COIMBATORE INSTITUTE OF TECHNOLOGY

(Government Aided Autonomous Institution Affiliated to Anna University, Chennai)

COIMBATORE - 641 014, TAMILNADU, INDIA

DIAMOND JUBILEE

(1956 - 2016)

Department of Mechanical Engineering

M.E. Heat Power Engineering

Curriculum and Syllabi

Under Choice Based Credit System

(For the students admitted during 2015 - 2016 and onwards)

CONTENTS

DEPARTMENT OF MECHANICAL ENGINEERING

COIMBATORE INSTITUTE OF TECHNOLOGY

VISION AND MISSION OF THE INSTITUTE

VISION

The Institute strives to inculcate a sound knowledge in engineering along with realized social responsibilities to enable its students to combat the current and impending challenges faced by our country and to extend their expertise to the global arena.

MISSION

The Mission of CIT is to impart high quality education and training to its students to make them World-class engineers with a foresight to the changes and problems, and pioneers to offer innovative solutions to benefit the nation and the world at large.

DEPARTMENT OF MECHANICAL ENGINEERING

COIMBATORE INSTITUTE OF TECHNOLOGY

VISION AND MISSION OF DEPARTMENT OF MECHANICAL ENGINEERING

VISION

The department aims to become one of the best mechanical engineering departments in the country within the next decade, in preparing engineers capable of working innovatively and creatively towards a better world.

MISSION

The mission of the department of mechanical engineering is to:

- Impart sound knowledge through effective teaching-learning methods
- Prepare students to address current and impending challenges facing the country and the world at large
- Create and nurture an environment for fostering innovation and research

DEPARTMENT OF MECHANICAL ENGINEERING

COIMBATORE INSTITUTE OF TECHNOLOGY

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

FOR

M.E. HEAT POWER ENGINEERING

The PEOs are to enable the students to :

PEO1

Acquire in-depth knowledge necessary for demonstrating expertise in thermal sciences

PEO2

Attain competency in advanced-level technical skills to analyze design aspects of thermal engineering and solve complex problems

PEO3

Possess motivation for life-long learning and display a professional attitude as an individual or as a team member with consideration for societal, ethical and environmental factors

DEPARTMENT OF MECHANICAL ENGINEERING

COIMBATORE INSTITUTE OF TECHNOLOGY

PROGRAMME OUTCOMES (POs)
FOR
M.E. HEAT POWER ENGINEERING

The students will be able to:

1. Demonstrate in-depth knowledge of mathematics, science and engineering principles in the areas of thermal sciences and allied fields
2. Apply their knowledge and training to solve complex problems related to thermal engineering
3. Demonstrate logical reasoning skills in order to model, analyze and solve practical problems related to thermal sciences
4. Demonstrate confidence to independently study scholarly publications in the field of thermal sciences for the pursuit of higher studies or for solving real-time problems
5. Use numerical techniques and experimental methods to model, simulate and solve complex thermal engineering problems
6. Work individually or in a project team of a multi-disciplinary nature
7. Visualize, plan and execute projects depending on resources, finance, and other design constraints
8. Demonstrate skills in oral and written communication to deliver effective presentations and technical reports
9. Engage in life-long learning with desire and self-motivation
10. Discharge professional duties with ethics and intellectual integrity
11. Independently work towards continuous performance improvement

COIMBATORE INSTITUTE OF TECHNOLOGY

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DEPARTMENT OF MECHANICAL ENGINEERING

Curriculum from the Academic Year 2015 - 2016 onwards

Name of the degree : M. E. (Full-Time)

Specialization : Heat Power Engineering

Semester I

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH11	Advanced Mathematics	4	0	0	4	FC
15MMH12	Principles of Conduction	4	0	0	4	PC
15MMH13	Dynamics of Incompressible Flow	3	0	0	3	PC
15MMH14	Energy Conversion and Energy Management	3	0	0	3	PC
	Elective-I	4	0	0	4	PE
	Elective-II	3	0	0	3	PE
	Total Credits				**21**	

Semester II

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH21	Advanced Thermodynamics	4	0	0	4	FC
15MMH22	Principles of Convection	3	0	0	3	PC
15MMH23	Refrigeration and Air-conditioning System & Design	4	0	0	4	PC
15MMH24	Turbomachinery	3	0	0	3	PC
	Elective-III	3	0	0	3	PE
	Elective-IV	3	0	0	3	PE
	PRACTICAL					
15MMH25	Advanced Thermal Engineering Laboratory	0	0	2	1	EEC
	TOTAL CREDITS				**21**	

Semester III

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH31	Principles of Radiation	4	0	0	4	PC
15MMH32	Dynamics of Compressible Flow	4	0	0	4	PC
	Elective-V	3	0	0	3	PE
	PRACTICAL					
15MMH41	Project Work and Viva-Voce	0	0	0	0	EEC
	Total Credits				**11**	

Semester IV

Course Code	Name of the Subject	L	T	P	C	Category
	PRACTICAL					
15MMH41	Project Work and Viva-Voce	0	0	0	18	EEC
	Total Credits				**18**	
	Grand Total Credits				**71**	

LIST OF ELECTIVES

Course Code	Name of the Subject	L	T	P	C	Category
15MMHE01	Design and Optimization of Thermal Equipment	4	0	0	4	PE
15MMHE02	Combustion and Internal Combustion Engines	3	0	0	3	PE
15MMHE03	Finite Element Analysis	4	0	0	4	EEC
15MMHE04	Cryogenics	3	0	0	3	PE
15MMHE05	Boiler Technology	4	0	0	4	EEC
15MMHE06	Absorption and Steam Jet Refrigeration Systems	3	0	0	3	PE
15MMHE07	Design and Analysis of Experiments	3	0	0	3	PE
15MMHE08	Research Methodology	3	0	0	3	PE
15MMHE09	Performance Analysis of Heat Exchangers	4	0	0	4	PE
15MMHE10	Solar Energy Utilization	3	0	0	3	PE

Abbreviations

FC - Foundation Course

PC - Professional Core

PE - Professional Elective

EEC - Employability Enhancement Course

COIMBATORE INSTITUTE OF TECHNOLOGY

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DEPARTMENT OF MECHANICAL ENGINEERING

Curriculum from the Academic Year 2015 - 2016 onwards

Name of the degree : M. E. (Part-Time)

Specialization : Heat Power Engineering

Semester I

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH11	Advanced Mathematics	4	0	0	4	FC
15MMH12	Principles of Conduction	4	0	0	4	PC
15MMH13	Dynamics of Incompressible Flow	3	0	0	3	PC
	TOTAL CREDITS				**11**	

Semester II

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH21	Advanced Thermodynamics	4	0	0	4	FC
15MMH22	Principles of Convection	3	0	0	3	PC
15MMH23	Refrigeration and Air-conditioning System and Design	4	0	0	4	PC
	PRACTICAL					
15MMH25	Advanced Thermal Engineering Laboratory	0	0	2	1	EEC
	TOTAL CREDITS				**12**	

Semester III

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH14	Energy Conversion and Energy Management	3	0	0	3	PC
	Elective-I	4	0	0	4	PE
	Elective-II	3	0	0	3	PE
	TOTAL CREDITS				**10**	

Semester IV

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH24	Turbomachinery	3	0	0	3	PC
	Elective-III	3	0	0	3	PE
	Elective-IV	3	0	0	3	PE
	TOTAL CREDITS				**9**	

Semester V

Course Code	Name of the Subject	L	T	P	C	Category
	THEORY					
15MMH31	Principles of Radiation	4	0	0	4	PC
15MMH32	Dynamics of Compressible Flow	3	0	0	3	PC
	Elective-V	4	0	0	4	PE
	PRACTICAL					
15MMH41	Project Work and Viva-Voce	0	0	0	0	EEC
	TOTAL CREDITS				**11**	

Semester VI

Course Code	Name of the Subject	L	T	P	C	Category
	PRACTICAL					
15MMH41	Project Work and Viva-Voce	0	0	0	18	EEC
	TOTAL CREDITS				**18**	
	GRAND TOTAL CREDITS				**71**	

Syllabi for Semester I

15MMH11 - ADVANCED MATHEMATICS

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

The objective is to incorporate the basic ideas of variational problems and Integral equations and to introduce Integral transform methods and Method of weighted residuals to solve ODE and PDE. The topics introduced will serve as basic tools for specialized studies in many Engineering fields.

COURSE OUTCOME

The student shall

1. *Have the ability and confidence to apply the knowledge gained to handle problems of specialized studies in engineering.*
2. *Have developed skills to visualize, understand and model problems pertaining to heat transfer study.*
3. *Have developed the ability to work in a group and collective thinking through assignments and tutorials*

CALCULUS OF VARIATIONS

Simple variational problems with fixed boundaries- Euler's equations-Conditional extrema-Isoperimetric problems-Approximate solutions-Direct methods-Euler's finite difference method-Ritz method. **(12)**

INTEGRAL EQUATIONS

Relation between integral and differential equations- Green's function-Fredholm's equation with separable kernels- Hilbert Schmidt theory- iterative methods for solving equations of second kind. **(12)**

LAPLACE TRANSFORM METHODS TO SOLVE ODE

Boundary value problems involving PDE-one dimensional heat conduction equation-one dimensional wave equation-Laplace equation-longitudinal vibrations and transverse vibrations of bar. **(12)**

FOURIER TRANSFORM METHODS TO SOLVE ODE

Fourier transform method for one dimensional heat conduction problems in finite, infinite and semi infinite rod-Laplace and Poisson equations. **(12)**

METHOD OF WEIGHTED RESIDUALS

Applications to ordinary and partial differential equations-sub-domain method-collocation method-Galerkin method-Least square method- finite element method. **(12)**

TOTAL : 60

REFERENCES

1. *Hildebrand F.B., "Method of Applied Mathematics", Dover Publications, 2012.*
2. *Venkataraman M.K., "Higher Engineering Mathematics for Engineering and Sciecnes", National Publishing Company, 2000.*
3. *Speigel M.R., "Theory and Problems of Laplace Tranforms", Schaum Series, McGraw Hill, NewYork, 1965.*
4. *Vasistha A.R. and Gupta R.K, "Integral Transforms", Krishna Prakashan Media (Private Limited), Meerut(UP), 2000.*
5. *Elsgolts L "Differential equation and Calculus of variations", MIR Publication, Moscow,2003.*
6. *Narayanan S., Manickavasagam Pillay T.K.,Ramanaiah G., "Advanced Mathematics for Engineering students", Viswanathan Printers and Publishers Private Limited, 1986.*

15MMH12 - PRINCIPLES OF CONDUCTION

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

To provide a post-graduate student with knowledge of the various mathematical techniques that can be used to analyze problems related to the conduction of heat. Problem-solving skills to apply and extend this learning shall be emphasized upon.

COURSE OUTCOME

The student will be able to:

1. *Apply Fourier's Law in Cartesian, cylindrical and spherical coordinate systems; Evaluate heat transfer rates across surfaces of specified orientations*
2. *Formulate governing differential equations using standard forms of the heat conduction equation; Solve them with relevant supporting information; Determine temperature distributions*
3. *Construct governing differential equations starting with basic energy conservation principles, and solve them after specifying relevant supporting information*
4. *Use Bessel functions and other special functions of mathematical physics to perform required calculations*
5. *Employ numerical approaches (finite-volume method) to obtain approximate solutions to problems in heat conduction*
6. *Interpret the solutions obtained and judge them for their correctness*

PRE-REQUISITES

The student must have successfully completed undergraduate level courses in Differential Equations and Heat Transfer.

GOVERNING EQUATIONS FOR CONDUCTION

Heat flux vector and Fourier's Law - Gradient of temperature - Derivation of the Heat Conduction Equation in a coordinate-free form - Divergence of heat flux - Fourier, Poisson and Laplace equations - Various kinds of Boundary Conditions and their mathematical specification - Solutions to simple one-dimensional steady state conduction in rectangular, cylindrical, and spherical coordinates - Derivation of steady-state temperature distributions in non-standard geometries using Alternative Conduction Analysis **(12)**

EXTENDED SURFACES

Introduction to various types of fins and extended surface profiles - Derivation of governing equation for one-dimensional fin temperature distributions - Obtaining solutions for straight fins of uniform profile (pin fins, fins of uniform cross-section), triangular profile and other non-uniform cross-sections - Bessel equations and use of Bessel functions - Analysis of annular fins of rectangular profile mounted on tubes - Fin performance **(12)**

TWO-DIMENSIONAL STEADY-STATE CONDUCTION

The Separation-of-Variables Technique for Homogenous and Non-Homogenous cases - Eigen values and Eigen functions - Superposition - Applications to plate-like planar geometries using rectangular and cylindrical coordinates **(12)**

ONE-DIMENSIONAL UNSTEADY HEAT CONDUCTION

One-dimensional unsteady conduction in plane walls and cylindrical pipe walls - Sturm-Liouville sytems and orthogonal eigen-functions - Transcendental equations for eigen-values - Variation of Parameters approach - Long-time periodic solutions to oscillatory input conditions - Semi-infinite solids subjected to various kinds of boundary conditions - Gaussian Error Function **(12)**

NUMERICAL METHODS IN CONDUCTION HEAT TRANSFER

Introduction to the Finite-Volume Method - Applications to one-dimensional problems involving steady or unsteady conduction with or without volumetric heat generation - Thomas Algorithm - Explicit and Implicit formulations and their comparisons - Extensions to two and three-dimensional geometries - The Gauss-Siedel approach - Validation of numerical solutions **(12)**

TOTAL : 60

REFERENCES

1. *Nag P.K., "Heat and Mass Transfer", 2nd Edition, McGraw-Hill, 2007.*
2. *Holman J.P., "Heat Transfer (in SI units)", 9th Edition., Tata McGraw-Hill, 2008.*
3. *Ozisik M.N., "Heat Transfer - A Basic Approach", McGraw Hill, 1985.*
4. *Arpaci V.S., "Conduction Heat Transfer", Addison-Wesley, 1966.*
5. *Kraus A.D., Aziz A., and Welty J., "Extended Surface Heat Transfer", John Wiley & Sons, 2002.*
6. *Nijaguna B.T., "Thermal Science Data Book", Tata McGraw-Hill Publishing Co. Ltd., 2005.*

15MMH13 - DYNAMICS OF INCOMPRESSIBLE FLOW

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

To provide a post-graduate student with knowledge of mathematical techniques needed to analyze the dynamics of incompressible flows. Problem-solving skills, using theoretical and numerical techniques, to apply and extend this knowledge shall be emphasized upon.

COURSE OUTCOME

The student will be able to

1. *Apply different descriptions of fluid flows (Lagrangian or Eulerian) to evaluate fluid velocities and accelerations*
2. *Demonstrate expertise in deriving and working with expressions for vorticity, fluid strain rates and fluid stresses in standard coordinate systems, and evaluate forces due to such stresses*
3. *Distinguish between rotational and irrotational flows, and obtain potential functions, stream-functions and equations (shapes) of flow streamlines*
4. *Derive the governing equations of fluid motion in standard coordinate systems and solve them to interpret some simple flow cases*
5. *Find pressure distributions, shear stresses, flow rates, lift and drag forces*
6. *Employ numerical approaches to analyze simple viscous and inviscid flows*

PRE-REQUISITES

The student must have successfully completed undergraduate level courses in Differential Equations and Fluid Mechanics.

GOVERNING EQUATIONS OF FLUID FLOW

Concept of a fluid and continuum - Coordinate systems and vector operators (gradient, divergence, and Laplacian) in 2-D and 3-D - Derivation of the continuity equation - Incompressible flows - Rates of strain - Strain rate tensor and its construction - Stress tensor - Newtonian fluid - Derivation of the Navier-Stokes equations in coordinate-free form and its specialization for the Cartesian coordinate system. **(9)**

FLOW KINEMATICS

Lagrangian vs. Eulerian viewpoint - Introduction to vorticity and irrotational flows - Potential function and Stream function - Streamlines, Pathlines and Streaklines - Physical meaning and usefulness of the stream function - Stream function-vorticity equation for two-dimensional flows - Flow circulation. **(9)**

IRROTATIONAL FLOWS IN A PLANE

The complex potential and complex velocity - Uniform irrotational flow, line source and sink flows, Line vortex flow, Doublet flow - Superposition of simple two-dimensional flows - Method of Images - Applications to flow over a Rankine shape and flow over a cylinder with or without circulation - Lift and Drag - Pressure coefficient. **(9)**

INCOMPRESSIBLE LAMINAR FLOWS

A few exact solutions to the laminar Navier-Stokes equations e.g. Couette-Poiseuille flow in a two-dimensional channel, circular pipe flow, flows inside annuli, gravity-driven flow on inclined planes (falling film) - Boundary Layer Theory - Blasius similarity solution and approximate solutions via momentum integral for flow over a flat plate - Skin-friction coefficient. **(9)**

NUMERICAL METHODS IN FLUID FLOW

Application of the Finite-Volume Method to hydro-dynamically fully developed flows in plane channels, pipe and/or annulus geometries - Analysis of two-dimensional irrotational flow inside passages of various shapes using the stream-function formulation - the plotting of streamlines - Validation of numerical solutions.

(9)

TOTAL : 45

REFERENCES

1. *Muralidhar K. and Biswas G., "Advanced Engineering Fluid Mechanics", 2nd Edition, Narosa Publishing House, New Delhi, 2005.*
2. *Bird R.B., Stewart W.E., and Lightfoot E.N., "Transport Phenomena", Wiley, N.Y., 1980.*
3. *Schlichting H., "Boundary Layer Theory", McGraw-Hill, N.Y., 1979.*
4. *Longwell P.A., "Mechanics of Fluid Flow", McGraw Hill, N.Y., 1966.*
5. *Batchelor G.K., "An Introduction to Fluid Dynamics", Cambridge University Press, 2000.*

15MMH14 - ENERGY CONVERSION AND ENERGY MANAGEMENT

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE DESCRIPTION

A course in energy engineering with emphasis on direct conversion systems, renewable energy systems, energy storage, and the principles of energy management and its economics.

COURSE OBJECTIVE

This course is intended to provide the principles of both non-renewable and renewable energy production, and deals with almost all the energy conversion systems except thermal and mechanical energy systems. It also provides knowledge to the students about the principles of energy management, energy planning, energy audits and energy economics.

COURSE OUTCOME

The students will have

1. *Fundamental knowledge of principles of energy conversion from renewable energy sources.*
2. *The ability to design direct energy converters and study their performance.*
3. *Knowledge of different energy storage methods and their design and application in relevant systems, cogeneration and its economics.*
4. *Knowledge of energy management principles, planning for energy management, energy audit, engineering aspects of energy management and the economics, and realization of its application, benefits and savings.*

ELECRICAL ENERGY SYSTEMS

Electrical, electromagnetic, chemical and other energy conversion systems - MHD, hydrogen fuel-cells, batteries, thermionic and thermoelectric generators, transformers, and motors. **(8)**

RENEWABLE ENERGY SYSTEMS

Wind energy, biomass and biogas energy, geothermal energy, ocean thermal energy, wave energy and tidal energy. **(15)**

ENERGY STORAGE

Energy storage systems, pumped hydro-, compressed air storage, energy storage by flywheel, electrical battery storage, super-conducting magnetic energy storage, thermal sensible energy storage, latent heat energy storage, chemical reaction storage. **(8)**

COGENERATION SYSTEMS

Applications of cogeneration, types of cogeneration processes, topping cycle plant, bottoming cycle plant, economics of cogeneration **(4)**

ENERGY MANAGEMENT

General principles of energy management, planning for energy management, building and site energy audits, energy efficiency analysis - Engineering aspects of energy management, the economics of efficient energy use **(10)**

TOTAL : 45

REFERENCES :

1. *Culp A.W., "Principles of Energy Conversion", Tata McGraw Hill, 2000.*
2. *Sorensen H.A., "Energy Conversion Systems", John Wiley and Sons, 1983.*
3. *Sorenson, B., "Renewable Energy", Academic Press, 2004.*
4. *El-Wakil, M.M.,"Power Plant Technology", McGraw Hill Book Company, 1985.*
5. *Rai, G.D.,"Non-Conventional Energy Sources", Khanna Publishers, 2008.*
6. *Smith, C.B., "Energy Management Principles", Pergamon Press, 1981.*

Syllabi for Semester II

15MMH21 - ADVANCED THERMODYNAMICS

(Use of Approved Steam Tables is permitted)

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

To provide a generalized view of classical thermodynamics needed to evaluate changes in thermodynamic properties, analyze heat and work interactions of single component or multi-component systems, and calculate energy transfers. Problem-solving skills to apply and extend this learning shall be emphasized upon.

COURSE OUTCOME

The student will be able to

1. *Apply postulates of classical thermodynamics to write the fundamental equations of thermodynamics and the Maxwell relations*
2. *Use Maxwell relations to derive expressions and calculate changes in important properties such as internal energy, enthalpy, entropy, Gibbs function, etc. for a simple compressible substance*
3. *Demonstrate the ability to work with different equations of state to predict ideal gas and real gas behavior*
4. *Evaluate mixture compositions, property changes and energy transfers during interactions of multi-component mixtures of ideal gases or real gases, using standard models*
5. *Apply concepts such as partial molar properties, chemical potential, fugacity, etc. to analyze multi-component systems*
6. *Calculate availability change, energy loss and irreversibility associated with various processes*

THERMODYNAMIC PROPERTY RELATIONS

Fundamental postulate of thermodynamics, Fundamental equations of thermodynamics for simple compressible systems, Maxwell relations, Relations for cp and cv, Relationships for calculating changes in internal exergy, enthalpy and entropy, Joule-Thompson coefficient, Expansion and compressibility coefficients, Speed of sound **(15)**

REAL GAS BEHAVIOUR

Real gas equations of state (EOS) e.g. Van der Waals, Redlich-Kwong EOS, Determination of EOS model constants from critical point data, Property relationships for real gases, Ideal gas vs. real gas mixtures, Dalton and Amagat models, Mixture rules for real gas mixtures, Entropy of mixing. **(12)**

MULTI-COMPONENT SYSTEMS

Chemical work, Fundamental equations of thermodynamics for multi-component systems, Maxwell relations, Chemical work and chemical potential, Partial molar properties, Gibbs-Duhem equation, Fugacity **(12)**

AVAILABILITY AND EXERGY

Reversible work, Irreversibility, Availability functions for closed and open systems, Degradation of exergy, Second law efficiency, Applications to various thermodynamic processes **(12)**

MULTI-PHASE EQUILIBRIUM

Phase equilibrium, Gibbs phase rule, Clapeyron's equation, Raoult's Law, Binary phase diagrams, Estimation of dew point and bubble point for refrigerant mixtures **(9)**

TOTAL : 60

REFERENCES

1. *P. K. Nag, "Engineering Thermodynamics", 5th Edition, Tata McGraw-Hill, 2013.*
2. *Michale Graetzel & Pierre Infelta, "The Bases of Chemical Thermodynamics", Overseas Edition, Overseas Press India Pvt. Ltd., 2006.*
3. *P. L. Dhar, "Engineering Thermodynamics - A Generalised Approach", Elsevier, New Delhi, 2008.*
4. *Kenneth Wark, "Advanced Thermodynamics for Engineers", McGraw-Hill, 1994.*
5. *Dittman R.H., Zemansky M.W., "Heat and Thermodynamics", 8th Edition, Tata McGraw-Hill, 2011.*
6. *Bejan, A., Advanced Engineering Thermodynamics, 3rd Edition, John Wiley, 2006.*

15MMH22 - PRINCIPLES OF CONVECTION

(Use of Approved Heat Transfer Data Book or Data Tables is permitted)

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course is intended to equip a post-graduate student with various mathematical techniques that can be used to analyze problems related to forced convection and natural convection. Development of skills required for formulations of problems, and solution techniques to apply and extend this learning shall be emphasized upon.

COURSE OUTCOME

The student will be able to

1. *Write governing differential equations for mass and momentum conservation, and various forms of the energy conservation equation; Solve differential equations to find temperature distributions in simple shear flows; Evaluate bulk temperatures, convective heat transfer coefficients and Nusselt numbers*
2. *Demonstrate the ability to use one-dimensional approaches to analyze heat transfer due to convection inside ducts with prescribed thermal conditions at the walls (known wall heat fluxes or wall temperatures)*
3. *Analyze hydro-dynamically and thermally fully-developed flows inside two-dimensional channels and pipes; Analyze convective heat transfer in thermal entrance regions of internal flows*
4. *Formulate and solve governing equations for thermal boundary layers in forced and natural convection (external flows) using exact and approximate analytical techniques*
5. *Employ numerical approaches (finite-volume method) to set up algebraic equations and obtain approximate solutions to problems in heat convection*

PRE-REQUISITES

The student must have successfully completed undergraduate level courses in Differential Equations and Heat Transfer, and at least one graduate-level course in fluid mechanics of incompressible flow.

GOVERNING EQUATIONS FOR CONVECTION

Mechanisms and types of convection - Definition of convective heat transfer coefficient - Formulation of the energy equation in various differential forms (in terms of internal energy, enthalpy, or specific heat and temperature) - boundary conditions and initial conditions - Application to one-dimensional Couette-Poiseuille flow with viscous dissipation - Bulk mean temperature and simple 1-D analysis using energy-balance and bulk-mean temperature principles **(9)**

FORCED CONVECTION IN INTERNAL FLOWS

Introduction to thermally fully-developed flow inside ducts - flow under constant wall heat flux and constant wall temperature conditions - Nusselt number estimation for laminar pipe flow and 2-D channel flow for constant wall flux and constant wall temperature conditions - Laminar entrance flow into a 2-D channel (the Graetz problem) **(9)**

FORCED CONVECTION IN EXTERNAL FLOWS

The thermal boundary layer - similarity solutions for convection from a semi-infinite flat plate under constant temperature and constant wall heat flux conditions - Effect of Prandtl number in limiting cases i.e. very small or very large Prandtl numbers - The von Karman-Pohlhausen integral approach - Average heat transfer coefficient - Treatment of partly laminar and partly turbulent flow regimes over a flat plate - Correlations for forced convection from cylinders in cross-flow - Applications to practical situations - Duhamel's superposition **(9)**

NATURAL CONVECTION

Dimensionless groups in natural convection - the Boussinesq approximation - Similarity solutions for free convection from a vertical semi-infinite flat plate - Correlations for natural convection inside ducts - Applications to practical situations **(9)**

NUMERICAL METHODS IN CONVECTION

The convection-diffusion equation - The central-difference and upwind schemes - Convection-diffusion flux - Applications to one-dimensional steady state problems with or without volumetric sources - Comparison with the exact solution and the role of the Peclet number - Validation of numerical solutions. **(9)**

TOTAL : 45

REFERENCES

1. *Nag P.K., "Heat and Mass Transfer", 2nd Edition, McGraw-Hill, 2007.*
2. *Bejan A., "Convection Heat Transfer", 3rd Edition, John Wiley & Sons, 2004 (or Wiley India Pvt. Ltd, 2013 reprint).*
3. *Kays W.M. and Crawford M.E., "Convective Heat and Mass Transfer", 3rd Edition, McGraw Hill International, 1993.*
4. *Schlichting H., "Boundary Layer Theory", McGraw-Hill, 1968.*
5. *Oosthuizen, P., "Introduction to Convective Heat Transfer Analysis", McGraw-Hill, 1999.*
6. *Nijaguna B.T., "Thermal Science Data Book", Tata McGraw-Hill Publishing Co. Ltd., 2005.*

15MMH23 - REFRIGERATION & AIR CONDITIONING SYSTEM AND DESIGN

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course is intended to study about the principles of refrigeration and their applications to air-conditioning systems and the analysis of the thermodynamic cycles involved in them.

COURSE OUTCOME

1. *Would have gained conceptual knowledge of various approaches and mathematical techniques relevant to pshychrometrics, and an ability to apply and extend this knowledge to industry*

Shall be able to:

2. *Design and analyze refrigeration cycles and numerical techniques available to be implemented in the industries(aero) with duct design*
3. *Contribute to a successful design or conduct of an experiment (involving either a physical set-up or a numerical experiment) on cooling and heating load calculation.*
4. *Formulate and solve problems involving heat gain and load calculations, Design and sizing of pipelines and insulation.*
5. *Function effectively on problem-solving teams and to coordinate in providing leadership for teams, including multidisciplinary teams.*
6. *Develop skills in assignment writing, reading, speaking and listening, needed to communicate logically and effectively.*

GAS CYCLE REFRIGERATION

Bell Coleman cycle analysis, actual cycle. **(4)**

AIR CRAFT REFRIGERATION

Simple cooling cycle, Boot strap, reduced ambient and regenerative cycles. **(6)**

VAPOUR COMPRESSION REFRIGERATION SYSTEM

Effect of refrigerants on global warming and ozone depletion. Latest trends in curbing CFCs. Performance analysis of refrigeration cycles using p-H and T-s charts, effect of sub cooling, superheating, suction and discharge pressures. Multi pressure systems- Compound compression and multiple evaporators. Cascade systems, sectionalizing. **(10)**

PSYCHROMETRICS

Properties of moist air, property calculations, psychrometric charts, psychometric process in air conditioning equipments. **(6)**

AIR CONDITIONING CYCLES

Advanced psychrometric- SHF- Grand sensible heat factor- Effective sensible heat factor- Air conditioning cycles- simple cooling cycle, bypass cycle recirculation and reheat cycles, calculation using psychrometric chart. **(12)**

AIR CONDITIONING DESIGN

Cooling load calculations, effective temperature, Design of comfort air conditioning systems, cooling and dehumidifying coils, Hybrid air conditioning system for energy conservation, air conditioning of operation theatre, library, textile mills, computer rooms. **(10)**

DESIGN OF DUCT AND AIR HANDLING UNIT

Transmission and distribution of air- Room air distribution. Air duct design- economic considerations, duct layout, insulation and sizing-Design procedure, pipelines - design and sizing of pipelines, Air Handling Units, problems. **(12)**

TOTAL : 60

REFERENCES

1. *Roy. J. Dossat, "Principles of Refrigeration", 4th edition, Pearson, 2007.*
2. *Manohar Prasad, "Refrigeration and Air conditioning", New Age International publishers, 2006.*
3. *Althouse and Turnquist, "Modern Refrigeration and Air conditioning", 19th edition, Good Heart WilCox publishers, 2013.*
4. *C.P. Arora, "Refrigeration & Air conditioning", 3rd edition, Tata McGraw Hill, 2008.*

15MMH24 - TURBOMACHINERY

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course aims

- *At giving an overview of different types of fluid machinery used for energy transformation, such as pumps, fans, compressors, as well as steam and gas turbines*
- *To Review/acquire thermo fluids concepts applicable to turbo machinery*
- *To provide a more thorough understanding flow fields within axial-flow turbo-machines*
- *To provide an appreciation of current design methods and the parameters which determine the overall layout and design of turbo-machines*
- *To make the student to understand the parameters which are used to describe the overall design of turbo-machine blade profiles*
- *At providing an understanding of analysis of the blade-blade and hub-casing flows and evaluate the importance of the parameters which affect these flows*

COURSE OUTCOME

The student will

1. *Have the necessary skills required to model and perform thermodynamic analysis of advanced problems related to turbo-machines.*
2. *Be able to demonstrate a thorough understanding of the principles and applications of Turbomachinery in modern industry.*
3. *Be able to apply his knowledge as an useful tool for designing and researching on Turbomachinery instruments*
4. *Be able to interpret results of analysis on turbo-machinery using commercial software packages*

PRINCIPLES OF TURBO-MACHINERY

Introduction to turbo-machines - Classification of turbo-machinery - Transfer of energy to fluids - Energy transfer between a fluid and a rotor - Euler turbine equation - Components of energy transfer - Performance characteristics - Fan laws - Dimensionless parameters - Specific speed - Selection of centrifugal, axial, and mixed flow machines **(10)**

RADIAL FLOW MACHINES

Radial flow pumps, compressors, blowers and fans - Theoretical characteristic curves - Euler's characteristics and Euler's velocity triangles - losses and hydraulic efficiency - Volute, diffusers - Leakage, disc friction, and mechanical losses - Multi-vane impellers of impulse type - Design of radial flow impellers **(10)**

ANALYSIS OF AXIAL FLOW MACHINES

Axial flow fans - Rotor design, airfoil theory, vortex theory, and cascade effects - Degree of reaction, surging and stalling - Mixed flow impellers - Axial flow pumps and compressors - Dimensionless parameters - Efficiency and utilization factor in turbo-machinery - Design of axial flow impellers. **(5)**

TESTING AND CONTROL OF FANS AND BLOWERS

Fan testing - Noise control - Materials and components - Blower regulation - Speed control, throttling control at discharge and at inlet **(10)**

TURBINES

Radial flow turbines - Inward flow turbines for compressible fluids - Velocity and flow coefficients - Impulse turbines **(10)**

TOTAL : 45

REFERENCES

1. *Church A.H., "Centrifugal pumps and blowers", John Wiley & Sons Inc., 1980.*
2. *Dixon D.L., "Turbomachinery", Pergomon Press, 2007.*
3. *Lewis R.I., "Turbomachinery Performance Analysis", Elsevier Science & Technology Books, 1996.*
4. *Osborne W.C., "Fans", Pergamon Press, 1986.*
5. *Venkanna B.K., "Fundamentals of Turbomachinery" PHI Learning Pvt. Ltd., New Delhi, 2010.*
6. *Valan Arasu A., "Turbomachines", Vikas Publishing House (P) Ltd, 2009.*

15MMH25 - ADVANCED THERMAL ENGINEERING LABORATORY

L	T	P	C
0	0	2	1

ASSESSMENT : PRACTICAL

COURSE OBJECTIVE

To equip a student with basic computational skills needed to analyze heat transfer and fluid flow problems. Computer programming, data collection through experiments, use of software tools, and report writing skills shall be emphasized upon.

COURSE OUTCOME

The student will be able to

1. *Develop algorithms for numerical analysis of heat transfer/fluid flow problems, and implement these on a computer using the C-programming language.*
2. *Use commercial software tools such as FLUENT® and Gambit®.*
3. *Write laboratory reports to explain and analyze data collected via experiments or data generated numerically, and draw proper inferences.*

TITLE OF EXPERIMENTS

1. Construction of pressure-crank angle diagram for Otto and Diesel cycle
2. Performance analysis on Centrifugal Blower/ Four stroke multi-cylinder spark ignition engine
3. Parametric study on variable compression ratio single cylinder engine
4. Numerical analysis of one-dimensional steady state heat conduction
5. Numerical analysis of two-dimensional steady state heat conduction
6. The use of FLUENT for analyzing simple multi-dimensional fluid flows

Syllabi for Semester III

15MMH31 - PRINCIPLES OF RADIATION

(Use of Approved Heat Transfer Data Book or Data Tables is permitted)

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course is intended to equip a post-graduate student with various mathematical techniques that can be used to analyze problems related to exchange of thermal radiation among surfaces. Development of skills required for formulations of problems involving thermal radiation exchange, and solution techniques to apply and extend this learning shall be emphasized upon.

COURSE OUTCOME

On completion of the course the student would be able to:

1. *Demonstrate the ability to calculate solid angles using spherical coordinates; Derive expressions for emissive power and irradiation using intensities of emitted and incident radiation; Derive and apply Stefan-Boltzmann Law and Wien's Displacement Law*
2. *Analyze radiation heat transfer between a pair of blackbody surfaces; Use blackbody radiation functions; Derive shape factors for standard pairs of surfaces using the integral definition*
3. *Analyze thermal radiation exchange between non-ideal (gray) surfaces; Construct radiation network diagrams (electrical analogies) and use matrix methods to solve resulting equations; Use enclosure rules to find shape factors*
4. *Calculate overall emissivity, absorptivity etc. based on spectral distributions; Calculate incident radiation flux; Explain atmospheric greenhouse effect*
5. *Set up the Radiative Transfer Equation for a participative medium (typically a gas)*

PRE-REQUISITES

The student must have successfully completed undergraduate level courses in Differential Equations and Heat Transfer, and at least one graduate-level course in conduction or convection heat transfer.

THE NATURE OF RADIATION

Introduction to radiation and the electromagnetic spectrum - Definition of solid angle - Calculation of solid angles using the spherical coordinate system - Intensity of emitted radiation - spectral and directional properties - Spectral emissive power and total emissive power - Intensity of incident radiation and irradiation **(12)**

BLACKBODY RADIATION

Planck's distribution for blackbody spectral emissive power - Derivation of the Stefan-Boltzmann Law - Wien's Displacement Law and determination of Wien's constant - The Rayleigh-Jeans Law - Radiation functions and band emission - Blackbody radiation exchange between surfaces - View factors and reciprocal relations - View factors for enclosures - Formal methods of estimating view factors **(12)**

RADIATION NETWORKS

Diffuse emitters - Spectral and total hemispherical emissivity - Absorptivity, reflectivity and transmissivity - Kirchhoff's Law - Radiosity - Surface resistance to radiation - Electrical circuit analogy - Radiation shields - Re-radiating surfaces - Matrix methods for radiation exchange analysis - Applications to practical situations. **(12)**

ENVIRONMENTAL RADIATION

Atmospheric and solar radiation - Sky temperature - Albedo - Solar heat gain through windows - Solar heating panels - Greenhouse effect **(12)**

GAS RADIATION

Radiation in participating media - emission, absorption and scattering - Beer's Law -Emissivity and absorptivity of gases and gas mixtures - Hottel charts - The Radiative transfer equation - The Discrete Transfer Radiation Model - Radiation pressure - Brief overview of the P-1 and Rosseland radiation models **(12)**

TOTAL : 60

REFERENCES

1. *Seigel R. and Howell J., "Thermal Radiation Heat Transfer", Taylor and Francis, 2002.*
2. *Modest M.F., "Radiative Heat Transfer", Academic Press, 2003.*
3. *Hottel H.C. and Sarofim A. F., "Radiative Transfer", 3rd Edition, McGraw Hill International, 1967.*
4. *Sparrow E.M. and Cess R.D., "Radiation Heat Transfer", Hemisphere Publishing Corp., New York, 1978.*

15MMH32 - DYNAMICS OF COMPRESSIBLE FLOW

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course aims to enable students of post-graduate heat power engineering to arrive at governing equations for compressible fluid flow through theoretical concepts and illustrations and to apply them to analyze flow in different situations.

COURSE OUTCOME

The student should be able to

1. *Deduce governing equations of fluid flow from Reynolds Transport Theorem and apply them for analyzing flow through ducts, both constant area and variable area, and with and without irreversibilities.*
2. *Explain flow through variable area and constant area ducts with aid of property diagrams*
3. *Estimate flow properties for flow involving shock*
4. *Design supersonic nozzles using method of characteristics*
5. *Compare different flow regimes and explain on real gas effects*

REVIEW OF THERMODYNAMIC CONCEPTS AND INTEGRAL FORMS OF GOVERNING EQUATIONS

Thermodynamic concepts - Reynolds Transport Theorem - Control Volume Analysis and Integral forms of governing equations - wave propagation and sonic velocity **(10)**

ADIABATIC FLOW THROUGH VARIABLE CROSS-SECTIONAL AREA

Flow of general fluid without losses - flow of perfect gases with losses - Reference Concept - nozzle and diffuser performance **(9)**

SHOCKS - STANDING NORMAL, MOVING AND OBLIQUE SHOCKS

Shock analysis and Normal Shock Relations - shocks in nozzle - shocks in wind tunnel operation - Normal velocity superposition - Tangential velocity superposition - boundary conditions of flow direction and pressure equilibrium **(12)**

PRANDTL MEYER FLOW AND SUPERSONIC NOZZLE DESIGN

Analysis of Prandtl- Meyer flow - Prandtl Meyer function - Over-expanded and Under-expanded Nozzles - Supersonic Airfoils - Method of Characteristics for Design of Supersonic Nozzles **(10)**

FANNO AND RAYLEIGH FLOW

Analysis for general fluid - governing equations for perfect gas - reference states - Friction and thermal Choking - Combination with normal shock - Applications of Fanno and Rayleigh flow **(10)**

REAL GAS EFFECTS

Semi-perfect Gas Behavior - development of Gas Table - Real Gas Behavior - Equations of State and Compressibility Factors - Constant Area Flow and Variable Area Flow with Variable **(9)**

TOTAL : 60

TEXT BOOK

1. *Robert D Zucker and Oscar Biblarz, Fundamentals of Gas Dynamics, John Wiley and Sons, 2nd Edition, New York, 2010.*

REFERENCES

1. *John D. Anderson Jr., Modern Compressible Flow - With Historical Perspective, 2nd Edition, McGraw Hill, 1990.*
2. *Muralidhar, K. and Biswas, G., Advanced Engineering Fluid Mechanics, Narosa Publishing House, New Delhi, 1999.*
3. *Alan Jeffrey, Advanced Engineering Mathematics, Academic Press, Elsevier India, 2002.*
4. *Murray, R. Spiegel, "Vector Analysis and an Introduction to Tensor Analysis", Schaum's Outline of Theory & Problems in, Schaum Publishing Company, USA, 1959.*
5. *Imries, B W., Compressible Fluid Flow, Butterworth, 1973.*

Syllabi for Elective Courses

15MMHE01 - DESIGN AND OPTIMIZATION OF THERMAL EQUIPMENT

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course introduces system simulation as a tool for energy analysis of power generating, air conditioning, refrigeration, and other thermal processing plants. Simulation is used in the design or development stage to evaluate energy requirements of the proposed system or to explore potential savings in first cost. Several optimization techniques used in industry are covered in this course.

COURSE OUTCOME

The student will be able to

1. *Upon completion of the course the student is expected to have the necessary skills required to model and solve problems related to design and optimization of thermal equipment using standard optimization techniques.*
2. *The background material will also be useful to the student when he/she tries to design and optimize the performance of thermal equipment*
3. *Develop the ability and the necessary skills to design thermal-fluid systems.*
4. *Analyze the performance characteristics of a number of components in thermal and energy systems including (but not limited to) heat exchangers, condensers, evaporators, pumps, fans, turbines, pipes and ducts.*
5. *Write computer programs and use existing commercial software such as Fluent to analyze and design thermal systems.*
6. *Communicate effectively through group participation in course project.*

DESIGN AND OPTIMIZATION

Overview of the steps followed for making decisions in engineering; Basic Considerations in Design, Formulation of the design problem need or opportunity; criteria of success; probability of success; market analysis; feasibility; iterations; research and development optimization **(12)**

EQUATION FITTING AND MODELING OF THERMAL EQUIPMENT

Mathematical modeling; matrices; polynomial representation; Lagrange interpolation; function of two variables; exponential forms; selecting versus simulating; counter flow heat exchangers; evaporators and condensers; pumping power and turbo machinery. **(12)**

SYSTEM SIMULATION AND OPTIMIZATION

Description of system simulation; information-flow diagrams; sequential and simultaneous calculations; successive substitution method; Newton-Raphson method; setting up the mathematical statement of the optimization problem in terms of a single objective function and a number of constraints; several illustrative examples. **(12)**

LAGRANGE MULTIPLIER METHODS

Calculus for optimizing unconstrained problems (single and multiple variables); Lagrange Multiplier equation (unconstrained and constrained problems); test of maximum or minimum. **(12)**

LINEAR PROGRAMMING

Mathematical statement and geometric visualization of the method; the Simplex Algorithm; maximization or minimization with inequality constraints; mixed equality and inequality constraints. **(12)**

TOTAL : 60

REFERENCES

1. *Stoecker, W.F, Design of Thermal Systems, 3rd edition, McGraw-Hill, 2011.*
2. *C. Balaji, Essentials of Thermal System Design and Optimization, Ane Books, New Delhi in India and CRC Press, 2010*
3. *Adrian Bejan, George Tsatsaronis , Michael Moran, Thermal Design and Optimization, John Wiely & Sons, Inc, 1996*
4. *Kakac. S. and Liu.H., Heat Exchangers, CRC Press, 2002.*
5. *Stoecker, W.F, Refrigeration and Air-Conditioning, McGraw Hill Book Company, 1985.*
6. *Ozisik M.N, Heat Exchanger, Tata McGraw Hill, 1988.*
7. *Arthur P.Fraas, Heat Exchanger Design, John Wiley & Sons, 1988.*
8. *Yogesh Jaluria, Design and Optimization of Thermal Systems, CRC Press, Taylors and Francis Group, 2007.*
9. *K. Deb, Optimization for Engineering Design-Algorithms and Examples, Prentice-Hall India, 1995.*

15MMHE02 - COMBUSTION AND INTERNAL COMBUSTION ENGINES

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course aims to enable first year post graduate students of heat power engineering to

- *Explain mechanism of combustion, and types of flames*
- *Distinguish normal and abnormal combustion in SI and CI Engines*
- *Develop simplistic model for combustion through theoretical and numerical illustrations*

COURSE OUTCOME

The student shall be able to

CO1 : *Explain thermodynamics and chemical kinetics of combustion*

CO2 : *Distinguish between types of flames, combustion mechanisms in engines and thermodynamic models for SI and CI engines with aid of diagrams*

CO3 : *Construct global one-step reaction model and two-zone model for engine combustion*

THERMODYNAMICS OF COMBUSTION, CHEMICAL KINETICS AND REVIEW OF TRANSPORT EQUATIONS

Properties of mixtures - Combustion stoichiometry - Heating values - Adiabatic flame temperature - Nature of combustion chemistry - Elementary reaction rate - Simplified models of combustion chemistry, Review of mass transfer - Conservation equations of mass, species, momentum and energy - Normalized form of conservation equations - Transport properties **(12)**

PREMIXED FLAMES AND DIFFUSION FLAMES

Physical processes - Flammability limits and flame quenching - Minimum energy for sustained ignition and flame propagation - turbulent premixed flames - Structure of non-premixed laminar free jet flames - Burke-Schumann jet diffusion flame - Turbulent jet flames - Condensed fuel fires **(9)**

DROPLET EVAPORATION AND COMBUSTION

Droplet vaporization in convective Flow - Droplet combustion - Initial heating of a droplet - Droplet diffusion **(6)**

FUEL-AIR CYCLE AND ACTUAL CYCLES

Fuel air cycle - Variation of specific heat - Dissociation and chemical equilibrium loss - Comparison of p-v diagram - thermal efficiency and fuel consumption - effect of variables - Actual cycle - Heat loss factor - Time loss factor - Exhaust blow-down **(9)**

COMBUSTION IN I.C. ENGINES

Auto-ignition and effect of pressure on auto-ignition - Piloted ignition, Normal and abnormal combustion in SI engines - Octane rating - Gasoline direct injection - Normal and abnormal combustion in CI engines - Cetane rating - Homogeneous charge compression ignition engine - Simplified two-zone model of engine combustion **(9)**

TOTAL : 45

TEXTBOOK

1. *McAllister S., Jyh Y-Cn and Fernandez-Pello A.C., "Fundamentals of Combustion Processes", Springer, New York, 2013.*
2. *Heywood J.B., "Internal Combustion Engines Fundamentals", 2nd Edition, McGraw Hill, 1989.*

REFERENCES

1. *Williams F.A., "Combustion Theory - The Fundamental Theory of Chemically Reacting Flows", 2nd Edition, The Benjamin-Cummings Publishing Company, 1985.*
2. *Turns S.R., "An Introduction to Combustion - Concepts and Applications", 3rd Edition, McGraw Hill, 2011.*
3. *El-Mahallawy F. and Habik S.E., "Fundamentals and Technology of Combustion", Elsevier Science, 2002.*

15MMHE03 - FINITE ELEMENT ANALYSIS

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

- *To provide procedure of finite element formulation and solution method to engineering problems.*
- *To acquire knowledge about various types of elements and their corresponding applications*
- *To gain knowledge about solving isoparametric and axisymmetric problems*
- *To solve heat transfer and fluid flow problems.*

COURSE OUTCOME

On completion of this course the student will be able to,

1. *Demonstrate finite-element modeling and model verification techniques.*
2. *Apply finite element techniques to formulate and solve, structural ,fluid, and thermal problems .*
3. *Critically analyze engineering problems and develop reasonable finite element models to simulate those problems.*
4. *Develop methods to enable life long learning in engineering problems.*

INTRODUCTION TO FINITE ELEMENT METHOD

Modeling and Discretization - Nodes, elements, degree of freedom, Interpolation, Boundary Conditions, Computational Procedure - Solution of equations- Ritz method, Variational method, method of weighted residuals, engineering application of finite element method **(12)**

ELEMENTS

1D, 2D and 3D elements - Element properties: interpolation polynomials - formulation of element characteristic matrices- linear, quadratic and cubic bar, triangular, rectangular and solid elements, assembly of element matrices and vectors and derivation of system equation - solution of finite element equation - computation of element resultants - nodal loads and elemental stresses. **(12)**

ISOPARAMETRIC AND AXISYMMETRIC FORMULATIONS

Isoparametric formulations of 1D bar, 2D triangular, quadrilateral, hexahedral elements, determination of shape functions-continuity equation, axisymmetric elements and its formulations - numerical integration. nodal loads - stress calculations, 2D and 3D problems and applications. **(12)**

HEAT TRANSFER

Basic equations of heat transfer - derivation of finite element equations - one and two dimensional conduction and convection heat transfer, axisymmetric and time dependent heat transfer - simple problems. **(12)**

FLUID MECHANICS

Basics equations of fluid mechanics - inviscid incompressible flows, potential and stream function formulation, one and two dimensional fluid flow problems, Viscous Flows - simple problems. **(12)**

TOTAL : 60

TEXT BOOKS

1. *Rao.S.S., "The Finite Element Method in Engineering", 5th Edition, Pergamon Press, 2010.*
2. *Daryl L.Logan, "A First Course in the Finite Element Method, 5th Edition, Cengage Learning, 2010.*

REFERENCES

1. *Kenneth H.Huebner, Dewhirst,D.L.Smith,D.E. and Byrom,T.G. "The Finite element Method for Engineers", John Wiley and Sons, 4th Edition,2008.*
2. *David V.Huton, "Fundamentals of Finite Element Analysis", Tata Mc-Graw-Hill, 4th Reprint 2008.*
3. *Vince Adamsand Abraham Askenazi, "Finite Element Analysis",Onword Press, 1st Edition , 1999.*
4. *Tirupathi.R.Chandrupatla and Ashok.D.Belegundu, "Introduction to Finite Elements in Engineering", Prentice -Hall of India Pvt Ltd, 4th Edition, 2012.*
5. *J.N.Reddy, "An introduction to the Finite Element Method, Tata McGraw-Hill, 3rd Edition, 2006.*
6. *Krishnamoorthy.C.S.,"Finite Element Analysis", Tata McGraw-Hill Publishing Co.Ltd., 2nd Edition , 2001.*

15MMHE04 - CRYOGENICS

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

This course is intended to make the student learn cryogenic engineering which involves the design and development of systems and components which produce, maintain and utilize low temperature well below -150ºC.

COURSE OUTCOME

The student will have

1. *Knowledge of low temperature properties of engineering materials and liquefaction systems of gases.*
2. *Engineering aspects of cryogenics as design and analysis of systems used to produce, maintain and utilize low temperatures.*
3. *Knowledge of rectification columns for separation of gases.*
4. *Knowledge of design of cryogenic fluid storage systems and the applications of cryogenics.*

GAS-LIQUEFACTION SYSTEMS

System performance parameters- ideal system, liquefaction systems-simple Linde Hampson, Claude systems-systems for Neon, Hydrogen and Helium. **(9)**

CRYOGENIC REFRIGERATION SYSTEM

Claude refrigerator-Philips refrigerator, Solvay, Gifford-MC Mahon refrigerators-magnetic cooling-magnetic refrigerators systems. **(9)**

SEPERATION AND PURIFICATION SYSTEMS

Theoretical plate calculations of Air columns-air separation systems-Linde double column systems-Argon, Neon, Hydrogen and Helium separation systems-Gas purification methods. **(9)**

MEASUREMENT SYSTEMS

Temperature, pressure, flow rate, fluid quality, liquid level measurement systems. **(9)**

STORAGE AND APPLICATIONS

Cryogenic fluid storage systems-vacuum technology-applications of cryogenics. **(9)**

TOTAL : 45

REFERENCES

1. *Randall F. Barron,"Cryogenic Systems" Oxford University Press, 1985.*
2. *Scott, R. B.,, "Cryogenic Engineering", Van Nostrand, Princeton, 1959.*
3. *Marshall sitting," Cryogenic Research and Application", 1973.*
4. *Guy K White "Experimental Techniques in Low Temperature Physics", 4th edition, Clarendon press,* Oxford,2002.
5. Thomas M Flynn, "Cryogenic Engineering", Kindle Edition, 2009.

15MMHE05 - BOILER TECHNOLOGY

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

- *Students will acquire fundamental core knowledge in the basic components of boilers and thermal parameters of boilers*
- *The operations of combustion, boiler thermodynamics, heating surfaces and boiler operation*
- *Design of boiler drum and its accessories*
- *ISI code's of testing and safety methods*

COURSE OUTCOME

On completion of the course, the student will

1. *Have conceptual knowledge and components of boilers and thermal parameters of boilers*

Be able to

2. *Understand the various processes in combustion, fuel handling, and energy balance in steam boilers.*
3. *Carry out design of boiler drum and its accessories along with inspection of steam generators.*
4. *Formulate and solve problems involving heat gain in a furnace and features of firing systems then, insulation and sizing of steam generator*
5. *Understand and apply safety methods in design of Boilers, Fuel firing with various burners available for combustion.*
6. *Write, read, speak and listen to technical articles and communicate logically and effectively*

INTRODUCTION

Parameter of a Steam Generator - Thermal Calculations of a Modern Steam Generator - Tube Metal Temperature Calculation and choice of Materials - Steam Purity Calculations and Water Treatment. **(12)**

HEAT BALANCE

Heat transfer in Furnace - Furnace Heat Balance - Calculation of Heating Surfaces - Features of Firing Systems for Solid, Liquid and Gaseous Fuels - Design of Burners. **(12)**

BOILER DESIGN

Design of Boiler Drum - Steam Generator Configuration for Industrial Power and Recovery Boilers - Pressure Loss and Circulation in Boilers. **(12)**

DESIGN OF ACCESSORIES

Design of Air Preheaters - Economisers and Superheater for high Pressure Steam Generators - Design Features of Fuel Firing Systems and Ash Removing systems. **(12)**

BOILER CODE

IBR and International Regulations - ISI Code's Testing and Inspection of Steam Generator - Safety Methods in Boilers - Factor of Safety in the Design of Boiler Drums and Pressure Parts - Safety of Fuel Storage and Handling - Safety Methods for Automatic Operation of SteamBoilers. **(12)**

TOTAL : 60

REFERENCES

1. *David Gunn, Robert Horton, "Industrial Boilers", Longman Scientific & Technical Publication, 1989.*
2. *Carl Schields, "Boilers - Type, Characteristics and Functions", McGraw Hill Publishers, 1982.*
3. *"Modern Power Station practice (8 Vol)", Central Electricity Generation Board, 1980.*
4. *Richard Dolezal, "Large Boiler Furnaces", Elsevier Publishing Company, 1980.*
5. *http://dipp.nic.in/boiler_rules_updated/foreword.htm*

15MMHE06 - ABSORPTION AND STEAM JET REFRIGERATION SYSTEMS

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

To give an idea about the absorption refrigeration system which is used for large industrial applications and about steam jet refrigeration systems which is widely used for food processing

COURSE OUTCOME

Upon completion of the course, the student shall

1. *Have an advanced level of understanding of the thermodynamic processes of providing refrigeration using multi-component liquid -vapour mixturesand steam ejectors.*

Be able to:

2. *Understand simple vapour absorption system, absorbent combination then thermal processes with binary mixtures.*
3. *Be able to confidentlyable to attempt and gain employment in the refrigeration and air-conditioning industries.*
4. *Formulate and solve problems involving heat gain in a furnace and features of firing systems then, insulation and sizing.*
5. *Get involved in principle of ejector refrigeration system, injector co-efficient and application.*
6. *Develop skills in assignment writing, reading, speaking and listening, needed to communicate logically and effectively.*

INTRODUCTION TO ABSORPTION SYSTEM

Simple vapour absorption system-maximum coefficient of performance-commonly used refrigerant-absorbent combination-advantages of absorption systems. **(9)**

BINARY MIXTURES

Evaporation and condensation characteristics of Homogeneous binary mixtures-adiabatic mixing of two streams - mixing with heat exchange-thermal processes with binary mixtures-differential and continuous vaporization and condensation. **(9)**

SEPERATION OF MIXTURES

Reflux cooling - coupled purification Column-modifications to simple vapour absorption systems-liquid-Liquid heat exchanger-dephlegmator-actual cycle-representation on enthalpy composition diagram-Electrolux refrigerator. **(9)**

EJECTOR REFRIGERATION

Vacuum refrigerator-centrifugal water vapour system-principle of ejector refrigeration system-water-cooling and equilibrium concentration. **(9)**

STEAM JET EJECTORS

Theoretical analysis of steam ejector-injection coefficient-efficiencies-refrigerant ejectors-applications.

(9)

TOTAL : 45

REFERENCES

1. *Arora C.P., "Refrigeration and Air Conditioning", 3rd edition, Tata Mc Graw Hill Publications, 2008.*
2. *Sparks and Dillio,"Mechanical Refrigeration", Mc Graw Hill,1959.*
3. *Anathanarayanan, P. N., Basic Refrigeration and Air Conditioning, 4th edition, Tata McGraw - Hill publishing company Limited, 2013.*
4. *Jain, V. K., Refrigeration and Air Conditioning, S. Chand & Company Ltd, 1986.*
5. *Manohar Prasad, Refrigeration and Air Conditioning, 2nd edition, 2003*
6. *Manohar Prasad, Refrigeration and Air Conditioning Data Book, 2nd edition 2003.*
7. *Ballany,P.L., Refrigeration and Air Conditioning, Khanna Publishers 2006.*
8. *Kenneth Wark, Advanced Thermodynamics for Engineers, McGraw Gill, 1994.*

15MMHE07 - DESIGN AND ANALYSIS OF EXPERIMENTS

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

To provide a thorough background into basic of design and analysis.

COURSE OUTCOME

On completion of this course the student will be able to,

1. *demonstrate different types of experimental designs and analysis of data.*
2. *design experiments, carry them out and analyze the data obtained from the experiment.*
3. *identify the problem, design and conduct experiments and optimize the solutions obtained*

INTRODUCTION

Basic principles, guidelines for designing experiments, Basic statistical concepts, inferences about the differences in mean, randomized, paired comparison designs, Analysis of variance. **(9)**

RANDOMIZED BLOCKS, LATIN SQUARES AND RELATED DESIGNS

Completely randomized, randomized, Latin square, Graceo-Latin square and crossover designs. **(9)**

FACTORIAL DESIGN

Advantage of factorials, description, calculation of direct and interaction effects. 2k factorial designs. Blocking and confounding - principles and use of confounded designs. **(9)**

FRACTIONAL FACTORIAL DESIGN

Two- three- and mixed-level fractional factorial designs-applications. **(9)**

RESPONSE SURFACE DESIGN

Fitting regression model. Response Surfaces - first and second order designs. **(9)**

TOTAL : 45

REFERENCES

1. *Douglas C.Montgomery, "Design and Analysis of Experiments",John Wiley & Sons, Inc., Fifth Edition, 8th edition, 2013.*
2. *Cochran W.G. and Cox G.M., "Experimental Designs", Second Edition, John Wiley & Sons, 2006.*
3. *JohnLawson and John Erjavee, "Modern Statistics for Engineering and Quality Imrovement" Duxbury, 2001.*
4. *Stephen R Schmidt and Robert G launsby, "understanding Industrial Designed Experiments", Air Academy Press, 199.*
5. *Davies O.L., "The Design and Anlaysis of Experiments", Longman Group Ltd., 1978.*
6. *Andre I Khuri and John A Cornel, "Response surfaces - Design and Analysis", 1987.*

15MMHE08 - RESEARCH METHODOLOGY

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE OBJECTIVE

To provide a thorough background of Research, design criteria, scaling techniques and report writing.

COURSE OUTCOME

The student after completion of the course shall be able to

1. *Identify and formulate a problem for research and also a methodology for solving the same.*
2. *Recognize reliable source of data and the techniques to assemble the same, for further analysis.*
3. *Develop and conduct experimental and/or theoretical methodologies for solving a problem, and interpret the results from the studies.*
4. *Present the methodology and the interpretation of the results skilfully, both in oral and written forms.*

DEFINING THE RESEARCH PROBLEM

Formulation of research problem; Identification and selection of problem. Meaning purpose and principles of research design. Design criteria-different types of research and Experimental design. **(9)**

METHODS OF DATA COLLECTION

Sources of data- methods of data collection- observation, questionnaire, interview schedules and interviews. **(9)**

MEASUREMENT AND SCALING TECHNIQUES

Measurement in research- measurement in scales- scaling techniques, scale constitution techniques- content analysis. Processing and analysis of data-processing operation- problem in processing, types of analysis. **(9)**

MULTIVARIATE ANALYSIS TECHNIQUES

Characteristics and application of multivariate analysis, classification of multivariate analysis, classification of multivariate analysis- important multivariate techniques, Factor analysis, path analysis. **(9)**

INTERPRETATION AND REPORT WRITING

Meaning and techniques of interpretation, significance of report writing, different types of steps in report writing, case studies. **(9)**

TOTAL : 45

REFERENCES

1. *Kothari C.R., "Research Methods: Methods and Techniques", 2nd Edition, New Age International, 2004.*
2. *Kidder L.H., "Research Methods in Social Relations", Hall Saunders International, 2002.*
3. *Sadhu A.N. and Singh A., "Research Methodology in Social Sciences", Himalaya Publishing House, Mumbai, 2013.*

15MMHE09 - PERFORMANCE ANALYSIS OF HEAT EXCHANGERS

L	T	P	C
4	0	0	4

ASSESSMENT : THEORY

COURSE OBJECTIVE

- *This course aims is covers a range of relevant topics including the main considerations for equipment selection and design, and different methods of analysis for performance and sizing.*
- *The goal is for students to become familiar with the design and specification of heat exchangers by solving practical problems using a synthesis of other mechanical engineering subjects such as thermodynamics, heat transfer, and fluid mechanics*
- *And also familiarize students with the applications of multiphase flows.*

COURSE OUTCOME

The student will be able to

1. *An ability to apply knowledge of mathematics, science, and engineering principles relevant to area of fluid/thermal*
2. *Selects and apply an appropriate models or simulations of the real world and analyzes outputof models/simulations to provide information for design decisions.*
3. *Performs feasibility analysis and uses results to choose candidate solutions and evaluates quality of solutions to select the best once.*
4. *An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, and sustainability*
5. *Select the proper model to solve problems by using modern software packages, employed as standard tools in the industrial and developmental environment.*

INTRODUCTION

Classification of Heat Exchangers - Heat Transfer Mechanisms - Flow Arrangements - Applications - Selection of Heat Exchangers **(3)**

ANALYSIS OF HEAT EXCHANGER

Introduction - Arrangement of flow paths in Heat Exchangers - Overall heat transfer co-efficient - LMTD and - NTU Method for heat exchanger analysis - Heat exchanger design methodology - Variable overall heat Transfer co-efficient - Heat exchanger design calculation. **(12)**

FORCED CONVECTION CORRELATIONS FOR SINGLE-PHASE HEAT EXCHANGERS

Introduction - Hydro dynamically developed & Thermally developing laminar flow in smooth circular ducts - Effect of variable physical properties - laminar flow of liquids and gases in ducts -Turbulent forced convection - Turbulent flow in smooth straight non- circular ducts - Turbulent flow liquid and gases in ducts. **(12)**

SHELL-AND-TUBE HEAT EXCHANGERS

Introduction - Basic components - Basic design procedure of a heat exchanger - Preliminary estimation of unit size -Rating of the preliminary design - Shell and tube -Side heat transfer, pressure drop, heat transfer coefficient -Bell-Delaware method- Design of heat exchanger subject to fouling. **(9)**

HEAT EXCHANGER PRESSURE DROP AND PUMPING POWER

Introduction - Tube-side pressure drop - Circular cross-section tubes - Non circular cross-sectional ducts - Pressure drop in tube bundles in cross flow - Pressure drop in helical and spiral coils - Pressure drop in bends and fittings - Pressure drop for abrupt contraction, expansion, and momentum change - pumping power **(12)**

HEAT EXCHANGERS WITH TWO-PHASE FLOW

Introduction - Characteristic of multiphase flow - Classification of two-phase flow -Evaporator - Condensers - Flow pattern maps for vertical and horizontal in-tube and shell side flows - Thome's flow pattern - Void fraction - dryness fraction. **(12)**

TOTAL : 60

REFERENCES

1. *Sadik Kakaç, Hongtan Liu , Anchasa Pramuanjaroenkij, Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2012*
2. *Arthur P.Frass, " Heat Exchanger Design ", Second Edition, John Wiley & Sons, New York, 1996.*
3. *T.Taborek, G.F.Hewitt and N.Afgan "Heat Exchangers ", Theory and Practice, McGraw Hill Book Co., 1980.*
4. *Walker, " Industrial Heat Exchangers " - A Basic Guide, McGraw Hill Book Co., 1980.*
5. *Holger Martin, "Heat Exchangers ", Hemisphere Publishing Corporation, London, 1992.*
6. *Ramesh K, Shah and Dusan P. Sekulic, "Fundamental of Heat Exchangers Design, John Wiley & Sons, Inc., 2003.*

15MMHE10 - SOLAR ENERGY UTILIZATION

L	T	P	C
3	0	0	3

ASSESSMENT : THEORY

COURSE DESCRIPTION

An introductory course into the mathematical framework necessary for the design and analysis of solar

COURSE OBJECTIVE

- *To introduce students to various applications of solar energy by enhancing their knowledge on solar energy availability, solar energy collection and utilization of solar energy*
- *To develop skills for estimation of solar energy availability and design of solar energy systems*
- *To be able to apply knowledge of mathematics, science and engineering principles that are necessary for the analysis, design, and application of solar energy*
- *To be able to recognize energy issues, understand and deal with the impact of solar energy solutions in a global and societal context*

COURSE OUTCOME

The student will be able to

1. *Upon completion of the course the student is expected to be able to analyze issues related to renewable solar energy*
2. *The background material will also be useful to the student when he/she tries to design solar energy collectors and assess their performance during operation*
3. *An ability to understand the impact of engineering solutions in a global, economic, environmental, and societal context.*
4. *An ability to visualize and design various thermal components, systems, or processes to meet desired needs amid realistic constraints such as economical, environmental, social, political, ethical, health and safety, manufacturability and sustainability*

INTRODUCTION TO SOLAR ENERGY

Introduction, overview of applications (solar drying, solar desalination, solar mechanical cooling, solar dessicant cooling, solar heat pump), calculation of solar constant, terminology related to solar radiation, definition and calculation of solar times, definition and calculation of all solar angles and related earth angles **(9)**

SOLAR CALCULATION AND SOLAR COLLECTORS

Calculation of extra-terrestrial irradiation on a horizontal surface on an hourly and daily basis, relationship between radiation on titled and horizontal surfaces, effect of atmosphere on solar radiation, Hottel's estimation of clear sky radiation, types and classification of solar collectors, terminology related to non-concentrating collectors, efficiency of a solar collector **(9)**

THERMAL MODELLING OF NON-CONCENTRATING COLLECTORS

Modeling of heat transfer processes in flat plate collector, formula for effective transmittance-absorptance product, estimation of top, bottom and overall heat loss coefficient using resistance network method, collector stagnation temperature, temperature distribution between tubes and along tubes, collector efficiency factor F, collector heat removal factor FR, collector heat exchanger modelling and combined efficiency factor FR **(9)**

THERMAL MODELLING OF CONCENTRATING COLLECTORS

Classification, design and performance parameters; Tracking systems; compound parabolic concentrators; parabolic trough concentrators; concentrators with point focus; Heliostats; comparison of various designs; central receiver system, parabolic trough system; solar power plant; solar furnace **(9)**

DESIGN OF SOLAR HEATING SYSTEMS

Calculation of space and water heating loads, degree-days, F-chart method for air and liquid based system, overview of active and passive heating, shading calculation using vector algebra, lumped modelling of unsteady effects in solar thermal storage devices. **(9)**

TOTAL : 45

REFERENCES

1. *Sukhatme S. P., "A Text book on Heat Transfer", 4th edition, University Press, 2005.*
2. *Garg H.P. and Prakash J., "Solar Energy: Fundamentals & Applications", Tata McGraw Hill, New Delhi, 2012.*
3. *Sukhatme S. P., "Solar Energy", Tata McGraw Hill, New Delhi, 3rd edition, 2008.*
4. *Duffie J. A. and Beckman W. A., "Solar Engineering of Thermal Processes", John Wiley & Sons Inc., New York, 2005.*
5. *Tiwari G.N. and Suneja S., "Solar Thermal Engineering System", Narosa Publishing House, New Delhi, 1997.*
6. *Tiwari G.N., Goyal R.K., "Greenhouse Technology: Fundamentals,Design Modelling and Application", Narosa Publishing House, 1998.*
7. *Rai G.D., "Solar energy Utilization", Khanna Publishers, New Delhi, 2002.*
8. *T.Bhattachariya, "Terrestial solar Photovoltaic", Narosa Publishers, New Delhi, 2008.*
9. *H.S.Rauschenbach, "Solar Cell Array Design Hand Book", Van Nostrand Reinfold Company, New York, 1980.*