# UNIVERSITY OF KERALA

## REGULATIONS, SCHEME AND SYLLABUS

**For**

# M.Tech. Degree Programme

**In**

## MECHANICAL ENGINEERING

## (2013 Scheme)

## Stream: PROPULSION ENGINEERING

# M.Tech. Programme

## Mechanical Engineering-Propulsion Engineering
## Curriculum and scheme of Examinations

**SEMESTER I**

| Code No. | Name of Subject | Credits | Hrs / week | End Sem Exam hours | Marks | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | Internal \ Continuous Assessment | End Semester Exam | Total | |
| MMA 1001 | Applied Mathematics | 3 | 3 | 3 | 40 | 60 | 100 | Of the 40 marks of internal assessment 25 marks for test and 15 marks for assignment. End sem exam is conducted by the university |
| MPC 1001 | Thermodynamics & Combustion Science | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPT 1002 | Turbomachinery | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPC 1002 | Advanced Fluid Mechanics | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPC 1003 | Advanced Gas Dynamics | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPC 1004 | Advanced Heat & Mass Transfer | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPC 1101 | Propulsion Engineering Lab I | 1 | 2 | - | 100 | - | 100 | No End semester Examination |
| MPC 1102 | Seminar | 2 | 2 | - | 100 | - | 100 | |
| | **TOTAL** | 21 | 22 | | 440 | 360 | 800 | Seven hours departmental assistance |

**SEMESTER II**

| Code No. | Name of Subject | Credits | Hrs / week | End Sem Exam hours | Marks | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | Internal \ Continuous Assessment | End Semester Exam | Total | |
| MPC 2001 | Air Breathing propulsion | 3 | 3 | 3 | 40 | 60 | 100 | Of the 40 marks of internal assessment 25 marks for test and 15 marks for assignment. End sem exam is conducted by the university. |
| MPC 2002 | Rocket Propulsion | 3 | 3 | 3 | 40 | 60 | 100 | |
| * | Elective I | 3 | 3 | 3 | 40 | 60 | 100 | |
| * | Elective II | 3 | 3 | 3 | 40 | 60 | 100 | |
| * | Departmental Elective | 3 | 3 | 3 | 40 | 60 | 100 | |
| MCC2000 | Research Methodology | 2 | 2 | 3 | 40 | 60 | 100 | End semester Examination is Conducted by Individual Institutions |
| MPC 2101 | Propulsion Engg Lab II | 1 | 2 | - | 100 | - | 100 | No End semester Examination |
| MPC 2102 | Thesis-Preliminary I | 2 | 2 | - | 100 | - | 100 | |
| MPC 2103 | Seminar | 2 | 2 | - | 100 | - | 100 | do |
| | TOTAL | 22 | 23 | | 540 | 360 | 900 | Six hours departmental assistance |

* Students can select a subject from the subjects listed under stream/department electives for the second semester as advised by course coordinator.

**STREAM ELECTIVES OFFERED IN PROPULSION ENGINEERING FOR SEMESTER II**

| **Stream Elective I** | **Stream Elective II** |
|---|---|
| MPE 2001 Measurements in Fluid Flow & Heat Transfer.<br>MPE 2002 Computational Methods in Fluid Flow & Heat Transfer.<br>MPE 2003 Heat Transfer in Space Applications. | MPE 2004 Rarefied Gas Dynamics.<br>MPE 2005 Control Systems<br>MPE 2006 Nuclear Science & Technology. |

**SEMESTER III**

| Code No. | Name of Subject | Credits | Hrs / week | End Sem Exam hours | Marks | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | Internal \ Continuous Assessment | End Semester Exam | Total | |
| * | Stream Elective III | 3 | 3 | 3 | 40 | 60 | 100 | Of the 40 marks of internal assessment 25 marks for test and 15 marks for assignment. End sem exam is conducted by the individual institutions |
| * | Stream Elective IV | 3 | 3 | 3 | 40 | 60 | 100 | |
| ** | Non Dept. (Inter Disciplinary) Elective | 3 | 3 | 3 | 40 | 60 | 100 | |
| MPC 3101 | Thesis-Preliminary part II | 5 | 14 | - | 200 | - | 200 | No End semester Examination |
| | TOTAL | 14 | 23 | | 320 | 180 | 500 | Six hours departmental assistance |

* Students can select a subject from the subjects listed under stream electives for the third semester as advised by the course coordinator.

** Student can select a subject from the subjects listed under Interdisciplinary electives for the third semester as advised by the course coordinator.

## STREAM ELECTIVES OFFERED IN PROPULSION ENGINEERING FOR SEMESTER III

| Stream Elective III | Stream Elective IV |
|---|---|
| MPE 3001 : Design of chemical rockets.<br>MPE 3002 : Optimization for Engineering Design | MPE 3003 : Multiphase Flow<br>MPE 3004 : Turbulence<br>MPE 3005 : Inverse Heat Transfer |

**SEMESTER IV**

| Code No. | Name of Subject | Credits | Hrs / week | Marks | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Continuous Assessment | | University Exam | | Total | Remark |
| | | | | Guide | Evaluation Committee | Thesis Evaluation | Viva Voce | | |
| MPC 4101 | Thesis Final | 12 | 21 | 150 | 150 | 200 | 100 | 600 | *5 % of the evaluation mark is earmarked for publication in journal/conference |
| | Total | 12 | 21 | 150 | 150 | 200 | 100 | 600 | 8 hours departmental assistance |

## DEPARTMENTAL ELECTIVES FOR SEMESTER II

1. MID 2001 Reliability Engineering
2. MID 2002 Modern Information System
3. MDD 2001 Computational Plasticity
4. MDD 2002 Bio Mechanics
5. MDD 2003 Introduction to Signal Processing
6. MPD 2001 Finite volume method for fluid flow and heat transfer
7. MPD 2002 Transport Phenomena
8. MTD 2001 Finite Element Analysis for Heat Transfer.
9. MTD 2002 Cryogenics Engineering

# M.TECH –PROPULSION ENGINEERING SYLLABUS

# FIRST SEMESTER

## MMA 1001: APPLIED MATHEMATICS 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- To introduce to the students some of the advanced tools in numerical methods, classical partial differential equations, optimization techniques, sampling theory and transform methods and their importance in modeling may engineering phenomena and applications to solving such problems. Knowledge of these methods are essential for higher studies and research.

**Learning Outcomes:**

- At the end of the course students will have become familiar with the use of some advanced classical and modern Mathematical tools in the areas of numerical methods, classical partial differential equations, optimization techniques, sampling theory and transform methods which are basic problem solving tools of an engineer.

**Module I**

**Ordinary Differential equations**, Series Solution,Singularity, Regular Singularity, Forbenius method, Bessel's equation, Legendre Equation,Hermiteequation (solution only),LaguerreEquation (solution only),Tschebyschevs' equation (solution only), Bessel functions of first and second kind, Recurrence relation for $J_n(x)$, Value of $J_{½}(x)$ , ,Generating function for $J_n(x)$, Equations reducible to Bessels equations,
Orthogonality of Bessel functions, Legendre polynomial, Rodrigues formula, generating function for $P_n(x)$, recurrence relation for $P_n(x)$ , orthogonality of Legendre polynomials
**PartialDifferential Equation**:-Classification of PDE,Solution of Boundary Value Problems in partial differential equations using Laplace Transform Method.

**Module II**

**Calculus of variations**: Functionals,Euler Equations and its alternative forms,solution of Euler equation, isoperimetric problem,problem of several independent variables, functional involving higher order derivatives,problem with variable end conditions.
**Integral equations**: Standard forms of integral equations- Fredholm equation, Voltera equation, reduction of an integral equation to differential equation, solutions for integral equation, integral equations of the convolution type, solution of Fredholm integral equation by the method of successive approximations,
**Fourier transforms**:-Descrete Fourier transforms, Linearity and periodicity, The inverse N-pointDFT, The DFT approximations of fourier coefficients ,Approximation of Fourier transform by an N point DFT , The Fast Fourier Transform.

**Module III**

**Linear algebra**: **(More weightage should be given to applications of results and problems)**

Vector space, subspace, linear combinations, linear spans, row space, null space, column space, basis and dimensions, coordinates, rank

Linear transformations-linear operators , algebra of linear transformations-operators, representation of linear transformation / linear operators by matrices, change of basis, invertible operators, Linear functionals and the dual space, Transpose of a linear transformation.

Inner product, Inner product space, orthogonalsets, Gram-Schmidtorthogonalizationprocess, Linear functionalsandadjoint operators.

**Text Books:**

1. Mathematical methods for Engineers and Physicists-A K Mukhopadhayay –Wheeler publishing
2. Advanced Engineering Mathematics-Peter V O 'Neil –Thomson
3. Higher Engineering Mathematics-Dr. B S Grewal-Khanna publications
4. Linear Algebra and its applications-David C Lay-Pearson
5. Theory and Applications of Linear algebra-Schaum's outline series-McGraw Hill
6. Higher engineering Mathematics –B V Ramana-TataMcGraw Hill
7. Introduction to Partial differential equations-K SankarRao-Prentice Hall of India

**References:**

1. Differential equations with applications and Historical notes-George F Simmons-Tata McGraw Hill
2. Elements of Partial Differential Equations, Ian Sneddon, Dover Books on Mathematics Series
3. Introduction to Wavelets through Linear Algebra-Michael W Frazier,Springer
4. Linear Algebra- Kenneth Hoff mann and Ray Kunze- PHI

**Structure of the Question paper**

For the end semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPC 1001: THERMODYNAMICS & COMBUSTION SCIENCE 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- After completing the course, the students should understand the concept and fundamentals of combustion clearly. These should enable them to provide new innovations which could be of practical importance. The student should be able to apply this knowledge to extend the existing technology for the design and development of new projects.
- After completing first section, the student should understand the basic principles of thermodynamics of reacting mixtures, bond energy, heat of formation, heat of reaction, adiabatic flame temperature, evaluation of equilibrium constants and equilibrium composition, elements of chemical kinetics, Law of mass action, order and molecularity of reaction, Arrhenius Law, activation energy and collision theory of reaction rates etc. The student should gain deep knowledge about basic of combustion which enables them to extend the new technologies for practical applications.
- After completing second section the student should be able to understand various theories of Ignition and flammability, factors affecting flammability limits, flame quenching, flame propagation, factors affecting flame speed, premixed and diffusion flames, characteristics of laminar and turbulent flames, flame stabilization and its stability diagrams etc. The students will be able to propose new ideas for further developments in the existing technologies.
- After competing third section the student will get an idea about droplet combustion, coal combustion, coal gasification, free burning fires, combustion generated air pollution, clean combustion systems etc. for developing the technologies and providing new innovations for improving mixing and provide better combustion characteristic in oil and gas burners, stoves etc.

**Learning Outcomes:**

For assessing students' knowledge in the subject, various assignments and quizzes may be conducted. Assignments like designing of a new product of improving an existing one may be assigned to groups of students. Students may be given a hands on experience to work with shock tubes, droplet combustion studies, flames, etc for better understanding of the combustion characteristics.

## Module-I

Microscopic approach to thermodynamics: The molecular model – requirement – properties of simple gas - extension to gas mixtures – real gas effects Kinetic theory of gases- Velocity distribution functions – The Boltzmann equation, equipartition of energy - Molecular flux - Survival equation- Collision theory – Collision cross-sections – collision dynamics. Transport Phenomena – Viscosity, Thermal conductivity and diffusion.

## Module-II

Combustion-Gravimetric and molal analysis, Introduction to thermo-chemistry, stoichiometry, bond energy, heat of formation, heat of reaction, adiabatic flame temperature Thermodynamics of reacting mixtures, entropy changes for reacting mixtures – chemical equilibrium – equilibrium criteria – evaluation of equilibrium constants and equilibrium composition, The equilibrium collision theory, The dissociation – recombination reaction, Chemical Potential and Gibbs Phase Rule. chemical reaction rates, Elements of chemical kinetics – Law of mass action – order and molecularity of reaction – rate equation – Arrhenius Law – activation energy – collision theory of reaction rates – transition state theory – general theory of chain reactions – combustion of CO and hydrogen.

## Module-III

Ignition and flammability – methods of ignition – self ignition – thermal theory of ignition – determination of self ignition temperature and experimental results – energy required for ignition- limits of inflammability – factors affecting flammability limits – flame quenching – effects of variables on flame quenching.

Flame propagation – factors affecting flame speed – premixed and diffusion flames, physical structure and comparison – characteristics of laminar and turbulent flames – theory of laminar flame propagation – empirical equations for laminar and turbulent flame velocities.

Flame stabilization – stability diagrams for open flames – mechanisms of flame stabilization, critical boundary velocity gradient – stabilization by eddies – bluff body stabilization – effects of variables on stability limits.

## References:


1. Holman, J.P., Thermodynamics, 4$^{th}$ Edition, McGraw-Hill Inc., 1998.
2. Sears, F.W. and Salinger G.I., Thermodynamics, Kinetic Theory and Statistical Thermodynamics, 3$^{rd}$ Edition, Narosa Publishing House, New Delhi, 1993.
3. Anderson, J.D., Modern Compressible Flow , 3$^{rd}$ Edition, McGraw-Hill Inc.,2004
4. Bird, G.A., Molecular Gas Dynamics and the Direct Simulation of Gas Flows, Clarendon Press – Oxford , 1994

5. Cengel,Y.A., & Boles, M.A., Thermodynamics – An Engineering Approach, Tata McGraw-Hill
6. Fundamentals of combustion – Streldow R. A.
7. Elementary Reaction Kinetics – J. L. Rathan
8. Flames – Gaydon A. G. &Wolfhard H. G.

**Note:**Question Paper shall contain 6 questions of 20 marks each out of which the students has to answer any 5 questions.

**Structure of the Question paper**

For the end semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPT 1002 : TURBOMACHINERY 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

To impart knowledge on various types of turbo machines and their operation, flow mechanism through the impeller, methods of their performance evaluation under various operation conditions.

**Learning Outcomes**

By undergoing the course, one will be able to understand the working of various turbomachines under different operating conditions and will be able to design a system for the required output at the given conditions.

**Module I**

Definition and Classification of Turbomachines, Principles of operation, Specific work-representations on enthalpy entropy diagram. Fundamental equation of energy transfer, flow mechanism through the impeller, vane congruent flow, velocity triangles, ideal and actual flows, slip and its estimation, losses and efficiencies, degree of reaction, shape number and specific speed.
Two dimensional cascades: cascade nomenclature, lift and drag, circulation and lift, losses and efficiency, compressor and turbine cascade performance, cascade test results, cascade correlations, fluid deviation, off –design performance, optimum space-chord ratio of turbine blades.

**Module II**

Axial flow turbines: Two dimensional theory Velocity diagram, Thermodynamics, stage losses and efficiency, Soderberg's correlation, stage reaction, diffusion within blade rows, efficiencies and characteristics.

Axial flow compressors: Two dimensional analysis Velocity diagram, Thermodynamics, Stage losses and efficiency, reaction ratio stage loading, stage pressure rise, stability of compressors.

Three-dimensional flows in axial turbines: Theory of radial equilibrium, indirect and direct problems, compressible flow through a fixed blade row, constant specific mass flow rate, free vortex, off-design performance, blade row interaction effects.

**Module III**

Centrifugal compressors: Theoretical analysis of centrifugal compressor, inlet casing, impeller, diffuser, inlet velocity limitations, optimum design of compressor inlet, prewhirl, slip factor, pressure ratio, choking in a compressor stage, Mach number at exit.

Radial Flow Turbines: Types of inlet flow radial turbines (IFR), thermodynamics of $90^{o}$IFR turbine. Efficiency, Mach number relations, loss coefficient, off-design operating conditions, losses, pressure ratio limits.

**References:**


1. S L Dixon: Fluid Mechanics and Thermodynamics of Turbo machinery, 1998
2. H I H Saravanamuttoo, G F C Rogers, H Cohen: Gas Turbine Theory,2001
3. P G Hill, C R Peterson: Mechanics and Thermodynamics of Propulsion
4. S M Yahya: Turbines, Compressors and Fans
5. V Kadambi and Manohar Prasad: An Introduction to Energy Conversion Vol III Turbo machinery
6. G F Wislicunes: Fluid Mechanics of Turbomachinery
7. G T Csandy: Theory of Turbo machines


**Structure of the Question paper**

For the End semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MPC 1002: ADVANCED FLUID MECHANICS** **3-0-0-3**

**Objective**

The subject is aimed at providing fundamental knowledge in fluid mechanics at an advanced level,with the help of vector calculus complex variable theory and differential equations. Capability to mathematical modeling of fluid flow and its solution.Analytical solution to potential flow, simpleviscous flow and boundary layer flow.Understanding of the fundamentals of turbulent flow.

**Learning Outcomes**

1. Two test papers of 50 marks each to understand whether the students have understood thefundamentals or not.
2. Test the capability to read and understand a journal paper based on fluid mechanics.
3. Assignment IV is aimed at testing the capability of the students to formulate and solve afundamental fluid mechanics problem.

**Module-I**

Fundamental Mathematics: Curvilinear, Cartesian and Polar Co-ordinates. Unit vectors – Relations between unit vectors of different coordinate system – Del Operator – Operations – Del of a scalar, Del of a Vector, Divergence, Curl, $\nabla^2$ Operation on scalar and vectors – Derivation of expressions in Cartesian and Polar Co-ordinates-Tensor Product of Vectors-Tensor Transformations-Applications of Tensors in Fluid Mechanics. Complex Variables-Analytical Functions, Cauchy Reimann Relations-Complex differentiation-Conformal Mapping-Cauchy's Integral Theorem-Taylor's and Laurent Series.

Concept of Continuum: Eulerian and Lagrangian Methods of Description – Velocity and Acceleration.

Analysis of Stress in Fluid System-Stress Tensor, Stokes Hypothesis-Analysis of Rate of Strain-Rate of Strain and Rotation Tensors. Reynolds Transport Theorem-Derivation of Conservation Equations of mass, momentum and energy in Integral and Differential Forms using Reynolds Transport Theorem, Navier Stokes equations for incompressible flow-Derivations in Cartesian and Polar Co-ordinates. Euler, Stokes and Potential Flow equations-Stream Function, Vorticity-Stream Function and Vorticity Formulation.

**Module-II**

Theory of Potential Flow – Complex Flow Potentials-Uniform Flow, Source, Sink, Vortex, Doublet –Development of Complex Flow Potentials by method of super positions- Flow past a cylinder with and without rotation. Calculation of Lift using theory of complex variable.Mapping of a Flat Plate into a Cylinder, Ellipse. Flow past a vertical flat plate. Joukowsky Transformations, Schwartz-Christoffel Transformations.

Exact Solutions to Navier Stokes Equations: Cases-Flow between concentric rotating cylinders-Developed flow in an annulus-Couette Flow-Fully developed velocity distributions in Triangular and Elliptical ducts.

**Module-III**

Boundary Layer Theory-Concept-Boundary Layer Thickness-Displacement Thickness-Momentum Thickness and Energy Thickness-Derivation of Prandtl Boundary Layer Equations-Blassius Solution for Flow over a Flat Plate, Momentum Integral Equations-Separation of Boundary Layers-Karman Pohlhausen method for approximate solution to momentum integral equation-separation and Vortex Shedding.

Turbulent flow: Characteristics –Transition time, average and fluctuating quantities, Governing equations based on time average quantities-Turbulence stress tensor, concept of Eddy viscosity-Boussinessque's Stress Model – Prandtl Mixing length Hypothesis-Friction velocity-Turbulent flow over a flat plate and a circular pipe-Universal velocity distribution.

**References:**


1. Advaanced fluid mechanics-K.Muralidhar and G.Biswas
2. Mechanics of fluids-Shames I.H.
3. Viscous fluid flow-F.M.White.
4. Elementary Fluid Mechanics-Schlichting H.


**Note: 20% choice may be given while setting the question paper.**

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MPC 1003: ADVANCED GAS DYNAMICS** **3-0-0-3**

**Course Objectives**

Gas flow is one of the main fundamental subjects of propulsion engineering. The objective of this course to teach the students this subject in an advanced level. Formulation different problems and solution to some of the simple cases is included to make the students capable of analyzing practical problems involving compressible flow.

**Learning Outcomes**

The students will be able to analyze a flow situation and capable of using these theories in a real life situation and take appropriate decisions with regard to design and manufacture of various fluid handling devices

**Module I**

Generalized 1D continuous flow- working equations and table of influence coefficients- Flow with constant specific heat and molecular weight-General methods of solution-simple type of flow. Examples of combine friction and area change- Examples of combined friction and heat transfer.
Plane waves in supersonic flow- weak and strong oblique shocks-shock polar diagram-expansion waves- Prandtl-Meyer expansion functions- Reflection and intersection of oblique shocks and expansion waves- Shock expansion theory –Thin aerofoil theory as applied to lifting flat plates and diamonds.

**Module II**

Small perturbation theory – Derivation of perturbation equations in two dimensions- Pressure coefficient-Boundary conditions- two dimensional flow past a wavy wall in high subsonic and supersonic flow- supersonic thin aerofoil theory-linearised theory-Biconvex and diamond airfoils-best airfoil shape.

Similarity rules- Two dimensional linearised flow- Prandtl-Gluert and Gothert rules-Linearised axially symmetric flow. The von Karman rule for Transonic flow. Hypersonic similarity.

**Module III**

Introduction to Hypersonic flow.The lift and drag of wings at hypersonic speeds.High temperature shock layer on a blunt body moving at hypersonic speed.Hypersonic shock wave relations.Compressible flow through Supersonic Wind Tunnels- Hypothetical Normal shock diffusers and oblique shock diffusers.Design of diffuser throat in supersonic wind tunnel.

**Reference:**

1. Shapiro,A.H.; Dynamics and Thermodynamics of Compressible Fluid Flow-Vol,I
2. Liepmann and Roshko; Elements of Gas Dynamics.
3. Becker E;Gas Dynamics
4. Owezarek J A ; Fundamentals of Gas Dynamics

*Note; Use of approved charts and tables will be permitted in the examinations.*

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPC 1004: ADVANCED HEAT & MASS TRANSFER 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- Additional lab sessions may be conducted to provide exposure to students the concepts of various modes of heat transfer ad mass transfer.
- Additional video presentations on the work of various thermal systems may be conducted to create enthusiasm in students towards the subject and also to expose them to the potential are3as of application.
- Facilitate field visits to have a real life experience of how various types of thermal systems are functioning.

**Learning Outcomes**

- For assessing students knowledge in the subject, various assignments and quizzes may be conducted. Students may be asked to design a typical thermal system components like a condenser for a particular application.
- A brain storming can be conducted on how to improve the performance of various thermal systems.

**Module I**

Conduction: Steady state conduction with uniform internal heat generation-temperature distribution and heat flux for regular solids with uniform heat generation-temperature dependent and location dependent heat generation-steady state conduction in two dimensional systems. Analytical, graphical analog and numerical methods. Unsteady state conduction: unsteady state heating or cooling-Newtonian heating or cooling- Heating or cooling of finite and semi-infinite slabs with negligible surface resistance for different boundary conditions-solutions of heating or cooling of regular solids with comparable internal and external resistance by simple analytical methods and use of charts-periodic variation of surface temperature of infinitely thick walls neglecting and considering surface resistances.

**Module II**

Convection:Forced convection: Equations of motion of a viscous fluid. General equation of energy transport -2D boundary layer equation for momentum and energy transport.
Laminar flow heat transfer: Exact solutions of the 2D boundary layer momentum and energy equations. Approximate calculations of the boundary layer by the momentum and energy integral equations. Turbulent flow heat transfer: Time averaged equations of continuity, momentum and energy. Analog methods- Reynolds, Prandtl and von Karman.
Free convection: Solutions of the boundary layer equations for a vertical plate and a horizontal cylinder – approximate solutions-free convection with a turbulent boundary layer-free convection in enclosed spaces.

**Module III**

Radiation:Radiative properties of real materials Radiative properties of metals and opaque non-metals-modifications of spectral characteristics. Exchange of radiant energy between black isothermal surfaces.Radiative exchange between two surfaces- methods for evaluating configuration factors –radiation in a black enclosure
Radiation exchange in an enclosure composed of diffuse-gray surfaces Radiation between finite areas-radiation between infinitesimal areas, Solar and gas radiation.

Mass Transfer: Ficks Law of diffusion – Analogy between Heat and Mass transfer – Derivation of various forms of Equation of continuity for a Binary mixture – Boundary conditions – Forced convection with mass transfer over a flat plate Laminar boundary layer = Concentration boundary layer and Mass Transfer coefficient – Evaporative cooling.

**References:**


1. Heat transfer Holman J P
2. Conduction heat transfer: Schneider
3. Convective Heat and Mass Transfer: William Kays / Michael Crawford / Bernhard Weighand
4. Fluid Dynamics and Heat Transfer- Knudsen and Katz
5. Thermal radiation Heat Transfer: Robert Siegel and John R Howell
6. Fundamentals of Heat and Mass Transfer- Incropera F P and Dewitt D P
7. Heat Transfer A Practical Approach – Yunus A Cengel
8. Heat Transfer – P S Ghoshdastidar


Note : Use of approved charts and tables will be permitted in the examinations.

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPC 1101 PROPULSION ENGINEERING LAB – I 0-0-2-1

1. Study of FLUENT software (grid generation and preparation of simple models)
2. 3 D mesh generation using butterfly mesh
3. Analysis of Turbulent flow and heat transfer over a flat plate.
   Evaluation of $C_D$, Nusselts number
4. Analysis of flow over aerofoils
   Evaluation of lift and lift coefficient
5. Flow through $C_D$ nozzle for different pressure ratios.
6. Experiment on Wind Tunnel
7. Steady temperature measurements using thermocouple and data acquisition systems.
   Calculation of heat transfer parameters.
8. Unsteady temperature measurement using thermocouples and data acquisition system.
   Calculation of heat transfer parameters

## MPC 1102 SEMINAR 0-0-2-2

The student has to present a seminar in one of the current topics in the stream of specialisation. The student will under take a detailed study based on current published papers, journals, books on the chosen subject, present the seminar and submit seminar report at the end of the semester.

Marks: Seminar Report Evaluation : 50
Seminar Presentation : 50

# SECOND SEMESTER

## MPC 2001: AIR BREATHING PROPULSION 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- Understand principles of operation of turbojet, turbofan, and turboprop engines.
- Develop the ability to select a cycle and size an engine for mission requirements.
- Develop the ability to perform fundamental component design and analysis.
- Develop the ability to perform component matching.
- Develop the ability to predict on-and off-design operating points.

**Learning Outcomes:**

- Develop an understanding of the potential benefits and technical challenges associated with airbreathing propulsion systems for high speed flight.

**Module I**

Air-breathing engines and classification- Airscrew, Turbojet, Turboprop, Turbofan, Turbo shaft, Ramjet, Scramjet. Thermodynamic analysis of Turbojet and Turbofan engine cycle. Aerothermodynamics of inlets, combustors and nozzles- Subsonic inlets and its flow pattern, Supersonic inlets- successive steps in the acceleration and over speeding of a supersonic inlet. External deceleration mechanism.Variable-geometry intake in supersonic aircraft.Gas turbine combustors- Fully annular combustion chamber and can-annular combustion chamber.Flame holders-Simplified model of a flame holder.Nozzles- Working principle of a variable exhaust nozzle in an afterburning Turbojet engine.

**Module II**

The atmosphere-characteristics of troposphere, stratosphere, thermosphere and ionosphere-pressure, temperature and density variations in the atmosphere
3D or finite aerofoils-effect of releasing the wing tip vortices-replacement of finite wing by horse shoe vortex system- the lifting line theory- wing load distribution-aspect ratio, induced drag- calculation of induced drag from momentum considerations. Skin friction and form drag-changes in finite wing plan shape.

**Module III**

Aircraft performance-straight and level flight-Power required and power available graphs for propellers and jet aircraft-gliding and climbing-rate of climb- service and absolute ceilings-gliding angle and speed of flattest glide-take-off and landing performance-length of runway required-aircraft ground run- circling flight-radius of tightest turn- jet and rocket assisted take-off-high lift devices-range and endurance of airplanes-charts for piston and jet engine aircrafts.

Elementary ideas on space travel –calculation of earth orbiting and escape velocities ignoring air resistance and assuming circular orbit-Definition of orbital elements-Elliptic orbits in vacuum.

**References:**


1. Mechanics of Flight- A.C.Kermode
2. Aerodynamics for Engineering Students- Houghton and Brook
3. Fundamentals of Aerodynamics- Anderson
4. Theory of Satellite orbits in an Atmosphere- Dermond King-Hele
5. Airplane Aerodynamics- Dommasch.
6. Mechanics and Thermodynamics of Propulsion. Philip G. Hill and Carl R. Peterson.


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPC2002: ROCKET PROPULSION 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

The student should develop an idea of the general operating principles of non-air breathing engines. They should be able to compare the non-air breathing engine based on the propulsion system used like nuclear, electrical etc.They should be able to judge the rocket performance parameters and their optimization principles .They should develop an in-depth understanding of liquid and solid propellant chemical rockets and rocket system components like ignition system, combustion system, fuel storage and feed systems etc.They should develop an awareness of the problems associated with combustion , combustion instabilities and the procedure of rocket testing. The student should become familiar with the advanced propulsion concepts.

**Learning Outcomes**

The students should show an understanding of the working of non air breathing engines and predict their performance at different operating conditions. The students should be able to analyze chemical rockets and design the different system components .They should be able to select the right propellant for a given application. The student should be able to predict and avoid combustion instabilities and also appreciate the new and emerging rocket propulsion concepts.

**Module I**

Introduction to non-air breathing engines- General operating principles of rocket motors- Comparative study of chemical, nuclear, electrical and solar rockets- Performance parameters for rocket motors and their relationship- Gas dynamics of a rocket motor and nozzle design. Staging of rockets-single stage and multi stage rockets- optimization of multistage rockets.

**Module II**

Chemical rockets-characteristics-analysis of an ideal rocket. Solid propellant rocket motors-classification and characteristics of solid propellants-Typical grain shapes-design of propellant grain-Combustion of solid propellants and internal ballistics- Igniters and ignition systems. Liquid propellant rockets- Classification and characteristics and selection of liquid propellants- Description and principles of design of pressure feed and turbo feed systems, injector, combustion chamber, cooling system and ignition system-

**Module III**

Combustion instabilities and simple methods of overcoming them – Thrust vectoring- Testing of rockets. Advanced propulsion systems- Nuclear propulsion-The solid core nuclear rocket, Advanced Nuclear rocket concepts. Electrical Rocket propulsion-Electrostatic propellant acceleration, the arc jet, steady crossed field accelerators, pulsed plasma accelerators, traveling wave accelerators. Solar rockets.Laser rockets.

**References:**

1. Sutton,G.P.: Rocket Propulsion Elements
2. Barrere et.al; Rocket Propulsion
3. Hill and Peterson: Mechanics and Thermodynamics of Propulsion
4. Holtzmann,R.T.: Chemical rockets
5. Hosny: Propulsion systems

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MCC 2000 RESEARCH METHODOLOGY 2-0-0-2**

**Structure of the Course**

Lecture : 2 hrs/ Week Credits : 2
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objective**:

To formulate a viable research question
To distinguish probabilistic from deterministic explanations
To analyze the benefits and drawbacks of different methodologies
To understand how to prepare and execute a feasible research project

**Outcome**

Students are exposed to the research concepts in terms of identifying the research problem, collecting relevant data pertaining to the problem, to carry out the research and writing research papers/thesis/dissertation.

**Module 1**

Introduction to Research Methodology - Objectives and types of research: Motivation towards research - Research methods *vs.*Methodology. Type of research: Descriptive *vs.*Analytical, Applied *vs.* Fundamental, Quantitative *vs.* Qualitative, and Conceptual*vs.* Empirical. Research Formulation - Defining and formulating the research problem -Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem. Literature review: Primary and secondary sources - reviews, treatise, monographs, patents.Web as a source: searching the web. Critical literature review - Identifying gap areas from literature review - Development of working hypothesis.

**Module 2**

Research design and methods: Research design - Basic Principles- Need forresearch design — Features of a good design. Important concepts relating to research design: Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction. Development of Models and research plans: Exploration, Description, Diagnosis, Experimentation and sample designs.Data Collection and analysis: Execution of the research - Observation and Collection of data - Methods of data collection - Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-Testing -Generalization and Interpretation.

**Module 3**

Reporting and thesis writing - Structure and components of scientific reports -Types of report - Technical reports and thesis - Significance - Different steps in the preparation, Layout, structure and Language of typical reports, Illustrations and tables, Bibliography, referencing and footnotes.Presentation; Oral presentation - Planning - Preparation -Practice - Making presentation - Use of audio-visual aids - Importance of effective communication.

Application of results of research outcome: Environmental impacts –Professional ethics - Ethical issues -ethical committees.Commercialization of the work - Copy right - royalty - Intellectual property rights and patent law - Trade Related aspects of Intellectual Property Rights - Reproduction of published material - Plagiarism - Citation and acknowledgement - Reproducibility and accountability.

**References:**


1. C.R Kothari, Research Methodology, Sultan Chand & Sons, New Delhi,1990
2. Panneerselvam, "Research Methodology", Prentice Hall of India, New Delhi, 2012.
3. J.W Bames," Statistical Analysis for Engineers and Scientists", McGraw Hill, New York.
4. Donald Cooper, "Business Research Methods", Tata McGraw Hill, New Delhi.
5. Leedy P D, "Practical Research: Planning and Design", MacMillan Publishing Co.
6. Day R A, *"How to Write and Publish a Scientific Paper"*, Cambridge University Press, 1989.
7. Manna, Chakraborti, "Values and Ethics in Business Profession", Prentice Hall of India, New Delhi, 2012.
8. Sople," Managing Intellectual Property: The Strategic Imperative, Prentice Hall of India, New Delhi, 2012.

## MPC 2101 PROPULSION ENGINEERING LAB – II 0-0-2-1

1. Analysis of Natural convection in an enclosure.
   Evaluation of Nusselts number and comparison with reported results.
2. Analysis of unsteady flow past a cylinder
3. Numerical simulation of shock tube flow.
4. Analysis of flow and heat transfer through porous media.
5. Flow and heat transfer in a rotating disc.
6. Pressure measurement using probes.
7. Experiment on flow visualization

## MPC 2102 THESIS PRELIMINARY PART-I 0-0-2-2

The main objective of thesis is to provide an opportunity to each student to do original and independent study and research on the area of specialization. The student is required to explore indepth and develop a topic of his/her own choice, which adds significantly to the body of knowledge existing in the relevant field.The thesis has three parts (Part I in semester-2 and Part-2 in semester -3 & Part-3 in semester -4). The thesis can be conveniently divided into three parts as advised by the guide and the first part is to be completed in this semester The student has to present a seminar before the evaluation committee at the end of the semester that would highlight the topic, objectives , methodology and expected results and submit a report of the work completed in soft bounded form .

**MPC 2103 SEMINAR 0-0-2-2**

The student is expected to present a seminar in one of the current topics in the stream of specialisation. The student will undertake a detailed study based on current published papers, journals, books on the chosen subject and submit seminar report at the end of the semester.

Marks: Seminar Report Evaluation : 50
Seminar Presentation : 50

# STREAM ELECTIVES OFFERED FOR SEMESTER II.

**MPE 2001: MEASUREMENTS IN FLUID FLOW & HEAT TRANSFER 3-0-0-3**

**Structure of the Course**

Lecture : 3 hrs/ Week    Credits :3
Internal Continuous Assessment    : 40 Marks
End Semester Examination    : 60 Marks

**Course Objectives**

Measurements are a valuable tool for practicing engineering students. The objective of the course is to feature and study extensive background materials in system response, measurement uncertainty, signal analysis, optics, fluid mechanical apparatus, the use of instruments and techniques for practical measurements required, automatic data acquisition, reduction and analysis as well as their incorporation for control purposes, wind tunnel studies, turbulence, the theory and application of the laws to measurement techniques, techniques of thermal anemometry, volume flow measurement techniques, and fluid mechanics measurement in non-Newtonian fluids.

**Learning Outcomes**

After the completion of the course, one should be able to understand the flow properties and basic principles related to measuring systems, measurement uncertainty, signal conditioning and analysis, background for optical experimentation, fluid mechanical apparatus, measurement techniques, measurement of flow pressure, measurement of flow rate, flow visualization techniques, measurement of local flow velocity, measurement of temperature.

**Module I**

Characteristics of Measurement Systems - Elements of Measuring Instruments Performance characteristics - static and dynamic characteristics - Analysis of experimental data - Causes and types of experimental errors - Error &uncertainity analysis- statistical & graphical methods - probability distributions.

Temperature measurements - Theory, Thermal expansion methods, Thermoelectric sensors, Resistance thermometry, Junction semiconductor sensors, Pyrometry, Temperature measuring problems in flowing fluids, Dynamic Response & Dynamic compensation of Temperature sensors, Heat Flux measurements.

**Module II**

Pressure Measurements – Mechanical & Electrical types, High pressure & Low pressure measurements, Differential Pressure Transmitters.

Laminar & Turbulent flow measurements - Determination of Reynolds stresses – Flow visualization techniques - Gross Volume Flow measurements - Measurement of Liquid level, Density, Viscosity, Humidity & Moisture, Compressible flow measurements.

**Module III**

Thermal Analysis Techniques - Measurements in combustion: Species concentration, Reaction rates, Flame visualization, Charged species diagnostics, Particulate size measurements.

Data Acquisition and Processing - General Data Acquisition system - Signal conditioning - Data transmission - A/D & D/A conversion - Data storage and Display - Computer aided experimentation.

**References :**


1. J P Holman : Experimental methods for Engineers
2. S. P. Venkatesan: Mechanical Measurements
3. Ernest O Doeblin : Measurement Systems - Application & Design
4. W.Bolton: Mechatronics.
5. Donald P Eckman : Industrial Instrumentation
6. Willard, Mertt, Dean,Settle : Instrumental Methods of analysis
7. D. Patranabis : Principles of Industrial Instrumentation
8. Beckwith & Buck : Mechanical Measurements
9. Nakra&Chaudary : Industrial Instrumentation


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MPE 2002: COMPUTATIONAL METHODS IN FLUID FLOW AND HEAT TRANSFER 3-0-0-3**

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- A number of physical problems related to Propulsion Engineering and Thermal Engineering can be modeled as partial differential equation and often non-linear. These equations cab not be solved by analytical methods and suitable numerical techniques are to be applied. The objective this stream elective is to give the students the necessary fundamentals ideas and their applications for real problems. An exposure to open source computational tools is also aimed. Reading and understanding at least two Journal Publications dealing with later developments in solution algorithms for flow and heat transfer.

**Learning Outcomes:**

- Mathematical formulation of physical problems and their solution.
- Capability to write computer programs based on the techniques learned.
- Development of a directory containing the basic and applied computer programs, tutorials and their document.

**Module I**

Governing equations of fluid flow and heat transfer-Programming in object oriented C++, Classes, Structures and Union (Portions up to this is for study by students themselves. Questions may be asked for the examinations). Governing equations in primitive variables – general scalar form for incompressible flow-conservative vector form for compressible flow-Linearisation -Jacobian-Mathematical nature of governing equations- Governing equations in terms of stream function and vorticity (2D and 3D).
Finite difference approximations for differential coefficients, order of accuracy, numerical examples-Stability, convergence and consistency of numerical schemes - Von-Neumann analysis for stability-Courant-Friedrich-Lewi criterion.

**Module II**

Rayleigh-Ritz, Weighted Residual, Galerkin and sub-domain methods, Interpolation and shape functions in FEM, FE discretisation of Laplace, Poissons and convection diffusion equations. Element equations for triangular, quadrilateral, tetrahedral and hexahedral elements.Numerical integration-Newton Cotes and Gauss quadrature.Application of boundary conditions, Solution of system of equations using TDMA and Conjugate gradient methods.

**Module III**

Finite volume discretisation of Laplace, Poissons and convection diffusion equations. Evaluation of gradients on regular and arbitrary cells, Upwind, Central and Power Law schemes. Structured and unstructured grids.Staggered and collocated grids, Pressure Poisson's equation, SIMPLE, PISO and PROJECTION algorithms for incompressible flow. Flux vector splitting method for compressible flow. Hybrid FE and FV, Semi Lagrangianand Spectral methods, Development of computer programs - Introduction to OpenFOAM. Computer assignments.

**References:**


1. Applied finite element analysis, Larry J. Segerlind
2. Numerical heat transfer and fluid flow, Suhas V. Patankar
3. Computational fluid dynamics: the basics with applications, John D. Anderson
4. Modern Compressible Flow: with Historical Perspective. John D. Anderson, JR
5. Introduction to Computational Fluid Dynamics, Anil W. Date


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 2003: HEAT TRANSFER IN SPACE APPLICATIONS 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

After completion of the course, student should get an awareness of different heat transfer phenomena existing in space applications and also can make an elaborated study of those phenomena including theory, mechanism, calculations and related literature.
The different heat transfer mechanisms such as that at high velocities, in rarified gases, in liquid metals, plasma heat transfer, ablation etc. will be dealt with throughout the study. Also special cooling methods like transpiration cooling, film cooling etc. are focused in the topic. A fair idea about two phase flow, convective boiling and condensation, contact resistance in solids etc. can also be acquired on completion of this course.

**Learning Outcomes**

For assessing student's knowledge in the subject, various assignments and quizzes may be conducted. Industrial visit may be given to students to ISRO to get a knowhow of the current applications. The study of the course gives a wide knowledge of the heat transfer problems in space applications in the present scenario which may benefit them for selecting relevant topics in their future studies.

**Module I**

Ablation-Physical process and calculation of ablation rates, hypersonic ablation of graphite-Heat transfer at high velocities. Heat transfer in rarefied gases-Transpiration and film cooling-Heat transfer considerations in the design of space power systems.

**Module II**

Two phase flow-flow regimes-Homogeneous, slip and drift flux models- pressure drop calculations in adiabatic and diabatic flows using different methods regimes of boiling – critical heat flux- convective boiling.

**Module III**

Heat transfer in condensation. Nusselt theory and improvements.Dropwise condensation. Thermal contact resistance and its calculation, ontact resistance between solids, between solids and liquid metals-Heat transfer to liquid metals. Plasma heat transfer.

**References:**

1. Developments in Heat Transfer- Ed. Rohsenow
2. Modern Developments in Heat Transfer- Ed. Ibele
3. Heat and Mass Transfer- Eckert and Drake
4. Convective Boiling and Condensation-John G Collie

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 2004: RAREFIED GAS DYNAMICS 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Objectives**

To learn the basic concepts of rarefied gas dynamics and the kinetic theory of gases. Understand the governing equations for gas flows in different regimes, from continuum to free molecular. Learn fundamental principles of the direct simulation Monte Carlo method and other numerical methods for solution of the Boltzmann equation.

**Outcome**

After learning the subject, the students will be in a position to understand and apply the fundamentals of rarefied gas flows to practical problems. They will understand to obtain all flow field equations from basic principles. The DSMC method along with other computational procedures will be useful for designing rarefied flow fields especially in re-entry cases.

**Module**

Molecular hypothesis.The Molecular Model.The requirement for a molecular description.The simple dilute gas.Macroscopic properties in a simple gas.Extension to gas mixtures.Molecular magnitudes.Elementary gas kinetic theory.Pressure and temperature.Molecular collisions and scattering.Binary collision dynamics. Collision frequency and mean free path.

**Module 2**

Velocity distribution function. The Boltzmann Equation: assumptions, derivation, non-dimensional form, Summational invariants. H-theorem and equilibrium. Maxwell velocity distribution function, experimental verification. Boltzmann H-function and entropy.Moment transfer equation.Conservation equations. Connection between BE and Euler, Navier-Stokes equations. Transport properties: viscosity, thermal conductivity, diffusivity, Knudsen layer,velocity slip and temperature jump.

**Module 3**

Overview of numerical methods of rarefied gas dynamics.Intermolecular potentials and molecular models.Introduction to DSMC. Review of relevant probability and statistics. Pseudo random number generators.Inverse-cumulative and acceptance-rejection sampling.DSMC algorithms.Collisional schemes, models for internal energy relaxation and chemical reactions.Gas-surface interaction.Discrete ordinate method.Quadratures.Numerical solution of linearized Boltzmann, BGK/ES model kinetic equations. Free molecular flows: expansion into vacuum, low-pressure damping in MEMS. Slip and transitional flows: Couette and Poiseuille problems. Thermal transpiration.Applications to microflows.Thruster exhaust plumes, satellite contamination.

**References**

G.A. Bird, Molecular Gas Dynamics and the Direct Simulation of Gas Flows. Oxford Science Publications, 2nd Rev. Edition, 1994 [Reprint 2004].
William Liou, Yichuan Fang, Microfluid Mechanics: Principles and Modeling (Nanoscience and Technology), McGraw-Hill Professional Publishing, 2005.
W.G. Vincenti, C.H.Kruger, Introduction to Physical Gas Dynamics. Krieger, 1965 [Reprint 2002]
E.H. Kennard, Kinetic Theory of Gases: With an Introduction to Statistical Mechanics. McGraw-Hill, 1938.
J. M. Haile, Molecular Dynamics Simulation. Wiley, 1997.

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 2005: CONTROL SYSTEMS 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

To impart knowledge about advances in control system in the areas of state-space modeling& stability of continuous & discrete system. It will also make students familiar with the non-linear system – their modeling and analysis

**Learning Outcomes**

At the end of the course a student will be equipped to handle linear and non-linear control problems.

**Module I**

Open loop-and closed loop control system: Transfer function -T.F of simple - Mechanical and Electromechanical system - Force voltage and force current analogy – block diagram representation – block diagram reduction – signal flow graph – Mason's gain formula – characteristics equation.
Control system components: DC and AC servo motor – synchro – magnetic amplifier – gyroscope – stepper motor – Tacho meter.

**Module II**

Time domain analysis of control systems: Transient and steady state responses – test signals – time domain specifications – first and second order systems – impulse and step responses – steady state error analysis – PID controllers – Tradeoff between steady state and transient behavior.
constructing Root loci – effect of feedback system – Routh's stability criterion – Root locus – General rules for constructing Root loci – effect of addition of poles and zeros.

**Module III**

Frequency domain analysis: Introduction – Node plot-Polar plot – Frequency domain specification: - Non-minimum phase system – transportation log – Nyquist stability criterion – gain margin – phase margin – stability analysis using bode plot. Nonlinear systems : Introduction – characteristics of nonlinear systems. Types of non-linearities. Describing function analysis – Determination of describing function of static non-linerities (saturation and ideal relay only) – application of describing function for stability analysis of autonomous system with single nonlinearity. Liapunov Stability – definition of stability – asymptotic stability and instability – Liapunov methods to liner and nonlinear systems.

**References:**


1. Katsuhiko Ogata, "Modern Control Engineering", Fourth edition, Person Education, New Delhi, 2002.
2. NagarathI.J. and Gopal M., "Control System Engineering", Wiley Eastern, New Delhi.
3. Richard C, Dorf, Robert. H. Bishop, "Modern Control System", Person Education, New Delhi – 11th Edition, 2007.
4. Norman S, Nise, "Control Systems Engineering", 5th Edition, Wiley Eastern, 2007.
5. Kuo B.C., "Automatic Control Systems", Prentice Hall of India, New Delhi, sixty edition, 1991.
6. Gibson &Tutter, "Control System Components", McGraw Hill.
7. Katsuhiko Ogata: "Modern Control Engineering", fourth edition, Pearson Education, New Delhi, 2002.
8. Nararath I, J and Gopal M, "Control System Engineering", Wiley Eastern, New Delhi.
9. Gopal M, "Modern Control System Theory", Wiley Eastern Ltd, New Delhi.


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 2006: NUCLEAR SCIENCE & TECHNOLOGY 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

To introduce the basic concepts of nuclear energy production, various types of reactors and factors involved in the construction of nuclear reactors and radiation protection.

**Learning Outcomes**

The students will be able to design a nuclear reactor and will be capable of handling nuclear fuels.

**Module I**

Review of elementary nuclear physics. Nuclear Reactions and Radiations: Principles of radioactive decay- interaction of α, β & γ rays with matter- neutron cross sections and reactions- the fusion process-chain reaction. Basic principles of controlled fusion. Nuclear reactor principles: Reactor classification-critical size- basic diffusion theory-slowing down of neutrons-neutron flux and power-four factor formula-criticality condition-basic features of reactor control.

**Module II**

Boiling water reactor: Description of reactor system-main components-control and safety features. Materials of reactor construction: Fuel, moderator, coolant-structural materials-cladding – radiation damage. Nuclear fuels: Metallurgy of uranium-general principles of solvent extraction-reprocessing of irradiated fuel-separation process- Fuel enrichment.

**Module III**

Reactor Heat Removal: Basic equations of heat transfer as applied to reactor cooling-Reactor heat transfer systems-heat removed in fast reactors. Radiation safety: Reactor shielding-radiation dozes- standards of radiation protection- nuclear waste disposal.

**References:**

1. Nuclear Reactor Engineering- Gladstone &Sesonske
2. Source book on Atomic Energy- S.Glasstone

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

# THIRD SEMESTER

## MPC 3101 THESIS – PRELIMINARY II 0-0-14-5

The student has to continue the thesis work done in the second semester in the same area. The student has to present two seminars.The first seminar shall be conducted in the first half of this semester mainly to highlight the progress of the work for the midterm evaluation and second seminar towards the end of the semester to access the quality and quantum of work done in this semester. The student has to submit a report of the work completed in soft bounded form. The seminars and the report shall be evaluated by the evaluation committee.

**Evaluation of marks for the Thesis-Preliminary Part II**

Evaluation of the Thesis-Preliminary work by the guide - 100 Marks
Evaluation of the Thesis–Preliminary by the Evaluation Committee-100 Marks

# STREAM ELECTIVES OFFERED FOR SEMESTER III.

## MPE 3001: DESIGN OF CHEMICAL ROCKETS 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

Design liquid rocket propulsion systems utilizing preliminary design decisions which include: estimating system mass and envelope; selection of propellant; choice of engine cycle and pressure levels; injection & ignition of liquid propellants.

Perform design trade off studies for thrust chambers and propellant feed system configurations and thrust vectoring.

Design solid rocket motors utilizing preliminary design decisions which includes

- component sizing techniques
- propellant burning rates
- fuels, oxidizers and binders
- performance prediction using lumped parameter methods
- ballistics with variations in spatial pressure
- calculating specific impulse mass flow and thrust

**Learning Outcomes:**

- Design rocket nozzle for a given mission requirement .
- Compare and contrast the utility and performance of solid and liquid rockets.
- Learn the criteria of propellant selection for a particular space application.
- Analyze, classify, and compare the performance of different solid and liquid propellants.
- Sketch and design the propellant feed systems in liquid rocket engines .
- Make appropriate assumptions to analyze the heat transfer process occurring in rocket motor systems.
- Develop understanding of overall and individual component design rules of solid, liquid, and hybrid rockets, as well as electric propulsion engines.

**Module I**

Components of Solid propellant Rockets- igniters, motor case, nozzle, thrust vectoring methods-design aspects and calculations. Internal ballistics and grain design.

**Module II**

Description of various component features and principles of design of injector, combustion chamber. Simple Thrust chamber design analysis

**Module III**

Design of cooling system, pressure fed and turbopump fed systems. Nozzle design and analysis in rocket engines.Nozzleconfigurations.Variable Thrust nozzles. Design requirements of pressure feed and turbopump feed system.

**References:**


1. G P Sutton: Rocket Propulsion Elements
2. BarrareN,et.al.: Rocket Propulsion
3. Williams F A : Fundamental Aspects of Solid Propellant Rockets, Agardograph-116
4. R D Geokler and K Klager: Solid Propellant Rocket Engines Ch.19, handbook of Astronautical Engineering H HKoelleed.
5. Huzel and Houng: Design of Liquid Propellant Rocket Engines, NASA SP 125.


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MPE 3002: OPTIMIZATION FOR ENGINEERING DESIGN 3-0-0-3**

**Pre-requisite**: Review of vectors and matrices, set theory.

**Course Objectives**

- Formulate the given problem in a mathematical format which is acceptable to an optimization algorithm.
- Understand the techniques and applications of engineering optimization.
- Choose the appropriate optimization method that is more efficient to the problem at hand.

**Learning Outcomes:**

- Appreciate the application of optimization problems in varied disciplines.
- Model a real-world decision problem as an optimization problem.
- Perform a critical evaluation and interpretation of analysis and optimization results.

**Module I**

Introduction to Optimization: Historical sketch; Engineering applications of optimization; Statement of an optimization problem; Classification of optimization problems.

Classical Optimization Techniques: Single variable optimization; Multivariable optimization with no constraints, with equality constraints and with inequality constraints.

Review of Linear Programming Problems (LPP). (to be completed in 3 hours)

**Module II**

Linear Programming (LP): Decomposition principle; Sensitivity analysis; Quadratic programming and LCP.

Non-Linear Programming (NLP): One-Dimensional Unconstrained Optimization – Single variable optimization; Fibonacci method; Golden-section method; Polynomial based methods (Brent's algorithm, Cubic polynomial fit); Unconstrained Optimization – Necessary and sufficient conditions for optimality; The steepest descent method; The Conjugate gradient method; Newton's method; Quasi-Newton method; Secant method.

**Module III**

Non-Linear Programming (NLP): Constrained Optimization – Problem formulation; Necessary and sufficient conditions for optimality; Rosen's Gradient Projection Method; Zoutendijk's method; Generalized Reduced gradient method; Sequential QP; Penalty function based methods.
Geometric programming; Dynamic programming; Integer programming; Goal programming.
Stochastic programming (Overview only)

**References**

1. H.A. Taha, Operations Research: An Introduction, Pearson Education

2. S.S. Rao, Engineering Optimization: Theory and Practice, New Age International Publishers.

3. A.D. Belegundu, T.R. Chandrupatla, Optimization Concepts and Applications in Engineering, Pearson Education.

4. H. M. Wagner, Principles of Operations Research, Prentice- Hall of India Pvt. Ltd.

5. Gross and Harris, Fundamentals of Queuing Theory, John Wiley & Sons

6. M.S. Bazaraa, J.J. Jarvis, H.D. Sherali, Linear Programming and Network Flows, John Wiley & Sons.

**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 3003: MULTIPHASE FLOW 3-0-0-3

### Structure of the Course

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

### Course Objectives

The course will give a general introduction to the underlying concepts of multiphase flows and different approaches to model such flows under different conditions. By the end of the course the student will be able to make a qualified judgment which models to choose and be able to analyze the validity of the underlying assumptions made by the chosen model.

### Learning Outcomes

By the end of this course, students should be able to:

1. Apply the principles of thermodynamics, fluid mechanics and heat transfer to analyzemulti phase flow problems.
2. Develop analytical models and solution methods to solve practical engineering problems.
4. Develop confidence to undertake challenging research problems and
4. Make them to work with practiced professional or researcher groups confidently.

### Module I

Methods of Analysis-flow patterns- vertical and horizontal channels- flow pattern maps and transitions. Void fraction- definitions of multiphase flow parameters- one dimensional continuity, momentum and energy equation- Pressure gradient components: frictional, acceleration and gravitational.

### Module II

Basic Flow Models: Homogeneous flow model-Pressure gradient-Two phase friction factor for laminar and turbulent flow-Two phase viscosity-Friction multiplier. Separated flow model-Pressure gradient relationship-Lokhart-Martinelli correlation- Parameter X and its evaluation.Empirical Treatments: Drift Flux model- Gravity dominated flow regime-Correlations for void fraction and velocity distribution in different flow regimes-pressure losses due to multiphase flow-velocity and concentration profiles.

**Module III**

Convective boiling: Thermodynamics of vapour/liquid systems-Super heat requirement-homogeneous nucleation- Bubble dynamic in pool boiling- Regimes of Convective boiling heat transfer-Boiling map-DNB-Critical Heat flux in forced convection boiling.Condensation: Liquid formation-Droplet growth-crude theory and its modifications – Nusselt theory on film condensation- Influence of turbulence-condensation on horizontal tubes-Condensation within vertical tube-Dropwise condensation-Pressure gradient in condensing systems.

**References:**


1. J G Collier: Convective Boiling & Condensation
2. G W Wallis: One Dimensional Two-Phase Flow
3. YY Hsu, R W Graham: Transport Processes in Boiling & Two Phase Flow


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 3004: TURBULENCE 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

- The study of turbulence is not easy, requiring a firm grasp of applied mathematics and considerable physical insight into the dynamics of fluids. In the first part students are exposed to the basic of tensor analysis, statistical methods and other involved matehematics for understanding turbulence. The student should understand how the turbulence stress are to be accounted for same engineering designs. Applications involving pollution problem, analysis of combustions, heat dissipation, weather modeling etc demands understanding of turbulence and therefore with this study the students are becoming able to handle such problems.
- In the of second part the student should understand what is turbulence modeling and study different types of turbulence models and their comparatives. Here the students are expected to able in selecting the particular model according to the type of problem for the analysis of various fluid flow. For this students are also introduced to some partial differential equations and their numerical techniques.
- After completion of the third part the student gets an exposure to the various measuring technique such as hot wire anemometry, Laser Doppler Velocimetryetc so that students should get some enhanced physical understanding and ideas in turbulence.

**Learning Outcomes:**

- For assessing students knowledge in the subject, various assignments and projects related to the field may be conducted. Mini projects may be assigned to groups of students. Students may be given a hands on training on CFD packages to enable students to select the type of turbulence models in solving problems and study their validity.

**Module I**

Introduction to turbulent flow-definition-characteristics-types.Elementary tensor analysis.Statistical methods in turbulent flow analysis-probability distribution-correlations.

**Module II**

Equations of motion-closure problem- Equations for Reynolds stresses.Basic features of some turbulent flows-dimensional analysis, statistical methods, integral and analytical methods.

**Module III**

Turbulence modeling- mixing length model, one-equation mode, two-equation models, Reynolds stress model, algebraic stress model.Computation of parabolic and Elliptic flows.Experimental techniques- hot wire anemometry- Laser Doppler anemometry.

**References:**


1. Tennekes& Lumley: A First Course on Turbulence
2. Bradshaw,P.: An Introduction to Turbulence and its Measurement
3. Bradshaw,P.: Turbulence
4. Reynolds,A.J.: Turbulent Flow in Engineering
5. Tulapurkara,E.G.; Introduction to Turbulence models and Prediction of Turbulent Flows, NAL, Bangalore Report No.SP 8715, 1978.
6. Garde,R.J.: Turbulent Flow
7. Hinze,O.: Turbulence: an Introduction to Mechanism and Theory


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

## MPE 3005: INVERSE HEAT TRANSFER 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

The principal objective of this course is to impart fundamental knowledge of solving inverse heat transfer problems using various mathematical techniques. The first part of the course introduces the concept inverse heat transfer problem and its application in various fields of thermal system design. After completion of first module, students will be able to understand the classification of inverse heat transfer problems and different gradient based optimization techniques to solve the parameter as well as function estimation problems.

In the second module, inverse heat conduction problems are discussed wherein the estimation of single as well as multiple parameters from measured or known steady and transient temperature field in a solid medium is the desired objective.

The last module deals with solution techniques for the estimation of boundary condition and inlet temperature profile in convection heat transfer problems, and the estimation of radiative properties, temperature profile and source term in radiative heat transfer problems.

**Learning Outcomes**

By the end of this course, students are expected to understand different solution techniques to solve inverse heat transfer problems for parameter as well was function estimation and apply their expertise in solving inverse heat transfer problems encountered in challenging practical engineering problems.

**Module I**

**Basic concepts**.Concept of inverse heat transfer problems, Applications, Brief introduction of solution techniques. Techniques for solving inverse heat transfer problems. The Levenberg-Marquardt method for parameter estimation. Conjugate Gradient method for parameter stimation. Conjugate Gradient method with adjoint problem for parameter estimation. Conjugate Gradient method with adjoint problem for function estimation Problems

**Module II**

**Inverse Conduction:** Estimation of constant thermal conductivity components of an Orthotropic Solid. Estimation of initial condition.Estimation of timewise variation of the Strength of a line heat source.Estimation of timewise and Spacewise variation of the strength of a volumetric heat source.Estimation of Temperature-Dependent properties and Reaction function.

**Module III**

**Inverse Convection:** Estimation of the inlet temperature profile in Laminar flow. Estimation of the transient inlet temperature in laminar flow.Estimation of the axial variation of the wall heat flux in laminar flow.

**Inverse Radiation:** Identification of the temperature profile in an absorbing, emitting and isotropically scattering medium. Simultaneous estimation of the temperature profile and surface reflectivity.Estimation of the radiation source term in a semitransparent Solid Sphere.

Note: Use of approved data book will be allowed in the examinations.

**References:**


1. Inverse Heat Transfer (Fundamentals and applications)- by M.NecatiOzisik, Helcio R. B. Orlande Publisher-Taylor and Francis
2. Radiative heat transfer-2nd edition, by Michael F Modest, Publisher-Elsevier
3. The mollification method and the Numerical solution of inverse problems, by Diego A. Murio, Publisher John wiley
4. Handbook of Numerical Heat transfer, by W.J. Minkowyez, E.M Sparrow, G.EShneider, R.HPletcher Publisher- Wiley


**Structure of the Question paper**

For the End Semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

# FOURTH SEMESTER

## MPC 4101 THESIS – FINAL 0-0-21-12

The student has to continue the thesis work done in the second and third semester. There shall be two seminars (a midterm evaluation on the progress of the work and pre submission seminar to assess the quality and quantum of the work). At least one technical paper is to be prepared for possible publication in journals / conferences. The final evaluation of the thesis shall be an external evaluation. The marks for the Thesis-Final may be proportionally distributed between external and internal evaluation as follows.

**Distribution of marks allotted for the Thesis**

Internal Evaluation of the Thesis work by the guide - 150 Marks
Internal Evaluation of the Thesis by the Evaluation Committee - 150 Marks
Final Evaluation of the Thesis work by the Internal and External Examiners:
(Evaluation of Thesis: 200 marks + Viva Voce: 100 marks) - 300 Marks

# DEPARTMENTAL ELECTIVES IN MECHANICAL ENGG FOR SEMESTER II

**MID 2001: RELIABILITY ENGINEERING 3-0-0-3**

**Objective:**

The objective of this course is to understand the theories and their practical uses with real-world examples and problems to solve. The course focuses on system reliability estimation for time independent and failure dependent models. It helps the students in assembling necessary components and configuring them to achieve desired reliability objectives, conducting reliability tests on components, and using field data from similar components. Also to provide more complex aspects regarding both the Maintainability, Availability and some fundamental techniques such as FMECA (Failure Mode, Effects, and Criticality Analysis) and FTA (Fault Tree Analysis) with examples.

**Outcome**

After the completion of the course one should be able to know:

- Reliability and Hazard Functions
- System Reliability Evaluation
- Time- and Failure-Dependent Reliability
- Estimation Methods of the Parameters of Failure-Time Distributions
- Parametric Reliability Models
- Models for Accelerated Life Testing
- Renewal Processes and Expected Number of Failures
- Preventive Maintenance and Inspection

**Pre-requisite:** Concepts of Probability and Statistics, Probability Distributions, Point Estimation, Interval Estimation, Goodness-of-fit Tests, Statistics of Extremes.

**Module I**

Introduction to reliability: definition, Reliability and Quality, failure and failure modes

Failure data analysis: Reliability and rates of failure, Reliability function, expected life, failure rate, hazard function, constant and time dependent hazard models, state dependent hazard models, Markov Analysis.

**Module II**

System Reliability models – Series, parallel, mixed configurations, k-out-of-m models
Redundancy techniques – component vs unit redundancy, mixed redundancy, Standby redundancy, weakest link technique
Reliability improvement, Reliability allocation

**Module III**

Fault tree analysis, use of Boolean algebra, Load strength analysis. Understanding of FMECA.
Maintainability- Definition, relationship between reliability and maintainability
Availability- Definition, relationship between reliability and availability, simple Markov models.

Case studies from industries demonstrating Reliability aspects. Computer softwares in reliability.

**References**


1) Charles E Eblings – An Introduction to Reliability and Maintainability Engineering, McGraw Hill
2) E. Balagrusamy - Reliability Engineering, Tata-McGraw Hill Publishing Company Limited, New Delhi, 1984.
3) L S Srinath – Reliability Engineering, East West Press
4) Lewis, E.E., Introduction to Reliability Engineering, John Wiley & Sons, New York, 1987.
5) O'Connor Patric D.T., Practical Reliability Engineering, 3/e revised, John Wiley & Sons, 1995.
6) StamatisD.H., Failure Mode and Effect Analysis, Productivity Press India (P) Madras, 1997.


**Structure of the Question paper**

For the End semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MID 2002: MODERN INFORMATION SYSTEMS** **3-0-0-3**

**Course Objectives**

- To learn about different information systems.
- To effectively use and manage information technology in today's network enterprises.
- To study inter connected networks of information systems for end user collaboration.
- To learn systems for making timely decisions based on organized informations.

**Learning Outcomes**

After the completion of the course the student is expected to

- Widen his knowledge about information technology that will enable him to solve management problems.
- Explore full potential of computer as a problem solving tool.

**Module I**

Introduction to information systems ,Types and examples of information systems, information technology infrastructure. System concepts, system design, development and analysis

**Module II**

Decision support systems: Overview, Data Mining and Warehousing, Modeling and. Analysis, Knowledge based DSS. Model management, modeling processes, modeling languages.

**Module III**

Neural computing, applications, advanced artificial intelligent systems and applications. Intelligent software agents, Impact of Management support systems.

## References


1. Kenneth C. Laudon and Jane P. Laudon, Management Information Systems – Managing the digital firm, , Pearson education, 2002.
2. Burch John.GJr and Others , Information Systems theory And Practice, John wiley&Sons
3. James A O'Briean, Management Information Systems, Tata McGraw Hill
4. Decision Support Systems and Intelligent Systems, , Prentice Hall International
5. Marakas, Decision Support System, Pearson Education
6. Robert Levine et al ,"Comprehensive Guide to AI and Expert Systems",McGraw Hill Inc..Henry C. Mishkoff, "Understanding AI", BPB Publication, New Delhi, 1986

**Structure of the Question paper**

For the End semester Examination there will be three questions from each module out of which two questions are to be answered by the students.

**MDD 2001: COMPUTATIONAL PLASTICITY** **3-0-0-3**

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**:

At the end of this course, the students will

- gain insight into the behavior of metals under loading and heating conditions,
- be able to use elementary theory of plasticity to formulate bulk forming processes,
- be able to master the basic formulations and their applications to sheet forming processes.
- be able to master and apply the basic theory of metal cutting,
- have the basic knowledge about the cutting tools, cutting fluids and the cutting
- parameters and how they affect the cutting performance,
- be able to optimize metal cutting operations for the selected criteria

**Learning Outcomes:**

At the completion of the course, students will be able to…

- Predict the changes in the mechanical behavior of materials due to thermo-mechanical processing based finite element modeling.
- Interpret and quantitatively determine elastoplastic behavior of metals.

**Module I**

Elements of continuum mechanics and thermodynamics – Kinematics of deformation - Infinitesimal deformations - Forces. Stress Measures - Fundamental laws of thermodynamics - Constitutive theory - Weak equilibrium. The principle of virtual work - The quasi-static initial boundary value problemThe finite element method in quasi-static nonlinear solid mechanics - Displacement - based finite elements - Path-dependent materials. The incremental finite element procedure – Large strain formulation - Unstable equilibrium. The arc-length method

**Module II**

Overview of the program structure of FEM for plasticity
The mathematical theory of plasticity – Phenomenological aspects - One-dimensional constitutive model - General elastoplastic constitutive model - Classical yield criteria – Plastic flow rules - Hardening laws

**Module III**

Finite elements in small-strain plasticity problems – Preliminary implementation aspects - General numerical integration algorithm for elastoplastic constitutive equations - Application: integration algorithm for the isotropically hardening vonMises model - The consistent tangent modulus – Numerical examples with the vonMises model - Further application: the von Mises model with nonlinear mixed hardening

**References:**

1. Eduardo de Souza Neto, DjordjePeric, David Owens, Computational methods for plasticity : theory and applications - 2008 John Wiley & Sons Ltd
2. A. Anandarajah, Computational Methods in Elasticity and Plasticity – 2010 Springer
3. Han-Chin Wu, Continuum mechanics and plasticity - CRC Press
4. D R J Owen, E Hinton, Finite Elements in Plasticity Theory and Practice – 1980 Peneridge Press Ltd.
5. Jacob Lubliner, Plasticity theory – 2006
6. J. Chakrabarty, Theory of plasticity third edition – 2006 BH
7. D W A Rees, Basic engineering plasticity an introduction with engineering and manufacturing applications - BH

**Structure of the Question paper**

For the End Semester Examination There will be three questions from each module out of which two questions are to be answered by the students.

## MDD 2002: BIO MECHANICS 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Objective:**

- To gain knowledge of bio mechanics
- To gain knowledge of designing of artificial implants
- To gain knowledge of viscoelastic material modeling
- Understand various bio materials

**Outcome:**

- Students will understand how the theory is used in analyzing human body and motions
- At the end of the course students will know the different bio materials

**Industrial relevance:**

This course is having direct application to industry.
In medical field, implementation of theory of mechanics will help in implementing various designs

**Module I**

Human Anatomy & physiology: Anatomy & Physiology of major systems of the body Basic Terminology-Major Joints - Major Muscle Groups -Tissue Biomechanics -Hard and Soft - Bones - Bone Cells and Microstructure- Physical Properties of Bone- Bone Failure (Fracture and Osteoporosis)- Muscle Tissue-Cartilage-Ligaments- Scalp, Skull, and Brain -Skin Tissue

**Module II**

Kinetics of Human Body -Forces Exerted across Articulating Joints -Contact Forces across Joints - Ligament and Tendon Forces- Joint Articulation
Rheology of body material-Viscoelasticity-Definition of Viscoelasticity 1D Linear Viscoelasticity (Differential Form Based on Mechanical Circuit Models- Maxwell Fluid- Kelvin–Voigt Solid- 1-D Linear Viscoelasticity (Integral Formulation)- 3-D Linear Viscoelasticity -Dynamic Behavior of Viscoelastic Materials

**Module III**

Biomaterials:- Different types of biomaterials - metals, polymers, ceramics, glasses, glass ceramics, composites. Material properties.Reactions to biomaterials - inflammation, wound healing & foreign body response, immunology and compliment system, -, prostheses and orthotics.Artificial bio-implants – Dental implants, heart valves, kidneys, joints.

**References:**


1. Principles of Biomechanics by Ronald L Huston-CRC Press
2. Introduction to continuum biomechanics by Kyriacos A. Athanasiou and Roman M. Natoli-Morgan & Claypool
3. Duane Knudson Fundamentals of Biomechanics –Springer
4. Text book of Medical Physiology – C., M. D. Guyton..
5. Biomechanics: Motion,Flow stress and Growth, Y.C. Fung- Springer, New
6. York, 1990
7. Leslie Cromwell, Fred J.Weibell and Erich A.Pferffer. Biomedical instrumentation and Measurements -Prentice Hall of India, New Delhi.


**Structure of the Question paper**

For the End semester Examination There will be three questions from each module out of which two questions are to be answered by the students.

## MDD 2003: INTRODUCTION TO SIGNAL PROCESSING 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

- Understand Fundamentals of DSP and its use in Noise and Vibration Enhancement
- Understand how to correctly implement and use the results of an FFT
- Interpretation of common Frequency Domain Measurements
- Understand the fundamentals and applications of Digital Filters
- Application and interpretation of Order Tracking analysis

**Learning Outcomes:**

As an outcome of completing this course, students will be able to:

- Understand how the combination of A/D conversion, digital filtering, and D/A conversion may be used to filter analog signals such as speech and music (1-D), and images (2-D).
- Understand the time- and frequency-domain concepts related to A/D conversion.
- Understand the time- and frequency-domain concepts related to D/A conversion.
- Understand the role of oversampling in A/D and D/A conversion.
- Understand the roles of downsampling and upsampling in digital processing of analog signals.
- Understand the respective roles of the magnitude and phase response of a digital filter.
- Understand the concepts of phase delay and group delay of a digital filter.
- Understand the relations between the DTFT, the DFT, and the FFT.
- Understand the computational issues in the implementation of digital filters.
- Understand the notion of random signals as an aid to filter design.
- Design FIR filters using the Windowing Method.
- Write reports on filter design and DSP applications projects
- Assess the societal impact of DSP, and the engineer's responsibilities in this regard.

**Module I**

**Introduction to Signal Processing:** Descriptions of Physical Data (Signals), Classification of Data. **Deterministic Signals:** Periodic, Almost Periodic and Transient Signals.Periodic Signals and Fourier series, Delta Function, Complex Form of the Fourier Series, Spectra. Fourier Integral, Energy Spectra, Properties of Fourier Transforms, Importance of Phase, Echoes, Continuous-Time Linear Time-Invariant Systems and Convolution, Group Delay (Dispersion), Minimum and Non-Minimum Phase Systems, Hilbert Transform, Effect of Data Truncation (Windowing).

**Module II**

Fourier Transform of an Ideal Sampled Signal, Aliasing and Anti-Aliasing Filters, Analog-to-Digital Conversion and Dynamic Range, Shannon's Sampling Theorem.Sequences and Linear Filters, Frequency Domain Representation of Discrete Systems and Signals, Discrete Fourier Transform, Properties of DFT, Convolution of Periodic Sequences, Fast Fourier Transform. Basic Probability Theory, Random Variables and Probability Distributions, Expectations of Functions of a Random Variable.

**Module III**

**Stochastic Processes:** Probability Distribution Associated with a Stochastic Process, Moments of a Stochastic Process, Stationarity, and the Second Moments of a Stochastic Process, Ergodicity and Time Averages.Single-Input Single-Output Systems,Estimator Errors and Accuracy, Mean Value and Mean Square Value , Correlation and Covariance Functions, Power Spectral Density Function, Cross-spectral Density Function, Coherence Function, Frequency Response Function .Description of Multiple-Input Multiple-Output (MIMO) Systems, Residual Random Variables, Partial and Multiple Coherence Functions, Principal Component Analysis.

**Reference:**


1. Fundamentals of Signal Processing for Sound and Vibration Engineers, K. Shing and J.K. Hammond, Wiley, 2007
2. Digital Signal Processing for Measurement Systems:Theory and Applications, G. D'Antona and Alessandro Ferrero, Springer
3. Digital Signal Processing, Alan V. Oppenheim, Ronald W. Schafer, Prentice hall


**Structure of the Question paper**

For the End Semester Examination There will be three questions from each module out of which two questions are to be answered by the students.

## MPD 2001: FINITE VOLUME METHOD FOR FLUID FLOW AND HEAT TRANSFER 3-0-0-3

**Structure of the Course**

Lecture : 3 hrs/ Week Credits :3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives:**

- A number of physical problems related to Propulsion Engineering and Thermal Engineering can be modeled as partial differential equation and often non-linear. These equations cab not be solved by analytical methods and suitable numerical techniques are to be applied. The objective this stream elective is to give the students the necessary fundamentals ideas and their applications for real problems. An exposure to open source computational tools is also aimed. Reading and understanding at least two Journal Publications dealing with later developments in solution algorithms for flow and heat transfer.

**Learning Outcomes:**

- Mathematical formulation of physical problems and their solution.
- Capability to write computer programs based on the techniques learned.
- Development of a directory containing the basic and applied computer programs, tutorials and their document.

**Module I**

Governing equations of fluid flow and heat transfer-Programming in object oriented C++, Classes, Structures and Union (Portions up to this is for study by students themselves. Questions may be asked for the examinations). Governing equations in primitive variables – general scalar form for incompressible flow-conservative vector form for compressible flow-Linearisation -Jacobian-Mathematical nature of governing equations- Governing equations in terms of stream function and vorticity (2D and 3D).
Finite difference approximations for differential coefficients, order of accuracy, numerical examples-Stability, convergence and consistency of numerical schemes - Von-Neumann analysis for stability-Courant-Friedrich-Lewi criterion.

**Module II**

Rayleigh-Ritz, Weighted Residual, Galerkin and sub-domain methods, Interpolation and shape functions in FEM, FE discretisation of Laplace, Poissons and convection diffusion equations. Element equations for triangular, quadrilateral, tetrahedral and hexahedral elements.Numerical integration-Newton Cotes and Gauss quadrature.Application of boundary conditions, Solution of system of equations using TDMA and Conjugate gradient methods.

**Module III**

Finite volume discretisation of Laplace, Poissons and convection diffusion equations. Evaluation of gradients on regular and arbitrary cells, Upwind, Central and Power Law schemes. Structured and unstructured grids.Staggered and collocated grids, Pressure Poisson's equation, SIMPLE, PISO and PROJECTION algorithms for incompressible flow. Flux vector splitting method for compressible flow. Hybrid FE and FV, Semi Lagrangianand Spectral methods, Development of computer programs - Introduction to OpenFOAM. Computer assignments.

**References:**

1. Applied finite element analysis, Larry J. Segerlind
2. Numerical heat transfer and fluid flow, Suhas V. Patankar
3. Computational fluid dynamics: the basics with applications, John D. Anderson
4. Modern Compressible Flow: with Historical Perspective. John D. Anderson, JR
5. Introduction to Computational Fluid Dynamics, Anil W. Date

**Structure of the Question paper**

For the End Semester Examination There will be three questions from each module out of which two questions are to be answered by the students.

## MPD 2002:TRANSPORT PHENOMENA 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

1.To develop and detailed understanding of the physics behind transport phenomena in engineering systems.
2. To learn solution techniques in advanced transport phenomana.

**Learning Outcomes**

1. Student will be capable of applying theoretical knowledge in various industrial and academic situations
2. They will be in a position to develop models for a particular problem involving heat and mass transfer.

**Module I**

Viscosity and the mechanism of momentum transport-pressure and temperature dependence of viscosity-Theory of viscosity of gases at low density- Theory of viscosity of liquids.

Thermal conductivity and the mechanism of energy transport-temperature and pressure dependence of thermal conductivity in gases and liquids-theory of thermal conductivity of gases at low density – theory of thermal conductivity of liquids- thermal conductivity of solids.

Diffusivity and the mechanism of mass transport- definitions of concentrations, velocities and mass fluxes-Fick's law of diffusion- temperature and pressure dependence of mass diffusivity- theory of ordinary diffusion in gases at low density- theories of ordinary diffusion in liquids.

**Module II**

Shell balance for momentum, energy and mass, boundary conditions, Adjacent flow of two immiscible fluids- heat conduction with a nuclear heat source-diffusion through a stagnant gas film-diffusion with heterogeneous chemical reaction- diffusion with homogeneous chemical reaction-diffusion into a falling liquid film: Forced convection mass transfer-diffusion and chemical reaction inside a porous catalyst; the "Effectiveness factor'.
The equations of change for isothermal, non isothermal and multi component systems- the equations of continuity of species A in curvilinear co-ordinates-dimensional analysis of the equations of change for a binary isothermal mixture.

**Module III**

Concentration distributions in turbulent flow- concentration fluctuations and the time smoothed concentration-time smoothing of the equations of continuity of A.

Inter phase transport in multi component systems-definition of binary mass transfer coefficients in one phase – correlations of binary mass transfer coefficients in one phase at low mass transfer rates-definition of binary mass transfer coefficients in two phases at low mass transfer rates- definition of the transfer coefficients for high mass transfer rates.

Macroscopic balances for multi component systems- the macroscopic mass, momentum, energy and mechanical energy balance-use of the macroscopic balances to solve steady state problem.

**References:**

**Text book**: Transport Phenomena Bird R B, Stewart W E and Lightfoot F N

Note: Use of approved charts & tables are permitted in the examinations.

**Structure of the Question paper**

There will be three questions from each module out of which two questions are to be answered by the students.

## MTD2001: FINITE ELEMENT ANALYSIS FOR HEAT TRANSFER 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

To impart an awareness regarding various types of equations and their methods of solving
To analyse a given situation to find out the temperature profiles and rate of heat transfer

**Learning Outcomes**

The students will be capable of analyzing theoretically any heat transfer problems by using FEM

**Module I**

Review of the fundamentals of the three modes of heat transfer. Governing differential equations.Initial and boundary conditions.

Review of the numerical techniques for the solution of matrix equations.
Basic concepts of Finite Element method. Mesh generation-
Types of elements, Node numbering scheme.Interpolation polynomials.Finite element equations and element characteristic matrices.Variational approach, Galerkin approach.Assembly of element matrices.Solution of finite element system of equations.

**Module II**

Steps involved in a thermal analysis. Analysis of linear and nonlinear conduction problems in steady and transient hea t transfer.1D, 2D and 3D analysis with simple examples.Axisymmetric heat transfer.Finite element solution in the time domain.

Effects of convection in heat transfer- advection-diffusion. Analysis of heat transfer problems with radiation.

**Module III**

Concepts of adaptive heat transfer analysis. Implementation of the adaptive procedure.

Computer programming and implementation of FEM. Introduction to general purpose FEM packages.

**References:**

1. R W Lewis, K Morgan, H R Thomas and K Seetharamu: The Finite Element Method in Heat Transfer Analysis
2. H C Huang and A Usmani: Finite Element Analysis for Heat Transfer
3. L J Segerland: Applied Finite Element Analysis
4. C Zeinkewicz: The Finite Element Method

**Structure of the Question paper**

For the End semester Examination There will be three questions from each module out of which two questions are to be answered by the students.

## MTD 2002 CRYOGENIC ENGINEERING 3-0-0-3

**Structure of the Course**

Lecture: 3 hrs/ Week Credits: 3
Internal Continuous Assessment : 40 Marks
End Semester Examination : 60 Marks

**Course Objectives**

- To impart a basic concepts of low temperature production and utilization
- To study various systems for low temperature production

**Learning Outcomes**

- The students will be capable of designing a liquefaction system
- They will be able to produce liquefaction systems with minimum energy consumption

**Module I**

Introduction: Historical development-present areas involving cryogenic engineering. Low temperature properties of engineering materials-Mechanical properties-Thermal properties-Electric and magnetic properties-Properties of cryogenic fluids.

**Module II**

Gas liquefaction systems: Introduction-Production of low temperatures-General liquefaction systems-Liquefaction systems for Neon, Hydrogen and Helium-Critical components of liquefaction systems.
Cryogenic Refrigeration systems: Ideal Refrigeration systems-Refrigerators using liquids and gases as refrigerants-refrigerators using solids as working media.

**Module III**

Cryogenic fluid storage and transfer systems: Cryogenic fluid storage vessels-Insulation-Cryogenic fluid transfer systems.
Applications of Cryogenics: Super conducting devices-Cryogenics in Space Technology-Cryogenics in biology and medicine.

**References:**


1. Cryogenic Systems – Randall Barron
2. Cryogenic Engineering- R.B.Scott
3. Cryogenic Engineering – J.H.Bell Jr.


**Structure of the Question paper**

For the End semester Examination There will be three questions from each module out of which two questions are to be answered by the students.