richest recurrence Law, Predictive relationships, temporal uncertainty, Probability computations, Seismic Hazard Curve, Logic tree methods

**Dynamic Soil Properties:** Introduction, Laboratory Tests: Resonant column, Ultrasonic Pulse Test, Cyclic Triaxial Test, Field Tests: Seismic Refraction, Seismic Refraction, Seismic Refraction, Seismic Cross-Hole, Seismic down-hole tests

**Site Response Analysis and Liquefaction:** Ground Response Analysis, Transfer Function. Non-linear approach. Site Classification and Liquefaction-Mechanism. Evaluation of Liquefaction Procedure.

**Introduction To Theory of Vibrations:** Undamped Free Vibration, Damped Free Vibration, Undamped Forced Vibration, Damped Forced Vibration, Critical Damping Coefficient, Damping Ratio, Logarithmic Decrement, Resonance, Overtuned and Undertuned Design.

### **CEL604 Advanced Geotechnical Engineering, 3 (3-0-0)**

*Pre-requisites :Soil Mechanics and Foundations*

**Soil composition and soil structure:** Soil formation, Types of soil and their characteristics, particle sizes and shapes, their impact on engineering properties, soil classification system, soil structure, clay mineralogy, Flocculation and dispersion of clay particles, diffused double layer theory, soil-air water interaction, consistency, soil compaction, concept of effective stress.

**Permeability and Seepage:** Permeability, Seepage force and effective stress during Seepage, Laplace equations of fluid flow for 1-D,2-D and 3D seepage, flow nets, Anisotropic and non-homogeneous medium, confined and unconfined seepage, Hydraulic uplift force under a structure, Filter design, Flow net construction for earth dams

**Compressibility And Consolidation:** stress and displacement in soil mass, pore water pressure due to undrained loading, Terzagah's 1-D consolidation theory, Numerical solution for one-dimension consolidation, one-dimension consolidation with viscoelastic models, Determination of coefficient of consolidation  $c_v$ , Normally and overconsolidated soils, compression curves, secondary consolidation. Radial consolidation, calculation of one-dimensional consolidation settlement, sand drains.

**Stress-Strain relationship and Shear strength of Soils:** Stress state, Mohr's circular analysis and pole, principal stress space, stress paths in p-q, Mohr-coulomb failure criteria and its limitations, correction with p-q space, stress-strain behavior: isotropic compression and pressure dependency, confined compression, large stress compression, definition of failure, interlocking concept and its interpretations, drainage conditions, triaxial behavior, Stress state and analysis of UC,UU,CU,CD, and other special tests, stress paths in triaxial and octahedral plane, Elastic modulus from triaxial tests.

**Introduction To Soil Modeling:** Basics Theory of Elasticity, General state of stress in three-dimensions in cylindrical coordinate system, Three-dimensional Mohr's stress Circle, Strain Transformation, Octahedral Strains, mohr's circle for Strain, Equation of Compatibility for Strain; Pore pressure and stress strain response of soil due to undrained loading, Volume Change Behavior, Peak State and Dilatancy, Rowe's Dilatancy Theory; Critical State Parameters, Failure line p'-q space and

$e'$ - $p$  space, Soil Yielding, Strain Hardening and Strain Softening; Introduction to failure theories of soils: Linear Elastic Model , Hyperbolic Model , Plaxis Soil Hardening Model, Mohr- Coulomp, Drunker - Prager , Tresca , Von- Mises, Cam Clay Model , their relative merits and demerits and applicability for different types of soil; Computer Applications; Suitability of these models in real – time geotechnical problems such as consolidation, retaining walls, sheet pile walls, reinforced earth walls, cut slopes, embankments and foundations.

### **CSS600 PG Seminar in Computer Science - Non Credit**

*Pre-requisites: Nil*

Current topics in computer science and engineering. Student can select any recent topic of research in computer science and present the seminar on that topic. Student is supposed to do literature survey and also submit a report along with the seminar.

## 5. Department of Computer Science & Engineering

### MS (Research) and PhD Courses

#### **CSL601 Computational Complexity: (3-0-0) 3 Credits**

Diagonalization, Space Complexity, Time Complexity, Polynomial Hierarchy and Alternations, Boolean Circuits, Interactive proofs, Cryptography and One-way functions, Introduction to PCP Theorem and hardness of approximation. Lower Bounds for Decision Trees. Circuit Lower Bounds, Proof Complexity. Lower Bounds in Algebraic Models of Computation. Complexity of Counting. Natural Proofs. Pseudorandom Constructions: Expanders and Extractors.

#### **CSL602 Computational Geometry: (3-0-2) 4 Credits**

Duality between points and lines, Geometric Searching: Point location, Slab and Chain methods, Planar Separator methods, Multidimensional binary tree (k-D trees), Segment trees, Range trees, Iterated Search and Fractional Cascading, Convex hulls: Graham's Scan, Jarvis's march, Divide-and-conquer algorithms. Gift-wrapping method, Convex hulls in three and more dimensions, Clustering, Closest Pair Problem, Locus Approach, Voronoi Diagrams, Computational aspects of Voronoi diagrams, Higher-order Voronoi diagrams, Euclidean Minimum Spanning Tree problem, Euclidean Traveling Salesman problem, Hidden Surface problem, Linear Programming, The rectangle intersection problem, Randomized Algorithms in Computational Geometry: Random Sampling, Incremental Construction and Backward Analysis, Combinatorial and discrete geometry.

#### **CSL603 Machine Learning (3-0-2) 4 Credits**

*Prerequisite: CSL201*

Linear models for regression —maximum likelihood estimation (MLS), least squares, regularized least squares, Linear models for classification —discriminant functions, Fisher's linear discriminant, logistic regression, Bayesian learning —maximum a posterior (MAP) estimation, naïve Bayes classifier, discrete and continuous attribute scenarios, Neural networks —feed —forward networks, error back propagation, regularization in neural networks, Kernel methods —radial basis function networks, support vector machines (SVM), multiclass SCMs, relevance vectors machines (RVM), Non —parametric methods —K-nearest neighbours, Parzen windows, Graphical models —Bayesian networks, Markov random fields, inference in graphical models, Combining models —boosting, bagging, committees, Model selection —performance evaluation metrics, experimental design, clustering —K-Means clustering, mixture of Gaussians, expectation maximization for mixture models (EM), Hierarchical clustering, Dimensionality reduction —principal component analysis, linear discriminant analysis.

Laboratory exercise will emphasize implementation and analysis of machine learning algorithms in matlab/R/octave.

#### **CSL604 Artificial Neural Networks: (3-0-0) 3 credits**

Neuron models, single layer networks and unconstrained optimization methods, LMS, perceptrons, multilayer perceptrons, back-propagation, generalization and overfitting with MLP, regularization and cross-validation, optimization methods for MLPs, radial basis function networks, The self organizing map (SOM), variants of SOMs, Learning vector quantization, temporal processing with feedforward networks, hopfield network, boltzmann machine, recurrent networks, deep learning networks.

#### **CSL606 DATA STRUCTURES aND ALgoRITHMS (3-0-0) 3**

*Pre-requisites NIL*

Stacks, queues, and linked lists, Trees (insertion, deletion, search, etc.), Balanced Trees (AVL, red-black, etc.), Hashing and collision resolution, Sorting, Graph traversal, Divide and conquer, Dynamic programming, Greedy algorithms, String algorithms, Max-flow min-cut, Bipartite matching, Number-theoretic algorithms, NP-completeness, Approximation Algorithms, Randomized algorithms.

### **CSL607 Multimedia Systems(2-0-4) 4**

*Pre-requisites CSL 201/Data Structures and Algorithms*

Foundation for students to build multimedia systems. Multimedia systems involve automated analysis and fusion of multiple types of data such as text, images, video, audio, social networks, and various sensors. The course covers state-of-the-art tools and techniques for multimedia content processing, compression, networking, fusion, summarization, search and retrieval applicable to different areas such as social media, homeland surveillance and privacy. The objective of this course is to prepare students to develop systems using multi-source information commonly and readily available in the form of Big Data in Internet of Things and Smart Cities paradigms.

### **CSL608 Foundations of Computer Science (3-0-0) 3**

*Pre-requisites NIL*

Sets and Relations, Functions and Cardinality, Logic and Proofs, Groups and semigroups, Finite automata and regular expressions, Pushdown automata and context-free grammars, Turing machines, Undecidability, Time and Space complexity, Hierarchy theorems, NP-completeness, Cook-Levin theorem, Savitch's theorem, PSPACE-completeness, Randomized complexity classes.

### **CSP609 PG SOFTWARE LAB (0-0-6)3**

*Pre-requisites: Data structures, programming in c/c++*

Vim/emacs, HTML, CSS2; preparing reports and presentations using latex, beamer, drawing software (e.g. inkscape, xfig, open-office), and graph plotting software (e.g., pyplot, gnuplot); programming support: IDE (e.g. eclipse, netbeans), Makefile, debugging tools, profiling tools (e.g. gprof, prof), version management (SVN/Git), code review; Basic Java, Java collections, interfaces; Unix basics: shell, file system, permissions, process hierarchy, process monitoring, ssh, rsync; Unix tools: e.g. awk, sed, grep, find, head, tail, tar, cut, sort, Bash scripting: I/O redirection, pipe; Programming using scripting language (e.g. python); Web programming: PHP/Javascript, mySQL; Optional topics (may be specific to individual students project): intro to sockets, pThreads, mobile apps. A project would be included which touches upon many of the above topics..

### **CSL610 Advanced computer Architecture(3-0-2)4**

*Pre-requisites: A UG course in computer architecture(equivalent to CSL211 of IIT Ropar)*

Classifications into parallel computing paradigms: Instruction level parallelism, data level parallelism, thread level parallelism; super scalar architectures: out of order, multiple issue, speculation, branch prediction; VLIW architectures and compiler techniques to extract parallelism; data level parallelism: vector, SIMD, GPU architectures; memory architectures for high performance computers; Multi-core : shared memory architectures, cache coherence; multi-processor: distributed memory, interconnection network, programming issues; introduction to cloud architecture.

### **CSL611 Real-Time Systems: (3-0-2) 4 Credits**

Typical Real-Time applications, hard versus soft real-time systems, a reference model of Real-Time systems, Real-Time scheduling, priority driven scheduling of periodic tasks, scheduling aperiodic and sporadic jobs in priority driven systems, multiprocessor scheduling, real time communication and operating systems.

### **CSL612 Artificial Intelligence: (3-0-2) 4 Credits**

Search methods, A\*, heuristic functions, local search, search trees, game playing (minimax search), constraint satisfaction, Knowledge representation (propositional, first order), knowledge inference, planning, reasoning with uncertainty, Bayesian networks, Dempster-Shafer theory, HMMs, learning, PAC learning, artificial neural networks, inductive logic programming statistical learning.

### **CSL613 Algorithms in Bioinformatics: (3-0-2) 4 Credits**

Primer on molecular biology, motif finding, global and local sequence alignment, multiple sequence alignment, partial and double digest problem, genome rearrangements, phylogeny problems (large and small parsimony), RNA folding, protein folding, Comparative Genomics, SNPs, analysis of Microarray data.

### **CSL614 Computer System Security: (3-0-2) 4 Credits**

This course will provide a broader understanding of various security aspects relevant for personal and enterprise software systems. Some of the topics covered in this course are: Need and goals for computer security, security threats. Building blocks for cryptography: symmetric and asymmetric key cryptography, cryptographic hash functions, digital signature schemes etc, with representative applications for each. Problems in network security; kinds of attacks, PKI, key exchange protocols, example protocols such as PGP, Kerberos, IPSEC/VPN, SSL, S/MIME etc. Protocol vulnerabilities: examples of protocol vulnerabilities such as in TCP/IP, denial of service attacks etc. Tools for network security such as firewalls and intrusion detection systems. Security in operating systems: models for access control, confidentiality, integrity, and hybrid models of access control such as Bell-LaPadula, Biba, Chinese Wall etc., discretionary v/s mandatory access control, low-level protection mechanisms. Malicious code such as viruses, worms, Trojan horses; how they work and how to defend against them. We will also discuss some case studies such as Android security model, Java access control policy specifications, SELinux security model and implementation. Topics such as program flaws/bugs which have security implications such as buffer overflows, race conditions etc. will also be discussed.

### **CSL615: Advanced Image Processing: (3-0-2) 4 Credits**

In-depth study of advanced methods and research topics of current interest in image processing and analysis. Topics include, but are not limited to: shape representations, deformable models, statistical shape analysis, scale-space, deterministic and stochastic spatio-temporal image models, transform domain processing, robust statistics and non-linear digital filtering. Applications to image restoration, registration, enhancement, segmentation, motion estimation, image compression and tomography.

### **CSL616: Wireless AD-HOC Networks (3-0-2) 4**

**Pre-requisites: A course in Computer networks**

Wireless networks: Introduction to wireless ad-hoc networks, Cellular networks, wireless mesh networks, wireless sensor networks.

Mobile ad-hoc networks: Introduction to MANETs, MAC protocols for MANETs, Basic routing protocols for MANETs (AODV, DSR, DSDV, etc.), Securing ad-hoc networks

Delay-tolerant networks: Introduction to DTNs, Routing protocols for DTNs (Epidemic, PROPHET, Spray-and-Wait, CBR, etc.), Cooperations in DTNs

Vehicular Networks: Introduction to VANETs, Infrastructureless vehicular networks, Intelligent transportation system, Routing in Vehicular adhoc networks

Wireless body area networks: Introduction to WBAN, Positioning of WBANs, WBAN specific protocols

### **CSL617: DIGITAL IMAGE PROCESSING & ANALYSIS (3-0-2)4**

*Pre-requisites CSL201*

Digital image processing techniques for enhancement, compression, restoration, registration, reconstruction, and analysis. Image Enhancement in Spatial Domain: Gray Level Transformation, Histogram Processing, Spatial Filters; Image Transforms: Fourier Transform, Other Transforms; Image Enhancement in Frequency Domain; Colour Image Processing; Image restoration; Image Registration: Rigid/Non-Rigid Transformations; Image Compression; Image Segmentation: edge detection, Hough transform, region based segmentation; Morphological operators; Representation and Description; Features based matching and Bayes classification; Introduction to some computer vision techniques; Imaging geometry, shape from shading, optical flow;

### **CSL618: COMPUTER VISION (3-0-2)4**

**Pre-requisites: NIL**

Introduction to computer vision, Filters and edge detection, Keypoints and feature descriptors, camera imaging geometry, stereo, motion estimation and tracking, face analysis, image classification, scene understanding, and deep learning with neural networks.

### **CSL619: SYSTEM LEVEL DESIGN AND MODELING (3-0-2)4**

*Pre-requisites : Computer Architecture, Digital design Understanding of operating system and compiler is useful (CSL211, CSL333)*

Systems design challenges, various abstraction models, system level design methodologies, models of computation, system modelling, specification languages, processor description languages, system synthesis, software synthesis: code generation, system partitioning and hardware software codesign, platform based design, hardware synthesis, processor synthesis, memory synthesis, power modelling, thermal modelling. Performance, power optimizations at system level, verification at system level, system level design practices.

Students would be exposed to various software available (in academia as well as in commercial space) for system level modelling.

### **CSL631 Physics of Medical Imaging: (3-0-0) 3 Credits**

The course provides the necessary physics background that underpins day-to-day medical imaging physics activities. It is aimed primarily at new entrants to the profession, but should be of benefit to post-graduate students of postdoctoral research workers, wishing to deepen or re-establish their understanding of the physics of medical imaging. This course introduces the physics behind most of the common medical imaging modalities including x-ray, ultrasound, CT, PET, SPECT, optical imaging and MRI. There is emphasis on the physics of MR in this course as this is an active area of research in the field. Some math is required, Fourier Transform theory is helpful, but it will be reviewed in the course. The course will provide the student with a good understanding of the strengths and weaknesses of the different imaging modalities, what areas are still being developed, and the key applications of each modality.

**CSL701 Approximation Algorithms: (3-0-2) 4 Credits** Combinatorial Algorithms: Set Cover, Steiner Tree, Traveling Salesman Problem, Multi-way cut, Knapsack, Bin Packing, Scheduling, Euclidean Traveling Salesman Problem. LP-based Algorithms: Set Cover, Maximum Satisfiability, Scheduling, Multi-cut and Integer Multi-commodity Flow, Multi-way Cut, Sparsest Cut, Steiner Forest, Steiner Network, Facility Location. Semidefinite Programming: Max Cut, 2-Satisfiability. Approximation of Counting problems, Hardness of Approximation.

### **CSL702 Randomized Algorithms: (3-0-2) 4 Credits**

Moments and Deviations, Tail Inequalities, Probabilistic Method, Markov Chains and Random Walks, Polynomial Identity Testing, Perfect Matchings, Interactive Proof Systems, Randomized Data Structures: Skip Lists, Hash tables, Universal hash functions and their applications. Randomization in Geometric Algorithms. Randomized Algorithms for Minimum Spanning Tree, Min-Cut and All-pairs Shortest Paths. Approximate Counting: Counting Perfect Matchings in bipartite graphs. Randomized Parallel and Distributed Algorithms: Maximal Independent Set. Number Theory: Randomized Primality Testing.

### **CSL703 Combinatorial Optimization: (3-0-2) 4 Credits**

Linear programming, Simplex Algorithm, Duality, Computational considerations for the Simplex algorithm, The primal-dual algorithm, Primaldual algorithms for maximum flow and shortest paths, Ellipsoid Algorithm, Interior-point methods, Minimum Spanning Trees, Matroids, Shortest Paths, Dijkstra's Algorithm, Maximum flow, Ford-Fulkerson Algorithm, Edmonds-Karp Algorithm, Push-Relabel maximum flow algorithms, Multi-commodity flows. Minimum Cost Flow: Primal dual algorithms, Bipartite matching, Algorithms for matching in general graphs, Weighted bipartite matching, Nonbipartite weighted matching problem, Integer programming, Total unimodularity, Gomory cuts, Cutting plane methods and branch-and-bound. NP-completeness and NP-complete problems.

### **CSL704 Advanced Operating Systems: (3-0-2) 4 Credits**

Topics include, but are not limited to: distributed operating systems, fault tolerance, synchronization, communication, distributed and shared memory, recent research breakthroughs in operating systems research.

**CSL705 Constraint Programming: (3-0-2) 4Credits**

Constraint satisfaction, propagation, search algorithms, global constraints, interval constraints, symmetry in constraints, constraint logic programming, applications to scheduling, planning, routing etc.

**CSL706 Advanced Software Architecture: (3-0-2) 4 Credits**

This course is intended to provide the needed breadth as well as depth in software architecture concepts and practices. Such knowledge is required to build dependable complex software systems. Some of the topics that we will study in this course are: What is software architecture and its role in software engineering, Architectural styles and techniques for designing and implementing them, Models for characterizing and reasoning about architectures, Understand system qualities such as security, performance, and reliability, How to use quality specifications to drive system design, Documenting software architecture, Evaluating software architecture, Architecture reuse. Design activities will be centered around the above-mentioned topics, but in context of some practical/contemporary problem.

**CSL707 Advanced Topics in Contemporary Computing Platforms: (3-0-2) 4 Credits**

Enterprise software applications today handle massive amounts of data. Their availability, scalability and other quality requirements have become much more demanding, which has led to the overall increase in complexity of such applications. At the same time, the computing platforms also keep evolving B virtualization based and cloud computing platforms are some of the examples. Major goal of this course is to impart some experience to the students in dealing with the design issues relevant to modern enterprise class of application. Emphasis is on imparting skills that will allow students to leverage the contemporary computing platforms such as cloud to address the above issues. Design activities will be centered around the above-mentioned topics, but in context of some practical/contemporary problem.

**CSL708 Advanced Topics in Internet Technologies: (3-0-2) 4 Credits**

The Internet is being used for a wide variety of application areas such as e-publishing, e-commerce, open learning etc. The goal is to give students some experience in dealing with those challenges that are unique to Internet based software systems. Some of the key topics include: Concurrency in Internet applications, Handling unpredictable load variations, Information security issues, Reliable and stateful user experience on top of unreliable connections and stateless protocols, Middleware frameworks for building Internet applications, Leveraging modern computing platforms such as cloud, Supporting multi-modal user interfaces. This course will offer significant hands-on activities for building Internet applications. Design activities will be centered around the above-mentioned topics, but in the context of some practical/contemporary problem.

**CSL709 Network Science: (3-0-2) 4 Credits**

Milgram's small world experiment (6 degrees of separation), Properties of real world networks and what do they hint? , Influence in social networks, strength of weak ties, modeling economic systems, community detection in networks, modeling the spread of epidemics in human networks, centrality measures and their applications, webgraphs: 2 pivotal results/observations, Navigation on networks.

**CSL710 Algorithms Exemplified: (3-0-2) 4 Credits**

Bare essential conceptual details of the problem, Programming techniques that reap better insight into the problem, Benevolent tools that are user/programmer friendly to solve the problem: Data structures, Sorting and Searching, Techniques in Linear Algebra, Optimization Techniques, Fourier Transforms. Students who are expected to perform data analysis/programming will find the course indispensable. While 70% of the course will comprise of most frequently used tools/techniques the rest 30% will be tailored to the needs of the student in accordance to the branch/discipline he/she belongs.

### **CSL712 Advanced Machine Learning: (3-0-0) 3 credits**

Advanced computational approaches to learning, Latent Models, Bayesian Inference, Exact Inference, Variational Inference, Time Series Prediction, Hidden Markov Models, Dynamic Bayesian Networks, Markov Random Fields, Kernel Methods, Advanced Neural Networks, Transfer Learning, Active Learning, Deep Learning, Collaborative Filtering, Boltzmann Machines, Feature Selection, Dimensionality Reduction, Manifold Learning, Nonnegative Matrix Factorization and Spectral Clustering.

### **CSL713: Game Theory in Wireless networks (3-0-0)3**

*Pre-requisites: CSL343*

Game theory: Introduction to game theory, Non-cooperative and cooperative games, Repeated games, Stochastic games, Stackelberg games, Evolutionary games, Rock-scissors-paper games, Bayesian games, Cooperative games, Coalitional games, Auction theory

Applications: Applications of repeated games, stochastic games, stackelberg games, evolutionary games, rock-scissors-paper games, bayesian games, cooperative games, coalitional games and auction theory in Wireless networks.

### **CSL715: BIOMEDICAL IMAGE PROCESSING & ANALYSIS (3-0-2)4**

Imaging Modalities: X-Ray, Ultrasound, MRI, CT, EEG. Visualization: Slicing , volume/Surface Rendering ,Multimodal Overlays: Image Reconstruction :Analytical and Iterative Algorithms; Image Enhancement : Non –linear filtering , Anisotropic Diffusion ; Image Segmentation: Clustering ,Adaptive Thresholding ,Level –Sets , Bayesian Estimation ,Scale –Space ; Shape Analysis; Descriptors ,Deformable Models, Bayesian Models; Image Registration :Rigid/Non Rigid Transformations, Similarity Metrics , Optimization & Interpolation ; Image Compression: Wavelet /ROI/HYBRID Lossless Techniques , Image Retrieval : Visual & Semantic Image Descriptors , Similarity Metrics.

### **CSL716: ADVANCED COMPUTER VISION (3-0-2)4**

*Pre-requisites: CSL618 Computer Vision*

Recent works in filters and edge detection, feature descriptors, large scale face analytics, large scale image classification, body pose and human action recognition, deep learning based scene understanding, image captioning, computer vision and interaction and visual question answering.

### **CSL717: Affective computing & Interaction (2-0-4)4**

*Pre-requisites: NIL*

Theory of emotions from neuroscience and psychology viewpoints, automatic emotion analysis for intelligent computer systems, avatars and emotion synthesis, state-of-art in affective computing, human computer interaction, social robots and human-robot interaction, human-human interaction analysis.

### **CSL718 Artificial Neural networks (3-0-2)4**

*Pre-requisites :CSL603 – Machine Learning*

Perceptron, multi-layer perceptron, deep feed forward networks, back propagation, optimization algorithms for deep feedforward networks, regularization for deep feedforward networks, convolutional neural networks, recurrent networks, long-short term memory, autoencoders, restricted Boltzmann machines, generative models, and adversarial networks, applications in computer vision, natural language processing, speech processing, and recommender systems, tensorflow/theano.

### **CSL719 : ADVANCED ALGORITHMS(3-0-0)3**

*Pre-requisites: For UG students: CSL 356 , For PG students: CSL 606*

Advanced Data Structures, LP and simplex algorithm, Primal-dual algorithms, Approximation algorithms, Randomized algorithms, Geometric algorithms, Spanning trees and matroids, Parallel and distributed algorithms.

### **CSL799 Independent Study, (3-0-2) 4 Credits**

This course will contain material that is research related, and not offered in other courses. A course outline along with details of the work to be performed one independent study can count towards the degree requirements.

### **CSL809 Special Topics in Complex Networks, 4 (3-1-0)**

This is special topic course in complex networks with the emphasis on centrality measures, community detection and contagion dynamics on a complex network. The syllabus comprises of nearly 30 papers that are included in the references section. This course assumes that the student is familiar with all the concepts that are part of CSL 709 network science course.

### **CSL811 Special Topics in Social Computing (3-1-0) 4 Credits**

*Prerequisite: Network Science (CSL709)*

Introduction to social computing, Crowdsourced Platforms, Twitter Behaviour and Social Structure, data mining and knowledge discovery of social interactions, signals and data that are the byproduct of social media services such as search engines social network sites, blogs, micro-blogs, wikis, etc. The course topics include, but are not limited to: web data mining, knowledge discovery on the web, web analytics, web information retrieval, ranking algorithms, recommender systems, human computation, models and theories about social networks, large graph and link-based algorithms, social marketing, monetization of the web, security/privacy issues related to social computing.

### **CSP797 M. Tech project I, (0-0-24)12**

*Pre-requisites: Nil*

Carrying out a research and/or development project; involves doing detailed literature survey, feasibility study, preparing work plan, executing according to work plan, writing detailed report and giving presentations.

### **CSP798 M. Tech project II, (0-0-32) 16**

*Pre-requisites: CSP797*

This course is continuation of M Tech Project I. Student is suppose to executing according to work plan, finish the project, write detailed report and giving presentation to defend the work done. In case of research project student is encouraged to publish the result in conference/journal. In case of implementation oriented project students are encouraged to release the work in open-source domain.

## 6. Department of Electrical Engineering

### M.TECH.

#### **EEL501 POWER CONVERTER ANALYSIS AND DESIGN, 3 (3-0-0)**

*Pre-requisites: NIL*

Recent trends in power electronics and applications. Role of power electronics in energy, drives and commercial applications.

**Semiconductor devices as switch:** Ideal switch, Diode, Thyristor, BJT, IGBT, MOSFET, VI characteristics, Equivalent circuit model for steady state, dynamic characteristics, Suitability of devices in applications. Design of gate driver circuits, snubbers, thermal aspects of the device.

**Magnetics:** Design of high frequency inductor and transformer.

**DC-DC Converters :** Design and analysis of buck , boost and buck boost converts and cuk converters . Closed loop control of DC-DC converts. voltage and current mode control . Applications. Introduction to digital control of DC- DC converters.

**AC- DC converters :** Controlled Rectifiers (converters ): Single phase / Three phase, Half wave/full wave, half controlled / fully controlled converters with R, RL and REL loads , Continuous and discontinuous current operations- Evaluation of performance parameters . Effects of source inductance – power factor improvement techniques – twelve pulse converters- Dual converters.

**DC- AC Converters:** Single phase, three phase inverters, PWM control of inverters, sinusoidal PWM, space vector PWM, evaluation of performance parameters. Multilevel inverters , three level Neutral point converters , cascaded inverters, flying capacitor configuration . Resonant converters . Introduction to digital control .

**AC- AC Converters:** AC voltage controllers, Cycloconverters, harmonic analysis and matrix converters.

#### **EEL502 – HV Power Equipment, 3 (3-0-0)**

*Prerequisite: Basic Principles of Electrical Engineering , Electromechanics*

Power transformers, equivalent circuit, surge phenomenon, standing and traveling wave theory , ladder network representation , shot circuit forces , impulse testing , diagnostics and condition monitoring of transformers, natural frequencies and its measurement , modern techniques . Introduction to HV switching devices , electric arcs, shot circuit currents, Transient Recovery Voltage , Circuit Breaker types , air , oil and SF6 Circuit Breaker , shot circuit testing.

### MS (R)

#### **EEL611 – Advanced Physical Electronics, 3 (3-0-0)**

Review of quantum mechanics, E-k diagrams, effective mass, electrons and holes in semiconductors, band diagram of silicon, carrier concentration, carrier statistics, carrier transport, junction devices(P-N junction, Metal –semiconductor junctions, solar cells etc), MOS capacitor as a building block for MOSFETs (Ideal MOS, real/Non ideal MOS, band diagrams, C-V characteristics, electrostatics of a MOSCAP), MOSFET, I-V characteristics, scaling, short channel and narrow channel effects, high field effects, Transport phenomenon in nanoelectronic devices (CNTFETs, Graphene Transistors)

#### **EEL612– Advanced Semiconductor Devices, 3 (3-0-0)**

MOS Capacitor as a building block for MOSFETs (Ideal MOS, Non-Ideal MOS), CV and IV technique MOSFET IV characteristics, Scaling, Short Channel and Narrow Channel Effects, High Field Effects, Gate oxide thickness scaling trend, SiO<sub>2</sub> vs High-k gate dielectrics. Integration issues of high-k, Interface states, bulk charge, band offset, stability, reliability - Qbd, SOI - PDSOI and FDSOI, Vertical

transistors - FinFET and Surround gate FET, Thickness measurement techniques: Contact - step height, Optical - reflectance and ellipsometry, AFM, Characterization techniques for nanomaterials: FTIR, XRD, AFM, SEM, TEM, EDAX etc., Optoelectronic devices, MESFETs, HBTs, HEMTs, MODFETs

### **EEL613– Topics In VLSI Fabrication Technology, 3 (3-0-0)**

Overview of Semiconductor IC Process technologies. Crystal growth (Czochralski, Float Zone, polishing, gettering, challenges) Oxidation (kinetics, Deal-Grove model, rate constants, high pressure oxidation, dopant effects, two and three dimensional effects, defects). Deposition techniques (vacuum evaporation, sputtering, CVD, LPCVD). Epitaxy (including MBE, MOCVD, CBE, UHV-CVD). Diffusion (Fick's model, concentration dependent models, field effect, band-gap narrowing effect, anomalous effects). Ion implantation (Ion stopping, range distributions, damage, annealing, high energy implants). Rapid thermal annealing. Lithography (optical, e-beam and x-ray; resists). Etching (wet chemical, dry reactive ion-etching, anisotropic etches, defect delineation). Interconnect technology

### **EEL614 Digital IC Design, 3 (3-0-0)**

Field-effect transistors: MOS capacitor, NMOS and PMOS transistors, i-v characteristics, channel length modulation, body-effect, MOSFET biasing, capacitance in MOS transistors; MOS based circuit design: NMOS inverter and its classification, NMOS logic gates, power dissipation, dynamic behavior; CMOS logic design: CMOS inverter, static and dynamic behavior, logic gates using CMOS, minimum gate size, static and dynamic latches and registers, optimization of sequential circuits, cell-based design methodology, timing issues; Modeling of high-speed interconnects: Interconnect parameters, electrical models – lumped versus distributed, SPICE based interconnect models; MOS based memory circuits: Design of memory circuits, RAM, basic memory cell, sense amplifiers, address decoders, cascade buffers.

### **EEL615 Synchrophasor Technology & ITS Applications In Power, 3 (3-0-0)**

Synchrophasor Technology- basic architecture and communication requirement, Phasor and frequency estimation, wide area monitoring and control in real time : basic principles, Transient stability monitoring and control, power oscillation monitoring and control, wide area power system stabilizers, synchrophasor applications in power system protection and emergency control, hybrid state estimation, Real time monitoring and control voltage stability, fault detection and location using synchronized measurements, Model development and validation using synchronized measurements

### **EEL616 HVDC and Flexible AC Transmission Systems, 3 (3-0-0)**

General aspects of DC transmission, converter circuits and their analysis, DC link controls, faults and abnormal operation and protection; Mechanism of active and reactive power flow control; Basic FACTS controllers: SVC, STATCOM, TCSC, TCPAR, UPFC; Modeling of FACTS Controllers; System static performance improvement with FACTS controllers; System dynamic performance improvement with FACTS controllers

### **EEL617 Transients in Power Systems, 3 (3-0-0)**

Aims and Objectives, Introduction, Switching Transients, Over voltages due to switching transients - resistance switching , load switching, waveforms for transient voltage across the load and the switch, Lightning transients, Theories in the formation of clouds and charge formation, mechanism of lightning discharges and characteristics of lightning strokes, Computation of transients , Traveling wave concept, step response, Bewely's lattice diagram

### **EEL618 Advances in HVDC Transmission Technology, 3 (3-0-0)**

Overview of HVDC Projects World Wide ,Developments in High Voltage, High Power Fully Controlled Semiconductors, HVDC Transmission System Configurations, Back-to-back, Monopolar, Bipolar and Multi-Level HVDC Systems, Concepts of VSC-HVDC, Vector Diagram, Multi-Level VSC Topologies, PWM Technique, Differences between CSC-HVDC and VSC-HVDC systems, HVDC aided by Power Cable Transmission, Space requirements and Right of Way, Advantages of HVDC Cable Transmission over HVDC Overhead Transmission, Latest developments in Power Cable Technology for HVDC Transmission.

### **EEL619 Nanotechnology and Nano-composites, 3 (3-0-0)**

Aims and Objectives, Introduction, Introduction to nanoscience and nanotechnology: History, background scope and interdisciplinary nature of nanoscience and nanotechnology, Synthesis and nanofabrication, Bottom-Up and Top-Down approaches. Chemical preparation methods, Physical Methods-Biological methods- Material Characterization Techniques, Nanocomposites, Composite material, Mechanical properties of Nano composite, Modeling of nanocomposites.

### **EEL620 Power Cables, 3 (3-0-0)**

Historical Perspective of Electrical Cables, Basic Dielectric Theory of Cable, Conductors, Electrical characteristics of Cables, Shielding of Cables, Sheaths, Jackets, armors, Standards and Specifications, Manufacturing, Installation, Splicing, Terminating and Accessories, Ampacity of Cables, Properties of Soil, Lightning Protection

### **EEL621 Power Transformers, 3 (3-0-0)**

Main aspects of Transformer Condition Monitoring, Thermal Modelling, Dissolved gas analysis, Frequency response analysis, Partial discharge analysis, Drawbacks of conventional techniques, Inaccuracy of empirical thermal models, Uncertainty in DGA, Intricate issues with winding deformities, Modelling of Transformer and Processing Uncertainty

### **EEL622 Signal Processing and Applications, 3 (3-0-0)**

Review of Signals and Systems, Sampling and data reconstruction processes. continuous time Fourier transform (CTFT), DTFT, Z transforms. Discrete linear systems. Frequency domain design of digital filters. Quantization effects in digital filters. Discrete Fourier transform and FFT algorithms. High speed convolution and its application to digital filtering. Applications.

### **EEL623 Feature Extraction and Pattern Recognition, 3 (3-0-0)**

Image Preliminaries, Wavelets and Multi-resolution Processing: Multi-resolution Expansions, Wavelet Transforms in 1-D and 2-D, The Fast Wavelet Transform, Wavelet Packets Transform. Feature Extraction: Color, Texture, Shape and structure Features in spatial and frequency domains, Corner Detection, Hough Transform, Principal Component Analysis, Linear Discriminate Analysis, Feature Reduction in Input and Feature Spaces. Pattern Recognition: The Unsupervised Clustering Algorithm, Bayes Classifier, Support Vector Machine, Neural Networks, Fuzzy Sets in Image Analysis.

### **EEL624 Advanced Digital Signal Processing, 3 (3-0-0)**

Multiresolution/ multiscale analysis, Piecewise constant approximation - the Haar wavelet, Building up the concept of dyadic Multiresolution Analysis (MRA), A review of discrete signal processing, Families of wavelets: Orthogonal and biorthogonal wavelets, Daubechies' family of wavelets in detail, Journey from the CWT to the DWT, Discretization in steps, Discretization of scale - generalized filter bank, Discretization of translation - generalized output sampling, Variants of the wavelet transform and its implementational structures, The wavepacket transform, The lattice structure, The lifting scheme, An exploration of applications.

### **EEL625 Computer Vision, 3 (3-0-0)**

Digital Image Formation and low-level processing. Depth estimation and Multi-camera views. Feature Extraction: Edges - Canny, LOG, DOG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT. Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection. Pattern Analysis: Clustering: K-Means, K-Medoids, Mixture of Gaussians, Classification: Discriminant Function, Supervised, Un-supervised, Semi-supervised; Classifiers: Bayes, KNN, ANN models; Dimensionality Reduction: PCA, LDA, ICA; Non-parametric methods. Motion Analysis, Shape from X, Applications: CBIR, CBVR, Activity Recognition, computational photography, Biometrics.

### **EEL627 Power System Protection , 3 (3-0-0)**

*Prerequisite: NIL*

Introduction to protection and the basic issues. Revision of fault studies and grounding. Fuses and switchgear. Relaying principals. Voltage and current sensors. Non pilot protection of transmission lines. Pilot protection of transmission lines. Protection of rotating machinery .Protection of transformers. System issues.

### **PHD Courses:-**

**These courses are open for MS(R)**

### **EEL601 Adaptive Signal Processing: (3-0-0) 3 Credits**

Introduction to discrete time stochastic processes, properties of correlation matrix and spectra, modelling of stochastic processes. AR, MA and ARMA modelling. Yule – Walker equations, Levinsons – Durbin and Schur algorithm, analysis and synthesis of lattice, joint process estimation, introduction to adaptive filters, examples from adaptive noise cancellation, equalization, echo cancellation and system identification. Methods of steepest descent , latest mean squares (LMS) algorithm, gradient adaptive lattice, block LMS algorithm, Recursive least squares formulation, filtering via orthogonal projection, Recursive least squares (RLS) based transversal and lattice filters, least squares lattice (LSL)algorithm, QR composition based adaptive filters, QRD-RLS, QRD-LSL, introduction to non linear adaptive filtering and modelling, blind deconvolution and constant modulus

### **EEL602 Signal Processing for wireless communications: (3-0-0) 3 Credits**

Digital modulation, Introduction to some wireless standards. Multiple Access principles (TDMA, CDMA, FDMA, OFDMA). Advanced modulation techniques. Spread spectrum: frequency hopping, direct sequence CDMA, RAKE Receiver, IS-95 CDMA uplink and downlink example, PN code coarse and fine time tracking, WCDMA introduction. Orthogonal frequency division multiplexing (OFDM).

Single carrier and multiple carrier examples, Multipath mitigation techniques, frequency domain equalization.

Radio propagation Characterization

AWGN channel, Rayleigh multipath fading, Rician multipath fading, delay spread concept (flat Vs frequency selective fading) indoor propagation measurements, outdoor propagation measurements.

Performance improvement techniques

Antenna receiver diversity techniques, switching, equal gain, maximal ratio, optimal combining, symbol timing recovery methods, equalization techniques. Linear decision feedback, MLSE, Equalization coefficient, adaptation schemes: LMS, RLS, LSL etc. Space time equalization: ML perspective, Generalized RAKE (G-RAKE), Adaptive antenna arrays: MMSE and MSINR based cost functions, Eigen – spectra investigation. Antenna transmitter diversity techniques: space – time block codes. Closed loop, MIMO

Digital Signal processing

Automatic frequency control, automatic gain control, channel quality estimation techniques, power control loops. Uplink and down link, multipath mitigation, multiuser detection in CDMA channels, Zero – forcing, MMSE and decision feedback techniques. Joint detection and single user detection in CDMA channels, Blind Channel and data estimation. MIMO- OFDM channel estimation. Joint channel and frequency offset estimation in OFDM.

### **EEL603 Digital Communications: (3-0-0) 3 Credits**

Baseband, narrowband and wideband signals and noise representation and characteristics of communication channels, linear and optimal filtering, baseband binary signal transmission intersymbol interference bit time recovery and errors, partial response signalling, line codes. M-ary signals orthogonal representations. Gram – Schmidt procedure, signal space concepts, bandwidth efficient digital modulation techniques, carrier synchronization. Spread spectrum techniques – codes, transmitters, receivers, performance.

### **EEL604 Steady State and Dynamics of Electric Machines: (3-0-4) 5 Credits**

Basic principles; Direct current machines; Reference frame theory; Symmetrical induction machines; Synchronous machines; Brushless DC machines; Operational impedances and time constants; Linearised motor dynamics; Reduced order machine dynamics; Two-phase induction machines. Experimental work includes simulation on PSCAD/EMTDC 4.2.

### **EEL605 Power Electronic Converters and Applications: (3-0-4) 5 Credits**

Introduction to power electronic devices, and driving circuits; DC-DC converters; AC-DC converters; DC-AC converters; AC-AC converters; multi-level inverters; matrix converters. Simulation of converters and applications.

### **EEL606 Simulation and Analysis of Modern Power Systems: (3-0-3) 5 Credits**

Modern power system operation and control, static and dynamic modeling, Load flow studies, transient stability and small signal stability of large power systems, voltage stability: P-V and Q-V curves, static analysis, sensitivity and continuation power flow method, Wide area real-time monitoring systems

### **EEL607 Fundamentals of Power System Operation Under Restructured Environment: (3-0-0) 3 Credits**

History of electric power systems restructuring, Electricity market structures, Market clearing mechanism, Transmission open access, Transmission pricing and loss allocation, Transmission congestion management, Ancillary services and system security in deregulation, Market power and generator bidding, Reforms in Indian power sector

### **EEL608 Optimization and Control of Power System Operation: (3-0-0) 3 Credits**

Introduction to optimization techniques, economic load dispatch of thermal and hydro-thermal plants, loss formula, real and reactive power optimization, optimal power flow, unit commitment, power system security constrained optimization, load-frequency control, energy control centers and power system state estimation, Wide area monitoring

### **EEL609 Industrial Imaging Techniques: (3-0-0) 3 Credits**

Sensors: capacitive, acoustic, thermal, radiation, chemical and gas. Signal acquisition, sampling, conditioning, A/D, D/A converters, Signal Processing – time domain, frequency domain.

Principles of X-rays and ionizing radiation – generation, absorption, scattering, contrast sensitivity, intensity. X and gamma-ray interaction with materials. X-ray and gamma-ray sources. Recording of radiation, radiographic film, intensifying screens, fluorescent screens, radiation detectors. Radiographic techniques – including film radiography, gamma radiography, radiographic sensitivity, flaw sensitivity, interpretation, digital image processing, computerized tomography.

Infrared radiation – radiometry, emissivity, Planck's law, temperature measurement. Heat transfer. Active and passive thermography.

Acoustic radiation principles – wave propagation, acoustic impedance, bulk and surface waves, near and far field. Ultrasonic modeling – Ultrasonic transducers – piezo-electric, magneto-restrictive. Ultrasonic measurement systems – pulse echo, through transmission, time of flight diffraction, guided wave technology.

### **EEL610 Optical Engineering: (3-0-0) 3 Credits**

Electromagnetic waves: scalar and vector waves, propagation in stratified media, Light-Matter interaction: Photons and atoms, Theory of interference and interferometers, Diffraction theory, Lasers; theory of Laser oscillation, Q-switching, Mode-locking and Ultra short pulse generation Principles and devices in Electro-Optics, Acousto-Optics, Guided Wave-Optics, Holography, Speckle, Fiber and Fourier Optics, Nonlinear-Optics: physical origin of optical nonlinearities. Wave propagation in nonlinear crystals, Second Harmonic Generation, sum and difference frequencies, Parametric processes, Self-focusing, Phase Conjugation and Photorefractive effect, Ultra-fast Optics.

### **EEL701 Optical Fiber Communication: (3-0-0) 3 Credit**

Introduction to optical communication, Optical Fiber Waveguides, Different Fiber Types, Fiber Limitations, Dispersion, Attenuation and Nonlinearities in fibers. Optical Transmitters and Receivers, Optical Transceivers, Noise Sources in Optical communication, Light Systems, CWDM (Coarse wavelength Division Multiplexing), ITU wave Grids, DWDM (Dense Wavelength Division Multiplexing), Optical Wave Multiplexers, De-Multiplexers, Fixed OADM (Optical Add-Drop Multiplexer), ROADM (Re-configurable Optical Add-Drop Multiplexer), Dispersion Compensation, Optical Amplifiers, EDFA (Erbium Doped Fiber Amplifiers), Raman Amplifiers, Optical DWDM Network Design Considerations, Optical Fiber Link Design Exercises.

### **EEL702 Advanced Signal Processing and Applications: (3-0-0) 3 Credit**

Discrete time signals and systems, Convolution and frequency response. Discrete time Fourier and Z – transforms. Properties, analysis of discrete time systems. The DFT, definition and properties, circular convolution calculation, FFT transform. Relationship between continuous and discrete time systems: sampling time and frequency normalization, discrete time processing of continuous time signals. Difference equation for digital filters definition and properties. FIR filters, IIR filters, Digital filter design techniques: impulse invariance, Bilinear transformation, finite difference, window design methods, introduction to multirate DSP, decimation and interpolation, polyphase decomposition , uniform DDFT filter banks, quadrature mirror filters and perfect reconstruction. Adaptive signal processing: time adaptive systems, LMS algorithm. Recursive least squares (RLS) algorithms, least square lattice (LSL) algorithm.

### **EEL703 Control & Instrumentation of Power Electronic Systems: (3-0-0) 3 Credits**

Review of power electronic converters; the regulation and tracking problem; feedback control principles; converter models for feedback; averaging methods and models; voltage and current mode for converters; comparator based control for rectifiers; proportional and PI control applications; small-signal analysis and linearization; control design based on linearization; hysteresis control; general boundary control; vector control of inverters; instantaneous p-q control of inverters; sensors and actuators.

### **EEL704 Power generation by renewable energy: (3-0-0) 3 Credits**

Importance and applicability of renewable energy sources; technology and economics of wind power; technology and economics of small hydro; technology and economics of biogas and biopower; generation of fuels from energy crops; technology and economics of solar thermal systems; technology and economics of photovoltaic systems; technology and economics of wave and tidal energy systems; energy analysis techniques; cost analysis techniques; environmental impact and its analysis.

### **EEL705 High Voltage Engineering: (2-2-0) 4 Credits**

Insulation system used in high voltage power equipment: gaseous, vacuum, liquid, solid and composite insulation, performance of insulation under electric stress, high voltage dielectric tests; Generation and measurement of high ac, dc and impulse voltages in test/research laboratories, generation and measurement of impulse current, digital techniques in HV measurements, calibration of HV measuring instruments and traceability of HV measurements, Recent developments in non-destructive insulation diagnostics and condition monitoring of high voltage equipments. P-Spice Simulation of HV apparatus.

### **EEL706 Image Acquisition and Processing: (3-0-0) 3 Credits**

Human visual system and image perception; monochrome and color vision models; image acquisition and display systems; video input/output devices; standard video formats; display and storage; 2-D signals and systems; 2D transforms; image enhancement; image restoration; Wiener filtering; image/video compression; motion compensation, motion estimation, water marking; image analysis, multi-resolution analysis, wavelet packets; image classification; morphological image processing; object recognition; color image processing. Experiments are based on MATLAB implementation of algorithms covered in the course.

### **EEL707 Transients in Powersystems: (3-0-0) 3 Credits**

Transient phenomena on transmission lines, method of its calculation, use of TNA, EMTP and PSPICE, lightning discharges, origin and characteristics of lightning and switching overvoltages, behavior of

apparatus and line insulation under overvoltage, VFTO in GIS, protection of apparatus against overvoltages, surge arresters and insulation co-ordination.

**EEL708 Advanced Analog IC Design: (3-0-2) 4 Credits**

MOS Models for Analog Design, Small signal MOS models; Noise- analysis and feedback; Amplifier design, Single-ended and differential OTAs, design of current sources; Feedback amplifiers, multistage amplifiers, biasing and references, Equalization, Design of equalizers circuits; Design of sample and hold and comparator circuits; High-speed electrical ling design, interconnect modeling and optimization; Lab sessions and poject assignments based on simulation of analog circuits using Cadence Design Tool.

**EEL709 Computational Electromagnetics: (2-0-0) 2 Credits**

Transient fields due to finite conductivity, method of images. Images in two-layer soil, numerical methods, finite difference, finite element and charge simulation methods to solve problems of electrostatics. Hera's Existence Theorem-Continuity equation. Maxwell's Equations, Poisson's and Laplace Equations in dielectric design.

**EEL710 Advanced Topics in VLSI Design: (4-0-2) 5 Credits**

High-speed link design, interconnect modeling and optimization; Low power electronic circuits; Carbon based nanoelectronics; Advances in device modeling and behavior (organic transistors, single electron transistors, RF transistors); Computer-aided-design of digital systems; Design methodologies, verification and testing; Introduction to semiconductor fabrication processes; Lab sessions and project assignments based on simulation of circuits using Cadence Design Tool, Ansys HFSS and Synopsys Tools.

**EEL711 Power System Dynamics Stability and Control: (3-0-0) 3 Credit**

*Pre-requisites :NIL*

Basic Concepts of dynamical Systems and Stability: Detailed modeling of synchronous machine, turbine –governor, and excitation system. Small signal stability: damping and synchronizing torque analysis, eigenvalue analysis; mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Transient stability: Analysis using digital simulation and energy function method, Voltage stability: P-V and Q-V curves , static analysis, sensitivity and continuation method.

## 7. Department of Humanities & Social Sciences

### PhD COURSES

#### **HUL601 KANT: Theoretical Philosophy, (3-0-0) 3 Credit**

This course is an invitation to read works of Kant that constitute his theoretical philosophy. These works include selections from treatises of the pre-critical period, significant portions of Critique of Pure Reason, Metaphysical Foundations of Natural Sciences, and Prolegomena to any Future Metaphysics, and a small part of Opus Postumum. The course will focus on the following issues : the nature of the critical project; transcendental arguments, deduction of categories, unity of apperception, refutation of idealism, critique of metaphysics, response to skepticism, paralogisms and so on.

Students who enroll for this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

#### **HUL602 KANT: Practical Philosophy: (3-0-0) 3 Credit**

Perhaps, after the Greeks, no moral theory has been as influential as that of Kant. This course aims at a study of Kant's works that form the architectonic of his practical philosophy: Groundwork for the Metaphysic of Morals, Critique of Practical Reason, Metaphysics of Morals and his essay, "On the Old Saying: This May be Right in Principle But Wrong in Practice". The issues this course will address, in the course of a close reading of these texts, include: aspects of volition, autonomy, the transformation of natural law within Kant's system, categorical imperative and hypothetical imperatives, kingdom of ends formula, the doctrine of right, implications of Kant's moral theory for liberalism and so on.

Students who enroll for this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

#### **HUL603 HEGEL: System and Metaphysics: (3-0-0) 3 Credit**

Undoubtedly, one of the defining characteristics of German Idealism (or post-Kantian German philosophy) is the penchant for constructing encyclopedic systems that seek to encompass topics ranging from logic understood as a doctrine of categories to systematic reflections on the trajectory of world history. In this regard, no idealistic system from this period shows as much comprehensiveness as that of Hegel, which, ironically, has also been taken to task for this very feature. This course intends to understand the motivations for the architectonic of Hegel's systems in the following ways: (1) understand the methodology that Hegel employs for deduction and examine whether the moves he makes are warranted; and (2) whether the details available in the parts of the system really allow for formation of the entire system in terms of coherence. While this course will primarily consider Encyclopedia Logik as the seminal text, we shall also study the role of Phenomenology of Spirit in serving as a propaedeutic to the system.

Students who enroll for this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

#### **HUL604 HEGEL: Practical Philosophy: (3-0-0) 3 credit**

Hegel's Elements of Philosophy of Right is one of the landmark in the history of political thought, along with Hobbes's Leviathan, Locke's Two Treatises, Rousseau's Social Contract and the Second Discourse, and Mill's Considerations on Representative Government. Like the lecture courses Hegel delivered towards the end of his life, Elements is at once an attempt at a critical history of political ideas and a systematic treatise in its own right. During the course, the primary task at hand would be to identify the methodological innovations and construct a historical narrative, which, in turn, provides both a historical critique and facilitates a systematic account of the typology of freedom, state, civil society, bildung, institutions and so on.

Students who enroll for this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

### **HUL605 Liberalism and its Critics: (3-0-0) 3 Credit**

Modern liberalism is founded on a theory of individual rights, anti-paternalism, negative liberty, private-public distinction, private property, democracy, and a non-partisan attitude towards lifestyle and religions. This course will consider writing of liberal thinkers such as Locke, Mill, Kant, Berlin, Rawls and Nozick, to explore the themes mentioned earlier. This course will also consider critiques of liberalisms that have been made available from a range of philosophical/political positions, such as libertarianism, egalitarianism, Marxism, communitarianism and feminism. Through a contrapuntal reading of the liberal position and those of the critics, this course will aim to bring to relief the issues surrounding alleged reconciliation between liberty and equality within liberalism, the nature of the contract, the historical conception of this subject, distribution, and possibility of allowing competitive practices and so on.

Students who enroll for this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

### **HUL606 Rights in History: (3-0-0) 3 Credits**

The aim of this course is to find an answer to the question: is the concept of rights a palimpsest? This course will be an attempt to understand how, in its long history and whose scattered sources of origin can be located in the writings of Stoics, the concept of right, for all its unequivocal connotations, has come to be a collection of disparate elements, comprising conceptual fragments, theories, folk reactions, crude distinctions that are useful in highly specific practical contexts, and tacit value assumptions. In answering this question, the course will focus on the possibility of thinking about rights within the framework of genealogical inquiry. Accordingly, the reading for the course will be drawn from a wide variety of sources, ranging from the writings of Stoics to that of natural law tradition, medieval political theology to issues of trade in the early modern period and the rise of various social classes.

Students who enroll in this course would be expected to read the original works and the required secondary material (which will be identified from time to time), write a paper (consisting of not more than 20 pages) and appear for the end-semester examination.

### **HUL607 English Syntactic Structure: 3-0-0 (3credit)**

The aim of the course is to introduce students to the theory of Syntax in general and to the study of the syntactic structure of English in particular. The concept and notions of different elements of syntax as well as practical syntactic analysis of sentences taken from English and other languages give the students an in-depth knowledge of the function of human languages at the syntactic level. The course will begin with general concepts of grammar and other linguistic elements and move towards the precise study of syntax of English in terms of words, phrases and clauses. Examination of syntactic structures and to see how they are formed, assigned, represented and tested is the goal of this course.

### **HUL608 Topics in Optimality Theory: (3-0-0) 3 Credits**

Goals of linguistic theory- Theory of constraints – Lexicon optimization – Architecture of OT grammar – Syllable structure and economy – Metrical structure – Constraint interaction – Distributional restriction – Constraint viability – Emergence of the unmarked – Learning algorithm – case studies (World languages)

### **HUL609 Cognitive Neuroscience of Language: (3-0-0) 3 Credits**

Introduction, Neurocognitive methods, EEG/ERP, ERP Components: ELAN, N400, LAN, P600. Neurocognitive models of language comprehension, syntactic processing, semantic processing, Phonological processing, Neurocognition of language comprehension and Indian languages.

### **HUL610 Self and Society: (3-0-0) 3 Credits**

The self in personality theories

    Type and trait approaches

    Psychoanalytic approaches

    Humanistic & existential approaches

The social self

    Development of the self

Cultural roots of the self  
Symbolic interaction  
The biological self  
Genetic contribution to personality  
The brain and self  
Embodies cognition

### **HUL611 Technical Communication: (2-1-0) 3 Credits**

The purpose of this course is to acquaint students with the principles of effective, audience centered technical communication. The course requires students to become familiar with the nature of communication, and discusses process of communication, non-verbal communication, business communication and barriers to communication. It also deals with global, ethical and legal aspects of communication. The course provides students with practice in writing letters, resumes and informal and formal reports. Finally, students are taught elements of style in writing and how to organize and present technical material orally in an effective manner.

### **HUL612 Research Methodology and Statistics: (3-0-0) 3 Credits**

Purpose and nature of research; Research ethics  
Research proposal and literature review: Defining the problem; Finding and managing information; Developing and stating hypotheses.  
Data collection: Observation; Experiments; Survey; Case study; Secondary data  
Measurement: Qualitative and Quantitative measurement; Scales of measurement; Reliability and validity of measurement.  
Sampling, Normal distribution; Parametric and non –parametric statics; significance of statistics  
Statistics: Descriptive and inferential statistics; Correlation; t ration; Regression analysis; Analysis of Variance; structural Equation Modeling  
The research report; writing a thesis; writing for publication

### **HUL613 Corpus Linguistics: (3-0-0) 3 Credits**

Introduction, Corpus, Early phase, Chomskyan Revolution, generation different types of corpus, Types of Annotation, Multilingual corpora, Qualitative vs Quantitative analysis, Frequency counts, Statistical analysis of corpus, Use of Corpus (in speech, grammar, semantics, psycholinguistics, pragmatics, stylistics etc.), corpus based approach of language processing.

### **HUL614 Computational Phonology: (3-0-0) 3 Credits**

Introduction to computational phonology- Optimality Theory- Phonological complexity- Two-level phonology- Concept of Finite state transducer and cascade- Paradigms of machine learning- Evaluation algorithm for OT system- Chomsky hierarchy- Karttunen method- Probabilistic model- Speech corpora- TTS

### **HUL615 Literary Theory: (2-1-0) 3 Credits**

The course introduces students to literary theory and examines the relationship between theory and philosophy, the question of what literature is and does, the emergence of literary theory in the history of modern criticism, and the nature of discourse. Students are expected to become familiar with the following: Liberal humanism, structuralism, poststructuralism and deconstruction, Postmodernism, psychoanalytic criticism, feminist criticism, Marxist criticism, new historicism and cultural materialism, postcolonial criticism, stylistics, narratology, ecocriticism and theory after ‘theory’.

### **HUL616 Canadian Literature: (2-1-0) 3 Credits**

Poetry: The work of three significant Canadian poets will be read in this unit. Each poet is introduced as an individual first with background information to set the stage for the poetry readings. Students are responsible for reading and studying all of the poetry in this unit. However, there is considerable choice in the assignments they must do. Within the choice, students will complete five poetry assignments by the end of the unit. Students will reflect upon, discuss and write about the images used by the poets, personal connections students make to the poem, comparisons with other poems they have read on similar themes, poetic devices.

Short Stories: Three short stories by three different writers are studied in this unit. Students will complete two formative assessment writing tasks for feedback and two summative writing tasks for

evaluation. Students will read their work, be provided with notes on the story and then be asked to think specifically about themes and characters presented.

Novel Study: In this unit students will read two novels by two Canadian novelists. The questions will cause students to read between and beyond the lines and reflect on their own experiences. Polished reflective writing is the main task of this unit.

Drama: The nature of Canadian drama will be interrogated. Three Canadian plays by three Canadian dramatists will be taken up for study, and the styles and themes of the plays will be examined.

### **HUL617 World Literature: (2-1-0) 3 Credits**

This course will survey major world authors from a variety of countries, including the U.S and Britain. Students may read, write and discuss a variety of world literature including Russian, Australian, South American, African, Asian and others. They will attempt to identify and analyze a variety of major works of world literature and discuss the characteristics of the major periods of world literature. The students will also discuss major literary genres that have emerged, and will compare and contrast writing styles and generic forms from different periods and cultures and identify major themes of representative poetic, fictional and dramatic works. They are also expected to trace the influence of one literature upon another.

### **HUL618 Research Methodology in language and Literature: (2-1-0) 3 Credits**

Theoretical Background: Meaning, Nature and Scope of Research; Difference between writing a popular article and research paper; a book and a dissertation

Methodology and approaches: Selection of Research Topic; Plan of work, Thesis Statement and its Feasibility; Survey of different critical approaches, Selection of a particular approach, Micro and Macro analysis

Material Collection: Primary and Secondary Sources, Reliability of Sources

Preparatory Steps: Writing of Synopsis, Literary Survey; Collection, Listing and Organization of Material, Note making, Use of Note cards and Reference Cards

Mechanics of Writing: Single and multi Tire Division of Chapters, Writing of the Main Chapters, Preparation and Presentation of Conclusions, Presentation of References, Working Bibliography, Indexing, Indexing, Use of MLA Style Sheet.

### **HUL619 The Novel as a Genre: (2-1-0) 3 Credits**

Background Survey: Fiction as a Genre, the meaning of fiction, fact in fiction, types of fiction.

Development of the Novel: Storytelling and Novel, the four Wheels of the Novel Epistolary Techniques, Novel in the 19th Century.

Science and Novel: Impact of Science & Technology on the Novel, changing Social Realities and their Reflection in the novel, Science Fiction.

Modernity: Concept of Modernity in the novel, the changing concept of Time, Stream of Consciousness techniques, the changing art of characterization.

Structural Pattern: Narrative Techniques, Plot and Structure, various theories of Interpretation.

Novel as a Global Art Form: Development of the Novel as an art form in Europe, Africa, America, Australia and India; influence of localized tendencies and movements.

### **HUL620 Fantasy Literature and Science Fiction: (2-1-0) 3 Credits**

Historical overview of the development of fantasy and science fiction; Definitions of key terms and techniques; In each work, primary focus on theme, with attention to narrative structure and characterization; Understanding the various trends developing in the genre; Discussion of the role of fantasy and science and technology in modern life, as reflected in the works; Exploration of the fruitful connections between fantasy and science fiction and postmodernism; Comparative analyses as well as close individual readings of specific texts; Exploration of the varieties of otherness in fantasy and science fiction.

### **HUL621 Applied Econometrics: (3-0-0) 3 Credits**

Stages in Empirical Econometric Research; Introduction to Statistical and Econometric Software Packages (E-VIEWS, STATA, RATS MFIT); Working with Basic Data Handling; Misspecification; Functional Forms; Model Selection; Qualitative Data; Time Series Models and Forecasting; Panel Data Models; Discrete Choice Models, etc.

### **HUL622 Financial Institutions and Corporate Finance: (3-0-0) 3 Credits**

This course will mainly covers theories of Corporate finance, Financial intermediation and Portfolio Theories.

1. Financial Markets (10): Analysis of Financial Markets-Fundamental analysis, Technical analysis, Efficient Market Hypothesis. (Advance Level)
2. Portfolio Theories (10): Mean Variance Criterion-Systematic & Unsystematic risk/Portfolio Diversification-Simple & Markowitz Efficient Frontier & Capital Market Line/Capital Asset Pricing Model (CAPM)/Arbitrage Pricing Theory (APT).
3. Financial Intermediation (10): (a) A brief discussion of theories about necessity of financial intermediation, in general. (b) Bank Intermediary-Special role of banks, Industrial Organization approaches to banking. (c) Banking runs, role of deposit insurance, role of banking regulations, role of prudential norms. (d). A discussion of Basel Accord in this context.
4. Corporate Finance (10): (a). Theories of Capital Structure: (i) Modigliani-Miller Hypothesis revisited (ii). Agency Cost theories. (iii). Theories relating to Asymmetric Information: Pecking order hypothesis and Signaling. (iv). A flavor of other theories about capital structure. (b). Dividend policy-forms of dividends-Lintner model-dividend irrelevance hypothesis-role of taxes, transaction costs, agency problems and asymmetric information. (c) Corporate finance and product markets.

### **HUL623 Multiethnic Literature of the United States: (2-1-0) 3 Credits**

This course will introduce students to a selection of multiethnic literatures of the United States through a comparative framework. It will involve a close reading and analysis of both key primary texts and influential criticism and theoretical writings, including, but not limited to, postcolonialism, narratology, deconstruction and globalization. Key aims for the course are to understand the relationship between literature, ethnic populations and the culture and social aspects of immigration. The exploration of this important body of literature will be guided by two central questions: what does literature by ethnic authors tell us about processes of identity formations? How does ethnicity shape the way authors tell stories and narrate the histories of their communities? To approach these questions about the relationship between identity and storytelling, issues of history and memory, migration and displacement, and forms of belonging and non-belonging in the United States will be examined. Further, the intricate relations among race, ethnicity, nation, class, generation and gender will be scrutinized in order to come to terms with the aesthetic and political dimensions of this literature.

### **HUL624 Diaspora and Postcolonial Studies: (2-1-0) 3 Credits**

The course examines the historical and contemporary movements of peoples and the complex problems of identity and experience to which these movements give rise as well as the creative possibilities that flow from the movement. Diaspora in contemporary thought involves the shifting relations between homelands and host nations from the perspective of those who have moved, whether voluntarily or not. Diaspora emphasizes the inescapable lived translocal experiences of many migrant communities that exceed the boundaries of the nation-state. Questions of nostalgia, of the dynamics of co-ethnic identification, of the politics of homeland and host nation, and of the inter-generational shifts in responses to all these are central to studies of diaspora. Various forms of dislocation such as exile, diaspora and migration have been explored in both postcolonial theory and literary texts. This course will investigate how and why these phenomena have become central to postcolonial thought. Under the generalized rubric of diaspora, this course will engage with some of the following issues: the experiences of displacement and homelessness, the ideologies of home and nation, the cultures of diaspora and the politics of multiculturalism, and the new phenomena of borders and borderlands. As diaspora is a multidisciplinary field, the course will draw on writings in various disciplines including post-structuralist theory, literary studies and cultural studies. Writers to be studied will include Edward Said, Homi Bhabha, Gloria Anzaldua, Paul Gilroy, Stuart Hall, James Clifford, Arjun Appadurai, Jacques Derrida, Deleuze and Guattari, Rey Chow, V. S Naipaul, Salman Rushdie, Vijay Mishra and Amitav Ghosh.

### **HUL625 Experimental Linguistics: (2-0-2) 3 Credits**

Principles and techniques of experimental design and research in linguistics, linguistic theory and experimental questions, the development of theoretically motivated hypotheses, designing linguistic experiments, data analysis (statistical analysis), data reporting.

**HUL626 Globalisation and Change: (3-0-0) 3 Credits**

Nature and Dynamics of Globalisation; The Global Local Dichotomy; Globalisation and its impact on language, communication and media; Globalisation trade and economy; The role of multinational corporations and international agencies of finance; Globalisation and culture; homogenisation and dominance; Diasporic communities ethnic communities and movements; Consequences of globalisation; discontents and different Perceptions.

**HUL627 Topics in Development Economics: (3-0-0) 3 Credits**

Views of development, measurement of economic development, growth vs development. Evolution of Institutions and their role in an economic development, role of financial Institutions on economic development, social networks as institutions, interaction and interdependence between formal and informal Institutions, impact of such interactions on economic development, social network as a source of informal credit and insurance. Micro finance mechanisms, peer selection, peer monitoring and dynamic incentives, solution to moral hazard, adverse selection, and costly state verification, Concept of informal sector, Evidence from developing countries, Determinants of size of informal sector & its linkage structure with the rest of the economy, role of informal sector in economic development.

**HUL628 Topics in International Economics: (3-0-0) 3Credits**

Theories of International Trade, International Movements of Capital, the Balance of Trade and other Measures of International Transactions, the Mundell-Fleming Open Economy Model, Exchange Rate Overshooting Model, Purchasing Power Parity (PPP), Saving-Investment Dynamics, Current Account Dynamics and Real Exchange Rate, International Finance (Financial Flows, World Bank/IMF, the Role of Multinational Corporations, Foreign Direct Investment, Capital and Labour Mobility), Crises in Emerging Markets: Causes, Solutions, and Prevention, Problems Faced by Transition Economies, Challenges of Developed Countries

**HUL629 Advanced Topics in Economic Geography and Urban Economics: (3-0-0) 3Credits**

Choice of Location, FDI and Spatial Dimension of Regional Spillover, FDI and Economic Geography, Spatial Economy and International Trade, Congestion Costs, Market Failure and Urban Sprawl, Fujita and Thisse (1996) and Fujita (1989) Model of Knowledge Spillover, Optimal City Size in a Spatial Economy, Spatial Agglomeration and Endogenous Growth

## 8. Department of Mathematics

### M.Sc.- Core Courses

#### **MAL411 Topics in Real Analysis, 4(3-1-0)**

*Pre-requisites: Basic Knowledge in Single variable Calculus*

Metric spaces, completeness, connectedness, compactness, Heine-Borel theorem, totally bounded sets, finite intersection property, completeness of  $\mathbb{R}^n$ , Banach fixed point theorem, perfect sets, the Cantor set. Continuous functions, relation with connectedness and compactness, discontinuity, uniform continuous functions, monotone functions, Absolutely continuous functions, total variation and functions of bounded variations. Differentiability and its properties, mean value theorem, Taylor's theorem, Riemann integral with properties and characterization, improper integral, Gamma function, Directional derivative, Partial derivative, Derivative as a linear transformation, Inverse and Implicit function theorems, multiple integration, Change of variables. Sequence and series of functions, point wise convergence, Fejer's theorem, power series and Fourier series, uniform convergence and its relation with continuity, differentiability and inerrability, Weierstrass approximation theorem, Equi-continuous family, Arzela-Ascoli theorem.

#### **MAL412 Basic Linear Algebra, 4 (3-1-0)**

*Pre-requisites: Nil*

Vector spaces over fields, subspaces, bases and dimension; Systems of linear equations, matrices, rank, Gaussian elimination; Linear transformations, representation of linear transformations by matrices, rank-nullity theorem, change of basis, dual spaces, transposes of linear transformations; Determinants, Laplace expansions, cofactors, adjoint, Cramer's Rule; Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonal-lization, rational canonical form, Jordan canonical form; Inner product spaces, Gram-Schmidt ortho-normalization, least square approximation, linear functionals and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators; Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, positive definiteness.

#### **MAL413 Introduction to Computing, 4(3-0-2)**

*Pre-requisites: Nil*

Introduction: Computers as universal computing devices, bits, datatypes and operations, digital logic structure, the von Neumann model Programming: Problem solving, debugging, assembly language programming, Introduction to programming in C++

Variables and operators, control structures, pointers and arrays, functions and reference variables

Introduction to classes and templates

Developing classes for scientific applications: selected examples

Introduction to parallel processing using MPI.

#### **MAL414 Ordinary Differential Equations, 4(3-1-0)**

*Pre-requisites: Nil*

Introduction: second and higher order differential equations, solutions of homogeneous and non-homogeneous equations, Method of variation of parameters.

Qualitative Properties of Solutions: Existence and uniqueness theorem, Oscillations and the Sturm Separation theorem, the Sturm Comparison theorem.

System of first order ODEs: Autonomous and non-autonomous system and stability.

Series solutions: Legendre equation and Legendre polynomials, Bessel equation and Bessel functions of first and second kinds.

Boundary Value Problems: Sturm-Liouville Boundary Value Problem, Green's Function to solve boundary value problem.

#### **MAL415 Algebra 4(3-1-0)**

*Pre-requisites: Nil*

Review of basics, Permutations, sign of a permutation, inversions, cycles and transpositions, groups, subgroups and factor groups, Lagrange's Theorem, homomorphisms, normal subgroups, Quotients of

groups, Cyclic groups, generators and relations, Cayley's Theorem, group actions, Sylow Theorems. Direct products, Structure Theorem for finite abelian groups. Simple groups and solvable groups, nilpotent groups; Free groups, free abelian groups. Rings, Examples (including polynomial rings, formal power series rings, matrix rings and group rings), ideals, prime and maximal ideals, rings of fractions, Chinese Remainder Theorem for pairwise comaximal ideals. Euclidean Domains, Principal Ideal Domains and Unique Factorizations Domains. Polynomial rings over UFD; finite field and field extensions.

### **MAL421 Topics in Complex Analysis 3(3-0-0)**

*Pre-requisites: Nil*

The complex number system. Extended complex plane. Analytic functions. Cauchy-Riemann conditions. Mappings by elementary functions. Conformal mappings and Mobius Transformation. Complex integration. Cauchy-Goursat theorem. Cauchy integral formula. The Homotopic version of Cauchy's theorem and simple connectivity. Morera's and Liouville's theorems. Uniform convergence of sequences and series. Taylor's and Laurent's series. Singularities, zeros and Poles. Isolated singularities and residues. Cauchy residue theorem. Evaluation of real integrals. The Argument Principle and Rouché's theorem. Maximum Modulus Theorem, Schwarz's lemma.

### **MAL422 Partial Differential Equations 4(3-1-0)**

*Pre-requisites: Nil*

Introduction to PDE. First order quasi-linear equations. Nonlinear equations. Cauchy-Kowalewski's theorem. Higher order equations and characteristics. Classification of second order equations. Riemann's method and applications. One dimensional wave equation and De'Alembert's method. Solution of three dimensional wave equation. Method of descent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions. BVPs for Laplace's and Poisson's equations. Green's functions and properties. Heat equation; Maximum principle, Uniqueness of solutions of IVPs for heat conduction equation. Green's function for heat equation.

### **MAL423 Stochastic Processes 4 (3-1-0)**

*Pre-requisites: Nil*

Introduction to probability theory: Probability and counting with some applications, Probability spaces, Random variables, Probability distribution functions, Independence and joint distributions, Expectation, Variance, The weak law of large numbers, Convergence of random variables, The strong law of large numbers, The central limit theorem, Simulation.

Stochastic Processes: Poisson process, Markov chains, Kolmogorov equations, Martingales, Doob's decomposition of a stochastic process,  $L^p$  inequality, Random walks, Brownian motion, Stopping times, Continuous time martingales, Recurrence of Brownian motion, Feynman-Kac formula, The Ito integral for Brownian motion, Processes of bounded quadratic variation, Some applications to real-world problems.

### **MAL424 Numerical Analysis 4(3-0-2)**

*Pre-requisites: Nil*

Definition and sources of errors, solutions of nonlinear equations; Bisection method, Newton's method and its variants, fixed point iterations, convergence analysis; Newton's method for non-linear systems; Finite differences, polynomial interpolation, Hermite interpolation, spline interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature, Richardson extrapolation; Differential equation Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, multistep methods and stability; Boundary value problems - finite difference method, collocation method.

### **MAL425 Topology 3(3-0-0)**

*Pre-requisites: Basic Knowledge in Real Analysis*

Topological spaces, Basis for a topology, Limit points and closure of a set, Continuous and open maps, Homeomorphisms, Subspace topology, Product and quotient topology.

Connected and locally connected spaces, Path connectedness, Components and path components, Compact and locally compact spaces, One point compactification Countability axioms, Separation axioms, Urysohn's Lemma, Urysohn's metrization theorem, Tietze extension theorem, Tychonoff's

theorem, Completely Regular Spaces, Stone-Cech Compactification.

### **MAL511 Functional Analysis 3(3-0-0)**

*Pre-requisites: Nil*

Normed linear spaces,  $C_0$ ,  $C$ ,  $l_p$ ,  $L_p$ ,  $1 \leq p \leq \infty$ ,  $C[a,b]$ , dimension, linear transformations -continuity and boundedness, linear functionals-continuity, compactness of unit ball of finite dementional spaces, equivalence of norms and continuity of linear transformations of finite dimensional spaces, dual spaces duals of  $C_0, l_p, L_p, 1 \leq p \leq \infty$ , separability, non-separability of  $l_\infty$ . reflexive spaces.

Horn-Banach theorem for real and complex normed linear spaces, uniform boundedness Principle and its applications, closed graph theorem, open mapping theorem and their applications. Inner product spaces, Hilbert spaces, orthonormal basis, projection theorem and Riesz representation theorem.

### **MAL512 Mathematical Methods 3(3-0-0)**

*Pre-requisites: Nil*

Fourier Series, Generalized Fourier series, Fourier Cosine series, Fourier Sine series, Fourier integrals. Fourier transform, Laplace transform, Solution of differential equation by Laplace and Fourier transform methods. Z-transform, Hankel and Mellin transform. Perturbation methods. Calculus of Variation. Introduction to Integral Equations.

### **MAL513 Optimization Techniques 4(3-1-0)**

*Pre-requisites: Nil*

Introduction to optimization, Formulation of linear Optimization problems, Convex set; Linear programming problem: Graphical method, Simplex method, Big M and two-phase Simplex method, revised simplex method, Duality: Primal-dual relationship & its economic interpretation, Dual Simplex algorithm, Sensitivity analysis; Network analysis: Transportation & Assignment problems; Integer programming problems: Formulation, Branch & Bound and Cutting Plane methods; Dynamic Programming (DP).

Non-linear Programming: Lagrange multipliers and Kuhn - Tucker conditions, Convex optimization; Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.

### **MAL601 Differential Equations: (4-0-0) 4 Credits**

Ordinary differential equations: Phase space, existence and uniqueness theorems, The method of successive approximations, dependence on initial conditions, Boundary value problems, Green's functions, Sturm-Liouville problems.

Partial differential equations: First order partial differential equation; Cauchy problem and classification of second order equations, Laplace equation; Diffusion equation; Wave equation; Methods of solutions (variable separable method, integral transform method).

### **MAL602 Advanced Analysis: (4-0-0) 4 Credits**

Real analysis: Metric Spaces, Completeness, Connectedness, Complete Review of Riemann Integral, Lebesgue measure, Lebesgue and convergence, LP spaces.

Complex analysis: complex-analytic functions, Cauchy's integral formula, power series, Liouville's theorem, maximum-modulus theorem, Isolated singularities, residue theorem, the Argument Principle, real integrals via contour integration. Mobius transformations, conformal mappings.

### **MAL603 Topics in Numerical Analysis: (3-0-2) 4 Credits**

Introduction to Error: its sources, propagation and analysis. Root finding of non-linear equations. Systems of linear and non-linear equations.

Finite difference operators, Polynomial interpolation and error analysis, Hermite interpolation, Spline interpolation, B-Splines, Numerical differentiation, Numerical integration: Trapezoidal and Simpson's rules, Newton-Cotes formula, Method of undermined coefficients and Gaussian Quadrature, Richardson Extrapolation.

Difference equations. Numerical solution of ordinary differential equations: Initial value problems: Numerical stability, Taylor series method, Euler and modified Euler methods and stability analysis, Runge-Kutta methods, Multistep methods, Predictor-Corrector method, convergence and stability. System of ordinary differential equations. Boundary Value Problems: Shooting and direct methods.

#### **MAL604 Water Wave Theory: (3-0-2) 4 Credits**

Kinematics of Fluids in Motion: Real Fluids and Ideal Fluids, Velocity of fluid at a point, Streamlines and Pathlines, Steady and Unsteady Flows, the Velocity Potential, Vorticity Vector, The Equation of continuity. Equation of motion of a fluid: Pressure at a point in fluid at rest, Pressure at a point in a moving fluid, Euler's equation of motion, Bernoulli's equation. Viscous and inviscid fluid, the Navier-Stokes equation of motion, rotational and irrotational flows.

Theory of surface wave: Equation of Motion, Wave Terminology, Analytical solution of the wave problem, Dispersion relation of the wave motion, Classification of water waves, Particle motion and Pressure, Superposition of waves, Wave reflection and standing wave, Wave energy and group velocity, Wave Refraction, Wave Diffraction. Finite amplitude waves: Mathematical formulation, Perturbation method of solution. Linear and Nonlinear diffraction theory.

#### **MAL605 Introduction to Nonlinear Dynamics: (3-0-0) 3 Credits**

Nonlinear equations: autonomous and non-autonomous systems, phase portrait, stability of equilibrium points, Lyapunov exponents, periodic solutions, local and global bifurcations, Poincare-Bendixon theorem, Hartmann- Grobmann theorem, Center Manifold theorem.

Nonlinear oscillations: perturbations and the Kolmogorov-Arnold-Moser theorem, limit cycles. Chaos: one-dimensional and two-dimensional Poincare maps, attractors, routes to chaos, intermittency, crisis and quasiperiodicity. Synchronization in coupled chaotic oscillators. Applications: Examples from Biology, Chemistry, Physics and Engineering.

#### **MAL606 Fields and Galois theory-3 (3-0-0)**

Galois theory: Field Extension, automorphisms, Normal extension, separable and Inseparable Extension, The fundamental Theorem of Galois theory; Some Galois Extension: Finite Fields, Cyclotomic Extensions, Norms and Traces, Cyclic Extension, Hilbert Theorem 90 and group Cohomology, Kummer Extension; Applications of Galois Theory; Discriminants, Polynomials of degree 3 and 4, Ruler and Compass Constructions, Solvability by Radicals; Infinite Algebraic Extensions, Infinite Galois Extensions, Krull topology, The Fundamental Theorem of Infinite Galois theory; Transcendental Extensions: Transcendence Bases, Linear Disjointness Affine Algebraic Function Fields, Derivation and Differentials.

#### **MAL607 Commutative Algebra -3(3-0-0)**

Rings and Ideals; Rings and ring homomorphism, Ideals, quotient rings, Zero divisors, Nil potent Element, Units, Prime Ideals, and maximal ideals, Nilradical and Jacobson radical, Operation on ideals, Extension and contraction; Modules; modules and modules homomorphism, sub module, Direct sum product of modules, restriction and extension of scalars, Exactness properties of the tensor product, algebras, tensor product of algebra; Rings and modules of fraction, Local Properties Extended and contracted ideals in the rings of fractions, Primary decomposition, Integral dependence, The going up theorem Integrally closed integral domains, Valuation Topologies and completion, Filtrations, Graded Rings and modules, The associated graded ring, Artin -Rees Theorem, Dimension Theory, Hilbert function, Dimensions theory of Noetherian local rings, Regular local rings, Transcendental dimension, Depth: M-Regular Sequences, Cohen -Macaulay Rings.

#### **MAL608- Operator Theory -4(3-1-0)**

Operators on Hilbert spaces: Bounded linear operator on Hilbert spaces, spectrum of an operator, weak, norm and strong operator topologies, normal, self-adjoint, unitary and compact operator and their spectra.

Diagonalization, Spectral theorem and applications: diagonalization for a compact self-adjoint operator, spectral theorem for compact norm operator and spectral calculus, application to Sturm-Liouville

problem.

Positive operators: positive linear maps of finite dimensional space and their norms, Schur products, completely positive maps.

### **MAL609 Mathematics of financial Derivatives –I-4(4-0-0)**

Introduction to Financial Derivatives: Futures and Options; Pricing with no –arbitrage principle, Black-Scholes equation for European style options; quick introduction to stochastic process; Basic facts about Brownian Motion and Martingales with applications in finance ;Stochastic integration , Stochastic Calculus (It's Formula,Girsanov theorem, connection with PDEs);Black-Scholes formula, Greek.

### **MAL610 Measure Theory, 4 (3-1-0)**

*Pre-requisites: Basic Knowledge in Single Variable Calculus*

Sigma- rings, sigma algebra, measurable space, countability and sub- additivity of a measure, Borel measure, Lebesgue outer measure, measurable sets, construction of non-measurable set, the cantor set. Measurable functions and their properties, almost everywhere property, approximation of measurable functions with the simple measurable functions and step functions. Egorov's theorem and Lusin's theorem. Lebesgue integral of functions, Lebesgue integral of integral functions and its linearity, Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem, Applications of convergence theorems. Signed measures, absolute continuous functions and their properties, singular measures, Radon – Nikodym theorem with applications.

### **MAL611: Analytic number theory**

The Fundamental theorem of Arithmetic, Arithmetical Functions and Dirichlet Multiplication: The Mobius function, The Euler totient function, product formula, The Dirichlet product of arithmetical Functions, Dirichlet inverses and the Mobius inversion formula, The Von-Mangoldt function, Multiplicative functions, Dirichlet multiplication, The inverse of a completely multiplicative function, Liouville's function, The divisor functions, Generalized convolutions, Formal power series, The Bell series of an arithmetical function, Bell series and Dirichlet multiplication, Derivatives of arithmetical functions, The Selberg identity; Averages of Arithmetical functions: Euler's summation Formula, Some elementary asymptotic formulas, An application to the distribution of lattice points visible from the origin, The partial sums of a Dirichlet product, Another identity for the partial sums of a Dirichlet product; Some Elementary Theorems on the Distribution Numbers: Chebyshev's functions, Prime number theorem, Some equivalent forms of the prime number theorem, Shapiro's Tauberian theorem, An asymptotic formula for partial sums, The partial sums of the Mobius function, Brief sketch of an elementary proof of the prime number theorem, Selberg's asymptotic formula.

### **MAL612 Modular forms: (4-0-0) 4 Credits**

*Pre-requisites: NIL*

Weakly modular functions, modular functions, The modular group, modular forms, cusp forms, Eisenstein series, Congruence subgroups, The j-function, Dedekind eta function, The space of modular forms, dimension formula, expansions at infinity, elliptic points, parabolic points and hyperbolic points of congruence subgroups, fundamental domain, Hecke operators, Theta functions, Automorphic forms.

### **MAL613 Theory of majorization (3-0-0) 3 Credits**

*Pre-requisites: MAL412-Basic Linear Algebra*

Majorization, definition and properties. Birkhoff's theorem, Characterization via doubly stochastic matrices, convex functions. Algebraic properties.

Weak majorization, definition and properties. Characterization via doubly substochastic matrices and monotone functions. Algebraic properties.

Majorization on diagonal elements and eigenvalues of a Hermitian matrix, majorization inequalities on eigenvalues and singular values of sum, product and Schur product of two matrices.

## **MAL614 APPLIED LINEAR ALGEBRA AND MATRIX ANALYSIS (3-0-0) 3 Credits**

*Pre-requisites: Basic Knowledge on Linear Algebra*

Spectral theorems: Spectral theorems, quadratic forms, discrete Fourier transform, complementary subspaces, orthogonal reduction.

Decompositions: Range-null space decomposition, orthogonal decomposition, singular value decomposition, orthogonal projections, least-square method, angle between subspaces.

Eigensystems: Eigensystem, system of differential equations, difference equations, Krylov method.

Perron Frobenius Theory: Positive, non-negative and stochastic matrices, applications to Markov chains.

## **MAL615 Elementary number theory (3-0-0) 3 Credits**

*Pre-requisites: NIL*

Euclid's algorithm for division, Greatest common divisor, fundamental theorem of arithmetic, primes, properties of the primes; Euclid's theorem on infinitude of primes, The greatest integer function, multiplicative functions, Euler's totient function, Möbius function, Riemann zeta-function, average orders; Chinese remainder theorem, Fermat's little theorem and Euler's generalization, Wilson's theorem, Lagrange's theorem, primitive roots; Quadratic residues: Legendre's symbol, Euler's criterion, Gauss's lemma, law of quadratic reciprocity, Jacobi's symbol; Quadratic forms: Representations by binary forms, Sums of two squares, Sums of four squares; Diophantine approximation, Continued fractions; Rational approximations; Number fields, units, primes and factorization, Euclidean fields, Gaussian field; Diophantine equations; The Pell equation, The Thue equation, The Mordell equation, The Fermat equation, The Catalan equation etc.

## **MAL616 Elements of Data Science (3-0-2) 4 Credits**

*Pre-requisites: NIL*

Overview of probability and statistics; statistical learning: definition, principles and different types of statistical learning, assessing model accuracy, bias-variance tradeoff; regression models: simple linear and multiple linear and non-linear; resampling methods: assessing model prediction quality, cross validation, bootstrap; model selection and regularization: dimensionality reduction, ridge and lasso; unsupervised learning: clustering approaches, K-means and hierarchical clustering; supervised learning: classification problem, classification using logistic regression, naive Bayes, classification with Support Vector Machines, neural networks.

## **MAL701 Algebraic Topology: (4-0-0) 4 Credits**

*Pre-requisite: General Topology*

Mainfolds: Identification (quotient) spaces and identification (quotient) maps; topology n-manifolds including surfaces,  $S_n$ ,  $RP_n$ ,  $CP_n$  and lens spaces.

Triangulated manifolds: Representation of triangulated, closed 2-manifolds as connected sums of tori of projective planes.

Fundamental group and covering spaces: Fundamental group, functoriality, retract, deformation retract; Van Kampen's Theorem, classification of surfaces by abelianizing the fundamental group, covering spaces, path lifting, homotopy lifting, uniqueness of lifts, general lifting theorem for maps, covering transformations, regular covers, correspondence between subgroups of the fundamental group and covering spaces, computing the fundamental group of the circle,  $RP_n$ , lens spaces via covering spaces

Simplicial homology: Homology groups, functoriality, topological invariance, Mayer-Vietoris sequence; applications, including Euler characteristic, classification of closed triangulated surfaces via homology and via Euler characteristic and orientability; degree of a map between oriented manifolds, Lefschetz number, Brouwer Fixed Point Theorem.

**MAL702 Introduction to Knot Theory: (3-0-0)**

Composition of knots, Reidemeister moves, links, Invariants of knots, Surfaces and Knots: Genus and Seifert surfaces, Torus knots and its properties, Satellite Knots, Hyperbolic Knots, Braid theory, Alexander polynomial, Bracket polynomial, HOMFLY polynomial, Jones polynomial, Vassiliev Invariants, Knot complements and 3-Manifolds.

**MAL703 Computational Partial Differential Equations: (3-0-2) 4 Credits**

Error Analysis: Introduction to Interpolation, differentiation and integration. Finite difference methods for Parabolic Equations: One space dimension, Convergence and stability analysis, two space dimensions. Elliptic Equations: Dirichlet, Neumann and Mixed problems. Hyperbolic equations: One space dimension, two space dimensions, first order equation, system of equations, Lax's equivalence theorem, Lax-Wendroff explicit method, CFL conditions, Wendroff implicit approximation. Finite Element Methods. Spectral Methods.

**MAL704 Hydrodynamic Stability Theory: (3-0-2) 4 Credits**

Basic concepts of stability theory. Evolution equations and formulation of the linear stability problem. Solution of the initial value problem and normal-mode analysis. Temporal stability of viscous incompressible flow. Spatial instability of viscous incompressible flow. Some general properties of Orr-Sommerfeld problem. Kelvin Helmholtz Instability. Rayleigh-Taylor Instability, Rayleigh-Benard Convection. Saffman-Taylor Instability.

**MAL705 Rings and Modules: (3-0-0) 3 Credits**

Artinian and Noetherian Ring, Primitive rings, Radicals, Completely reducible modules, Completely reducible ring, Semiprime rings and their properties, Projective and injective modules, Rings of endomorphism of injective modules, Classical ring of quotients, Regular Ring of quotients, Tensor product of modules exact sequence.

**MAL706 Group Ring: (3-0-0) 3 Credits**

Definition of Group Ring, Basic facts in Group Ring, Augmentation ideals, Partial Augmentations, Ideals in Group Ring, Units in Group Ring, Annihilators, Semiprime Group Rings, Prime Group Rings, Chain Condition in Group Rings, Linear identity, The Delta method, Dimension Subgroup, Polynomial identities, Crossed Products, Zero divisor free Group Ring.

**MAL707 Hyperbolic Conservation Laws: (3-0-2) 4 Credits**

Mathematical theory of hyperbolic conservation laws, first order wave equation, method of characteristics, Burger equation: Discontinuous solutions and expansion waves, Solutions to the Cauchy problem, Uniqueness and continuous dependence, Vanishing viscosity approximations, Hyperbolic system of PDE's: entropy, symmetrizability, constant coefficient linear systems, definition of wave types, truly non linear fields and linearly degenerate fields, Lax criterion, Riemann problem. Finite differences method, stability, consistency and accuracy of numerical schemes, conservative schemes, Lax-Wendroff theorem. Numerical schemes for scalar equations: 1-D Godunov method, finite volume method, Examples from traffic flow, gas-dynamics and magneto hydrodynamics.

**MAL708 Advanced Mathematical Ecology: (4-0-0) 4 Credits**

Introduction to Modeling and simulation in Ecology; Single Species Population Dynamics: Exponential and Logistic Growth; Structured Population Dynamics; Population Dynamics of Interacting Species: The Lotka-Volterra Predator-Prey Models and simulation; Qualitative analysis: Stability and phase plane analysis; Modeling of Infectious diseases: SIR models; Qualitative analysis of epidemic models: Computation of  $R_0$ , stability, equilibria; Spatial Dynamics: Metapopulation models, Diseases in Metapopulation; Adding Stochasticity to models: Sample paths and stochastic differential equations, General stochastic diffusion processes; Key models in Behavioral Ecology: Diet-choice and foraging, Evolutionarily Stable Strategies, Search and predation.

### **MAL709 Basic Algebraic Number Theory-3(3-0-0)**

Localization, Integral Dependence, Discrete Valuation Rings and Dedekind Rings, Fractional Ideals and the Class group, Class numbers, Norms and Traces, Extension of Dedekind Rings, Discriminant, Ramification, Norms of ideals, Cyclotomic Fields, Lattice in Real Vector Spaces, The unit Theorem, and The Finiteness of class number; Valuations, Local Norms and the Traces and The Product Formula; Decomposition and Inertia groups, The Frobenius Automorphism, The Artin Map of Abelian Extension; Moduli and Ray classes, Dirichlet Series, Characteristics of Abelian groups, L-series and Product Representatives, Frobenius Density Theorem.

### **MAL710 P-Adic Number Theory-3(3-0-0)**

Historical introduction, Bernoulli numbers, p-adic norm and p-adic numbers Hensel's Analogy, Solving Congruence modulo prime power, Absolute Values on the field of rational numbers, completion with respect to p-adic norms, exploring Hensel's Lemma, Local and Global Principles, p-adic interpolation, A formula for Riemann zeta function at even integers. p-adic function L-function, The P-adic Riemann zeta function as a Mellin – Mazur transform, p-adic distributions, Kummer's congruence, Bernoulli distributions, Measures and integration, Leopoldt's formula for p-adic L-function, p-adic regulator, p-adic gamma function, p-adic di-gamma function, p-adic Euler –Lehmer constant and their generalizations.

### **MAL711 Geometric Aspects In Functional Analysis 4(4-0-0)**

CLASSIC BANACH SPACES: Sequence spaces  $C_0$ ,  $C$ ,  $L_p$ ,  $1 \leq p \leq \infty$ , particular properties of  $l_1$ ,  $l_\infty$ , function spaces  $L_p$ , for  $1 \leq p \leq \infty, \epsilon(K)$ ; STRICT CONVEXITY AND SMOOTHNESS: Strictly convex and uniform convex Banach spaces, Gateaux differentiability, Frechet differentiability duality relation between convexity and smoothness; PROXIMAL SUBSPACES: Metric projections and their continuity properties, metric projections on Frechet and polyhedral spaces, proximality and strong proximality – their continuity properties, preduality maps, strong proximality via finite codimension.

### **MAL712 Virtual knot Theory, 3 (3-0-0)**

Definition of virtual knots and links, definition and properties of flat virtual knots, Reidemeister moves, virtual isotopic knots, Gauss codes, surface interpretations of virtual knots, long virtual knots, parity and the odd writhe, invariants for virtual knots, Bracket polynomial, parity Bracket polynomial, Z-move, Jones polynomial, Arrow polynomial for virtual and flat virtual knots and links, Virtual braids, categorical structure for the virtual braid groups, Alexander theorem and Markov moves for virtual braids.

### **MAL713 Numerical Method for Mathematical Finance, 4 (3-0-2)**

- Time-dependent one-dimensional convection-diffusion-reaction equations in finance
- Finite difference methods – theta methods: stability and convergence
- Modelling (local) stochastic volatility: an example of multi-dimensional PDEs with mixed derivative terms
- Splitting schemes of ADI type: Stability and convergence
- Comparison with other methods: Locally one dimensional (LOD) method, IMEX method.
- Numerical example

### **MAL714 Mathematics Of Financial Derivatives II, 4(4-0-0)**

- Risk-neutral valuation
- Black-scholes and beyond (Non-constant Volatility, stochastic interest rate, multi-asset options)
- American options: Early exercise and free boundary problem
- Exotic options: Path dependency
- Introduction to interest rate theory: Models and products
- Introduction to FX options: a case study

**MAL715: Transcendental number theory**

Liouville's theorem, Irrationality of some known constants, Transcendental Numbers, Approximation of Algebraic Numbers, Parameters for Algebraic Numbers and Polynomials, Thue's Equation, Hermite's Theorem, Lindemann's theorem, The Lindemann-Weierstrass theorem, The maximum modulus principle, Siegel's lemma, The six exponentials theorem, Estimates for derivatives, Theorems of Dyson and Gel'fond, Roth's Theorem, The Schneider-Lang theorem, Linear Forms in the Logarithms of Algebraic Numbers, Baker's theorem and its applications, Schanuel's conjecture.

**MAL716: BANACH ALGEBRAS,4 (3-1-0)**

*Pre-requisites: Basic Knowledge In Operator Theory*

Banach Algebras- Definition and examples; the spectrum; multiplicative linear functionals; the Gelfand transform and applications; maximal ideal spaces; Non-unital Banach Algebras. C\*-algebras - Definition and examples; commutative C\*-algebras; the spectral theorem and applications; polar decomposition; positive linear functional and states; The GNS Construction; non unital C\*-algebras. Topologies on  $B(H)$ .

**MAL799 INDEPENDENT STUDY (4-0-0) 4 Credits**

*Pre-requisites: NIL*

This course will contain material that is research related, and not offered in other courses. A course outline along with details of the work to be performed one independent study can count towards the degree of requirements.

## 9. Department of Mechanical Engineering

### **M.Tech courses**

#### **MEL501 Advanced Composites: (3-0-0) 3 Credits**

Definition of composite materials: classification: particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites. Metal-matrix composites, carbon-carbon composites, molecular composites, micro and multi layer composites. Theory of reinforcement, particulate and dispersion hardening, reinforcement by continuous and discontinuous fibres; concept of microfibril; effect of orientation and adhesion. Mechanical behaviour of composites: stress-strain relationship, strength, fracture, toughness and fatigue. Properties of fibre reinforcement and matrices, production technology of composites.

#### **MEL502 Advanced Welding Technology: (3-0-0) 3 Credits**

Physics of welding arc: characteristics of arc and mode of metal transfer. Welding fluxes and coatings: type and classification, electrode codes and their critical evaluation. Welding machine characteristics conventional and pulsed power sources, inverter type, power sources for resistance welding. Weldability- weldability of cast iron, plain carbon and low alloy steels, determination of preheat temperature, use of Schaeffler's diagram, weldability test. Residual stress and distortion- theory of residual stresses and distortion calculation, welding codes, joint design, analysis of fracture and fatigue of welded joints- fracture, energy consideration, fracture toughness testing and its application to welded joints. Automated welding systems: microprocessor control of arc welding and resistance welding, Quality assurance in welding, welding fumes and their effect on the environment.

#### **MEL503 Solidification Processing: (3-0-0) 3 Credits**

Plane front solidification of single phase alloys, interface stability, Czochralski growth, growth of single crystals of high perfection, cellular solidification, cellular-dendritic transition, plane front solidification of polyphase alloys, macro and micro morphology of eutectic growth. Growth of graphite in cast irons some problems in solidification of polyphase alloys, inclusions-their formation and distribution, rheocasting, Thixocasting, electroslag casting, casting of composites.

#### **MEL504 Advanced Metal Casting Technology: (3-0-0) 3 Credits**

Casting processes, classification and their characteristics, technology of selected casting processes, clay bonded, oil bonded, synthetic resin bonded, inorganic material bonded mould and core making processes. Sand additives and mould coatings; metal mould casting processes, centrifugal and continuous casting processes solidification, gating and risering, nucleation and grain growth. Solidification of pure metals, short and long freezing range alloys. Rate of solidification, macrostructure and microstructure. Solidification contraction: gating and risering design calculations. Fluidity and its measurement. Mould metal interface reactions, cast metals and alloys, family of cast irons, melting and casting technology. Inoculation, technology of steel and non ferrous cast metals. Gases in metals, melting furnaces and refractories.

#### **MEL505 Industrial Robotics: (3-0-0) 3 Credits**

History of development of industrial robots. Fields of application and future scope; Anatomy and structural design of robot, manipulation arm geometry, drives and control (hardware) for motions. End effectors and grippers, pickups, etc. Matching robots to the working place and conditions; interlock and sequence control. Reliability, maintenance and safety of robotic systems, application studies in manufacturing processes, e.g. casting, welding, painting, machine tools, machining, heat treatment and nuclear power stations. Synthesis and evolution of geometrical configurations, robot economics, educating, programming and control of robots.

**MEL506 Surface Engineering: (3-0-0) 3 Credits**

Surface-dependent engineering properties, surface initiated engineering failures - nature and causes, surface degradation, importance and necessity of surface engineering, tailoring of surfaces of advanced materials, surface protection (physical), surface modification (chemical) techniques: classification, principles, methods, and technology, conventional surface engineering methods applicable to steel, cast iron, non-ferrous metals/alloys, ceramics and composites, advantages and limitations of conventional processes, recent trends in surface engineering including cold spraying, post-coating techniques, characterization (microstructural & compositional) and testing/evaluation of surface-properties. Technological aspects of laser surface engineering.

**MEL507 Engineering Design Optimization: (3-0-0) 3 Credits**

Basic concepts. unconstrained and constrained problems. The Kuhn-Tucker conditions; function of one variable; polynomial approximations, Golden section method. finding the bounds on the solution, a general strategy for minimizing functions of one variable; unconstrained functions of n variable: zero-order first-order and second-order methods, convergence criteria; constrained functions of n variables: linear programming, sequential unconstrained minimization techniques. Direct methods; approximation techniques; duality; general design applications.

**MEL508 Advanced Mechanics of Solids: (3-0-0) 3 Credits**

Shear centre and unsymmetrical bending. Beam columns: beams on elastic foundations, curved beams, Rotating discs and thick cylinders, Virtual work; minimum potential energy; Hamilton's principle. plate theory: formulation by Hamilton's principle: bending and buckling of homogeneous and sandwich plates. Shell theory: introduction to theory of surface; formulation by Hamilton's principle; membrane, bending and buckling analysis of shells of revolution.

**MEL 509 Convective Heat Transfer: (3-0-0) 3 Credits:**

Forced Convective Heat Transfer: Introduction to heat transfer by convection, a review of viscous flow, conservation of mass and momentum – the continuity and Navier-Stokes equation, boundary layer equation, laminar boundary layer a flat plate, boundary layer separation, energy equation, derivation of energy equation, energy equation in non dimensional form, deviation of thermal boundary layer equation, heat transfer in a parallel flow over a flat surface, forced convection in internal flows, concept of entrance length and fully developed flow, heat transfer characteristics for internal flow

Natural Convection Heat Transfer: Governing equation and similarity considerations, free convection in laminar flow over a vertical plate, empirical co-relation in external free convection flows, inclined plates, long horizontal cylinder, spheres, free convection in enclosures, and cavities, combined free and forced convection.

Heat Transfer with Phase Change: Heat transfer in boiling, modes of boiling, regimes of pool boiling, pool boiling correlation, critical heat flux in nucleate pool boiling, forced convection boiling, modes of condensation, theory of film condensation, drop wise condensation.

**MEL510 Rotor Dynamics and Condition Monitoring: (3-0-2) 4 Credits:**

Modeling of rotor-bearing system by various techniques - transfer matrix, finite element, influence coefficients and modal methods. Critical speed maps. Unbalance response and orbital analysis. Disc gyroscopic. Rotor instability due to fluid film forces, hysteretic effects and parametric excitations. Rigid rotor balancing. Influence coefficient and modal balancing techniques for flexible rotors. Balancing standards. Torsional vibration analysis of rotating machines including branched systems-response to steady state and transient excitations. Instrumentation for bending and torsional vibration measurements on rotor-bearing systems.

Maintenance Principles, FMECA, Basics of Machine Vibration, Signal Analysis, Computer aided data acquisition, Time Domain Signal Analysis, Frequency Domain Signal Analysis, Fault Detection Transducers and Monitoring, Vibration Monitoring, Field Balancing of Rotors, Condition Monitoring of Rotating Machines, Noise Monitoring, Wear & Debris Analysis, Thermography, Electric Motor Current Signature Analysis, Ultrasonics in Condition Monitoring, NDT Techniques in Condition Monitoring, Case studies.

### **MEL511 Atomistic Simulation and Modeling of Materials: (3-0-0) 3 Credits**

This course uses the theory and application of atomistic computer simulations to model, understand, and predict the properties of real materials. Specific topics include: energy models from classical potentials to first-principles approaches; density functional theory and the total-energy pseudopotential method; errors and accuracy of quantitative predictions: thermodynamic ensembles, Monte Carlo sampling and molecular dynamics simulations; free energy and phase transitions; fluctuations and transport properties; and coarse-graining approaches and mesoscale models. The course employs case studies from industrial applications of advanced materials to nanotechnology. Simulations of classical force fields, electronic-structure approaches, molecular dynamics, and Monte Carlo.

### **MEL512 Nanocomposites-Processing, Characterization and Applications: (3-0-0) 3 Credits**

Nanocomposites-Introduction to Carbon Nano Tubes; Introduction to nanocomposites - where are they from and where are they going; Materials science of nanocomposites - understanding the pieces inside a nanocomposite part; Properties of nanocomposites - identifying the property advantages of these interesting materials; Particulates - the building blocks of nanocomposites

Structural and distribution characterization - seeing what is too small to be seen

Property characterization - realizing the performance of engineered parts; Introduction of Nano Mechanics; Nanoscale Characterization with Atomic Force Microscopy; Principles of imaging surfaces with AFM; magnitude of error, practical misconceptions; Quasistatic and dynamic modes; domains of application, pitfalls. Metrics of surface topography; examples of technological surface analysis. Compositionally sensitive methods. Shear forces, revealing crystallinity and disorder. Phases imaging for high spatial resolution on delicate samples; physical interpretations and corresponding misconceptions

Distance-dependent forces; liquid environments and chain molecule conformational states.

### **MEL513 Introduction to Plasticity: (3-0-0) 3 Credits**

Review of Stress, Strain and Elastic Stress-Strain Relations, Isotropic Yield criteria due to Hardening and their experimental verifications, Strain and Strain Rate Measures for Plastic Deformation, Plastic Potential and Flow Rule, Plastic Constitutive Relations (Stress-Strain Rate and Incremental Stress-Incremental Strain relations), Concept of plastic anisotropy and plastic instability, Formulation of Plasticity Problem, Approximate Methods of Analysis: Upper and Lower Bound Methods, Slip-Line Field Method, Bending of a beam with symmetric Cross-Section, Torsion of a Circular Cylinder, Hole expansion in an infinite Plate, Deep Drawing, Compression of a Cylinder (Forging), Necking of a cylinder, Wire Drawing, Bending of a circular Plate.

### **MEL514 Metallic Corrosion: (3-0-0) 3 Credits**

Fundamentals of metallic corrosion. Forms of corrosion-uniform corrosion, intergranular corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, erosion-corrosion, stress corrosion cracking (SCC), biological corrosion and high temperature corrosion (HTC). Corrosion mechanisms. HTC of alloys and coatings-formation and growth of oxide scales. Design strategies for new corrosion-resistant alloys. Corrosion and erosion-corrosion in boilers and gas turbines. Corrosion problems in the petrochemical industry and modern incinerators. Sulfidation of metallic materials. Corrosion problems

in metal forming and other manufacturing processes. Oxidation of metal matrix composites. Corrosion evaluation-modern analytical techniques. Brief introduction to commonly used techniques for corrosion control.

**MEL515 Bone Biology: (3-0-0) 3 Credits:**

Structure and development of the skeleton, Mesenchymal stem cells and osteoblast lineage, Transcriptional control of osteoblast differentiation, Osteocyte and biomechanics of bone, Osteoclastogenesis, Regulation and function of osteoclast, Bone matrix I: collagen and noncollagenous proteins, Bone matrix II: intercellular junctions and cell-cell, communication in bone, Bone remodeling and mineral homeostasis, Mechanotransduction in bone cells, Local regulators of bone: Statins and bone, Craniosynostosis, Bone Fracture Healing, Bone tissue engineering, Methods in bone research.

**MEL516 Orthopedic Biomechanics: (3-0-2) 4 Credits:**

The Musculoskeletal System; Physiology of the Neuro-Musculoskeletal System; Loads and Motion in the Musculoskeletal System; Bone Tissue Mechanics; Soft Tissue Mechanics; Structural Analysis of Musculoskeletal Systems; Bone-Implant Systems; Bone Mechanotransduction; Biomechanics of Fracture Healing; Fracture Fixation Devices; Total Hip Replacements; Total Knee Replacements; Articulating Surfaces.

**MEL517 Sustainable Design and Manufacturing: (2-0-4) 4 Credits**

General sustainability, sustainability and its importance, environment, ecology and the planet, material life cycle, renewable and non-renewable resources, climate change, sustainability measures such as environmental impact, factors, indicators, and influences; assessment methods, Triple Bottom Line (TBL) approach; Life Cycle Assessment (LCA), method and tools, standards and directives, reporting initiatives; eco-design, eco-design principles, tools and techniques; sustainable manufacturing, processes and techniques, energy usage during manufacturing, sustainable manufacturing techniques. Laboratory experiments: analysis of products, use of sustainability tools, design of sustainable products, energy usage monitoring during machining.

**MEL 518 Robot Manipulators: Kinematics, Dynamics and Control: (3-0-2) 4 Credits:**

Serial and parallel manipulators, Characteristics of robotic manipulators, Transformations, Forward and inverse kinematics of serial manipulators, Jacobian analysis, Trajectory planning, Forward and inverse dynamics of serial manipulators --- Newton-Euler and Lagrangian techniques, Robot control strategies. Special topics: Advance methods of motion planning, Kinematics and dynamics of parallel manipulators, Robot vision.

**MEL519 Biological Materials: (3-0-2) 4 Credits**

Nano and microstructure of biological materials, Biominerals, Proteins, Biological ceramics, Biological Polymer and polymer composite, Biological Elastomers, Functional Biological materials, Bioinspired materials.

**MEL520 Advanced Topics in Biomedical Engineering: (3-0-2) 4 Credits**

Lectures: Concepts of Biomedical Engineering, Advance topics of Genetic Engineering, Advance topics of Cell Culture Engineering, Biomedical Instrumentations: Anesthesia and Cardiac instruments, Concepts of Biomolecular Engineering, Advance Engineering of Immunity, Advance topics of Cardiovascular Physiology, Advance topics of Renal Physiology, Advance topics of Biomechanics and Orthopedics, Advance topics of Bioimaging, Advance topics of Tissue Engineering, Biomedical Engineering and Cancer, Artificial Organs.

### **MEL521 Computational Fluid Dynamics (3-0-2) 4 Credits:**

A brief overview of the basic conservation equations, classification of PDE and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. Common methods of discretization. Explicit and implicit schemes, consistency, stability and convergence. Numerical solution of systems of linear algebraic equations and iterative schemes and their convergence. Steady and transient diffusion problems (1-D and 2-D). Convection-diffusion problems: Central difference, upwind, exponential, hybrid and power-law schemes, concept of false diffusion, QUICK scheme. Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity and artificial compressibility methods, requirement of a staggered grid. MAC, SIMPLE, SIMPLEC and SIMPLER algorithms. An introduction to unstructured grid finite volume methods.

### **MEL 522 Air Conditioning and Ventilation (3-0-0) 3 Credits**

Psychrometry, simple psychometrics processes, use of psychometrics chart. Comfort and industrial air conditioning. Air filtration. Principles of ventilation. Physiological factors. Comfort index. Air conditioning systems: Spray systems, chilled water and DE Coils, absorption and adsorption systems. Humidifiers. Air conveying: fans, ducts and air diffusion equipment. Estimation of air conditioning load, determination of supply state. Design and constructional details of Unitary air conditioning equipment. Noise level and acoustic control. Automatic controls in air conditioning.

### **MEL 523 Refrigeration systems (3-0-0) 3 Credits**

Reverse Carnot cycle and standard vapour compression refrigeration cycle- analysis, comparison and Ewings construction. Compressor – reciprocating, centrifugal, rotary, screw type. Volumetric efficiency and performance of single stage refrigeration system, its limitations. Multistage multi evaporator and Cascade systems. Properties of refrigerants: primary, secondary and mixtures, piping design and lubricants. Absorption refrigeration systems: LiBr-water and aqua-ammonia systems, calculations by h-x diagram. Electrolux system. Steam jet refrigeration, vortex tube, thermoelectric refrigeration, Gas Cycle refrigeration. Air liquefaction cycles. Condenser and evaporators, overall heat transfer coefficient, classification, design and performance. Expansion valves; performance and balance point. System balancing of condensing unit and evaporator.

### **MEL524 Energy Conservation and Waste Heat Recovery: (3-0-0) 3 Credits:**

Potential for energy conservation, optimal utilization of fuels, methods of conserving energy, total energy approach.

Combined plants and cogeneration: Gas turbine-steam turbine plant, magneto hydro dynamic (MHD)-steam power plant, thermionic-steam power plant, thermoelectric-steam power plant, integrated gasification of combined cycle, cogeneration.

Utilization of industrial waste heat: sources and uses of waste heat, fluidized bed heat recovery systems, using waste heat in HVAC systems, heat pumps, heat recovery from incineration, heat exchangers, waste heat boilers, heat pipes, thermoelectric system to recover waste heat.

Energy storage and usage: using low grade rejected heat, electrical, magnetic, chemical and biological methods, thermo-economic optimization.

### **MEL525 FLUID MACHINES, 3 (3-0-0)**

*Pre-requisites :Fluid Machines or equivalent*

Fluid Mechanics (Review): Governing equations: equation of continuity, momentum, energy conservation, entropy; Navier –Stokes equations, Hagen- Poiseuille flow. Boundary layer Theory. Basics of Turbulence.

**Introduction to Fluid Machines:** classification of fluid machines, concept of energy transfer, principles of similarity and specific speed. Analysis of force and power generation.

**Turbines:** Impulse turbine – Reaction turbines, concept of performance characteristics for water

turbines.

**Pumps:** Rotodynamic pumps, Energy Transfer in Centrifugal Pumps, Cavitation, Axial Flow Pump, Reciprocating Pumps.

**Compressors, Fans and Blowers.**

**Dimensional Analysis:** Fundamental dimension- Physical Quantity and Dimensions-

Dimensional Homogeneity- Non Dimensional parameters,  $\pi$  –Theorem dimensions analysis, choice of variables, Determination of Dimensionless parameters.

### **MEL601 Advanced Tribology: (3-0-0) 3 Credits**

Introduction, Surfaces: nature, characterization and effects. Friction: mechanisms and types. Wear: nature, mechanism and types. Lubrication: lubrication regimes, hydrodynamic and hydrostatic lubrication, lubricants: characterization, types and effects, lubrication and bearings, properties and testing of lubricants. Mechanics of fluid flow-Reynolds equation and its limitations, idealized bearings: infinitely long plane pivoted shoe and fixed shoe sliders, infinitely long journal bearings, infinitely short (narrow) bearings, lightly loaded infinitely long journal bearing (Petroff's solution), finite bearings, approximate analytical solution, numerical solution and electrical analogy method. Hydrostatic oil bearing: thrust and journal bearings. Squeeze film bearings: gas lubricated bearings, hydrodynamic bearings, hydrostatic bearings, porous bearings, elasto-hydrodynamic lubrication, Friction and wear of metals, polymers and composites, case studies, methods of improving tribological behavior, friction control and wear prevention.

### **MEL602 Finite Element Methods in Engineering: (3-0-0) 3 Credits**

Basic concepts: The standard discrete system, Finite elements of an elastic continuum- displacement approach, Generalization of finite element concepts-weighted residual and variational approaches. Element types: triangular, rectangular, quadrilateral, sector, curved, isoparametric elements and numerical integration. Automatic mesh generation schemes. Application to structural mechanics problems: plane stress and plane strains. Axisymmetric stress analysis, introduction to three dimensional stress analysis. Introduction to use of FEM in steady state field problems-heat conduction fluid flow and non linear material problems, plasticity, creep etc., Computer procedure for Finite element analysis.

### **MEL603 Machine Vibration Analysis: (3-0-0) 3 Credits**

Characterization of engineering vibration problems. Model study through single degree of freedom analysis. Two degrees and multidegree of freedom systems with applications. Continuous medium. Vibration measuring instruments, computational techniques like matrix iterations, transfer matrix method and other methods, Lagrange's mechanics, system stimulation technique.

### **MEL604 Vibration and Shock Isolation: (3-0-0) 3 Credits**

Multidegree of freedom system excited by force and motion with two planes of symmetry. Natural frequencies for T.P.S. problems in isolation application. Natural frequencies for T.P.S. and O.P.S. inclined isolators and decoupling of modes. Velocity shock elastic and in elastic impact, effect of snubbing and preloading. Isolation of shock force that causes small and large displacements. Properties of material, design an isolation. Particular application of isolators.

### **MEL605 Friction and Wear in Machinery: (3-0-0) 3 Credits**

Introduction, surface: nature, characterization and effects, Friction: Mechanisms and types, wear Nature, mechanism and types, surface temperatures : formulation and measurements, Lubrication: Regimes, Hydrodynamic and hydrostatic lubrication, Lubricants: characterization, types and effects. Experimental methods, friction and wear of polymers and composites, Methods of improving tribological behaviour, Case studies.

**MEL606 Modern Manufacturing Processes: (3-0-0) 3 Credits**

Theory and application of machining by abrasive jet, water jet, abrasive flow, ultrasonics thermal assistance, total form matching and low stress grinding. Electrochemical machining and grinding, polishing, sharpening, honing and turning. Electrochemical discharge grinding: electrostream and shaped tube electrolytic machining. Chemical and thermochemical machining, thermal energy methods of material processing (machining/ welding/ heat treatment) by electro-discharge, laser and electron beam, plasma arc and ion beam. Physical vapour and chemical vapour deposition and plasma spraying. High energy rate forming and electroforming.

**MEL607 Rapid Prototyping: (3-0-0) 3 Credits**

Introduction to rapid prototyping (RP), need of RP in context of batch production, FMS and CIM and their application, basic principles of RP, steps in RP, process chain in RP in integrated CAD-CAM environment, advantages of RP. Classification of different RP techniques-based on raw materials, layering technique (2-D or 3-D) and energy sources, process technology and comparative study of stereo-lithography (SL) with photo polymerization SL with liquid thermal polymerization, solid foil polymerization. Selective laser sintering, selective powder binding, ballistic particle manufacturing-both 2-D and 3-D, fused deposition modelling, shape melting, laminated object manufacturing, solid ground curing, respective masking and deposition, beam interference solidification, holographic interference solidification. Special topic on RP using metallic alloy-laser engineered net shaping and electron beam melting. Rapid prototyping of small components-Micro stereo lithography, programming in RP representation of 3D model in STL format. Repair of STL files, rapid tooling.

**MEL608 Mechatronics: (3-0-0) 3 Credits**

Basic solid state components and devices elements of electromechanical energy conversion, starting, inversion and control of electrical drives. Coupling of mechanical loads to DC and AC electrical drives and speed control. Optoelectronic encoding, sensing, signal shaping and processing devices and techniques. Basics of digital signal processing data acquisition. Special simulation techniques for mechatronic systems, special techniques for solving of shift system model with switching and delay components. Elements of telemetry and remote control of mechatronic systems, theory of linear observers, optimal filters and their digital implications. Introduction to design and implementation of digital control strategies for mechanical systems.

**MEL609 Solar Thermal Engineering: (3-0-0) 3 Credits:**

Fundamentals of Solar Radiation, Atmospheric Absorption, Planck's Law and Wein's displacement Law, Radiative transport in participating media, Sky Radiation, Optical Properties of Layered Media, Flat-Plate Collectors, Concentrating Collectors, Energy Storage, Solar Loading, Solar Water Heating: Active and Passive, Building Heating: Active and Passive, Solar Thermal Power Systems, solar thermal energy utilization.

**MEL610 Advanced Conduction & Radiative Heat Transfer: (3-0-0) 3 Credits:**

Multi-dimension conduction, finite difference method, implicit and explicit schemes, steady- state and transient cases, flow of heat in infinite and semi infinite bodies; flow of heat in sphere, cone, cylinders; phase – change, black- body radiation, Plank's Law and Wein's displacement law, radiative transport equation, participative media, surface radiation.

**MEL611 Combustion Engineering: (3-0-0) 3 Credits:**

Combustion and thermo chemistry, chemical kinetics and reaction mechanisms. Rates of reaction, chain reactions, surface reactions, flame velocity, ignition and quenching, laminar premixed and diffusion flames, turbulent premixed flames, solid combustion, pollution and environment impact.

**MEL612 Turbulent Flow: (3-0-0) 3 Credits:**

Introduction to turbulence, equation of fluid flow, continuity and momentum equations, Reynolds stresses, turbulence modeling, Turbulent boundary layers, wall turbulence and free – turbulence, jets and Wakes, Free stream turbulence, scales of turbulent flow, length and time scales, velocity spectra, dissipation factor, skewness, flatness, turbulence measurement techniques.

**MEL613 Science of Machining: (3-0-0) 3 Credits**

Mechanics of chip formation, chip curl. Bluntness and cutting forces. Thermal aspects of machining. Tool wear, tool life and economics of machining. Mechanics of grinding, forces and specific energy, temperature. Wheel wear and surface finish

Cutting fluid and surface roughness, Nomenclature of cutting tools, Chip control, Machine tool vibration, Mechanisms of material removal in various non-conventional machining processes.

**MEL614 Nonlinear oscillations: (3-0-0) 3 Credits**

Review of linear systems and stability. Nonlinear systems: fixed points and linearization, stable and unstable manifolds, Stability and Lyapunov functions, index theory, Floquet's theory. Elementary bifurcation theory: normal forms of saddle node, transcritical, and pitchfork bifurcations, Hopf bifurcation. Maps: 1-D maps, stability of periodic orbits, symbolic dynamics and conjugacy. Chaos: Lyapunov exponent, routes to chaos.

**MEL615 Advanced Material Characterization Techniques: (2-0-4) 4 Credits**

SEM: Provide an understanding of scanning electron microscopy theory and principles: SEM gun construction, Get acquainted with scanning electron microscope construction and controls. Operation of scanning electron microscopy: Electron gun parameters, Imaging parameters, Image contrast (topographic and atomic number contrasts), Environmental scanning electron microscopy, Sample preparation, High resolution SEM imaging, EDS measurements.

**MEL 616 Fracture and Fatigue: (3-0-0) 3 Credits**

Fracture: Energy release rate, crack tip stresses and deformation fields, plastic zone, Elasto-plastic fracture through J-integral and CTOD, Dynamic fracture, Testing for Fracture, Toughness, Fatigue: Endurance limit and S-N diagram, strain-life equation, Crack nucleation and growth, Factors influencing fatigue strength, Influence of stress concentration, Fatigue life prediction, Statistical analysis, Fatigue testing modules.

**MEL 617 Biology for Engineers: (3-0-0) 3 Credits**

Biochemistry, Genetics, Genetics, Molecular Biology, Gene Regulation, Protein Localization, Recombinant DNA, Cell Biology, Developmental Biology, Cell Cycle/Signaling, Cancer, Virology/Tumor Viruses, Immunology, AIDS, Genomics, Nervous System, Stem Cells/Cloning, Molecular Medicine, Molecular Evolution, Human Polymorphisms and Cancer Classification, Future of Biology.

**MEL618 Molecular, Cellular and Tissue Biomechanics: (3-0-2) 4 Credits**

Molecular Mechanics: Mechanics at the Nanoscale (Intermolecular forces and their origins, Single molecules, Thermodynamics and statistical mechanics); Formation and Dissolution of Bonds

(Mechanochemistry, Motion at the molecular and macromolecular level, Muscle mechanics, Experimental methods at the single molecule level - optical and magnetic traps, force spectroscopy, light scattering.)

Tissue Mechanics: Elastic (time independent); viscoelastic and poroelastic (time-dependent) behavior of tissues; Continuum and microstructural models; Constitutive laws; Electromechanical and physicochemical properties of tissues; Physical regulation of cellular metabolism; Experimental methods - macroscopic rheology.

Cellular Mechanics: Static and dynamic cell processes; Cell adhesion, migration and aggregation; Mechanics of biomembranes; The cytoskeleton and cortex; Microrheological properties and their implications; Mechanotransduction; Experimental methods - passive and active rheology, motility and adhesion assays.

### **MEL619 Engine Management: (3-1-0) 4 Credits**

Diesel engine management: cylinder charge control systems; Diesel fuel injection system: parameters, various designs etc.; Fuel supply systems, Governors and control systems: inline, distributor, helix and port controlled distributor injection pumps; Overview of discrete cylinder systems; Unit injector and Unit pump systems; Common rail direct injection systems (CRDI); Fuel Injection nozzles; Emission control; Electronic diesel Control (EDC), Electronic control unit (ECU); Gasoline engine management: Gasoline fuel injection, Fuel supply, Electronic fuel pump; Manifold and direct fuel injection; Ignition systems; Sensors; Electronic control systems.

### **MEL620 Fluid Flow and Heat Transfer in Biological Systems: (3-0-0) 3 Credits**

The role of transport processes in biological systems, Definition of transport processes, Relative importance of transport processes, Transport in cells, Physiological transport systems, Application of transport processes in disease pathology, treatment, and device development, Blood and its flow and rheological properties, Approximate methods for analysis of complex physiological flow, Transport through porous media, Diffusion in biological systems, Charge transport in biological systems, Heat transport in biological systems.

### **MEL621 Micro and Nanoscale Heat Transfer: (3-0-0) 3 Credits**

Statistical Thermodynamics, Quantum Mechanics, Thermal Properties of Molecules, Kinetic Theory, and Micro/Nanofluidics, Thermal Transport in Solid Micro/Nanostructures, Electron and Phonon Scattering, Size Effects, Quantum Conductance, Electronic Band Theory, Tunneling, Nonequilibrium Heat Conduction, Energy Transfer in Nanostructures, and Analysis of Solid State Devices Such As Thermoelectric Refrigeration and Optoelectronics, Nanoscale Thermal Radiation and Radiative Properties of Nanomaterials, Radiation Temperature and Entropy, Surface Electromagnetic Waves, and Near-Field Radiation for Energy Conversion Devices and Applications in Thermal Management, Microfluidics, and Energy Conversion.

### **MEL622 Engine Instrumentation and Combustion Diagnostics: (3-0-0) 3 Credits**

General Engine Instrumentation; Dynamometers: AC, DC, Eddy Current & Chassis; Crank angle encoders; Pressure and temperature sensors; Measurement of fuel, combustion air and oil consumption; Injection and spark timing control methods; Test cell control and data acquisition, Combustion diagnostics by cylinder pressure measurement: knock, cyclic variations, IMEP, Efficiency, Combustion noise; Fast Response FID; In-Cylinder Flow Field Measurement: LDA, PIV; In-Cylinder soot concentration and particle size measurement; Fuel injection and spray characterization; Gas temperature measurement.

### **MEL623 Alternative Fuels and Advances in Engines (3-0-0) 3 Credits**

Combustion process in IC engines; Principle quality requirement of automotive fuels; Conventional Fuels for Land Transportation; Liquid alternative Fuels, Advantages, Potential problems associated with utilization, Vegetable oils, Biodiesel, Fischer-Tropsch Diesel, Alcohols, Pyrolysis bio-oil, Effect on Lubricating oils; Gaseous Alternative Fuels, Hydrogen, Compressed Natural Gas, Liquified petroleum Gas, Di-methyl ether; Multi-fuel engines; Modern developments in IC Engines, GDI, Low temperature combustion concepts, HCCI, RCCI, PPC; Sources and Nature of various types of pollutants: Pollution

monitoring instruments and techniques, Control measures, Emission legislations.

#### **MEL624 Crystal Plasticity, 4 (3-0-2)**

Elements of Tensor Analysis; Theory of Strains and Stresses; Basic Equations of Solid Mechanics; Symmetry of Elastic Properties; Failure Theories; Flow Rule; Isotropic and Kinematic Yield Criteria; Finite Element Method; Metallurgical Fundamentals of Plastic Deformation; Crystalline Anisotropy; Constitutive Behavior of Single Crystal; Homogenization Models for Polycrystals; Numerical Aspects of Crystal Plasticity Finite Element Method Implementations; Microscopic, Mesoscopic and Macroscopic Examples.

#### **MEL625 Engineering Ethics: (3-1-0) 4 Credits**

Evolution of the engineering profession; Basis for universal human values and ethical human conduct; Engineering profession in the light of comprehensive human goal; Responsibility in engineering; Social and value dimensions of technology; Ethics in science and engineering; Ethical issues in engineering practice; Engineering education and engineering for social justice; Environmental ethics and sustainability; Ethics in innovation; Ethics in Medicine and Business; Research ethics; Engineering for health; Case Studies.

#### **MEL626 Theory of Elasticity: (3-0-0) 3**

Credits Generalized Coordinates, Analysis of stress and strain, Infinitesimal and finite deformation elasticity, Constitutive equations, Uniqueness and superposition, Boundary value problems in plane stress and plain strain, Stress functions, Bending and Torsion of non circular cross sections, Kelvin problem and 3-D problems, Anisotropic Elasticity.

#### **MEL627 Micromechanics, 3 (3-0-0)**

Mathematical Preliminaries on Tensor Algebra and Tensor Calculus, Review of basic concepts in Continuum Mechanics (Kinematics of deformation, deformation rate, stress and strain tensors etc.), Homogenization Methods for Heterogeneous Materials (Specially particle and fiber reinforced composites), Plasticity in Metals, Crystal Plasticity (single and polycrystal plasticity), Fundamentals of Cohesive Surface Modelling and its application in modelling crack propagation, Discrete dislocation Plasticity (Concept of dislocations, stress and displacement field associated with dislocations, Application of discrete dislocation plasticity in solving boundary value problems).

#### **MEL628 Introduction to Virtual Instrumentation, 4 (2-0-4)**

Introduction to virtual Instrument(VI), Lab VIEW Environment, Data Flow Techniques, Advantages of VI Techniques, Basic Editing and Debugging Technique; Creating a VI :Icon and connector, Sub VI; Loops and Charts, List of Shift Registers,; Arrays and Graphics ;Case structure , Sequence structure, and Graphics ;Case structure , Sequence structure, I/O Operations, Sensors, Transducers and Signal Conditioning,; Common Transducers for Displacement, Temperature, Load, Pressure, flow, etc; Single Ended, Floating and Differential Inputs, grounding, Noise and Filtering, Data Acquisition Basics; AD DAC, DIO, Counters and Timers, Pc Hardware structure, Timing, PCI buses; Exploratory data Analysis Using Lab VIEW.

#### **MEL629 Advanced Fluid Mechanics (3-0-0) 3 Credits**

Fluid kinematics. Governing equations: equation of continuity, momentum equation, energy conservation, entropy; Navier-Stokes equations, Turbulent flow, Reynolds equations of turbulent flow, Turbulence modelling, Boundary layer theory, Hagen - Poiseuille flow.

Exact solutions of Navier-Stokes Equations: Couette flows, Poiseuille flows, Fully developed flows in non-circular cross-sections, Unsteady flows, Creeping flows.

Elements of Stability Theory: Concept of small-disturbance stability, Orr-Sommerfeld equation, Inviscid stability theory, Boundary layer stability, Thermal instability, Transition to turbulence.

Compressible flow: isentropic flows; normal shock wave relations, oblique shock waves, weak and strong shocks, and shock wave structure; compressible flows in ducts with area changes.

Dimensional Analysis: Fundamental dimensions- Physical Quantity and Dimensions-Dimensional Homogeneity- Non Dimensional parameters, p-Theorem dimensional analysis, Choice of variables, Determination of Dimensionless parameters.

### **MEL630 MODELLING TECHNIQUES FOR METAL FORMING PROCESSES: (3-0-0) 3 Credits**

Process Modelling, Plasticity Fundamentals, Uniform Energy Method, Slab Method, Slip-line Field Technique, Upper Bound Technique, Viscoplasticity Technique, Finite Element Method

### **MEL631 MANUFACTURING SCIENCE – I (3-0-0) 3 Credits**

Casting processes and analysis: Gating design, cooling and solidification, defects;

Forming processes and analysis: Rolling, Forging, Extrusion, Drawing, Shearing, Deep Drawing

Machining processes and analysis: Mechanics of machining, Tool life, Turning, Drilling, Milling, Multipoint machining, finish operations

Joining processes and their analysis: Principles of Welding; Solid phase, Arc, Resistance, Gas, Thermit welding.

Advanced applications in general engineering, aerospace, automobile and biomedical industries.

### **MEL632 Mathematics for Engineers, 3 (3-0-0)**

*Pre-requisites :Nil*

Properties of Vector Algebra, Vector space, subspace, basis, null and range space, invertibility and matrix representation; Cartesian Tensor notation and vector analysis; Matrices and Matrix algebra, Echelon form, orthogonalization; Eigen values and eigenvectors of a linear operator; Calculus of scalar, vector and tensor fields; Linear ODEs: Second and higher order Linear Differential equations; System of differential equations, Methods of Taylor and Frobenius, Laplace and Fourier transforms, Fourier series; Legendre and Bessel functions; Sturm Louville Problem; classification of PDEs; Analytical solution of linear PDEs.

### **MEL633 Numerical Methods in Mechanical Engineering, 3 (3-0-0)**

*Pre-requisites :Nil*

Introduction to Scientific Computing, Error Analysis, Solutions of Equations of One Variable (Root Solving), Interpolation and Polynomial Approximation, Least-Squares and FFTs, Numerical Integration and Differentiation, Solution of Systems of Linear Algebraic Equations, Solution to Matrix Eigen Problems, Solution of Nonlinear Equations, Solution of Ordinary Differential Equations, Linear and Nonlinear Elliptic, Parabolic and Hyperbolic Partial Differential Equations and Integral Equations, Finite Difference and Finite Volume Discretizations, Finite Element Discretizations, Boundary Element Discretizations, Direct and Iterative Solution Methods.

Manufacturing.

### **MEL634 Computer Integrated Design and Manufacturing Systems (2-0-4) 4 Credits**

Manufacturing system concepts; CAD/CAM/CAE/CIM; geometric modeling; mathematical representation of curves, surfaces and solids; solid modeling, solid representation; methodology of interactive, graphical, engineering design; computer numerical controlled machines; manual and automated CNC programming; automation; automatic tool changers; modern cutting tools; coordinate measuring machine; rapid prototyping systems; group technology; flexible manufacturing systems; industrial robotics.

### **MEP501 Control Engineering Laboratory: (0-0-4) 2 Credits**

Laboratory experiments on the design and use of Pneumatic Hydraulic and Electronic controllers for control of parameters like Displacement/Position Pressure Flow rate Temperature level Speed, etc.

Analog and Digital motor control plant and related experiments.

### **MEP502 Experimental Methods for Engineers: (1-0-6) 4 Credits**

*Pre-requisites :NIL*

Topics for introductory lectures/theory: Introduction to hypothesis formulation, Hypothesis testing, Analysis of variance, data analysis and interpretation, measurement uncertainty, experiment design; Experiments on calculating cooling load using air-conditioning and Refrigeration tutors; Quantification of the amount of heat transfer taking place due to natural and forced convection

mechanisms; Experimental methods to determine damping and transmissibility of vibrating system; uni-axial tensile and stress relaxation behavior of visco – elastic material ; measurement of machining forces and tool life during orthogonal cutting, Comparison with analytically predicted forces via Merchant’s model; estimation of mean fusion zone temperature in welding (either SMAW or MIG or TIG);

**MEP601 Advanced Mechanical and Materials Engineering Laboratory: (0-0-6) 3 Credits**

Any Twelve experiments

Measurement of cutting force and Temperature in turning; Measurement of Grinding force and estimation of temperature; Assessment of residual stress in ground surface; Imparting geometry to cutting tools; Effects of tool coating on performance of drills; Effects of tool coating on performance of turning tool inserts; Assessment of micro – structural changes due to grinding; Non – traditional manufacturing; Electro jet drilling

Electro – discharge Machining; Wire – EDM; Ultrasonic Machining; Laser beam machining; Micro-machining using Excimer Laser; Electrofoaming; Chemical Machining; To characterize a given materials by XRD, SEM/EDS, TEM analysis.

**MEP602 Material Engineering Laboratory: (0-0-4) 2 Credits:**

Determination of eutectic phase diagram; observation of case iron microstructure; heat treatment of steels-annealing, normalization, hardening and tempering and observation of their microstructure; harden ability determination by Jominy test; heat treatment of tool steels; pack carburizing of steels; age hardening of Al-base alloys, Determination of crystal structure by X-Ray diffraction.

## 10. Department of Physics

### M.Sc.- Core Courses

#### **PHL411 Classical mechanics, 4(3-1-0)**

*Pre-requisites :NIL*

Constrained motion, degree of freedom, virtual work, d'Alembert's principle, Lagrange's equation of motion: simple examples; small oscillations, normal modes and frequencies; Hamilton's principle, derivation of Lagrange's equation of motion from Hamilton's principle; Legendre transformation, Hamilton's equation of motion; Principle of least action; Canonical transformations: examples; integral variant of Poincare; infinitesimal canonical transformation; Lagrange and Poisson brackets; conservation theorem and angular momentum relation in Poisson bracket formalism; Liouville's theorem; Hamilton-Jacobi equation; Hamilton characteristic function, action and angle variables; example of simple harmonic oscillator; Classical chaos: periodic motion and perturbation, attractors, chaotic trajectories, Lyapunov exponents, the logistic equations; Rigid body dynamics: orthogonal transformation and rotation; Euler's theorem and Euler's angles; inertia tensor and principal axis theorem; Euler's equations; Heavy symmetrical top with one-point fixed on the axis; Special theory of relativity: Review (Lorentz transformation, length contraction and time-dilation); Time-like and space-like vectors, 4-vectors, 4-dimensional velocity and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle; Deformable bodies: strain and stress tensor, energy of elastic deformation; Fluid dynamics: permanency of vortices, Navier-Stokes theorem.

#### **PHL412 Mathematical Physics, 4 (3-1-0)**

*Pre-requisites :NIL*

Brief Introduction to vector calculus, Linear vector space: linear independence, orthogonality, Gram-Schmidt orthogonalization; Linear operators; Algebra of matrices: rank, elementary transformations, solution of linear equations, linear transformation, change of basis, eigen values and eigenvectors, diagonalization. Infinite dimensional function space, Hilbert space, Brief review of complex algebra: analytic function, Cauchy-Riemann equations. Complex calculus: integration in complex plane, Cauchy's integral formula, Singularity (poles and branch points, Riemann sheets), Residue theorem and its application to definite integrals. Integrals involving branch point singularity, Fourier and Laplace transformations and their inverse; Convolution; Solution of differential equations by transform methods, Brief review of differential equations and their series solutions; brief review of special functions (Bessel, Hermite, Legendre, Laguerre); Green's functions of differential equations; Integral equations (Fredholm and Volterra equations), Introduction to Tensor analysis: covariant and contravariant forms, addition, subtraction, outer and inner products, symmetric and anti-symmetric tensors, raising and lowering of indices, Christoffel symbols, Group theory: Group postulates, order of a group, subgroup, rearrangement theorem; invariant subgroups; generators, isomorphism and homomorphism, cyclic and permutation group; reducible and irreducible representation; character tables; infinite groups: rotation group, SU(2) and SU(3) groups; applications of groups in Physics.

#### **PHL413 Quantum Mechanics I, 4(3-1-0)**

*Pre-requisites :NIL*

Introduction: Origin of quantum theory, de-Broglie hypothesis and wave-particle duality, Wave packet, Gaussian wave packet, Fourier transform, Spreading of Gaussian wave packet, Schrodinger equation, coordinate and momentum representation, One-dimensional problems: potential step, potential barrier, potential well,  $\delta$ -function and double- $\delta$  potential, Application: Kronig-Penney model, One dimensional harmonic oscillator, Spherically symmetric potentials: separation of variables in spherical polar coordinate, orbital angular momentum, hydrogen atom, System of identical particles: Indistinguishability, symmetric and antisymmetric wave functions, incorporation of spin, Slater determinants, Pauli exclusion principle, Hilbert space formalism and Dirac notation: Operators and observables, significance of eigenfunctions and eigenvalues, commutation relations, uncertainty principle, harmonic oscillators by operator method, coherent states; Matrix representation of states and operators, continuous basis, Angular momentum: angular momentum algebra, eigenvalues of  $J^2$  and  $J_z$ , spinors and Pauli matrices, addition of angular momenta, CG coefficient, Symmetry operations and unitary transformations, generators, conservation principles, space and time translations, rotation, space inversion and time reversal, symmetry and degeneracy.

### **PHL414 ELECTROMAGNETIC THEORY4 (3-1-0)**

*Pre-requisites :NIL*

Laplace's equation in 1, 2 and 3 dimensions; Uniqueness theorems; Method of images; Separation of variables; Multipole expansions for scalar and vector potentials. Polarization; Field due to a polarized object; Linear dielectrics; Magnetization; Field due to a magnetized object; Linear and nonlinear media, Boundary conditions. Faraday's law; Maxwell's equations in free space and matter. Charge, energy and momentum conservation; Poynting's theorem; Maxwell's stress tensor. Monochromatic EM waves in vacuum; Reflection and transmission of EM waves across an interface – normal and oblique incidence, Fresnel's equations, Brewster's angles, parallel and perpendicular polarization. EM waves in conductors; Skin depth; Reflection at a conducting surface; Frequency dependence of permittivity; Anomalous dispersion. Wave guides, Coaxial transmission line, Cavity resonators. Scalar and vector potentials; Gauge transformations; Coulomb and Lorenz gauge; Retarded potentials, Jefimenko's equations; Lienard-Wiechert potential; Field due to a moving point charge. Dipole radiation-electric and magnetic; Radiation power; Radiation reaction. Relativistic electrodynamics – Field transformation, EM field tensor, Potentials.

### **PHL415 Electronics & Lab., 5(2-0-6)**

*Pre-requisites :NIL*

Introduction to semiconductor Physics, load lines, applications of diodes in circuits: dc power supply, voltage multipliers, limiters, clampers and peak-to-peak detectors, special purpose diodes, Bipolar junction transistors, small signal amplifiers, CE, CB and CC configurations, Input & output impedances and amplification factors, multistage amplifiers, FET and differential amplifiers. Power amplifiers: push-pull amplifiers, ac compliances, load line, OP-Amp: linear and nonlinear amplifiers with Op-Amp, negative feedback amplifiers and its parameters stabilization, Oscillators: Monostable, bistable & astable multivibrators, 555 timer and its applications, Digital techniques and applications (registers, counters, comparators and similar circuits); Data Acquisition System: Brief introduction to digital electronics, A/D & D/A converters, Microprocessor and microcontroller basics.

### **PHP420 Physics Lab - I, 4 (0-0-8)**

*Pre-requisites :NIL*

X-ray diffraction, Hall Effect and four probe measurements, Band gap measurement, Electron spin resonance, Magnetism and superconductivity.

### **PHL421 Quantum Mechanics- II, 4(3-1-0)**

*Pre-requisites :NIL*

Review of Symmetry; Rotation group, homomorphism between  $SO(3)$  and  $SU(2)$ ; Explicit matrix representation of generators for  $j=1/2$  and  $j=1$ ; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckert theorem, Time-independent perturbation theory with non-degenerate levels: First and second-order correction to the energy eigenvalues; first-order correction to the eigenvector; Case of degenerate levels; Applications (fine structure, Stark effect, Zeeman effect and hyperfine splitting of levels, relativistic mass correction), Variational method: Application to Helium atom, WKB method, Time-dependent perturbation; Fermi's Golden Rule; Sudden and adiabatic approximation; Application: interaction of an atom with em field (semiclassical and quantum approach), Scattering Theory; Scattering of a particle by a fixed centre of force. Scattering amplitude differential and total cross sections. Method of partial waves. Phase shifts. Optical theorem. Scattering by a hard sphere and potential well. Integral equation for potential scattering. Green's function. Born approximation. Yukawa and Coulomb potential., Relativistic quantum mechanics; Klein-Gordon equation: covariant notation, negative energy and negative probability density, antiparticles; Introduction to Dirac equation: properties of Dirac matrices, non-relativistic limit, Measurement theory of quantum mechanics; EPR paradox, Bell inequality, Entanglement.

### **PHL422 statistical mechanics, 4(3-1-0)**

*Pre-requisites :NIL*

Review of thermodynamics: Laws of thermodynamics, Thermodynamics potential, Maxwell's relations; Objective of statistical mechanics, concept of macrostates, microstates, phase space and ensembles, ergodic hypothesis, postulate of equal a-priori probability and equality of ensemble average and time

average. Boltzmann's postulate of entropy. Counting the number of microstates in phase space: connection to thermodynamics, Entropy of ideal gas : Sackur-Tetrode equation and Gibbs' paradox; Canonical and grand-canonical ensemble, formulation of partition functions, Energy fluctuation, application of partition functions: ideal gas, harmonic oscillators, rigid rotors, para-magnetism, negative temperature; Quantum statistics: Density Matrix (properties, pure and mixed states); Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices – one electron in a magnetic field, particle in a box; Identical particles; Ideal Fermi and Bose gases, their energy distribution BE: Bose-Einstein condensation, superfluidity, Planck's law, phonon gas, Debye theory of specific heat. FD: Fermi energy, ideal electronic gas, Landau levels, Landau diamagnetism, white dwarf and neutron stars; Strongly interacting systems: Ising model (Heisenberg and Ising Hamiltonian), solution of 1D Ising system in matrix methods, Mean-field approximation; Phase transitions and critical phenomena: critical indices, Landau's order parameters; Fluctuations: Thermodynamic fluctuations, Brownian motion, Langevin theory, Fokker-Planck equation, The fluctuation-dissipation theorem.

### **PHL423 Atomic and molecular physics, 4(3-1-0)**

*Pre-requisites :NIL*

Quantum states of an Electron in an Atom: Bohr's Postulates, Bohr's Model for the One Electron Atom, Wilson-Sommerfeld Quantization Rules; Sommerfeld's Extension of Bohr's Model and Quantum Mechanics of Hydrogen Atom, Electron Spin, Pauli's Principles and Hund's rule, L-S & J-J Couplings, Selection Rules, Spectrum of Helium and Alkali Atom, Normal and Anomalous Zeeman effects, Stark Effects, Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, Molecular Spectra, Electric dipole Transitions and Selection

Rules; Electronic Transition in Diatomic Molecules, Rotational and Vibrational Spectra of Diatomic Molecules, X-ray Spectra, Raman Spectra and Franck-Condon Principle, Absorption, Fluorescence, Phosphorescence, Electron spin resonance, Nuclear magnetic resonance and Advances in Molecular Spectroscopy.

### **PHL424 Nuclear and Particle physics, 4(3-1-0)**

*Pre-requisites :NIL*

Foundations of nuclear and particle physics: discovery of nucleus, size, shape and charge distribution, spin and parity. Origin of nuclear energy: mass defect, binding energy, semi-empirical mass formula and liquid drop model. Nuclear forces and two-body problem: nuclear stability and forces between nucleons, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces, Deuteron problem: ground and excited states of deuteron, normalization of deuteron wave function – radius of deuteron. Evidence of shell structure: single-particle shell model, its validity and limitations. De-excitation of excited nuclei: elementary ideas of alpha, beta and gamma decays and their selection rules, Nuclear reaction dynamics: classification of nuclear reactions, fusion, fission, (non)compound and direct reactions

The fundamental forces and the carrier particles & their quantum numbers (i.e., charge, spin, parity, isospin, strangeness, etc.), Gell-mann-Nishijima formula, Quark model, Baryons and Mesons. Invariance principles and conservation laws: translation and rotation, parity, charge conjugation, Charge Conservation and Gauge Invariance, Baryon and lepton conservation, CPT Theorem, CP violation and T violation, Isospin symmetry, Relativistic kinematics: Space & time mixing, "usual" relativistic effects, particle-decay, particle collisions & scattering.

### **PHL425 Condensed Matter Physics, 4(3-1-0)**

*Pre-requisites :NIL*

Bonding in solids - Ionic, covalent, Metallic and vander Waals bonds; Crystalline and amorphous solids; Lattice, basis and crystals; Unit cell; Lattice parameters; Primitive cell; Crystal symmetry: Point and space groups; Miller indices

X-ray diffraction; Classical theory of lattice vibration under harmonic approximation; Vibrations of 1D monatomic and diatomic lattices; Elastic wave quantization; Free electron models; band theory of solids; Band gap; Electrons and Holes; Effective mass; Carrier concentration in intrinsic semiconductor; mobility of charge carriers; Fermi surface and metals Optical, dielectric, and magnetic properties of solid Phenomenological description of superconductor; Effect of magnetic field; AC resistivity; Meissner effect; Energy gap; Isotope effect; Penetration depth; Type-I and Type-II superconductors; Introduction to BCS theory and High Tc superconductors.

### **PHP510 Physics Lab II, 4(0-0-8)**

*Pre-requisites :NIL*

Fabry-Perot Interferometer, Michelson-Interferometer, Fresnel Biprism, Fiber optics, Malus Law, Diffraction grating, Kerr effect, Absorption spectroscopy, Balmer series and Emission spectra, Zeeman effect, Magneto-optical effects.

### **PHP511 modern optics, 4(3-1-0)**

*Pre-requisites :NIL*

Particle and wave-nature of light, Maxwell's equations, wave equation, coherence of light (spatial and temporal), Superposition of waves, two wave interference, multiple beam interference, Michelson interferometer, Fabry-Perot interferometer, light at planar interface, Fresnel Equations, TE and TM modes, optics of multilayer films, antireflection coatings, diffraction of light, single, and double slit, circular aperture, diffraction grating, polarizations, dichroism, Jones Matrix, different kinds of polarizers, optical activity, optical modulators, optics of liquid crystals, Light in anisotropic media, double refraction, light in conducting medium. Magneto optics and electro optics, Thermal radiation and modes in cavity. The concept of light quanta, Planks theorem. Light pressure, spontaneous and stimulated emission, population inversion, laser threshold, properties of laser radiation, Introduction to non-linear optics, second and third order effects, harmonic generation, kerr effect.

### **PHL512 Experimental Methods 4(3-0-2)**

*Pre-requisites: Students registered for MEL471 are not allowed to register for PHL512 course.*

Error analysis and data reduction: classification and propagation, probability distributions, graphical handling and curve fitting, Vacuum pumps, Gauges, Cryogenics, Transducers, Sources, Accelerators and Detectors, Signal processing: Signal transmission and impedance matching; noise sources; signal noise optimization; pre-amplifiers, amplifiers and pulse shaping, Measurement of voltage, current, charge, frequency, etc.; overview of digital and analog systems in measurement; data acquisition, X-Ray Diffraction: Basic and X-ray diffraction techniques, XRD of single crystal, polycrystalline and amorphous materials, Transmission Electron Microscopy: Imaging and diffraction, data interpretation, Neutron diffraction, Introduction to the techniques, analysis for magnetic structures of a crystal, Magnetic materials and its properties, Superconducting Quantum Interferometer Device, Vibrating Sample Magnetometer, Physical Properties Measurement System, Four point probe, Van der Pauw methods, Hall effect, Scanning Probe Microscopy: Contact, non-contact and tapping modes, current sensing AFM, STM and STS, Scanning Electron Microscopy: Imaging and EDX, X-ray Photoelectron Spectroscopy: calibration, elemental analysis, depth measurement, Auger spectroscopy, Ultraviolet photoelectron spectroscopy, Optical sources and tables, beam parameters, Absorption, reflection and transmission measurements, FTIR, Raman and Laser induced breakdown spectroscopy, optical microscopy and imaging, near field microscopy, Optical coherence tomography, Images analysis, Light amplifiers, time resolved spectroscopy.

### **PHL513 Numerical Methods & Programming, 5(2-0-6)**

*Pre-requisites :NIL*

Basic concepts and ideas in numerical analysis: Introduction to error, accuracy and stability. Data Reliability assessment: parameter sensitivity, experimental perturbations, Interpolation (Lagrange's method, divided difference formula, splines), integration (Simpson's method, Romberg's method, quadrature formula), extrapolation, discretization, convergence, regression, quadrature, Random numbers, Solution of linear algebraic equations (elimination methods, LU decomposition), Eigenvalue problems, numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods. Introduction to numerical solutions of partial differential equations; Von Neumann stability analysis; alternating direction implicit methods and nonlinear equations.

### **PHL551 Nano-optics 3(3-0-0)**

*Pre-requisites :NIL*

(Review) Maxwell's equations, wave equation in vacuum, crystal structures, Bragg diffraction reciprocal lattice vectors, basic semiconductor physics,.

Introduction to nanophotonics as a new way to manipulate light, semiconductor quantum dots, quantum wells, nano-wires, Meta-materials, Photonic crystals, photonic band gap, spontaneous emission control, photon density of states, light in disordered nanostructures, surface plasmons, localized surface plasmons, near-field optics, optical micro/nano cavities, nano-lasers, optical circuits.

Overview of different synthesis methods and characterization of nano-optics structures, nanophotonics devices, negative refractive index materials.

### **PHL552 Physics of Nanomaterials and Nanotechnology, 3(3-0-0)**

*Pre-requisites :NIL*

Physics of 0D, 1D, 2D and 3D confinement; Density of states and Surface plasmons; Excitons in nanomaterials and Coulomb blockade; Size and surface dependence of physical; electronic; optical; magnetic; catalysis and mechanical properties

Nanoparticles growth using homogenous nucleation and heterogeneous nucleation

Fundamental of evaporation-dissolution growth; vapor-liquid solid; vapor-solid and vapor-solid-solid growth mechanisms; control the size of nanowires; template based synthesis; tunable growth of nanowire; nanotubes and nanoflute; Fundamental of thin film growth; Thermodynamics of nucleation and growth; kinetics process in nucleation and growth; growth models and superlattice; Carbon nanomaterials: nanofullerenes; nanotubes; graphene; nanodiamond; coreshell nanostructures; nanoflute Characterization of nanomaterials and application to Molecular and nanoelectronics; biological application of nanomaterials; band gap engineering; nanomechanics; nanowires based hazardous chemical sensors; 1-D nanomaterials based mass sensors; antenna and laser and solar cells.

### **PHL553 surface and interfacial forces, 3 (3-0-0)**

*Pre-requisites :NIL*

Forces between atoms and molecules: Introduction, Forces of nature, Thermodynamic and statistical aspects of intermolecular forces, Covalent and coulomb interactions, Polar molecules and polarization, Van der Waals forces, Casimir force, Force measuring techniques, Forces in liquids, Hydrogen bonding, hydrophobic and hydrophilic forces

Forces between particles and surfaces: Concepts in intermolecular and interparticle forces, Differences between Intermolecular, Interparticle and Intersurface forces, VdW forces between particles and surfaces, Electrostatic double layer, Capillary forces,

Hydrodynamic forces, Adhesion and wetting, Friction and lubrication, Self assembly, Applications

### **PHL554 NONLINEAR OPTICS, 3(3-0-0)**

*Pre-requisites :NIL*

Introduction: Maxwell equations and Propagation of light waves in different media, Introduction to nonlinear optics and Nonlinear Optical Interactions; Nonlinear Polarization and Nonlinear Susceptibility, Wave Equation for nonlinear Optical Media; Quantum Mechanical Description, Second order nonlinear optical Process: Second Harmonic Generation (SHG), Sum and Difference Frequency Generation, Phase Matching Conditions, Optical Parametric Generation and Amplification, SHG from surfaces and interfaces, Third order nonlinear optical Process: Third Harmonic generation, Four photon Parametric Interactions (four wave Mixing), Self Focusing, Self-Phase-Modulation, Refractive Index in Nonlinear Optics, Optical Phase conjugation, Coherent Anti-Stokes Raman Spectroscopy (CARS), Sum Frequency Generation Vibrational Spectroscopy.

### **PHL555 Nuclear Reactions & Instability 3(3-0-0)**

*Pre-requisites :NIL*

Alpha decay: semi classical theory of  $\alpha$ -decay,  $\alpha$ -particle energies and selection rules, Gamow's theory, Beta decay: energy spectrum allowed and forbidden transitions, decay rates, electron capture, Fermi-curie plot and mass of neutrino, comparative half-life, Gamma decay: energetics, Mossbauer Effect, angular momentum and parity selection rules, internal conversion, Non-conservation of Parity and Wu's experiment, Nuclear reactions: energy spectra, angular distributions, cross-sections, elastic scattering and nuclear size – electron scattering and optical model for nuclear scattering, direct reactions – angular momentum transfer and selectivity, Compound Nucleus Hypothesis – formation and resonances in CN, low energy neutron induced

fission, Introduction to heavy ion reactions: elastic and direct reactions, fusion, deep inelastic reactions and limits to fusion.

### **PHL556 Particle and Radiation Detectors 3(3-0-0)**

*Pre-requisites :NIL*

Interactions of heavy ions, gamma-rays and neutrons with matter: Bethe-Bloch formula, energy dependence, Bragg curve, projectile dependence, medium dependence stopping power, photo-electric effect, Compton scattering, pair production, attenuation and neutron moderation, Gas filled detectors:

Ionization Chamber, Proportional Counter, GM counter, Semiconductor detectors: surface barrier and HPGe, solid state– segmented detectors, detector performance, energy resolution, peak-to-total ratio, Scintillation detectors: plastic detectors and PMTs, Neutron detectors: slow and fast neutron detectors, Particle identification: E-dE telescopes, time of flight, Idea of particle-gamma and gamma-gamma coincidence measurements.

### **PHL557 Data Reduction and Measurement Techniques 3(3-0-0)**

*Pre-requisites :NIL*

Presentation of physical quantities: Precision and accuracy, Processing and interpretation of experimental data, Orders of magnitude approximation (Fermi estimates), Graphical handling of data with errors: Normalization, Least squares fitting, Rejection of Data, Weighted average, Fitting functions to data: Linear and nonlinear curve fitting, Chi-square test, general least-squares fit, accuracy of parameters, F-test on significance of the fit, From binomial to normal distributions: binomial, multinomial, Poisson, and normal - Gaussian distributions, Introduction to ROOT and GEANT, Signal processing and control: conditioning and recovery. Impedance matching, amplification, filtering and noise reduction, shielding and grounding, coupling of Analog and digital electronics.

### **PHL558 Nuclear Scattering and Heavy Ion Reactions, 3(3-0-0)**

*Pre-requisites :NIL*

Introduction: A brief review of different types of nuclear reactions and Q-equation, cross-section, CN hypothesis and Ghosal experiment, Statistical theory of reactions, pre-compound emission and direct reactions: PEE, pair-transfer and multi-nucleon transfer reactions, The nuclear optical model: optical model at low energies, Formal derivation of the optical model potential, Kinematics and theory of stripping and pick-up reactions, Heavy-Ion reactions: Physical description of heavy ion interaction, elementary idea of classical and approximate quantum mechanical theories, classical and semi-classical analysis of heavy ion reaction data, nuclear rainbow scattering, Exotic and super heavy nuclei: complete and incomplete fusion, idea of sub-barrier fusion, high-spin states, the relativistic heavy-ion collisions (introduction), Sub-barrier fusion, Coulomb excitation.

### **PHL559 Physics of Low Dimensional Systems 3(3-0-0)**

*Pre-requisites :Knowledge of Quantum mechanics*

Introduction to layered and low dimensional materials (organic and inorganic), quasi low dimensional materials, quantum wells, dots, and their synthesis, Quantum mechanical approach to realize the bands of low dimensional materials, and their consequences, Electrical and thermal conduction in low dimensional materials, charge statistics and transport, Coulomb blockade in low dimensional systems and single electron transistors, Tuning of the electrical and other properties by electric field and magnetic field, effect of functionalization on the electrical properties of low dimensional materials, For fabrication of nano-devices from low dimensional materials with electron beam lithography, Application of low dimensional systems in fabrication of transistors, sensors, LEDs, solar cells.

### **PHL560 Semi conductor physics, 3(3-0-0)**

*Pre-requisites :Knowledge of Quantum mechanics*

Semiconductor crystal growth, doping technique, wafer fabrication, Lithographic techniques for device fabrications using mask and maskless lithographic techniques, Quantum theory of Solids, Formation of energy bands, The k-Space diagram, Electrical conduction in solids, Extension to three dimensions, Density of states function, Charge carriers in semiconductors equilibrium, distribution of electrons and holes, Dopant atoms and energy levels, Statistics of donors and acceptors, Position of Fermi energy level, Non-equilibrium excess carriers in semiconductors, Carrier generation and recombination, Characteristics of excess carriers, Ambipolar transport, Quasi-Fermi energy levels, Excess-carrier lifetime, Basic structure of the pn junction, Zero applied bias, Reverse applied bias, Non-uniformly doped junctions, Bipolar transistor action, Minority carrier distribution, Optical devices, Optical absorption, pn junction solar cell, Photo-detectors.

### **PHL601 Classical and Mathematical Physics, 3 (3-0-0)**

Mathematical Physics: Fourier series; Fourier and Laplace Transforms: Sine and Cosine Transforms, Convolution and Correlations, Application-oriented problems; Linear vector space: properties, Gram-Schmidt orthogonalization; Matrices: inverse, rank, eigenvalues and eigenfunctions, diagonalization; Solution of linear equations: linear transformation, change of basis; Tensors: rank, products, contraction,

tensors with special forms, examples in physics; Complex calculus: Integration in complex plane, Cauchy's integral formula, singularities, residue theorem, definite integration; Group Theory: Isomorphism and homomorphism, cyclic and permutation group, reducible and irreducible representation, character tables, finite and infinite groups, crystallographic and molecular symmetries  
Classical Mechanics: Lagrange's and Hamilton's equations of motion: scope of the application, introductory problems, Poisson's bracket, Liouville equation; Damped and forced harmonic oscillation, Q-factor; Small oscillations of coupled systems, Normal modes; Classical theory of harmonic crystal: monoatomic and diatomic one-dimensional chain, dispersion relations; Special theory of relativity: Length contraction and time dilation, four-vector notations, Lorentz transformations.

### **PHL602 Quantum and Statistical Physics, 3 (3-0-0)**

Quantum Mechanics: Schrodinger equation in time-independent potential: Particle in a box, Barrier and well (Outline of calculations, emphasis on essential physics), tunnelling and bound state; resonant tunnelling in two quantum wells; Harmonic oscillator: Outline of calculations in wave function and operator approach, Comparison with barrier and well; vibrational modes of a linear chain of coupled harmonic oscillators: phonons; Electron energy levels in periodic potentials: Bloch's theorem; band structures; density of states; concept of holes; Particle in a central potential: Hydrogen atom, Outline of calculations; angular momentum algebra, symmetry; Case studies: rotation of diatomic molecules, charged particle in a magnetic field (Landau levels); Scattering of a particle by a fixed center of force: cross sections, Fermi's Golden Rule, partial waves, phase shift, optical theorem; Born approximation  
Statistical Mechanics: microcanonical, canonical, and grand canonical ensembles; examples, partition functions; paramagnetism, negative temperatures; Ideal Bose systems: thermodynamic properties, examples: black-body radiation, liquid Helium II; Ideal Fermi systems: Thermodynamic properties, examples: Pauli paramagnetism, Landau diamagnetism.

### **PHL603 Physics of Electromagnetic Waves 2,3 (3-0-0)**

Classical Electrodynamics: Maxwell's equations: Energy and momentum of electromagnetic field, Radiation pressure, Boundary conditions of electromagnetic field at interfaces, reflection, refraction, and transmission, Brewster's angle; Solution in free space, concept of polarization, Stokes' parameters, Jones' matrix; Solution in a dielectric media: theory of local field and polarization, Clausius-Mossotti relation, atomic polarizability, Kramers-Kronig relation, Lorentz-Lorentz formula for dispersion, normal and anomalous dispersion, electrical conductivity in a metal, plasma frequency, negative refractive index; Radiation from electric dipole, multipole radiation, Radiation of a uniformly moving charged particle; Relativistic electrodynamics: electromagnetic field tensor, Lorentz force in vacuum, energy-momentum tensor in material media, radiation reaction; mechanical property of electromagnetic field of a charge

Optics: Light propagation inside a metal: reflection and refraction, optical constant of metal; Light propagation inside a crystal: Fresnel's formula, optical properties of uniaxial and biaxial crystals, double refraction, interference; Nonlinear susceptibility, phase matching and second harmonic generation;

Intermolecular Forces: Forces between atoms and molecules, Forces between particles and surfaces.

### **PHL604 Physics of Atoms, Molecules And Solids, 3 (3-0-0)**

Quantum Mechanics: Quantization of electromagnetic field, emission and absorption of photons by atoms, Einstein's A and B coefficients, Concepts of lasers; Rayleigh, Thomson, and Raman scattering, Resonance Fluorescence, Dispersion relation; Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation, simple solutions, relativistic covariance; negative energy solutions, hole theory; revisit of Hydrogen atom problem; Perturbation theory: time-independent theory up to second order, Zeeman and Stark shifts; time-dependent theory with sinusoidal fields, Rabi oscillation; Addition of angular momentum, electron spin, L-S coupling in atoms, Zeeman effect revisited, electric dipole transition and selection rules

Applications: Molecular spectra: selection rules, rotational and vibrational spectra, Raman and IR spectra; Crystal structure: reciprocal lattice, X-ray diffraction and Bragg's law, Bravais lattice and Brillouin zone; Electron gas in metals: Sommerfeld's theory, Fermi surface, thermodynamic properties; Case of weak periodic potentials: perturbation approach, energy levels near Bragg plane, bands and Brillouin zones, effective mass of electron and holes.

### **PHL605 Numerical Methods, 3 (3-0-0)**

Basic concepts and ideas in numerical analysis: Introduction to error, accuracy and stability. Data Reliability assessment: parameter sensitivity, experimental perturbations, Interpolation (Lagrange's method, divided difference formula, splines), integration (Simpson's method, Romberg's method, quadrature formula), extrapolation, discretization, convergence, regression, quadrature, Random numbers, Solution of linear algebraic equations (elimination methods, LU decomposition), Eigenvalue problems, numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods. Introduction to numerical solutions of partial differential equations; Von Neumann stability analysis; alternating direction implicit methods and nonlinear equations.

Computer organization and programming: Fundamental computer concepts in hardware, software, Programming in C++ for scientific computations (hands-on with basic programming), Use of graphical software: Basics of curve fitting. Introduction to grid/parallel computing  
Fast Fourier Transforms and Convolution, Monte Carlo techniques.

### **PHL606 Pre-Thesis Literature Survey And Seminar, (2-0-0)**

Title, Introduction, Problem definition, Literature Survey, Objectives, Methodology, References, Report Writing, Seminar.

### **PHL610 quantum optics I: fundamentals 3(3-0-0)**

Quantization of electromagnetic field, number states, coherent states, squeezed states, variances in electric field, phase properties; Coherence properties of em field: field correlation functions, optical coherence, spatial coherence, photon-photon correlations, bunching and antibunching, higher-order correlations, Hanbury Brown-Twiss experiment, phase dependent correlation functions; Representation of em field: P, Q, and W representation, general theory; Nonclassicality of em field: Mandel's Q-parameter, squeezing parameter, nonclassical statistics, other measures of nonclassicality, mixed non-classical states, quantum state tomography; Two-mode squeezed states: its nonclassicality, phase-space representation, Type I and II parametric down-conversion, second harmonic generation, optical bistability; Optical interferometry with single photons: beam splitter operation with number states, Hong-Ou-Mandel experiment, beam splitter operation with two-mode squeezed states, Mach-Zehnder interferometer with photons and two-mode squeezed states, Balanced homodyne interferometer, sensitivity of an optical interferometer, quantum statistics of the output field; Atomic coherent states, spin-squeezing, Ramsey interferometry.

### **PHL611 Introduction to Quantum Computation and Communication 3(3-0-0)**

Reviewing Quantum mechanics: Hilbert space and Dirac notation, Linear operators and matrices, Quantum observables as operators, measurement of observables, density operator, The Q-bit: Idea of a qubit, Bloch sphere representation, rotation operations on the Bloch sphere, single qubit measurement, pure and mixed states of a qubit, entanglement of two qubits, EPR paradox and Bell inequality, different physical realization of qubit, Quantum gates and quantum circuit: Reversibility, Single qubit gates, Two-qubit gates, Circuit representation of quantum gates, Toffoli and Fredkin gates, Quantum Algorithms: Basics of classical computation and computational complexity, principle of quantum computation, different quantum algorithms: Deutsch-Jozsa algorithm, Quantum Fourier transform, Shor's factoring algorithm, Grover's search algorithm, phase estimation algorithm, Quantum Communication: Classical cryptography, The no-cloning and no-deleting theorem, Quantum cryptography-BB84 protocol, quantum key distribution, Dense coding, Quantum teleportation, Physical realization: DiVincenzo's criteria, NMR, Ion trap, cavity-QED, linear optics, neutral atoms, quantum dots.

### **PHL612 Thin Films Science and Technology 3(3-0-0)**

Pre-requisites : Nil

Basic vacuum concept; pumping systems and detection; Materials in Vacuum; Leak Detection Thermodynamics of nucleation and growth; kinetics process in nucleation and growth; Volmer-Weber, Frank-Van der Merwe and Stranski-Krastanov growth models and textured of thin films Physics and chemistry of evaporation; Basics of Plasma; discharge and arc; reactions in plasma; physics of sputtering; ion beam induced surface modification; DC, RF and reactive sputtering process; magnetron sputtering; plasma etching; hybrid and modified PVD process; confocal and combinatorial sputtering Thermodynamics of CVD process; gas transport; film growth kinetics; thermal CVD, PE-CVD process and MOCVD Classical and quantum theory of electron transport; various conduction

mechanism (Thermionic, field enhanced, hopping, polaron conduction); conduction in ionic and insulating thin films; electron transport in semiconductor thin films

Characterization of thin films; Application of thin films in solar cells (active and passive); thin film transistors; heaters; chemical sensors and optical coatings.

### **PHL614 LASER PHYSICS, 3(3-0-0)**

Interaction of light with matter: basics, spontaneous emission, stimulated emission, density of states and relation to decay rates, Einstein coefficients, population inversion, condition for population inversion, laser gain, Two, three and four level gain medium, rate equation, pumping schemes, homogenous and inhomogeneous line broadening, Resonator theory, different kinds of laser cavities, stability of laser resonator, unstable resonators, ring cavity, gain saturation, threshold curve, laser properties and beam parameters.

Laser cavity modes: Fabry Perot cavity modes, longitudinal and transverse modes, mode, Characteristics, spectral and spatial hole burning, CW and pulsed lasers, Mode locking and Q switching, active and passive mode locking, line broadening, single mode and multimode lasers, different kinds of lasers.

Lasing cooling and trapping of atoms, application of lasers in medicine, industry and in communication. Random lasers and lasing without cavity.

### **PHL615 Introduction to Quantum information 3(3-0-0)**

*Pre-requisites :Knowledge of basic Quantum mechanics and basic linear algebra*

Classical information:Information and disorder: relation to statistical mechanics, quantifying information (Shannon's entropy); classical data compression (Shannon's noiseless coding theorem), capacity of noisy channel , Tools of quantum mechanics: Brief review (Hilbert space, eigenvalues, qubit, measurement), density matrix (pure state and mixed state), reduced density operator, partial trace and partial transpose, Schmidt decomposition, Quantum information: Quantum data compression (Schumacher's noiseless channel coding theorem), accessible information and Holevo bound, capacity of a Bosonic channel; Fidelity, von Neumann entropy, conditional entropy, mutual information, relative entropy and its interpretation, equalities and inequalities related to entropy, entropy increase due to eraser, Landauer eraser, relative entropy and thermodynamics, Entanglement: EPR paradox, non-locality, Bell inequalities (pure and mixed states), separable state, Detection of entanglement: Entanglement witness, Peres-Horodecki criterion, spin-squeezing criterion, Measures of entanglement: Properties of entanglement measures, entanglement of formation, entanglement of distillation, concurrence, negativity, quantum discord, relative entropy and entanglement, Error Correction: Concept of decoherence, Kraus operators; quantum noise, bit flip and phase flip, amplitude and phase damping,; quantum error correction, three-qubit bit-flip and phase-flip code, Shor code, independent error model, Hamming bound, classical linear codes, CSS code, stabilizer code, Relation of classical information and thermodynamics to entanglement.

### **PHL616 quantum optics II: basic applications 3(3-0-0)**

*Pre-requisites :Nil*

Brief review of time-dependent perturbation theory, sudden and adiabatic approximation; Brief review of Maxwell's equations inside dielectric media: absorption, dispersion, Kramers-Kronig relation; Semiclassical treatment of light-matter interaction: Two-level systems, Rabi oscillation, optical Bloch equation, coherence and applicability of rate equations; Absorption and dispersion spectra, optical saturation, resonance fluorescence from a driven two-level system; Coherent Control of absorption: Coherent population trapping, Stimulated Raman adiabatic passage, electromagnetically induced transparency; Coherent control of dispersion: slow light, storage of optical pulse, superluminal propagation, issue of causality, magneto-optical effects; Quantum treatment of light-matter interaction: Jaynes-Cummings model, collapse and revival, Wigner-Weisskopf formula, stimulated emission, dressed state theory for Mollow spectrum; Mechanical effects of light: radiation forces, cooling and trapping of atoms; Polarization and orbital angular momentum of quantum fields: Stokes parameters, HG and LG modes; Quantum optics in other different systems: cavity QED, ion trap, NMR, superconductors.

### **PHL617 Ion beam fundamentals and patterning 3(3-0-0)**

*Pre-requisites :Nil*

Introduction, Interatomic potentials, Binary elastic collisions, Cross sections, Ion stopping, Ion range, Ion distributions, Radiation damage and Spikes, Sputtering

Instabilities during sputtering, Kinetic processes contributing to surface evolution

Factors for patterning – Energy, Angle of incidence, Temperature; Fluence, Crystallinity

Regimes of patterning – Linear, Nonlinear, Theoretical approaches – Scaling concepts, KS equation, Redeposition models, Applications.

### **PHL618 LINEAR & NONLINEAR LASER SPECTROSCOPY 3(3-0-0)**

*Pre-requisites :Nil*

Light matter Interaction; UV-Vis absorption Spectroscopy; Phenomena and Characteristic of Fluorescence Emission: Jablonski Diagram, Stokes Shift, Fluorescence Lifetime and Quantum Yields, Detailed theory and applications of Raman and IR Spectroscopy; ATR-FTIR spectroscopy, Concept of Static and Dynamic Light Scattering and applications, Second and Third Order nonlinear Susceptibility, Three and Four Wave Mixing Spectroscopy and its applications, Laser Induced Transient Grating, Photon Echo spectroscopy and Pump-Probe Transient Absorption spectroscopy, Light scattering spectroscopy, Stimulated Raman Scattering, Stimulated Brillouin Scattering, Stimulated Kerr Scattering, Coherent Anti-Stokes Raman Spectroscopy, Detailed discussion on Second Harmonic and Sum Frequency Generation Scattering Spectroscopy with recent days applications.

### **PHL619 Particle Physics, 3(3-0-0)**

*Pre-requisites :Nil*

Particle Phenomenology: Elementary particles and interactions – fundamental interactions, deep inelastic scattering and quark jets, Classification of particles: fermions and bosons, leptons and hadrons, particles and resonant states, Quark model: quark flavours, confinement and QCD potential, Isospin, Baryon octets and decuplet, Gell-Mann-Nishijima relation, baryon isospin, colour degree of freedom, Magnetic moments of baryons, Elementary ideas of QED, Standard model: Symmetries, and conservation laws, Group theories, gauge invariance, Lagrangian of the Standard Model, Flavor group, flavor-changing neutral currents, CKM quark mixing matrix, GIM mechanism, Rare processes, Neutrino masses, Seesaw mechanism, QCD confinement and chiral symmetry breaking, instantons, strong CP problem, QCD.

### **PHL620 Nuclear Models, 3(3-0-0)**

*Pre-requisites :Nil*

Nuclear Models I: Shell structure and magic numbers, Single particle model and its applications, The spin-orbit coupling; spin, magnetic moment and quadrupole moment, Single particle model, seniority, reduced isotopic spin, Ground state spins of odd-odd nuclei (Nordheim's rule), configuration mixing, The individual (independent) particle model: LS and jj coupling schemes, Nuclear Collective Models: Varieties of collective motion, Nuclear rotational motion: rotational energy spectra and the nuclear wave functions for even-even and odd-A nuclei, nuclear moments, Collective oscillations: liquid drop model quadrupole deformation, kinetic energy and potential energy for quadrupole deformation, Deformation in nuclei: The Nilsson model, Coupling between modes of collective excitation: rotation vibration interaction, Rotation-particle coupling, core excitation

### **PHL621 Superconductivity and magnetism, 3(3-0-0)**

*Pre-requisites :Knowledge of Quantum mechanics*

Superconductivity - Different classes, different theories, and their ranges of validity, theory for superconductivity, Explain type-I and type-II superconductivity, Discuss vortices and their properties, Equations for Josephson junctions and its applications. Magnetism: Paramagnetism, magnetically ordered materials: Ferromagnets, Ferrimagnets and Anti Ferromagnets. exchange interactions, phase transitions, magnetic ordering and domains, spin waves (magnons), itinerant magnetism, Magnetism in insulators, Amorphous materials. Transformer steel. Various forms of magnetic energies: Magnetostatic, Magnetic Anisotropy and Magnetostriction. Direct, Indirect, super and double exchange. Magnetism in thin films, multilayers and fine particles, Superparamagnetism, Recent developments: Giant Magneto resistance, Colossal magnetoresistance, Tunnel magnetoresistance. Spin values. Basics of spin polarized transport and spintronics. Ferromagnetic Resonance, Basics of spin-wave theory, Spin wave resonance. Magnetostatic modes.