

**M. Tech. Degree
PROGRAMME
In
Thermal and Fluids Engineering**

**CURRICULUM
(w.e.f. Session 2025-2026)**



**DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
KURUKSHETRA-136119**

E. D. P. Kumar
Pravini

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 be a role model in Mechanical Engineering education and research responsive to global challenges.
- 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.
- Committed to the cause of Value-Based Education in Mechanical Engineering, envisions itself as a fountain head of innovative human enterprise, with inspiration initiatives for Academic Excellence.
- To be a centre of excellence in the field of Mechanical Engineering where the best of teaching, learning and research synergize and add endeavours to be recognized globally for outstanding education and research leading to well qualified engineers, who are innovative, entrepreneurial and successful in advanced fields of mechanical engineering to cater the ever changing industrial demands.

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. Further, to provide consultancy to the neighborhood and cultivate the spirit of entrepreneurship.
- M6**- To undertake research that generates cutting-edge technologies & futuristic knowledge, focusing on the overall needs.
- M7**- To prepare professionals with emphasis on leadership, team work and ethical conduct.
- M8**- To impart quality education in the field of Mechanical Engineering by inculcating values in students which will sensitize them to serve the needs of the industry and society by aiding in its overall progress and development by keeping dynamic equilibrium with its social, ecological and economic environment.

VISION OF THE PROGRAMME

- To be a role model in Mechanical Engineering and Research responsive to global challenges.

MISSION OF THE PROGRAMME

- M1-** To impart quality Mechanical Engineering education that develops innovative professionals to undertake research/investigations/developmental works independently.
- M2-** To develop professionals with mastery in Mechanical Engineering field to generate cutting-edge technologies & futuristic knowledge, focusing on the socio-economic needs.
- M3-** To prepare professionals with emphasis on leadership, team work, adaption to changing needs and ethical conduct.

PROGRAMME: - THERMAL AND FLUIDS ENGINEERING

Programme Education Objectives (PEOs)

- PEO1:** To impart students with in-depth knowledge of contemporary science and mechanical engineering related subjects focusing on thermal and fluids engineering.
- PEO4:** To provide opportunity to the students to explore research and development in thermal and fluids engineering.
- PEO3:** To prepare the students to take-up career in different industries or to pursue higher studies and research in thermal and fluids engineering.

Programme Outcomes (POs)

PO1: Students shall be equipped with theoretical and practical skills to investigate and undertake complex projects of inter-disciplinary nature with wide impact.

PO2: Students shall be able to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Students shall imbibe social and environmental ethics, readily adapting to ever changing and transforming technical requirements and working towards sustainable development of the society

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**MASTER OF TECHNOLOGY SCHEME IN MECHANICAL ENGINEERING
(THERMAL AND FLUIDS ENGINEERING)**

SEMESTER-I

S.No.	Course Code	Course Title	Lecture	Tutorial	Practical	Credits
1	MMEC301	Advanced Fluid Engineering	4	-	-	4
2	MMEC303	Convective Heat Transfer	4	-	-	4
3	MMEC305	Refrigeration Engineering	4	-	-	4
4	MMEC307	Mathematical Methods for Engineers	4	-	-	4
5	MMEC309	Advanced Internal Combustion Engines	4	-	-	4
6	M_____	Elective-I	4	-	-	4
7	MMEL301	Advanced Thermal Engineering Laboratory	-	-	3	1
8	MMES301	Seminar			2	1
	Total		24		5	26
	Total Contact Hours		29			

SEMESTER-II

S.No.	Course Code	Course Title	Lecture	Tutorial	Practical	Credits
1	MMEC302	Computational Fluid Dynamics	4	-	-	4
2	M_____	Elective-II	4	-	-	4
3	M_____	Elective- III	4	-	-	4
4	M_____	Elective-IV	4	-	-	4
5	M_____	Elective-V	4			4
6	MMEO__	Open Elective (Non Departmental)	4	-	-	4
7	MMEL302	Computational Fluid Dynamics Lab	-	-	3	1
8	MMEP302	Project			2	1
	Total		24		5	26
	Total Contact Hours		29			

SUMMER VACATION

Course Code	Course Title	L	T	P	Credits
MMEP303	Summer Academic Activity /Preparatory work for dissertation/ Industrial Training/Training on software	-	-	-	0

SEMESTER - III

Course Code	Course Title	L	P	T	Credits
MMED301/ MMEP301/ MMEI301	Dissertation /Project/Internship Part-I				14
M_____	Online Course (Value added)	3	-	-	3 #

optional

SEMESTER - IV

Course Code	Course Title	L	P	T	Credits
MMED302/ MMEP302/ MMEI302	Dissertation /Project /Internship Part-II				14

TOTAL CREDITS: 80 + 3 (for value added course)

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LIST OF ELECTIVES

S.No.	Course Code	Course Title	Credits
1	MMEE331/MMEE332	Direct Energy Conversion	4
2	MMEE333/MMEE334	Air Conditioning	4
3	MMEE335/MMEE336	Nuclear Engineering	4
4	MMEE337/MMEE338	Fuels and Combustions	4
5	MMEE339/MMEE340	Renewable Energy & Energy Management	4
6	MMEE341/MMEE342	Turbulence and its Modeling	4
7	MMEE343/MMEE344	Gas Dynamics	4
8	MMEE345/MMEE346	Solar Energy	4
9	MMEE347/MMEE348	Gas Turbine and Jet Propulsion	4
10	MMEE349/MMEE350	Conductive and Radiative Heat Transfer	4
11	MMEE351/MMEE352	Design of heat exchangers	4
12	MMEE353/MMEE354	Non- conventional cooling methods	4
13	MMEE355/MMEE356	Bio Energy technologies	4
14	MMEE357/MMEE358	Viscous Fluid Flow	4
15	MRIC203	Operations Management	4
16	MRIC207	Designs of Experiments	4
17	MRIE245/MRIE246	Modeling and Simulation	4
18	MRIE251/MRIE252	Strategic entrepreneurship	4
19	MRIE253/MRIE254	Total Quality Management	4
20	MMEC101	Applied Numerical Methods	4
21	MMEC107	Finite Element Methods	4
22	MMEE133/MMEE134	Measurement and Control	4

LIST OF OPEN ELECTIVES FOR OTHER DEPARTMENTS

S.No.	Course Code	Course Title	Credits
1	MMEC301	Advanced Fluid Engineering	4
2	MMEC302	Computational Fluid Dynamics	4
3	MMEC303	Convective Heat Transfer	4
4	MMEC305	Refrigeration Engineering	4
5	MMEC307	Mathematical Methods for Engineers	4
6	MMEC309	Advanced Internal Combustion Engines	4
7	MME3E39/MME3E40	Renewable Energy & Energy Management	4
8	MME3E45/MME3E46	Solar Energy	4
9	MME3E49/MME3E50	Conductive and Radiative Heat Transfer	4

**MMEC301
ADVANCED FLUID ENGINEERING**

L	T	P/D	Cr.
4	-	-	4.0

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. **(9 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 **(8 hrs)**

3. Viscous flow

Exact solution; plane Poiseuille and Couette flows; Hagen-Poiseuille flow through pipes; flows with very small Reynold's numbers; Stokes flow around a sphere, Elements of hydrodynamic theory of lubrication. **(6 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. **(8 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 (7 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 Couette 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 Currie, 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

MMEC303
CONVECTIVE HEAT TRANSFER

L	T	P/D	Cr.
4	-	-	4.0

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. (7 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. (9 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. (9 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. (9 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, Prandtl 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.

MMEC305
REFRIGERATION ENGINEERING

L	T	P/D	Cr.
4	-	-	4.0

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. **(8 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. **(8 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. **(8 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 **(8 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.

MMEC307
MATHEMATICAL METHODS FOR ENGINEERS

L	T	P/D	Cr.
4		0	4

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 (11 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) (11 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; (11 hrs)

4. Partial differential equations (PDE)

1-D heat and wave equations and 2-D Laplace equation (in Cartesian coordinates): solutions using separation of variables, D'Alembert's solution for wave equation, Laplace transform technique for heat equation (7 hrs)

5. 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.

MMEC309
ADVANCED INTERNAL COMBUSTION ENGINES

L	T	P/D	Cr.
4	-	-	4.0

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.

(11 hrs)

2. Heat Transfer

Instantaneous heat transfer calculations, engine heat transfer equations, overall heat loss-radiative and convective heat transfers.

(6 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.

(9 hrs)

5. Flow Processes

Characterisation of flow in the cylinder, Swirl, Squish and turbulence calculations.

(4 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.

MMEL301
ADVANCED THERMAL ENGINEERING LABORATORY

L	T	P/D	Cr.
-	-	3	1.0

Lab Learning Objectives

- To analyse the performance characteristics of various internal combustion engines with different configurations.
- To familiarize the students with the construction and operation of Petrol and Diesel engines using motorised cut-section models.
- To analyse exhaust emissions using modular diagnostic system and understand their significance.
- To understand the methodology for determining the calorific values of solid and liquid fuels using bomb calorimeter.
- To explain the working principle and theoretical performance aspects of a two-stage reciprocating air compressor.

Lab Experiments

1. To study the construction and working of Compression Ignition Engines and Spark Ignition Engines using motorised cut-section models.
2. To study the performance of single cylinder, Compression Ignition Engine with variable compression ratio connected to eddy current dynamometer with open ECU.
3. To study the performance of 3 cylinder, 4 stroke, Spark Ignition Engine connected to eddy current dynamometer.
4. Analysis of exhaust gases from single cylinder/multi cylinder CI/SI engines by using Modular Diagnostic System.
5. To study the performance of multi cylinder, 4 stroke, Compression Ignition Engine connected to eddy current dynamometer.
6. To study the performance of multi-fuel, single cylinder, petrol engine connected to regenerative type dynamometer.
7. To study the working principle and theoretical performance of a two-stage reciprocating air compressor.
8. To study the working principle of determining the calorific value of solid and liquid fuels using a bomb calorimeter.

Lab Course outcomes:

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

- To understand the practical importance of contemporary engines equipped with open ECU.
- To understand the effects of transient operations of vehicle on emissions and types of emissions.
- To perform various tests on contemporary engines equipped with open ECU.
- To interpret engine exhaust emissions using diagnostic tools and relate them to fuel type and engine operation.
- To explain the theoretical procedure for determining the calorific value of solid and liquid fuels using a bomb calorimeter.
- To explain the working principle and performance parameters of a two-stage reciprocating air compressor.

MMEC302
COMPUTATIONAL FLUID DYNAMICS

L	T	P/D	Cr.
4	-	-	4.0

Course Learning Objectives

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

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)

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)

Discretization methods

Finite difference methods, difference equations, explicit & implicit approach, errors & analysis of stability. Basics of finite control volume method

(5 hrs)

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)

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)

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)

Case Studies

CFD Codes and Case Studies: Introduction to commercial CFD codes and their application to some simple cases. Role of CFD in sustainable development.

(4 hrs)

Course outcomes

At the end of the course student will be able to

- apply PDEs to CFD problems.
- apply discretization techniques to CFD problems.
- numerically solve heat conduction and incompressible fluid flow problems
- to understand the limitations and errors involved in solution to CFD problems.

Reference Books:

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

MMEL302

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:

Students shall be able to

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. understand the limitations and errors involved in solution to CFD problems.

**MMEE349/MMEE350
CONDUCTIVE AND RADIATIVE HEAT TRANSFER**

L	T	P/D	Cr.
4	0	-	4

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.

(20 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 radiative

(20 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)*

**MMEE333/MMEE334
AIR -CONDITIONING**

L	T	P/D	Cr.
4	-	-	4.0

Course Learning Objectives

1. Learning the fundamental principles and different methods of air conditioning.
2. Understand the basic air conditioning processes on psychrometric 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. (9 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. (8 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. (8 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. (11 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.

**MMEE331/MMEE332
DIRECT ENERGY CONVERSION**

L	T	P/D	Cr
4	-	-	4

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. **(6hrs)**

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. **(10hrs)**

4. Thermoelectric Generators

Introduction, Thermoelectric effects, thermoelectric generator, Types of thermoelectric generators, Economic aspects of thermoelectric generation **(6 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 **(6hrs)**

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. Mieleles.
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

**MMEE335/MMEE336
NUCLEAR ENGINEERING**

L	T	P/D	Cr.
4	-	-	4.0

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. (7hrs)
2. **Neutron Interaction**
Advantages of using neutron, neutron moderation, fission chain reaction, thermalisation of neutrons, fast neutrons, prompt and delayed neutrons, fission products. (5hrs)
3. **Energy Release**
Mass energy equivalence, mass defect, binding energy, energy release in fission & fusion, thermonuclear reaction, fusion bomb. (5hrs)
4. **Reactor Materials**
Fissile & fertile materials, cladding & shielding materials, moderators, coolants. (5hrs)
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-Wakil, 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

**MMEE337/MMEE338
FUELS AND COMBUSTIONS**

L	T	P/D	Cr.
4	-	-	4

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.

(7hrs)

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.

(9hrs)

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.

(7hrs)

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.

(9hrs)

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 Corp.
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.

MMEE339/MMEE340
RENEWABLE ENERGY & ENERGY MANAGEMENT

L	T	P/D	Cr.
4		-	4

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.

(7 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.

(7 hrs)

3. Wind energy

Basic principles of wind energy conversion; design of windmills; wind data and energy estimation; site selection considerations.

(5 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.

(6 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. **(4 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.

**MMEE341/MMEE342
TURBULENCE AND ITS MODELING**

L	T	P/D	Cr.
4	-	-	4

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. **(5 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 **(5 hrs)**

5. Canonical turbulent flows

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

MMEC207
EXPERIMENTAL DESIGNS

L	T	P/D	Cr
4	0	-	4

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 $3/4$ 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

**MMEE343/MMEE344
GAS DYNAMICS**

L	T	P/D	Cr.
4	-	-	4.0

.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. **(14 hrs)**

2. Shock Waves

Normal and oblique shocks; supersonic expansion by turning; Prandtl-Mayer function, Reflection, refraction and intersection of oblique shock waves; detached shocks. **(12 hrs)**

3. Supersonic and Subsonic Flow

Linearisation and small perturbation 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

MMEC101
APPLIED NUMERICAL METHODS

L	T	P/D	Cr.
4	-	-	4

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, Fourier's 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.
(4 hrs)

7. System of Linear Algebraic Equations

Introduction, Methods for Large Linear Systems, Direct Methods, LU- Decomposition Methods, Iterative Methods, III-conditioned Systems. (8 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
5. Gerald, F. Curtis, "Applied Numerical Analysis", Pearson Education

**MMEE345/MMEE346
SOLAR ENERGY**

L	T	P/D	Cr.
4	-	-	4

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. **(6 hrs)**
2. **Flat Plate Collectors**
Description, theory, Heat capacity effects, Time constant, Measurement of thermal performance, Air heaters. **(7 hrs)**
3. **Evacuated Tubular Collectors**
One axis, Two axis, Solar tracking, Cylindrical, Spherical and Parabolic and Paraboloid concentrators. Composite collectors, Central receiver collectors. **(7hrs)**
4. **Heat Storage**
Sensible and latent heat storage, Chemical energy system, performance calculations. **(6 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.

MMEE347/MMEE348
GAS TURBINE AND JET PROPULSION

L	T	P/D	Cr.
4	0	-	4

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, Bernoulli's principle, Compressibility, Thermodynamics laws & Process, isentropic flows, speed of sound, Shock Waves Normal & Oblique shock Waves.
(12hrs)

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.

(12 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 Roy IIT Bombay
(<https://nptel.ac.in/courses/101101002/37>).
9. Aerospace Propulsion by Dr. P.A. Ramakrishna IIT Madras (<https://nptel.ac.in/courses/101106033/4>).

MMEC107
FINITE ELEMENT METHODS

L	T	P/D	Cr.
4	-	-	4

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. (6hrs)

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. (12 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. (12hrs)

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 programming 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

**MMEE133/MMEE134
MEASUREMENT AND CONTROL**

L	T	P/D	Cr.
4	-	-	4.0

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. **(4 hrs)**

2. Instrumentation Characteristics:

Static and dynamic characteristics, first and second order systems response, classification & sources of error, loading facts, mechanical, electrical. **(6 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. (8 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.

MMEE251/MMEE252
STRATEGIC ENTREPRENEURSHIP AND START-UPS

L	T	P/D	Cr.
4	0	-	4

Course Learning Objectives

This course is designed to articulate students to

- Evaluate the business skills and commitment necessary to successfully operate an entrepreneurial venture and review the challenges and rewards of Entrepreneurship.
- Students will learn about themselves, their decisions, and their goals to determine how entrepreneurship can play a role in their lives and demonstrate the understanding of how to launch the individual's entrepreneurial career and to recognize the innate entrepreneurial potential within themselves.
- Learn entrepreneurship from an economic perspective, the concepts of environmentally sustainable practices, social entrepreneurship and ability to recognize a business opportunity that fits their skill sets and recognize the critical importance of values and ethics when engaged in entrepreneurial activities
- Recognize the critical importance of values and ethics when engaged in entrepreneurial activities.
- Make them aware and expose to latest policies of Government regarding Start-Ups and entrepreneurship.

Course Contents

1. Entrepreneurs and Entrepreneurship

Concept, Role and Significance of Entrepreneurship; Entrepreneurial Myths; Entrepreneurs - Types and Characteristics; Special Entrepreneurial Aspects - Social Entrepreneurship, Women

Entrepreneurship, International Entrepreneurship, Rural Entrepreneurship, Corporate Entrepreneurship, Technical Entrepreneurship; Entrepreneurship. 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. (14hrs)

2. 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. (10 hrs)

3. 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. (08 hrs)

4. Start-Ups

Why a start-up, Types of Start-Ups, Characteristics of Start-Ups , Start-Up Ecosystem, Reasons for starting business, Concepts of TAM, SAM , MVP, GTM, PMF. AIDA model, Sales funnel, Team Building, Hiring. Knowledge about MCA policies regarding Start-Ups and role of various financial institutions, how to launch a company in India, Factors Entrepreneurs Consider while Launching a Start-up Raising Investments- Venture Capitalists, Angel Investors, Start-ups Best Practices, Some Examples of Startup Business Ideas and Successful Start-Ups, Techno-Economic feasibility project report, SWOT analysis. (10 Hrs)

Course Outcomes:

CO 1-Ability to recognize a business opportunity that fits the individual skill-sets.

CO 2-Demonstrate the ability to provide a self-analysis in the context of an entrepreneurial career and find an attractive market that can be reached economically and create appropriate a business model.

CO 3-Apply effective written and oral communication skills to business situations.

CO 4-Analyze the global business environment, the local business environment and use critical thinking skills in business situations and develop an ethical understanding and perspective to business situations

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).
6. Handbook of Entrepreneurship - Rao and Pareek
7. Entrepreneurship, 4e - Barringer, Pearson Publication
8. (McGraw-Hill).

MMEE253/MMEE254
TOTAL QUALITY MANAGEMENT

L	T	P/D	Cr.
4	0	-	4

Course Objectives:

- The objectives of this course is to introduce the main principles of business and social excellence, to generate knowledge and skills of students to use models and quality management methodology for the implementation of total quality management in any sphere of business and public sector and to describe it in its broader perspective.
- To provide a forum for discussion on quality, and to provide an exposure and discussion on quality issues to analyze some existing methods and techniques of quality management within an organization and to advise on how to overcome various quality issues.
- To give exposure to students on a basic competence with the tools and techniques used by real-life quality assurance department in maintaining quality w.r.t Implication of Quality on Business and challenges in Quality Improvement Programs.

Course Contents

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, framework and realize the importance of significance of quality leading to identification of requirements for quality improvement programs
2. Know the principles of total quality management and peculiarities of their implementation.
3. Analyze the TQM tools and techniques to improve the product and process quality.
4. Use quality management methods for analyzing and solving problems of organization by applying modern tools to improve quality of the product.
5. Know business excellence models and be able assess organization's performance making reference to their criteria.

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.

MMEC203
OPERATIONS MANAGEMENT

L	T	P/D	Cr.
4	0	-	4

Course Learning Objectives

1. The prime objective of this course is to improve students understanding of the concepts, principles, problems, and practices of operations management.
2. To understand how Enterprise Resource Planning. JIT and MRP systems are used in managing operations.
3. To increase the knowledge, and broaden the perspective of the world in which the incumbents will contribute their talents and leadership in business operations.
4. To understand the managerial responsibility for Operations, even when production functions are outsourced, or performed in regions far off from corporate headquarters.

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 TQM

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

Course Outcomes:

Upon completion of this course, the students will be able to

1. Identify the elements of operations management and various transformation processes to enhance productivity and competitiveness.
2. Analyze and evaluate various facility alternatives and their capacity decisions, develop a balanced line of scheduling & production / sequencing techniques in operation environments.
3. Develop learning for Business Process Reengineering.
4. Appreciate and improve suitable materials handling principles and practices in the operations.
5. Understand and analyze operations and supply chain management issues in a firm

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 Katayani, 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.

**MMEE245/MMEE246
MODELING AND SIMULATION**

L	T	P/D	Cr
4	-	-	4

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

Course Contents

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 Event System 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 of Automated Manufacturing System", Prentice-Hall of India.
6. Theory of Modeling & Simulation, B.P. Zeigler, Taggon 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 Kerim Tumay, 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.

**MMEE351/MMEE352
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.

**MMEE353/MMEE354
NON-CONVENTIONAL COOLING METHODS**

L	T	P/D	Cr.
4		0	4

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 (8 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(14 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.

**MMEE355/MMEE356
BIO ENERGY TECHNOLOGIES**

L	T	P/D	Cr.
4		0	4

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.

**MMEE357/MMEE358
VISCOUS FLUID FLOW**

L	T	P/D	Cr.
4	-	-	4.0

Course Learning Objectives

- Provide a general review of basic concepts, physics and mathematical descriptions of viscous flow;
- Introduce Navier-Stokes equations and some of the exact solutions;
- Understand the boundary layer model and different analytic methods;
- To Introduce flow instability and transition from laminar flow to turbulence;

Fundamental concepts and conservation laws: Viscosity, continuum, streamlines, pathlines; Derivation of the Navier-Stokes equations; Cartesian tensor notation; Stress-strain relationships and shear deformation; Introduction to vorticity dynamics; Dimensional analysis and similarity; Some exact solutions of N-S equations: Steady and unsteady parallel flows - Couette-Poiseuille flow, parallel plates, concentric cylinders; Concept of similarity transformations-2D stagnation point flow **[10 hrs]**

Flow at very low Reynolds number; Stokes flow equations Applications: lubrication theory, flow past a small sphere; Wall-bounded flows: Boundary layer approximation and parameters; Transformations for BLs over thin wedges and flat plates; Approximate methods, momentum-integral relations; Effects of pressure gradients, wall suction and blowing **[10 hrs]**

Free shear flows: Jets, wakes and mixing/shear layers; Similarity solutions for plane jets and plane wakes, Heat transfer and compressibility effects; Energy balance equations for viscous and inviscid fluids; Thermal boundary layers, adiabatic and isothermal walls; Aerodynamic heating, effects of Prandtl and Mach numbers; Transformations for compressible boundary layers **[12 hrs]**

Flow separation; Shape of velocity profile; Separation in relation to, but without, transition to turbulence, Introduction to hydrodynamic stability; Linearized small-disturbance theory, application to simple flows; Physical mechanisms: Kelvin-Helmholtz, Rayleigh-Taylor, Gortler; Parametric effects: heat transfer, Mach number. Turbulence: introductory concepts: Disorder, mixing, intermittency; averaging, Introduction to transition to turbulence: Experimental observations; Modern research developments **[12 hrs]**

Course Outcomes:

CO1: Understand the fundamentals of fluid mechanics from an advanced point of view, with emphasis on the mathematical treatment of viscosity effects in laminar flows of a Newtonian fluid

CO2: To understand the Navier Stokes equations and some of its exact solutions available in simplified configurations.

CO3: To know about Stokes-flow regime of very low Reynolds numbers, flows with wall and free-shear boundaries, and the effects of pressure gradients, heat transfer and compressibility

CO4: To understand an introduction to the phenomena of instability and transition to turbulence.

Reference Books:

1. Boundary Layer Theory by H. Schlichting and K Gersten, Springer-Verlag
2. Viscous Fluid Flow by White, F. M., McGraw-Hill
3. Viscous Flow by Sherman F. S., McGraw-Hill
4. Incompressible Flow by Panton, R.L., Wiley
5. A First Course in Turbulence by Tennekes & Lumley.