M.Tech. Degree

PROGRAMME

In

Thermal Engineering

CURRICULUM

(w.e.f. Session 2019-2020)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
KURUKSHETRA-136119

VISION OF THE INSTITUTE

- To be a role model in technical education and research, responsive to global challenges.

MISSION OF THE INSTITUTE

- To impart technical education that develops innovative professionals and entrepreneurs.
- To undertake research that generates cutting-edge technologies and futuristic knowledge, focusing on the socio-economic needs.

VISION OF THE DEPARTMENT

To make contribution in the development of nation and evolution of technology by creating highly ethical professionals in Mechanical Engineering who are technically competent and are aware of their social responsibilities.

MISSION OF THE DEPARTMENT

- M1: To produce highly qualified, socially responsible, ethical and motivated students having sound theoretical and practical knowledge of Mechanical Engineering as well as communicative skills who can serve the nation as well as at global level.
- M2: To inspire students to be a part of research and development activities.
- M3: To carry out research in order to serve the needs of industries, government and society.
- M4: To encourage students to participate in conferences, workshops, seminars and research activities.
- M5: To develop partnership with government agencies and industries.

PROGRAMME: - THERMAL ENGINEERING

Programme Education Objectives (PEOs)

1. To impart education in Thermal Engineering to have all-round development of students in order to serve the global society.
2. To develop the critical thinking and problem solving ability amongst the students through application of various aspects/fundamentals of Thermal Engineering to understand/ analyze/ solve the critical situations in the area amicably.
3. To develop independent research attitude through projects/dissertations and its administrative & financial management as well as its dissemination to the PG students.
4. To create awareness amongst the students for collaborative and multidisciplinary activities through usage of modern/emerging tools, technologies and research publications.
5. To encourage students to be ethically and socially responsible and articulate themselves to be a lifelong learner.

Programme Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area of Thermal Engg. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4: An ability to develop and apply software and hardware tools / techniques for the analysis of problems related to design, manufacturing and optimization.

PO5: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

MASTER OF TECHNOLOGY SCHEME IN MECHANICAL ENGINEERING (THERMAL ENGINEERING)

SEMESTER-I

S.No.	Course Code	Course Title	Lecture	Tutorial	Practical	Credits
1	MME3C01	Advanced Fluid Engineering	3	-	-	3
2	MME3C03	Convective Heat Transfer	3	-	-	3
3	MME3C05	Refrigeration Engineering	3	-	-	3
4	MME3C07	Mathematical Methods for Engineers	3	-	-	3
5	MME3C09	Advanced Internal Combustion Engines	3	-	-	3
6	MME3E__	Elective-I	3	-	-	3
7	MME3L01	Advanced Thermal Engineering Laboratory	-	-	3	1
8	MME3S01	Seminar			2	1
	Total		**18**		**5**	**20**
	Total Contact Hours		**23**			

SEMESTER-II

S.No.	Course Code	Course Title	Lecture	Tutorial	Practical	Credits
1	MME3C02	Computational Fluid Dynamics	3	-	-	3
2	MME3E__	Elective-II	3	-	-	3
3	MME3E__	Elective- III	3	-	-	3
4	MME3E__	Elective-IV	3	-	-	3
5	MME3E__	Elective-V	3			3
6	MME3O__	Open Elective-VI (Non Departmental)	3	-	-	3
7	MME3L02	Computational Fluid Dynamics Lab	-	-	3	1
8	MME3P02	Project			2	1
	Total		**18**		**5**	**20**
	Total Contact Hours		**23**			

SUMMER VACATION

Course Code	Course Title	P/T	Credits
MME3PW02	Short Term Courses on Personality Development / Soft Skills Preparatory Work for Dissertation / Project		0

SEMESTER - III

Course Code	Course Title	P/T	Credits
MME3D01/ MME3P01/ MME3I01	Dissertation /Project/Internship Part-I		14

SEMESTER - IV

Course Code	Course Title	P/T	Credits
MME3D02/ MME3P04/ MME3I02	Dissertation /Project/Internship Part-II		14

TOTAL CREDITS: 68

LIST OF ELECTIVES

S.No.	Course Code	Course Title	Credits
1	MME3E31/MME3E32	Direct Energy Conversion	3
2	MME3E33/MME3E34	Air Conditioning	3
3	MME3E35/MME3E36	Nuclear Engineering	3
4	MME3E37/MME3E38	Fuels and Combustions	3
5	MME3E39/MME3E40	Renewable Energy & Energy Management	3
6	MME3E41/MME3E42	Turbulence and its Modeling	3
7	MME3E43/MME3E44	Gas Dynamics	3
8	MME3E45/MME3E46	Solar Energy	3
9	MME3E47/MME3E48	Gas Turbine and Jet Propulsion	3
10	MME3E49/MME3E50	Conductive and Radiative Heat Transfer	3
11	MME3E51/MME3E52	Design of heat exchangers	3
12	MME3E53/MME3E54	Non- conventional cooling methods	3
13	MME3E55/MME3E56	Bio Energy technologies	3
14	MME2C03	Operations Management	3
15	MME2C07	Experimental Designs	3
16	MME2E45/MME2E46	Modeling and Simulation	3
17	MME2E51/MME2E52	Strategic entrepreneurship	3
18	MME2E53/MME2E54	Total Quality Management	3
19	MME1C01	Applied Numerical Methods	3
20	MME1C07	Finite Element Methods	3
21	MME1E33/MME1E34	Measurement and Control	3

LIST OF OPEN ELECTIVES FOR OTHER DEPARTMENTS

S.No.	Course Code	Course Title	Credits
1	MME3C01	Advanced Fluid Engineering	3
2	MME3C02	Computational Fluid Dynamics	3
3	MME3C03	Convective Heat Transfer	3
4	MME3C05	Refrigeration Engineering	3
5	MME3C07	Mathematical Methods for Engineers	3
6	MME3C09	Advanced Internal Combustion Engines	3
7	MME3E39/MME3E40	Renewable Energy & Energy Management	3
8	MME3E45/MME3E46	Solar Energy	3
9	MME3E49/MME3E50	Conductive and Radiative Heat Transfer	3

MME3C01
ADVANCED FLUID ENGINEERING

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To provide the students the necessary analytical skills to solve and analyse phenomena involving fluids in various engineering applications.
2. To understand the concept of boundary layer and its importance in fluid engineering.
3. To study the compressible flow and implications of shock wave formation
4. To acquaint the students with important concepts of aerodynamics.

Course Contents

1. **Introduction and basic laws**
   Review of basic concepts of fluid mechanics, Non Newtonian fluids, Stress at a point, derivation of Navier Stokes equation, Basic laws in integral form, Reynolds transport theorem, continuity, momentum and energy equations in integral form and their applications. **(7 hrs)**

2. **Ideal fluid flow**
   Kinematics of fluid flow, potential flow, source, sink, doublet and vortices; superimposition of uniform stream with above; flow around comers; Rankine ovals, flow around uniform cylinders with and without circulation, pressure distribution on the surface of these bodies **(6 hrs)**

3. **Viscous flow**
   Exact solution; plane Poiselle and Coutte flows; Hagon-Poiselle flow through pipes; flows with very small Reynold's numbers; Stokes flow around a sphere, Elements of hydrodynamic theory of lubrication**.** **(4 hrs)**

4. **Laminar and Turbulent boundary layer flows**
   Elements of two dimensional boundary layer theory; displacement thickness, momentum thickness, energy thickness; Von Karman Momentum Integral Equation Laminar boundary layer, Turbulent boundary layer, Boundary layer separation. **(6 hrs)**

5. **Compressible flow**
   Wave propagation and sound velocity, Mach number and compressible flow regimes, basic equations for one dimensional compressible flow, isentropic flow relations, variation of velocity with area, normal shock wave, oblique shock wave, Fanno and Rayleigh lines, flow in a converging diverging nozzle **(6 hrs)**

6. **Vortex motion**
   Definitions; vortex lines, surfaces and tubes; vorticity, circulation, Kelvins circulation theorem, Helmholtzs vorticity theorem, Biot-savart law for induced vorticity, system of vortex filaments, horse-shoe vortex filaments, ring vortices, vortex street **(6 hrs)**

Course Outcomes:

1. Students will be able to understand and apply standard equations for fluid problems.
2. Students will be able to understand and analyse the flow around various bodies.
3. Students will be able to calculate pressure in hydrodynamic bearings using Coutte flow.
4. Students will be able to understand the concept of boundary layer and skin friction drag.
5. Students will be able to understand the basics of aerodynamics, concepts of compressible flow, supersonic flow and consequences shock waves generation.

Reference Books:

1. Fundamentals of Mechanics of Fluid by Curriec, Mc Graw-Hill
2. Foundation of Fluid Mechanics, Yuan, Prentice Hall
3. Engineering Fluid Mechanics, K.L. Kumar, Eurasia
4. Fluid Mechanics and its applications, Gupta and Gupta, Willey Eastern
5. Introduction to Fluid mechanics and Machines, Som & Biswas, TMH
6. Fundamental of Compressible Flow, S M Yahya, New Age
7. Fluid Mechanics, Frank M White, TMH

MME3C03
CONVECTIVE HEAT TRANSFER

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objective

1. To give the student insight about boundary layer flow.
2. Knowledge of laminar and turbulent flows.
3. To understand the conservation principles of mass, momentum and energy in boundary layer flows.

Course Contents

1. **Governing Equations**
   Definitions and flow classifications, Conservation equations, viscosity and stress terms, Boundary layer approximations to momentum and energy. **(6 hrs)**

2. **Laminar External flow and heat transfer**
   Similarity solutions for flat plate (Blasius solution), Integral method solutions for flow over an isothermal flat plate, flat plate with constant heat flux and with varying surface temperature (Duhamel's method), flows with pressure gradient (von Karman-Pohlhausen method). Finite-difference solutions of boundary layer equations. **(8 hrs)**

3. **Laminar internal flow and heat transfer**
   Developing Internal (ducted) flows within boundary layer approximations, fully developed flows and heat transfer in circular and non-circular ducts, use of superposition techniques. Integral method for internal flows with different wall boundary conditions. **(8 hrs)**

4. **Natural Convection heat transfer**
   Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical plate with constant wall temperature and heat flux conditions, Integral method for natural convection flow past vertical plate, effects of inclination, Natural convection in enclosures, mixed convection heat transfer past vertical plate and in enclosures. **(8 hrs)**

5. **Turbulent convection**
   Governing equations for averaged turbulent flow field (RANS), nature of turbulent flows –phenomenology of near-wall turbulence, turbulence models (zero, one and two equation models), analogies between heat and Mass transfer (Reynolds, Prandt l-Taylor and von Karman analogies), turbulent flow and heat transfer across flat plate and circular tube, turbulent natural convection heat transfer. **(10 hrs)**

Course Outcomes:

1. Awareness of governing equations for convective heat transfer
2. Ability to formulate ODEs and PDEs along with boundary conditions for the convective heat transfer problems and obtain analytical solutions
3. Ability to solve conjugate heat transfer problems
4. Ability to solve 1D, 2D, and 3D convective problems in heat transfer

Reference Books:

1. Convective Heat and Mass Transfer by W. Kays, M. Crawford and B. Weigand, McGraw Hill International.
2. Convection Heat Transfer by A. Bejan, John Wiley.
3. Fundamentals of Heat and Mass Transfer by F.P. Incropera and D. Dewitt, John Wiley.
4. Convective Heat Transfer by S. Kakac and Y. Yener, CRC Press.
5. Boundary Layer Theory by H. Schlichting and K. Gersten, Springer-Verlag.

MME3C05
REFRIGERATION ENGINEERING

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives:

1. Use of Thermodynamic processes in different refrigerating systems
2. Application of Heat transfer in different thermodynamic systems
3. Learning the fundamental principles and different methods of refrigeration
4. Study of various refrigeration cycles and evaluate performance using refrigeration charts and refrigerant property tables.
5. Study of different refrigerants with respect to properties, applications and environmental issues
6. To understand different applications of Refrigeration Systems.

Course Contents

1. **Introduction**
   Reverse Carnot cycle, Limitation of reverse carnot cycle with vapour as a refrigerant, simple vapour compression cycle, design consideration of components, Ewing's construction, Standard rating cycle and effect of operating conditions, Deviation of actual vapour compression cycle with that of theoretical, Properties of refrigerants & mixture of refrigerant. **(7 hrs)**

2. **Air Refrigeration System**
   Bell-Coleman cycle, advantages and disadvantages of air refrigeration system, necessity of cooling the aero-plane, simple cooling and simple evaporative type, Boot Strap type, regenerative type & reduced ambient type air refrigeration systems. **(7 hrs)**

3. **Multi-Stage Vapour Compression Systems**
   Method of improving the COP, optimum intermediate pressure for two-stage refrigeration system, Multi-stage or compound compression with flash inter cooler, single expansion and multi expansion. Multi evaporator system with single compressor, individual compressor with compound compression, single expansion and multi-expansion. Limitations of simple vapour compression system, cascade system, production

of solid carbon dioxide, Joule-Thomson effect, liquification of gases-hydrogen & helium, application of low temperature. **(12 hrs)**

4. **Steam Jet Refrigeration**

   Steam Jet Refrigerator, components of steam Jet refrigeration plant, advantages and limitations of steam jet refrigeration system, performance of the system. Determination of equilibrium concentration. **(6 hrs)**

5. **Vapour Absorption System**

   Simple vapour absorption system, Maximum co-efficient of performance, modification of simple vapour absorption system, actual vapour absorption cycle and its representation on Enthalpy –composition diagram, absorption system calculation. Rich and poor solution concentration. Lithium–Bromide water system **(6 hrs)**

Course Outcomes:

1. Illustrate the fundamental principles of producing refrigeration and applications of refrigeration
2. Understand the principles and remember the applications of refrigeration systems
3. Present the properties, applications and environmental issues of different refrigerants
4. Analyze performance of vapor compression refrigeration system
5. Understand the function of each of the major refrigeration system components: evaporator, compressor, condenser, and metering device
6. Understand the working principles of heat operated systems.
7. Students will be able to design refrigerating systems for multiple evaporator temperatures

Reference Books:

1. Mechanical Refrigeration by Sporks and Diffio.
2. ASHRAE Handbook (Fundamentals) by ASHRAE.
3. Thermal Environment Engineering by Threlkeld.
4. Refrigeration and Air-conditioning by C.P. Arora.
5. Refrigeration and Air –conditioning by Stocker.
6. Refrigeration and Air conditioning by Stocker, Mc-Graw Hill.

MME3C07
MATHEMATICAL METHODS FOR ENGINEERS

L	T	P/D	Cr.
3		0	3

Course Learning Objective

1. To introduce mathematical techniques which are used widely in modern engineering studies
2. Engineering mathematics relevant to students intending to pursue design and research

Course Contents

1. Vector and Tensor calculus

Curves and surfaces; gradient, divergence and curl, directional derivatives, vector identities: Line (Curve), surface and volume Integrals, Gauss (Divergence), Stokes and Green's theorems, Introduction to tensors, tensor operations, higher orders tensors, tensor derivatives **(10 hrs)**

2. Linear algebra

Matrix algebra(symmetric, positive definite and orthogonal matrices, rank, inverse); system of linear algebraic equations (existence and uniqueness of solution, Gauss elimination, L-U decomposition and Gauss-Seidel iterative methods); eigen values and eigenvectors (properties like multiplicities and linear independence, eigen values of symmetric, positive definite and orthogonal matrices) **(8 hrs)**

3. Ordinary differential equations (ODE)

First order linear and non-linear ODE (separation of variables, integrating factor for reduction to exact form); second order linear differential equations (homogeneous/non-homogeneous) with constant coefficients, initial and boundary value problems, Euler-Cauchy equation; Fourier series **(8 hrs)**

4. Partial differential equations (PDE)

1-D heat and wave equations and 2-DLaplace equation (in Cartesian coordinates): solutions using separation of variables, D' Alembert's solution for wave equation, Laplace transform technique for heat equation **(6 hrs)**

5. Transform calculus

Concept of Transforms, Complex form of Fourier integral, introduction to Fourier transform, properties of general (complex) Fourier transform, concept and properties of Fourier sine transform and Fourier cosine transform, evaluation of Fourier transform, Applications **(4 hrs)**

6. Statistics

Random variables: Mean, median and standard deviation; normal, Poisson and binomial distributions **(4 hrs)**

Course Outcomes:

1. Formulate and solve physical problems using mathematical modeling
2. Utilize vector and tensor calculus in engineering problems
3. Utilize various methods for solving ODEs and PDEs

Reference Books:

1. E.Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, International.
2. B. Dasgupta, Applied Mathematical Methods, Pearson Education.
3. Peter V O’Neil, Advanced Engineering Mathematics, Cengage Learning.
4. Gilbert Strang, Introduction to Linear Algebra.
5. Mary L. Boas, Mathematical Methods in the Physical Sciences, John Wiley and Sons, International.

MME3C09
ADVANCED INTERNAL COMBUSTION ENGINES

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To make students familiar with the design and operating characteristics of modern internal combustion engines.
2. To apply analytical techniques to the engineering problems and performance analysis of internal combustion engines.
3. To study the thermodynamics, combustion, heat transfer, friction and other factors affecting engine power, efficiency and emissions.
4. To introduce students to the environmental and fuel economy challenges facing the internal combustion engine.
5. To introduce students to future internal combustion engine technology and market trends.

Course Contents

1. **Cycle Analysis**
   Thermodynamic properties of gases and combustion products, combustion charts, Fuel-air cycle, calculations for Otto, Diesel and dual cycles, Losses due to dissociation, burning time and heat flow. Combustion processes for SI and CI engines; flame propagation and spray burning processes; energy release calculations; actual Vs fuel air cycle, effects of various operating conditions, two and four stroke engine cycles. **(10 hrs)**

2. **Heat Transfer**
   Instantaneous heat transfer calculations, engine heat transfer equations, overall heat loss-radiative and convective heat transfers. **(5 hrs)**

3. **Gas Exchange**
   Generalised equations for in-flow and outflow processes; filling and emptying methods and wave action calculations; two stroke engines, gas exchange processes; types and phases of scavenging, Kadney effect. Super charging of SI 7 CI engines; super charger and turbocharger systems, matching of atomization and spray formation; pump characteristics. **(10 hrs)**

4. **Fuel Injection**
   Fuel injection: fuel line hydraulics; compressibility effects; wave and nozzle ends; mechanism of atomization and spray formation; pump characteristics. **(8 hrs)**

5. **Flow Processes**
   Characterisation of flow in the cylinder, Swirl, Squish and turbulence calculations. **(3 hrs)**

6. Fuels

Petroleum fuels, Gasoline grades, desirable properties of SI & CI engines fuels, rating of fuels. **(4 hrs)**

Course Outcomes:

1. Differentiate among different internal combustion engine designs.
2. Recognize and understand reasons for differences among operating characteristics of different engine types and designs.
3. Given an engine design specification, predict performance and fuel economy trends with good accuracy.
4. Based on an in-depth analysis of the combustion process, predict concentrations of primary exhaust pollutants.
5. Exposure to the engineering systems needed to set-up and run engines in controlled laboratory environments.
6. Develop skills to run engine dynamometer experiments.
7. Learn to compare and contrast experimental results with theoretical trends, and to attribute observed discrepancies to either measurement error or modeling limitations.
8. Develop an understanding of real world engine design issues.

Reference Books:

1. I.C. Engine Vol. 1 & II by Taylor.
2. Thermodynamics and Gas Dynamic of I.C. Engine, Vol. I & II by Horlock and Winterbone.
3. I.C. Engine, Vol. I & II by Benson and Whitehouse.
4. Thermodynamic Analysis of Combustion Engines, by Campbell.

MME3L01
ADVANCED THERMAL ENGINEERING LABORATORY

L	T	P/D	Cr.
-	-	3	1.0

Lab Learning Objectives

- To provide a fundamentals of refrigeration and air conditioning
- To determine psychometric properties of air
- To learn heat transfer mechanism in boiling and condensation heat transfer phenomenon
- To understand working and performance of various types of engines

Lab Experiments

1. To study the performance of refrigeration cycle using different expansion devices.
2. To compare C.O.P. of the refrigeration test rig when working as heat pump refrigerator.
3. To study the constructional details of hermetically sealed reciprocating compressor.
4. To determine the overall heat transfer co-efficient of both Drop and Film Wise Condensation
5. To study the boiling heat transfer phenomena and determine critical heat flux for pool boiling of water.
6. To study the performance of single cylinder, diesel engine with variable compression ratio connected to eddy current dynamometer in computerized mode.
7. To study the performance of 3 cylinder, 4 stroke, petrol engine connected to eddy current dynamometer in computerized mode.
8. Analysis of exhaust gases from single cylinder/multi cylinder diesel/petrol engine by using Modular Diagnostic System
9. To study the performance of 4 cylinder, 4 stroke, diesel engine connected to eddy current dynamometer in computerized mode.
10. To study the performance of multi-fuel, single cylinder, petrol engine connected to regenerative type dynamometer
11. To study combustion process through simulation
12. To study heat distribution on a brake assembly
13. To perform heat transfer analysis of an oven

Lab Course outcomes:

At the end of the lab course student will be able to

1. Study of refrigeration cycle and heat pump cycle and working of four way valve.
2. To understand constructional details of hermetically sealed reciprocating compressor
3. To determine amount of heat exchange in phase change processes like boiling and condensation for different geometries.
4. To understand the practical importance of contemporary engines equipped with open ECU.
5. At the end of the course, the students shall be able to understand the effects of transient operations of vehicle on emissions and types of emissions.
6. The students shall be able to perform various tests on contemporary engines equipped with open ECU.

MME3C02
COMPUTATIONAL FLUID DYNAMICS

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To be able to apply PDEs to CFD problems.
2. To be able to understand fundamentals of discretization and apply them to CFD problems.
3. To be able to formulate and solve problems related to heat transfer and fluid flow using Finite Difference and Finite Volume Methods.
4. To be able to understand the limitations and errors involved in solution to CFD problems.

Course Contents

1. **Introduction**
   Introduction to C.F.D., models of flow, governing differential equations – continuity equation, momentum equation, energy equation, Navier- Stokes equation, physical boundary conditions. **(5 hrs)**

2. **Mathematical behaviour of governing equation**
   Classification of quasi linear partial differential equation, General method of determining the Classification of partial differential equation, hyperbolic, parabolic, elliptic equations. **(5 hrs)**

3. **Discretization methods**
   Finite difference methods, difference equations, explicit & implicit approach, errors & analysis of stability. Basics of finite control volume method **(5 hrs)**

4. **Heat conduction problem**
   Solution of One dimensional heat conduction through a fin, solution of two dimensional steady state and transient heat conduction problems, heat conduction problems in cylindrical coordinates: axisymmetric and non-axisymmetric problems. **(7 hrs)**

5. **Heat conduction with convection & diffusion**
   Steady state one dimensional convection and diffusion, upwinding, exact solution, exponential scheme, hybrid scheme, power law scheme, Discretization equation for two dimensions & three dimensions, false diffusion **(8 hrs)**

6. **Fluid flow problem**
   Viscous incompressible flow, solution of the couette flow problem by F.D.M., calculation of the flow field using stream function – vorticity method, numerical algorithms for solving complete Navier-Stokes equation – MAC method; SIMPLE method. **(10 hrs)**

Course outcomes:

1. Understand the concepts of PDEs and apply them to CFD problems.
2. Understand discretization and its application to problems.
3. Solve problems related to heat transfer and fluid flow using Finite Difference and Finite Volume Methods.
4. To understand the limitations and errors involved in solution to CFD problems.

Reference Books:

1. Suhas. V. Patankar, Numerical heat transfer and fluid flow, Hemisphere.
2. John. D. Anderson, Jr, Computational fluid dynamics, McGraw Hill.
3. Vesrteeg and Malalsekera, An Introduction to Computational fluid dynamics- The Finite Volume Method, Longman Scientific and Technical.
4. Anil .W. Date, Introduction to Computational fluid dynamics, Cambridge University Press.
5. Niyogi, Chakraborty and Laha, Introduction to Computational fluid dynamics, Pearson Education.

MME3L02
Computational Fluid Dynamics Lab

L	T	P/D	Cr.
-	-	3	1.0

Lab Learning Objectives

1. To be able to apply PDEs to CFD problems.
2. To be able to apply discretization to CFD problems.
3. To be able to formulate and solve problems related to heat transfer and fluid flow using Finite Difference and Finite Volume Methods.
4. To be able to understand the limitations and errors involved in solution to CFD problems.

Lab Experiments

1 To make and validate a computer programme for the one dimensional pin fin steady state conduction.

2 To make and validate a computer programme for the one dimensional transient heat conduction.

3 To make and validate a computer programme for a slab in two dimensions in steady state conduction.

4 To make and validate a computer programme for a slab in two dimensions in transient state.

5 To make and validate a computer programme for the comparison of explicit, implicit and Crank-Nicholson methods of computation of heat transfer equation.

6 To make and validate a computer programme for the fully developed laminar flow in circular pipe.

7 To make and validate a computer programme for the couette flow.

8 To make and validate a computer programme to solve the Navier Stokes equation.

9 To make and validate a computer programme to solve a model problem by stream function vorticity method.

10 To make a project using MAC/ SIMPLE method.

Lab Course outcomes:

1. Apply PDEs to CFD problems.
2. Apply discretization to problems.
3. Solve problems related to heat transfer and fluid flow using Finite Difference and Finite Volume Methods.
4. To understand the limitations and errors involved in solution to CFD problems.

MME3E49/MME3E50
CONDUCTIVE AND RADIATIVE HEAT TRANSFER

L	T	P/D	Cr.
3	0	-	3

Course Learning Objective

1. To understand intricacies involved in heat transfer using conduction & radiation laws
2. To understand various engineering application involving conduction and radiation heat. transfer.

Course Contents

1. **Conduction**
   Derivation of heat conduction equation. Summary of basic 1D conduction. Fins with variable cross-section. Multi-dimensional steady and unsteady problems in Cartesian and Cylindrical coordinates. Semi-infinite solids. Duhamel's Superposition Integral. Solidification and Melting. Inverse heat conduction. Microscale heat transfer. **(18 hrs)**

2. **Radiation**
   Physical mechanism. Laws of thermal radiation. Radiation properties of surfaces. View factors for diffuse radiation. Radiation exchange in black and diffuse gray enclosures. Radiation effects in temperature measurement. Enclosure theory for surfaces with wall temperatures that are continuous functions of space. Spectrally diffuse enclosure surfaces. Specularly reflecting surfaces. The equation of radiative properties in participating media. Radiative properties of molecular gases. Approximate solution methods for one-dimensional media: The optically thin and optically thick approximations. Radiation in participating media: Gas radiation. **(18 hrs)**

3. **Combined Conduction and Radiation**
   Example of a spacecraft radiator. Solar radiation. Greenhouse effect. **(4 hrs)**

Course Outcomes:

1. Applications of governing equations for conductive heat transfer in Cartesian, cylindrical and spherical coordinates for isotropic and anisotropic materials.
2. Ability to formulate ODEs and PDEs along with boundary conditions for the conductive heat transfer problems and obtain analytical solutions
3. Ability to apply the governing equations of radiation heat transfer and determine approximate solution for one-dimensional media
4. Solve combined conduction and radiation problems

Reference Books:

1. Fundamentals of Heat and Mass Transfer by *Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, Adrienne S. Lavine* (*John Wiley and Sons*)
2. Heat and Mass Transfer by *Yunus Cengel, Afshin Ghajar(McGraw-Hill)*
3. Heat Conduction by *Latif M Jiji (Springer)*
4. Radiative Heat Transfer by *Michael F. Modest (Academic Press)*

MME3E33/MME3E34
AIR -CONDITIONING

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. Learning the fundamental principles and different methods of air conditioning.
2. Understand the basic air conditioning processes on psychometric charts, calculate cooling load for its applications in comfort and industrial air conditioning.
3. Design Air-Conditioning Systems using Cooling Load Calculations.
4. To familiarize with industrial protocols, regulations in the field.

Course Contents

1. **Introduction**
   Psychrometric and psychrometric properties, psychrometric relations and processes, adiabatic temperature, psychrometric chart, summer and winter air-conditioning system, year-round air-conditioning, factors influencing-human comfort, effective temperature, factors governing optimum effective temperature, Air Washer. **(8 hrs)**

2. **Cooling Load Calculations**
   Types of loads, building heat transmission, solar-radiation infiltration, occupants, electric lights, products load, other internal heat sources, fresh-air miscellaneous streams. **(7 hrs)**

3. **Air Conditioning Systems**
   Design of air-conditioning systems, central station, unitary, district, self-contained direct expansion, all water, all air, air-water system, arrangement of components, air-cleaning and air filters, humidifiers, dehumidifiers air-washers, fan and blowers, grills and registers. **(7 hrs)**

4. **Air Conditioning Control System**
   Heating and cooling coils, basic principles of control system, temperature humidity, pre-heating and humidification, cooling and dehumidification, reheat and all-year conditioning control systems. Elements of control, Deflective element (bimetallic, bulbs and below, electrical resistance, electromagnetic sensitive and pressure sensitive, controlling room conditions at partial load (ON-OFF control), by pass control, reheat control and volume control), Inverter AC. **(10 hrs)**

5. **Miscellaneous**
   Ventilation and ventilation standards, duct design and air-distribution system, noise and noise control, solar air-conditioning, applications of AC. **(8 hrs)**

Course Outcomes:

1. Students will be able to understand psychrometric properties and processes.
2. Students will be able to calculate cooling load for air conditioning systems used for various
3. Analyze the air conditioning processes using principles of Psychrometry.
4. Students will be able to design AC systems for summer and winter seasons
5. Students will be able to design duct and air distribution systems for conditioned space.
6. Students will be able to understand the AC control mechanism

Reference Books:

1. Refrigeration and air conditioning by C.P. Arora.
2. Refrigeration and air conditioning by Jordan and Priester
3. Refrigeration and air conditioning by William
4. ASHRAE Hand Book (Fundamentals) by ASHRAE
5. Elementary Refrigeration and air conditioning by Stoecjer McGraw Hill
6. Air Conditioning Engineering by Jones Arnold.

MME3E31/MME3E32
DIRECT ENERGY CONVERSION

L	T	P/D	Cr
3	-	-	3

Course Learning Objectives

1. Learning Basic knowledge of Direct Energy Conversion.
2. To make understand on Solar Thermal Technologies.
3. General understanding of the design of a Photovoltaic.
4. Understanding of Direct energy conversion devices.
5. Learning Basic technologies of future fuel cells.

Course Contents

1. **Introduction**
   Conversion of energy from one form to another, direct energy conversion, Application of direct energy conversion. **(5hrs)**

2. **Solar Energy**
   Introduction, Solar Technologies, Solar Alternative Fuels, Solar Hydrogen Production, Concentrated Solar Power, Thermal Energy Storage, and Benefits, Comparison of Various CSP Technologies, Hybrid CSP Systems, Direct Solar-to-Salt Design, Combined Open-Air Brayton Cycle with Natural Gas Peaking, Integrated Solar Combined Cycle System. **(16hrs)**

3. **Photo-voltaic Power Generation**
   Solar PV energy conversion, PV device structures, wafer-based PV technologies, solar cell thickness, performance metrics for future PV applications, PV technology trends, materials, graphene-based solar cells, Design of PV system. **(9hrs)**

4. **Thermoelectric Generators**
   Introduction, Thermoelectric effects, thermoelectric generator, Types of thermoelectric generators, Economic aspects of thermoelectric generation **(5 hrs)**

5. **Fuel Cells**
   Introduction, Principle of Fuel Cells, Thermodynamic Analysis of Fuel Cells, Types Of Fuel Cells, Fuel Cell Batteries, Applications Of Fuel Cells, Fuel Cell Vehicle, Hydrogen Fuel Cell Features, Differences Between Fuel Cell Cars And Other EVS **(5 hrs)**

Course Outcomes:

1. Know overview of direct energy conversions.
2. Design & analysis of solar thermal system
3. Design of PV system for lighting applications.
4. Know working of Thermoelectric Generators
5. Know the future Fuel cells and its application to automobiles.

Reference Books:

1. Renewable Energy Sources and Conversion Technology by N.K. Bansal, M.Kleeman and M. Mieles.
2. Direct Energy Conversion by G.W.Sutton.
3. Energy Conversion by S.S.L. Chang
4. Fuel Cells for Electric Utility Power generation
5. Advances in Energy Systems and Technology by A.P. Fickett

MME3E35/MME3E36
NUCLEAR ENGINEERING

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To be able to understand the concepts of neutron physics and various nuclear Processes involved in Nuclear Power Plants.
2. To be able to calculate heat generation from nuclear reaction.
3. To be able to design and analyze the performance of nuclear power plants.
4. To get acquainted with applications of radioactivity.
5. To be able to appreciate the hazards associated with radioactivity and the necessity of waste disposal.

Course Contents

1. **Concepts of Nuclear Physics**
   The atom, structure, the nucleus, nuclear structure, atomic transmutation of elements, detection of radio-activity, particle accelerator, decay, natural of elements, nucleus interactions, decay rates, half-life, transuranic elements. **(6hrs)**
2. **Neutorn Interaction**
   Advantages of using neutron, neutron moderation, fission chain reaction, thermalisation of neutrons, fast neutrons, prompt and delayed neutrons, fission products. **(4hrs)**
3. **Energy Release**
   Mass energy equivalence, mass defect, binding energy, energy release in fission & fusion, thermonuclear reaction, fusion bomb. **(4hrs)**
4. **Reactor Materials**
   Fissile & fertile materials, cladding & shielding materials, moderators, coolants. **(4hrs)**
5. **Reactor Technology**
   Basic principles, fuel assembly, neutron balance, reactor kinetics, reactor coefficients, reactor stability, excess reactivity, Xenon poisoning, burnable absorbers, reactivity control, heat balance, production& transfer of heat to the coolant, structural considerations. **(10 hrs)**
6. **Nuclear Reactors**
   Types of nuclear reactors, pressurized water reactors, boiling water reactors, CANDU type reactors, gas cooled & liquid metal cooled reactors, fast breeder reactors. **(6hrs)**
7. **Safety Considerations & Waste Disposal**
   Hazards, plant site selection, safety measures incorporated in; plant design, accident control, disposal of nuclear waste. **(4hrs)**

8. **Health Physics & Radio-isotopes**
   Radiation: units, hazards, prevention, preparation of radio-isotopes& their use in medicine, agriculture & industry. **(2hrs)**

Course outcomes:

1. Understand the concepts of neutron physics and various nuclear Processes involved in Nuclear Power Plants.
2. Calculate heat generation from nuclear reaction.
3. Design and analyze the performance of nuclear power plants.
4. Get acquainted with applications of radioactivity.
5. Appreciate the hazards associated with radioactivity and the necessity of waste disposal.

Reference Books:

1. M. M. El-Wakel, Nuclear Power Engineering, McGraw Hill
2. Shultis and Faw, Fundamentals of Nuclear Science and Engineering, CRC Press
3. Stephenson, Introduction to Nuclear Engineering, McGraw Hill
4. Murray, Nuclear Energy, Butterworth-Heinemann

MME3E37/MME3E38
FUELS AND COMBUSTIONS

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To understand the types of fuels.
2. To understand the principles of combustion and combustion equipments.
3. To understand the thermodynamic process behind the combustion.

Course Contents

1. **Characterization**
   Fuels, types and characteristics of fuels, Determination of Properties of Fuels, Fuels Analysis - Proximate and Ultimate Analysis, Moisture Determination, Calorific Value, Gross & Net Calorific Values, Calorimetry, DuLong's Formula for Calorific Value estimation, Flue gas Analysis, Orsat Apparatus, Fuel & Ash Storage & Handling - Spontaneous Ignition Temperatures. **(6hrs)**

2. **Solid of liquid fuels**
   Solid Fuels Types, Coal Family, Properties - Calorific Value - ROM, DMMF, DAF and Bone Dry Basis - Ranking - Bulk & Apparent Density - Storage - Washability - Coking & Caking Coals – Renewable Solid Fuels - Biomass - Wood Waste - Agro Fuels - Manufactured Solid Fuels.
   Liquid Fuels Types - Sources - Petroleum Fractions - Classification - Refining - Properties of Liquid Fuels - Calorific Value, Specific Gravity, Flash & Fire Point, Octane Number, Cetane Number etc, - Alcohols - Tar Sand Oil - Liquefaction of Solid Fuels. **(8hrs)**

3. **Gaseous fuel**
   Gaseous Fuel Classification, Composition & Properties, Estimation of Calorific Value, Gas Calorimeter. Rich & Lean Gas - Wobbe Index - Natural Gas - Dry & Wet Natural Gas - Stripped NG - Foul & Sweet NG - LPG - LNG - CNG - Methane - Producer Gas - Gasifiers - Water Gas - Town Gas - Coal Gasification - Gasification Efficiency - Non - Thermal Route - Biogas - Digesters - Reactions - Viability - Economics. **(6hrs)**

4. **Combustion : stoichiometry & kinetics**
Stoichiometry – Mass Basis & Volume Basis – Excess Air Calculation – Fuel & Flue Gas Compositions - Calculations – Rapid Methods – Combustion Processes – Stationary Flame – Surface or Flameless Combustion – Submerged Combustion – Pulsating & Slow Combustion Explosive Combustion. Mechanism of Combustion – Ignition & Ignition Energy – Spontaneous Combustion – Flame Propagation – Solid, Liquid & Gaseous Fuels Combustion – Flame Temperature – Theoretical, Adiabatic & Actual – Ignition Limits – Limits of Inflammability. Thermo Chemistry - Equilibrium combustion products. Low temperature combustion products – High temperature combustion products.
(12hrs)

5. **Combustion equipments**
Coal Burning Equipments – Types – Pulverized Coal Firing – Fluidized Bed Firing – Fixed Bed & Recycled Bed – Cyclone Firing – Spreader Stokers – Vibrating Grate Stokers – Sprinkler Stokers, Traveling Grate Stokers. Oil Burners – Vaporizing Burners, Atomizing Burners – Design of Burners. Gas Burners – Atmospheric Gas Burners – Air Aspiration Gas Burners – Burners Classification according to Flame Structures – Factors Affecting Burners & Combustion. **(8hrs)**

Course outcome:

1. On successful completion of this course, the student will understand combustion in engines, various types of fuels and combustion equipment.

Reference Books:

1. B.I. Bhatt and S.M. Vora, Stoichiometry, Tata McGraw Hill.
2. Blokh A.G., Heat Transfer in Steam Boiler Furnace, Hemisphere Publishing Corpn.
3. Civil Davies, Calculations in Furnace Technology, Pergamon Press, Oxford.
4. Holman J.P., Thermodynamics, McGraw-Hill Inc.
5. Samir Sarkar, Fuels & Combustion, 2nd Edition, Orient Longman.
6. Sharma SP., Mohan Chander, Fuels & Combustion, Tata Mcgraw Hill.
7. Yunus A. Cengel and Michael A. Boles, Thermodynamics, McGraw-Hill Inc.

MME3E39/MME3E40

RENEWABLE ENERGY & ENERGY MANAGEMENT

L	T	P/D	Cr.
3		-	3

Course Learning Objectives

1. To understand the basic concepts of Renewable Energy and apply them to address the practical applications.
2. To understand the basic concepts and applications of sources of renewable energy.
3. To impart the knowledge to the students about various contemporary methods to utilize different sources of renewable energy.
4. To impart the knowledge to the students about energy conservation management.

Course Contents

1. **Solar Energy**
   The sun as a perennial source of energy, direct solar energy utilization; solar thermal applications – water heating systems, space heating and cooling of buildings, solar cooking, solar ponds, solar green houses, solar thermal electric systems; solar photovoltaic power generation; solar production of hydrogen. **(6 hrs)**

2. **Energy from Oceans**
   Wave energy generation – energy from waves; wave energy conversion devices; advantages and disadvantages of wave energy; Tidal energy – basic principles; tidal power generation systems; estimation of energy and power; advantages and limitations of tidal power generation; ocean thermal energy conversion (OTEC); methods of ocean thermal electric power generation. **(6 hrs)**

3. **Wind energy**
   Basic principles of wind energy conversion; design of windmills; wind data and energy estimation; site selection considerations. **(4 hrs)**

4. **Hydro power**
   Classification of small hydro power (SHP) stations; description of basic civil works design considerations; turbines and generators for SHP; advantages and limitations. **(5 hrs)**

5. **Biomass and bio-fuels**
   Energy plantation; biogas generation; types of biogas plants; applications of biogas; energy from wastes. **(5 hrs)**

6. **Geothermal energy**
   Origin and nature of geothermal energy; classification of geothermal resources; schematic of geothermal power plants; operational and environments problems. **(5 hrs)**

7. **Energy conservation management**
   The relevance of energy management profession; general principles of energy management and energy management planning; application of Pareto's model for energy management; obtaining management support; establishing energy data base; conducting energy audit; identifying, evaluating and implementing feasible energy conservation opportunities; energy audit report; monitoring, evaluating and following up energy saving measures/projects. **(10hrs)**

Course Outcomes:

1. The students will be able to understand importance of Renewable Energy Sources.
2. The students will be able to utilize different sources of renewable energy in engineering applications.
3. The students will be able to work on different methods to utilize renewable sources.
4. The students will be able to understand and make energy audit report.

Reference Books:

1. 'Renewable Energy Resources'. John W Twidell and Anthony D Weir.
2. 'Renewable energy – power for sustainable future'. Edited by Godfrey Boyle. Oxford University Press in association with the Open University.
3. 'Renewable energy sources and their environmental impact'. S.A.Abbasi and NaseemaAbbasi. Prentice-Hall of India.
4. 'Non-conventional sources of energy'. G.D. Rai. Khanna Publishers.
5. 'Solar energy utilization'. G.D. Rai. Khanna Publishers.
6. 'Renewable and novel energy sources'. S.L.Sah. M.I. Publications.
7. 'Energy Technology'. S.Rao and B.B. Parulekar. Khanna Publishers.

MME3E41/MME3E42
TURBULENCE AND ITS MODELING

L	T	P/D	Cr.
3	-	-	3

Course Learning Objectives

1. To give the students a sound background in the physics and mathematics of turbulence
2. To introduce the concepts and tools needed in using and developing turbulence models and turbulence simulation methods.
3. To introduce the concepts of turbulence simulation techniques such as Reynolds-averaged Navier Stokes (RANS) model, large eddy simulation (LES) and hybrid RANS-LES models.

Course Contents

1. **Introduction**
Background on turbulence, nature of turbulent flows, Introduction to tensors. **(4 hrs)**

2. **The governing equations of fluid motion**
continuum fluid properties, Eulerian and Lagrangian fields, the continuity equation, the momentum equation, the role of pressure, conserved passive scalars, the vorticity equation, the rate of strain and rotation, transformation properties. **(6 hrs)**

3. **The scales of turbulent motion**
Kolmogorov hypothesis and energy cascade, correlation functions and intensity, probability density functions and averaging**.** **(6 hrs)**

4. **Mean-flow equations**
Reynolds-averaged Navier Stokes equations, Closure problem, Reynolds stresses, the mean scalar equation, gradient-diffusion and turbulent-viscosity hypothesis **(4 hrs)**

5. **Canonical turbulent flows**
Free shear flows: The round jet, homogeneous shear flows, grid turbulence. Wall flows: channel flow, boundary layers, turbulent structures **(4 hrs)**

6. **Reynolds-averaged Navier Stoke (RANS) Models**
Algebraic models, turbulent kinetic energy models, one equation model, two equation model, Reynold stress models, Reynold stress models vs. eddy-viscosity models, non-linear eddy-viscosity models, limitations of eddy-viscosity closures **(8 hrs)**

7. **Large-eddy simulation**
Filtering, Filtered conservation equations, sub-grid scale (SGS) modelling, Smagorinsky model, dynamic models, one- equation model. **(4 hrs)**

8. **New frontiers**
   Direct numerical simulation: numerical issues, domain size, resolution requirements. unsteady RANS models, hybrid RANS-LES models, partially-averaged Navier Stokes (PANS) models. **(4 hrs)**

Course outcomes:

1. Cultivate an appreciation for the importance of turbulence over a range of disciplines.
2. Cultivate the skill and insight needed to affect a successful unsteady turbulent-flow simulation appropriate for the geometry and boundary conditions under consideration.
3. Simplify and model full governing equations pertaining to turbulent flows
4. Critically appraise results from commercial computational fluid dynamics packages

Reference Books:

1. H. Tennekes and J.L. Lumley, A First Course in Turbulence, The MIT Press, Cambridge, Massachusetts, and London, England.
2. S.B. Pope, Turbulent Flows, Cambridge University Press, UK.
3. D.C. Wilcox, Turbulence modeling for CFD, DCW industries, La Canada, CA
4. P. K. Kundu, I. M. Cohen and D. R. Dowling, Fluid Mechanics, Academic Press, Elsevier, UK.

MME2C07
EXPERIMENTAL DESIGNS

L	T	P/D	Cr
3	0	-	3

Course Learning Objectives

1) To introduce the concept of experimentation
2) To expose students to different types of experimental designs like Latin Square Design and Graeco Latin Square Design
3) To understand the nature of full factorial designs with two levels
4) To understand the concept of fractional factorial designs with two levels
5) To understand Taguchi's DOE Approach and Response Surface Methodology

Course Contents

1. Introduction

Introduction, Objectives for experimental designs, Basic design concepts, Steps for the design of experiments, Types of experimental designs, Analysis of Means, Experimental designs and six sigma **(6 hrs)**

2. Completely Randomized Design

Model for a completely randomized design with a single factor, ANOM for a completely randomized design, Randomized Block Design, Incomplete Block Designs, Latin Square Design, Graeco-Latin Square Design **(8 hrs)**

3. Full Factorial Designs With Two Levels

Nature of Factorial Designs, Deleterious Effects of Interactions, Effect Estimates, The 2^3 Design, Built –In- Replication, Role of expected mean squares in experimental design **(6 hrs)**

4. Fractional Factorial Designs with two Levels

2^{k-1} Designs, Effect Estimates and Regression Coefficients, 2^{k-2} Designs, Design Efficiency, John's ¾ Designs **(6 hrs)**

5. Robust Designs

DOE and Taguchi Approach, Experimental Design using orthogonal arrays; Experimental Designs With Two-Level Factors Only; Experimental Designs With Three and Four Level Factors; ANOVA; Analysis using Signal- to Noise Ratios; Some case studies; QT4 Software; Response Surface Methodology; Response surface experimentation; Process improvement with Steepest Ascent; Analysis of Second-order response Surfaces; Central Composite Design; Box-Behnken Design; Analyzing the fitted surface; Design-Expert Software **(10 hrs)**

Course Outcomes:

1) Become conversant with different types of experimental designs
2) Select a suitable design for undertaking experimental investigation in any field of engineering
3) Learn effectively Taguchi's parameter design approach for solving all kinds of Industrial problems
4) Learn effectively Response Surface Methodology for modeling and optimizing responses

Reference Books:

1) Modern Experimental Design by Thomas P Ryan. John Wiley
2) Response Surface Methodology by Myers R H and Montgomery Dc. John Wiley
3) Design of Experiments using the Taguchi Approach by Ranjit K Roy. John Wiley
4) Design and analysis of Experiment by Montgomery D.C. Wiley India
5) Taguchi Methods: A Hands-on Approach by Glen Stuart Peace Addison-Wesley

MME3E43/MME3E44
GAS DYNAMICS

L	T	P/D	Cr.
3	**-**	**-**	**3.0**

.**Course Learning Objectives**

1. To learn conservation laws, propagation of disturbances, isentropic flow, compressible flow with area changes, Fanno and Rayleigh flow.
2. To prove students with a firm understanding of shock waves and Prandtl-Meyer expansion waves
3. To learn about the equations governing supersonic and subsonic flow along with their solution

Course Contents

1. **Introduction**
General differential equations of continuity; momentum and energy applied to compressible inviscid fluids; sonic velocity; Mach number and propagation of disturbance in a fluid flow; isentropic flow and stagnation properties; flow through nozzles and diffusers; Fanno, Rayleigh and isothermal flows through pipes. **(12 hrs)**

2. **Shock Waves**
Normal and oblique shocks; supersonic expansion by turning; Prandtle-Mayer function, Reflection, refraction and intersection of oblique sock waves; detached shocks. **(10 hrs)**

3. **Supersonic and Subsonic Flow**
Linearisation and small pertuburation theory; general solutions of supersonic flow; elements of supersonic thin airfoil theory; method of characteristics for solving non-linear equations; Hodograph method for mixed subsonic and supersonic flow. Wind tunnel and its instrumentation. **(18 hrs)**

Course outcomes:

1. Apply the fundamental flow equations (conservation of mass and momentum and energy) and basic solution techniques in solving compressible one-dimensional flows
2. Determine the strength of oblique shock waves on wedge shaped bodies and concave corners. Determine the change in flow conditions through a Prandtl-Meyer expansion wave.
3. Provide the solution of problems involving supersonic flow and subsonic flow.

Reference Books:

1. Gas Dynamics by E. Rathakrishnan
2. Fundamentals of Gas Dynamics by S.M. Yahya
3. Gas Dynamics by Cambell and Jennings
4. Gas Dynamics by Becker
5. Fundamentals of Gas Dynamics by R.D.Zucker
6. Fluid Mechanics by A.K. Mohanty

MME1C01
APPLIED NUMERICAL METHODS

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1) To introduce the fundamentals of numerical methods used for the solution of engineering problems.
2) To impart the knowledge to the students about solution of simultaneous linear algebraic equations and non-linear simultaneous linear algebraic equations of engineering systems.
3) To review and implement the basic principles of curve fitting, interpolation, spline interpolation and approximation of functions.
4) To use numerical methods for differentiation and integration with engineering applications.
5) To understand the processes of numerical solution of ordinary differential equations and partial differential equations of engineering systems.

Course Contents

1. Approximations and Errors in Computations
Introduction, Numbers and their Accuracy, Errors and their Computation, Error in Series Approximation. **(3 hrs)**

2. Numerical Solution of Ordinary Differential Equations
Introduction, Solution by Taylor's Picard's Method, Euler's Method, Runge-Kutta Methods, Predictor-Corrector Methods, the Cubic Spline Method, Simultaneous and Higher Order Equations, Boundary Value Problems: Finite-Difference Method, The Shooting Method, The Cubic Spline Method. **(9 hrs)**

3. Numerical Solution of Partial Differential Equations
Introduction, Finite-Difference Approximations, Laplace's Equation: Jacobi's Method, Gauss-Seidel Method, SOR Method, ADI Method, Parabolic Equations, Iterative Methods, Hyperbolic Equations. **(9 hrs)**

4. Numerical Differentiation and Integration
Introduction, Numerical Differentiation, Numerical Integration, Euler-Maclaurin Formula, Adaptive Quadrature Methods, Gaussian Integration, Singular Integrals, Fouriers Integrals, Numerical Double Integration. **(6 hrs)**

5. Least- square Curve Fitting and Function Approximation
Introduction, Least-square Curve Fitting, Spline Interpolation, Cubic Splines, Chebyshev Minimax Approximation, Chebyshev Polynomials. **(5 hrs)**

6. Numerical Solution of Nonlinear Systems
Introduction, Picard Iteration, Newton's Method, Perturbed Iterative Scheme. **(2 hrs)**

7. System of Linear Algebraic Equations

Introduction, Methods for Large Linear Systems, Direct Methods, LU- Decomposition Methods, Iterative Methods, III-conditioned Systems. **(6 hrs)**

Course Outcomes:

1) Students will be able to understand the nature and operations of Numerical Analysis, demonstrate familiarity with theories and concepts used in Numerical Analysis.
2) Students will be able to identify the steps required to carry out derivation of the Numerical Methods, studying their convergence rate and performance, applicability of the methods on different test examples.
3) Students will be able to solve simultaneous linear algebraic equations, non-linear simultaneous linear algebraic equations and select appropriate numerical methods to apply to various types of problems in engineering and science.
4) Students will be able to use standard interpolation methods to estimate intermediate values from a set of discrete values and determine an interpolating function for a set of data points.
5) Students will be able to conduct numerical integration and differentiation.
6) Students will be able to solve ordinary differential equations with initial and boundary values and partial differential equations.

Reference Books:

1. Niyogi, Pradip, “Numerical Analysis and Algorithms”, Tata McGraw –Hill
2. Balagurusamy,E., “Numerical Methods”, Tata McGraw –Hill
3. Sastry, S.S., “Introduction Methods of Numerical Analysis”, PHI
4. Chapra, S.C. and Canale, R.P., “Numerical Methods for Engineers”, Tata McGraw –Hill
Gerald, F. Curtis, “Applied Numerical Analysis”, Peason Education

MME3E45/MME3E46
SOLAR ENERGY

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1. To understand the basic concepts of Renewable Energy, specifically solar energy and apply them to address the practical applications.
2. To understand the basic concepts and applications of solar energy.
3. To impart the knowledge to the students about various contemporary methods to utilize solar energy.
4. To impart the knowledge to the students about solar thermal power generation.

Course Contents

1. **Solar Radiation**
   Characteristics, Earth-sun relations, Estimation on horizontal and tilted surfaces, Radiation characteristics of opaque and transparent material. **(5 hrs)**

2. **Flat Plate Collectors**
   Description, theory, Heat capacity effects, Time constant, Measurement of thermal performance, Air heaters. **(6 hrs)**

3. **Evacuated Tubular Collectors**
   One axis, Two axis, Solar tracking, Cylindrical, Spherical and Parabolic and Paraboloid concentrators. Composite collectors, Central receiver collectors. **(6 hrs)**

4. **Heat Storage**
   Sensible and latent heat storage, Chemical energy system, performance calculations. **(5 hrs)**

5. **Flow Systems**
   Natural and forced flow systems, Water heating systems for domestic, industrial and space heating requirements, Solar distillation. **(5 hrs)**

6. **Solar Heating and Cooling**
   Direct, indirect and isolated heating concepts, Cooling concepts, Load calculation methods, Performance evaluation methods. **(4 hrs)**

7. **Solar Thermal Power Generation**
   Introduction, Paraboloidal concentrating systems, Cylindrical concentrating systems, Central receiver system. **(5 hrs)**

8. **Solar Refrigeration and Air Conditioning Systems**
   Introduction, Solar refrigeration and air conditioning systems, Solar desiccant cooling.
   (4 hrs)

Course Outcomes:

1. The students will be able to understand importance of Solar Energy amongst Renewable Energy Sources.
2. The students will be able to utilize different sources of renewable energy in engineering applications.
3. The students will be able to work on different contemporary methods to utilize solar energy, especially solar thermal power generation.

Reference Books:

1. Solar Thermal Engineering Process by Duffie and Beckman.
2. Advanced Solar Energy Technology by H.P. Garg.
3. Solar Energy by S.P. Sukhatme.
4. Solar Energy by J.S. Hsieh.
5. Solar Thermal Engineering by P.J. Lunde.

MME3E47/MME3E48
GAS TURBINE AND JET PROPULSION

L	T	P/D	Cr.
3	0	-	3

Course Learning Objectives

1. Basic knowledge of physical principles of Aerodynamics
2. To create awareness on various gas turbine technology.
3. To make understand on jet propulsion like ramjet and its technology.
4. General understanding of how the design of a hypersonic influences performance.

Course Contents

1. **Introduction**
   Fundamentals of Aerodynamics quantities & equations, Bernoullli's principle, Compressibility, Thermodynamics laws & Process, isentropic flows, speed of sound, Shock Waves Normal & Oblique shock Waves. **(10hrs)**

2. **Gas Turbine**
   Principle of Gas Turbines &Components of the Gas Turbine Engine, air breathing engines like Turbojet, Turboprop, Turbofan, Turbojet and Ramjet & Scramjet Engine working, Compressors, Turbines, Nozzles and Diffusers, combustor & its thermal coating,. Efficiencies of air breathing, Cycle analysis of air breathing systems, Calculations for Thrust and Fuel Consumption, Thermodynamic Analysis of the Engine and Numerical. **(10 hrs)**

3. **Ramjets**
   Thermodynamics cycle, Engines Component analysis, Supersonic Intake, full size supersonic combustor, injection and flame holding strategies, performance Thrust Calculations, Specific thrust, fuel consumption, efficiency, design, energy equations and gas laws fundamental issues in supersonic combustion, issues in developing a supersonic combustor Turbo ramjets and Numerical. **(10 hrs)**

4. **Hypersonic**
   Introduction, Mach number, Need, Scramjets propulsion fuels, Combustors, HyperMat Materials, Zirconium boride, ultra-high temperature ceramics, c-sic composite Hypersonic vehicle shapes, Flow with heat addition, Stoichiometry, hypersonic facilities, Design of a supersonic wind tunnel, control volume analysis, overall engine analysis, Future challenges and Numerical. **(10 hrs)**

Course Outcomes:

By the end of this education program, the students will be able to:

1. Understand the aerodynamics laws and its concepts.
2. Understanding the components of gas turbine.
3. Analysis of Ramjets engine and its operation.
4. Understand how scramjet propulsion fits within context of aerospace propulsion and modelling the performance of a 2D simple scramjet engine.

Reference Books:

1. Fundamentals of Gas Dynamics by V. Babu, ANE Student Edition.
2. Fundamentals of Propulsion by V. Babu ANE Student Edition.
3. Mechanics and Thermodynamics of Propulsion-Philip Hill and Carl Peterson, Addison Wesley.
4. Elements of Gas Turbine Propulsion-J D Mattingly, McGraw-Hill.
5. Introduction to Aeronautical Engineering online course edx by Tu Delft university. (https://courses.edx.org/courses/course-v1:DelftX+AE1110x+2T2018/course/)
6. Gas Dynamics and Propulsion - Video course by Prof. V. Babu Department of Mechanical Engineering IIT Madras (https://nptel.ac.in/courses/112106166/).
7. Hypersonics – from Shock Waves to Scramjets online course Edx by University of Queensland .(https://courses.edx.org/courses/coursev1:UQx+Hypers301x+1T2018/course/)
8. Jet Aircraft Propulsion (Video) by Prof. Bhaskar RoyIIT Bombay (https://nptel.ac.in/courses/101101002/37).
9. Aerospace Propulsion by Dr. P.A. RamakrishnaIIT Madras (https://nptel.ac.in/courses/101106033/4).

MME1C07
FINITE ELEMENT METHODS

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1) To understand the basic concepts of finite element method, discretization of the solution domain with one, two and three dimension elements.
2) To understand the weak and strong form of governing equations.
3) To understand the concept weighted residual error over the solution domain.
4) To understand the computer implementation of fem for various engineering problems.

Course Contents

1. Introduction to Finite Element Method
Basic Concept, Historical background, Engineering applications, general description, Comparison with other methods. **(4hrs)**

2. Integral Formulations And Variational Methods
Need for weighted-integral forms, relevant mathematical concepts and formulae, weak formulation of boundary value problems, variational methods, Rayleigh-Ritz method, and weighted residual approach. **(10 hrs)**

3. Finite Element Techniques
Model boundary value problem, finite element discretization, element shapes, sizes and node locations, interpolation functions, derivation of element equations, connectivity, boundary conditions, FEM solution, post-processing, compatibility and completeness requirements, convergence criteria, higher order and isoparametric elements, natural coordinates, Langrange and Hermite polynomials. **(12 hrs)**

4. Applications To Solid and Structural Mechanics Problems
External and internal equilibrium equations, one-dimensional stress-strain relations, plane stress and strain problems, axis-symmetric and three dimensional stress-strain problems, strain displacement relations, boundary conditions, compatibility equations, Analysis of trusses, frames and solids of revolution, computer programs. **(10 hrs)**

5. Applications To Heat Transfer Problems
Variational approach, Galerkin approach, one-dimensional and two-dimensional steady-state problems for conduction, convection and radiation, transient problems. **(5 hrs)**

6. Applications To Fluid Mechanics Problems
Inviscid incompressible flow, potential function and stream function formulation, incompressible viscous flow, stream function, velocity-pressure and stream function-vorticity formulation, Solution of incompressible and compressible fluid film lubrication problems. **(6 hrs)**

7. Additional Applications

Steady-state and transient field problems. **(10 hrs)**

Course outcomes:

1) Understand the basic concepts of finite element method as applied to solve problems of heat, fluid flow and deformation of solids.
2) Understand the difference between weak and strong form of solutions.
3) Understand the concept of residual error to obtain the solution subjected to various boundary conditions.
4) Understand the basic concepts for programing of fem as applied to various problems arising engineering.

Reference Books:

1. The Finite Element Method by Zienkiewicz, Tata McGraw Hill
2. The Finite Element Method for Engineers by Huebner, John Wiley
3. An Introduction to the Finite Element Method by J.N. Reddy, McGraw Hill
4. The Finite Element Method in Engineering by S.S. Rao, Pergamon Press

MME1E33/MME1E34
MEASUREMENT AND CONTROL

L	T	P/D	Cr.
3	-	-	3.0

Course Learning Objectives

1) To impart the knowledge to the students about significance, applications and types of measurement, identification of functional elements of a measuring system.
2) To study the instrument characteristics, time and frequency response of measuring systems, classification, sources and statistical analysis of errors.
3) To make students understand the construction, working principle and application of various types of transducers.
4) To learn types of control system, represent system by transfer function, block diagrams, signal flow graphs and Mason's formula.
5) To understand the working of different types of controllers, transient and steady state response of control systems.

Course Contents
Part A – Measurement

1. Measurements and Measurement Systems:
Introduction, significance of measurement, methods of measurement, primary secondary and tertiary measurements, mechanical electrical and electronics instruments, applications of measurement system, elements of a generalized measurement system and its functional elements, classifications of standards, primary, secondary and working standards. **(3 hrs)**

2. Instrumentation Characteristics:
Static and dynamic characteristics, first and second order systems response, classification & sources of error, loading facts, mechanical, electrical. **(5 hrs)**

3. Analysis of Experimental Data:
Errors and uncertainties in experiments, role of statistics and variance types of data, presentation of the observations, criteria for rejecting data, specifying result of experiments, confidence level, uncertainty analysis, overall uncertainty. graphical analysis and curve fitting, theory of least squares, application in calibration, goodness of fit, significant figures and rounding off. **(6 hrs)**

4. Transducers:
General criteria for selection, strain gauge, rosettes; types, applications. Variable inductance transducers, capacitive, piezo-electric transducers. Advantages and limitations of digital transducers over analog transducers, digital encoding transducers, classification of encoders, construction of encoders, shaft encoder, optical encoder. **(8 hrs)**

Part B - Control

5. Control systems:
Introduction, types of control systems, performance analysis, mathematical modeling, block diagram representation, representation of systems or processes, comparison elements, transfer function, representation of temperature control systems, signal flow graphs. **(6 hrs)**

6. Types of controllers:
Introduction, types of control action, hydraulic controllers, electronic controllers, controllers. **(6 hrs)**

7. Transient and steady state response:
Time domain representation, laplace transform representation, system with proportional control, proportional cum derivative control, proportional cum integral control, error constants. **(6 hrs)**

Course Outcomes:

1) Identify functional elements in the measuring system.
2) Understand the various instrument characteristics and error measurement.
3) Explain working principles of sensors and transducers.
4) Formulate mathematical model for physical systems and transfer function representation of processes & control elements.
5) Handle any kind of process by framing it in block diagram and different process variables and different types of controller like electronic, pneumatic and hydraulic.

Reference Books:

1. A course in Mechanical Measurement & Instrumentation by A.K. Sawhney, Dhanpat Rai & Sons.
2. Mechanical Measurement by Beckwith & Buck
3. Instrumentation for Measurement in Engineering by S. Gupta
4. Theory and application of Automatic Controls by B.C. Nakra.

MME2E51/MME2E52
STRATEGIC ENTREPRENEURSHIP

L	T	P/D	Cr.
3	0	-	3

Course Learning Objectives

1) To make students aware on significance and various facets of entrepreneurship.
2) To create awareness on role of SSIs and EDPs in economic development of the country.
3) To make students understand basics of marketing and financial management.
4) To create awareness on basics of business incubation and create awareness on incubation facilities in the country.

COURSE CONTENTS

1. **Entrepreneurs and Entrepreneurship**
   Concept, Role and Significance of Entrepreneurship; Entrepreneurial Myths; Entrepreneurs - Types and Characteristics; Need for Entrepreneurs; Special Entrepreneurial Aspects - Social Entrepreneurship, Women Entrepreneurship, International Entrepreneurship, Rural Entrepreneurship, Corporate Entrepreneurship, Technical Entrepreneurship; Entrepreneurship. **(8 hrs)**

2. **Small Scale Industries And Entrepreneurship Development**
   Concept, Types and Role of Small Scale Industries; Problems of Small Scale Industries; Industrial Sickness and Remedies; Entrepreneurship Development; Entrepreneurship Development Programmes (EDPs) - Objectives and Contents; Government and Non-Government Agencies involved in Entrepreneurship Development. **(10 hrs)**

3. **Marketing Management and Financial Management**
   Market Analysis; Industrial Potential Survey; Demand Forecasting; Marketing Aspects for Entrepreneurs - Pricing, Branding, Packaging, After Sales Service, Advertising, Sales Promotion etc.; Sources of Finance for Entrepreneurs; Factors affecting Selection of Sources of Finance; Role of Banks and Financial Institutions in Entrepreneurship Development. **(12 hrs)**

4. **Business Incubation**
   Introduction; Origin and Development of Business Incubators in India and Other Countries; Types of Business Incubator Models; Business Supports; Thrust Areas for Business Incubation in India; Role of Business Incubators for Entrepreneurs, Institutes, Government and Society; Sustainability Issues for Business Incubators in India. **(10 hrs)**

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Course Outcomes:

1) Understanding the dynamic role of entrepreneurship and small businesses
2) Role of SSIs in economic development and government support for entrepreneurship development.
3) Market research and financial planning for small business.
4) Strategic business supports being provided by Business Incubators.

Reference Books:

1. Small Business Management An Entrepreneur's Guidebook (McGraw-Hill)
2. Project Management - Strategic Design and Implementation by David Cleland (McGraw-Hill).
3. Marketing Management by Kotler (Prentice Hall of India)
4. Sustainable Strategic Management by Steed and Steed (Prentice Hall of India)
5. Engineering Economics Principles by Henry Steiner (McGraw-Hill).

MME2E53/MME2E54
TOTAL QUALITY MANAGEMENT

L	T	P/D	Cr.
3	0	-	3

Course Objectives:

To understand concept of quality management and apply this knowledge to understand the working of corporate world.

1. **Concept of Quality**
   Products and services, quality of products and services, definition of quality, dimensions of quality and their measure **(4 hrs)**

2. **Quality Management Practices**
   Various approaches to control and management of quality,: inspection oriented, statistical process control oriented, assurance oriented and TQM oriented approaches. **(8 hrs)**

3. **Cost of Quality**
   Productivity and quality relationship, concept of cost of quality, cost of conformance, prevention, appraisal and failure cost, internal and external failures, quality cost estimation in engineering and service industries. **(4 hrs)**

4. **Organizing for Quality**
   Company wide organization for quality management, prevention, control and improvement, continuous improvement process. **(4 hrs)**

5. **Human Aspects in Management of Quality**
   Commitment, motivation, and involvement for quality, top management, management and worker participation, zero defects, quality circle, small group activity. **(4 hrs)**

6. **Quality Systems**
   Introduction, ISO 9000 Series of standards, Other quality systems, ISO 14000 series standards, concepts of ISO 14001, requirements of ISO 14001, EMS benefits. **(6 hrs)**

7. **Some Case Studies TQM**
   Minimum four Case Studies to be explained. **(4 hrs)**

Course Outcomes:

1) Develop an understanding of quality management philosophies and framework.
2) Discuss the need of customer expectations, employee involvement and supplier partnership.
3) Analyze the TQM tools and techniques to improve the product and process quality.
4) Apply modern tools to improve quality of the product.
5) Describe ISO 9001, Environmental Management Standards and ISO 14001 Certification process.

Reference Books:

1. Besterfield, D.H, Michna, C.B, Besterfield, G. H and Sacre, M.B, “Total Quality Management” Pearson Education Asia.
2. Mukherjee, P. N., “Total Quality Management” Prentice Hall of India.
3. Rajaram, S., “Total Quality Management” Biztantra.
4. Ramasamy, S. “Total Quality Management” Mc Graw Hill Education.

MME2C03
OPERATIONS MANAGEMENT

L	T	P/D	Cr.
3	0	-	3

Course Learning Objectives

1) To understand concept of operation management
2) Apply this knowledge to understand the working of corporate world.

Course Contents

1. Basics of Production Management:

Types of production, life cycle approach to production system, Productivity and Productivity measures, types of productivity index, productivity improvement, MRP.
(7 hrs)

2. JIT:

JIT, requirements and problems in implementing JIT, Benefits of JIT, Introduction to JIT purchasing and JIT quality management, Lean manufacturing, Agile manufacturing
(6 hrs)

3. Supply chain management:

Supply chain management, its importance, objectives and applications. Tenabled supply chain supply chain drives concepts of stockless, VRM and CRM. **(6 hrs)**

4. Business Process Reengineering:

Re-engineering-characteristics, organizational support, responsibility of re-engineering, re-engineering opportunities, choosing the process to re-engineer, success factors and advantages. **(6 hrs)**

5. ERP:

Evolution of ERP, Characteristics, approaches, methodology for implementation, Success factors. **(6 hrs)**

6. Waste Management:

Introduction, classification of waste, systematic approach to waste reduction, waste disposal. **(5 hrs)**

7. Some Case Studies in OM

Minimum four Case Studies to be explained. **(4 hrs)**

Course Outcomes:

1) Develop an understanding of Production systems and their characteristics.
2) Understand and analyze operations and supply chain management issues in a firm.
3) Evaluate MRP and JIT systems against traditional inventory control systems.
4) Understand basics of ERP and methodology for implementation of ERP.
5) Discuss the approach to waste reduction.

Reference Books:

1) Mohanty, R. P. and Deshmukh, S. G. "Advanced Operations Management" Pearson Education.
2) Krishnaswamy, K. N.,"Case in Production/ Operations management" Prentice Hall of India.
3) Muhlemann, A., Oakland, J., Lockyer, K., Sudhir, B. and Katyayani, J., "Production and Operations Management", Pearson Education South Asia.
4) Adam, E.E and Ebert, J.R.J," Production and Operations Management" Prentice Hall of India.

MME2E45/MME2E46
MODELING AND SIMULATION

Course Learning Objectives:

1. To understand the basics of modeling and simulation
2. To understand the various statistical models used in modeling and simulation
3. To understand stochastic simulation and its applications to queuing models and inventory models
4. To understand the modeling and simulation of manufacturing and material handling systems
5. To carry out modeling of simulation of manufacturing and material handling systems

1. Introduction to Modeling: Concept of system, continuous and discrete systems; Types of models and simulation; Discrete event simulation: Time advance mechanisms, components and organization of simulation model, steps in simulation study, advantages and disadvantages of simulation (**6hrs**)

2. Statistical Models in Simulation: Discrete, continuous, Poisson and empirical distributions, output data analysis for a single system, comparing alternative system configurations, statistical procedures for comparing real world observations with simulation output data, generation of arriving processes, verification and validation of simulation models. **(12hrs)**

3. Stochastic Simulation: Random number generation: Properties of random numbers, techniques of generating random numbers, generation of random variates, Monte Carlo simulation and its applications in queuing models and inventory models. **(10hrs)**

4. Simulation of Manufacturing and Material Handling Systems:
Models of manufacturing systems, models of material handling systems, goals and performance measures; Issues in manufacturing and material handling simulation: Modeling downtime failures, trace driven models. **(8hrs)**

5. Case Studies on Simulation Packages: Simulation of queuing system (bank/job shop), simulation of manufacturing and material handling systems. (**6hrs)**

Course Outcomes:

1. Understand the basics of modeling and simulation
2. Understand the various statistical models used in modeling and simulation
3. Understand stochastic simulation and its applications to queuing models and inventory models
4. Understand the modeling and simulation of manufacturing and material handling systems
5. Carry out modeling of simulation of manufacturing and material handling systems

Reference Books:

1. Banks, J., Nelson, B.L., Carson, J. S., and Nicol, D., “Discrete EventSystem Simulation”, Pearson Education.
2. Law, A.M., and Kelton, W.D., “Simulation Modeling and Analysis”,McGraw-Hill.
3. Schwarzenbach, J., and Gill, K.F., “System Modeling and Control”,Butterworth-Heinemann.
4. Carrie, A., “Simulation of Manufacturing Systems”, John Wiley &Sons.
5. Viswanadham, N., and Narahari, Y., “Performance Modeling ofAutomated Manufacturing System”, Prentice-Hall of India..
6. Theory of Modeling & Simulation, B.P. Zeigler, Taqgon Kim and Herbert Praehofer, Academic Press.
7. Handbook of Simulation: Principles, Methodology, Advances, Applications & Practice, Jerry Banks.
8. Discrete Systems Simulation, Khoshnevis.
9. Simulation Made Easy, Charles Harrell and KerimTumay, Engineering and Management Press.
10. Simulation with Arena, W. David Kelton, Randall P. Sadowski, and Deborah A. Sadowski, McGraw-Hill.
11. Pro Model Software - Student Version, Published by the Day Grp.

MME3E51/MME3E52
DESIGN OF HEAT EXCHANGERS

L	T	P/D	Cr.
3	_	0	3

Course Learning Objectives

1) To understand the different configurations of heat exchangers.
2) To solve different rating and sizing problems of heat exchangers.
3) To be able to design heat exchangers that are used in numerous heat transfer applications.
4) To develop ways of heat transfer enhancement in heat exchangers.

1. Classification and basic design methodologies for heat exchanger
Classification of heat exchanger, selection of heat exchanger, overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multi-pass and cross flow heat exchanger, effectiveness-NTU method for heat exchanger analysis, fouling, cleanliness factor, techniques to control fouling, additives, rating and sizing problems, heat exchanger design methodology. **(8hrs)**

2. Design of double pipe heat exchangers
Thermal and hydraulic design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, total pressure drop, design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangements. **(7hrs)**

3. Shell and tube heat exchangers
tube layouts, baffle spacing, classification of shell and tube exchangers, design calculation of shell and tube heat exchangers, shell-side film coefficients, shell-side equivalent diameter, true temperature difference in a 1-2 heat exchanger, influence of approach temperature on correction factor, shell and tube sides pressure drop; performance analysis of 1-2 heat exchangers, design calculation of shell and tube heat exchangers; flow arrangements for increased heat recovery. **(9 hrs)**

4. **Direct contact type heat exchangers**
   Classification of cooling towers, wet-bulb and dew point temperatures, Lewis number, cooling-tower internals, heat balance, heat transfer by simultaneous diffusion and convection; Design and analysis of cooling towers, determination of the number of diffusion units, performance evaluation of cooling towers, influence of process conditions and operating variables on their design. **(7hrs)**

5. **Heat Transfer Enhancement and Performance Evaluation**
   Heat transfer enhancement, heat transfer and pressure drop, plate fin heat exchanger, tube fin heat exchanger, Performance evaluation of Heat Transfer Enhancement technique. **(6 hrs)**

Course Outcomes:

1. The students will be able to design heat exchangers employing all the three modes of heat transfer.
2. The students will be able to identify different types of heat exchangers and use them for appropriate applications.

Reference Books:

1. Incropera, Dewitt, Bergmann and Levine, "Fundamentals of Heat and Mass Transfer", Wiley India.
2. D.S. Kumar, "Heat and Mass Transfer", Katson Publication.
3. Kern, D. Q., Process Heat Transfer, Tata McGraw-Hill.
4. Fraas, A. P., Heat Exchanger Design, Second Edition, John Wiley & Sons.
5. N.H. Afgan and Schliinder, "Heat Exchangers Design and Theory", McGraw Hill.

MME3E53/MME3E54
NON-CONVENTIONAL COOLING METHODS

L	T	P/D	Cr.
3		0	3

Course Learning Objectives

1. To understand the different technologies of producing cooling effect.
2. To design Vapor absorption system of different cooling capacities.
3. To design ejector cooling system.
4. To work on desiccant cooling techniques

1. **Introduction:** Thermo-mechanical refrigeration: Rankine cycle, Sterling cycle; Solar electric refrigeration, Thermo-electric system, Vortex tube refrigeration, Pulse tube refrigeration, Magnetic refrigeration (6 hrs)

2. **Vapor Absorption System:** Ideal and non-ideal solutions, Raoult's law, Enthalpy change of the mixture, temperature- composition diagram, Electrolux refrigerator

   Aqua Ammonia Solution: Duhring plot, vapor concentration and enthalpy, enthalpy composition diagram, Description on h-x diagram: Adiabatic mixing, mixing of two streams with heat rejection, heat transferred followed by separation into liquid and vapors, throttling; Drawback of water vapors in evaporator and condenser, Ammonia enrichment process, Description on h-x diagram: dephlegmator-cum rectification column, generator cum exhausting column, analysis of double rectification column; Numerical Problems

   Water Lithium Bromide Solution: Thermal analysis of the Water LiBr system, Commercially available single /double drum system, Dual/triple effect system, Numerical Problems(12 hrs)

3. **Ejector Cooling System:** Fundamentals of compressible flow, Stagnation properties, speed of sound, Mach Number, one dimensional isentropic flow through nozzles, normal shock in convergent divergent nozzle, Fanno and Rayleigh flow.

   Fluid flow in ejector, velocity pressure distribution in ejector, mode of operation, Ejector refrigeration system, Keenan theory, Monday &Bagster theory, constant pressure/area mixing model, single phase performance evaluation model: Huang model, performance characteristics, effect of ejector geometry. Introduction to ejector enhanced vapor compression system, heat pipe and ejector cooling system.(13 hrs)

4. **Desiccant Cooling System**

   Adsorption process, regeneration process, adsorption rate, regeneration rate, factor affecting adsorption and regeneration of desiccant material,Desiccant materials, classification of desiccant material, desiccant bed, desiccant wheel

   Solid Desiccant System:

   Principle of solid desiccant system, Pennington cycle, Recirculation cycle, Dunkle cycle, SENS cycle

   Liquid Desiccant System: Principle of liquid desiccant system, performance of the liquid desiccants (9 hrs)

Course Outcomes:

1. The students will be able to design vapor absorption system.
2. The students will be able to design ejector cooling system.
3. The students will know about the desiccant cooling systems and some other non-conventional cooling techniques.

Reference Books:

1. G. Rogerio Oliveira and Centro De Alegrete, Solar Powered Sorption Refrigeration and Air Conditioning, Nova Publishers.
2. J. C. MC Veigh and A. A. M. Sayigh, Solar Air Conditioning and Refrigeration, Pergamon.
3. Refrigeration and Air Conditioning - C.P. Arora, Tata McGraw-Hill
4. Basic Refrigeration and Air Conditioning- Ananthana and Rayanan, McGraw-Hill
5. Refrigeration and Air Conditioning- Arora and Domkundwar, Dhanpat Rai.

MME3E55/MME3E56
BIO ENERGY TECHNOLOGIES

L	T	P/D	Cr.
3		0	3

Course Learning Objectives

1. To make the students understand the basics of bio-gas and different feed-stocks.
2. To make the students understand the importance and applications of bio-energy.
3. To provide knowledge of bio-ethanol production.
4. To provide knowledge of bio-diesel production
5. To understand the working of bio-gas plant.

1. **Introduction to Bio-Energy**
   Introduction to bio-energy; Properties of biomass;Review of organic chemistry; Review of carbohydrate chemistry, starch, cellulose, hemicelluloses, lignin, pectin, vegetable oil and extractives; Sugar crops, starch crops, agriculture residues, herbaceous biomass, woody biomass, oilseeds, microalgae, storage and handling of biomass.

2. **Bio-Gas**
   Introduction to biological processes; Kinetics and microbiology of biological processes; Anaerobic digestion for biogas production; Factor affecting anaerobic digestion; Anaerobic digesters and biogas up-gradation & purification.

3. **Biological Process for Ethanol Production**
   History of alcohol fermentation and ethanol as fuel; Bio-ethanol production process; saccharification and hydrolysis for fermentable sugar production; fermentation process; ethanol purification and byproducts.

4. **Bio-Diesel Production**
   Introduction;Feedstock for bio-diesel production; Production of bio-diesel and unit operation process in biodiesel production.

Course Outcomes:

1. Understand different bio-mass resources and bio-energy.
2. Analyze practical problems in bio-gas generation.
3. Understand bio-mass resource potential and assessment for energy generation.
4. Get the knowledge about the energy potential of bio-ethanol and bio-diesel.

Reference Books:

1. Jay Cheng, Biomass to renewable Energy Processes, CRC Press, Taylor & Francis Group
2. K .M. Mital, *Biogas Systems: Principles and Applications by*, New Age Publishers.
3. A Chakraverthy, *Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes* by Oxford &IBH publishing Co.
4. R. S. Khoiyangbam, Navindu Gupta and Sushil Kumar, *Biogas Technology: Towards Sustainable Development*, The Energy and Resources Institute.
5. B.T. Nijaguna, *Biogas Technology*, New Age International Publishers.