Nirma University
Institute of Technology
School of Engineering

Mechanical Engineering Department

M.Tech Thermal Engineering

3ME2104 Exergy Analysis of Thermal Systems [3 1 0 4]

Course Learning Outcome:

After successful completion of the course, student will be able to

- apply first law, second law and entropy principle to various thermodynamic systems.
- analyze and apply exergy, irreversibility and second law concepts to various engineering processes occurring in thermodynamics systems.
- evaluate performances of various thermal systems using exergy analysis concept.

Syllabus:

Introduction to thermodynamics: Basic concepts of energy analysis of thermal systems.
Basic exergy concepts: Classification of forms of exergy, concepts of exergy, exergy concepts for control volume, physical exergy, exergy concepts for closed systems analysis, non flow analysis
Elements of Plant Analysis: Control volume analysis, criterion for performance, pictorial representation of exergy balance, exergy based property diagram.
Exergy Analysis in Process: Expansion process, compression process, heat transfer process, mixing process, separation process, and combustion processes.
Energy and Exergy Analysis of gas turbine, steam power plant, captive power plant, combined cycle power plant, refrigeration plant, heat exchanger.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self study contents.

Tutorial Work:

Tutorial work will be based on above syllabus will be incorporated.

References:

1. Adrian Bejan, Advanced Engineering Thermodynamics, John Wiley & Sons, Inc.
2. Winterbore D. E., Advance Thermodynamics for Engineers, Arnold Publication
3. Kenneth Wark, Advanced Thermodynamics for Engineers, McGraw Hill
4. Adrin Bejan, Entropy Generation Minimization: The Method of Thermodynamic Optimization of Finite Size and Finite Time Processes, CRC Press.
5. Michel J. Moran, Howard N. Shapiro, Daisie D. Boettner, Margaret B. Bailey, Fundamentals of Engineering Thermodynamics, John Wiley & Sons, Inc.
6. Richard E. Sonntag, Claus Borgnakke and Gordon J. Van Wylen, Fundamentals of Thermodynamics [CD] by, John Wiley & Sons, Inc.

3ME2107 Viscous Fluid Flow [3 0 0 3]

Course Learning Outcome:

After successful completion of the course, student will be able to:

- apply the fundamentals of kinematics and conservation laws to fluid flow systems.
- apply the principles of high and low Reynold number flows to fluid flow systems.
- review the concepts of boundary layer and flow in transition.
- analyse and apply the fundamentals of turbulent flow to various fluid flow systems.

Syllabus

Review of basic concepts and fluid properties: basic laws of Fluid Motion, internal stresses and external forces on fluid elements, Review of concepts of Kinematics of fluid motion, vorticity, circulation, velocity potential and stream function, irrational flow.
Governing equations of fluid flow in differential form: Navier Stokes Equation and exact solutions, energy equation and solution of fluid flow with thermal effects.
Dynamics of ideal fluid motion: applications, integrations of Euler's Equation of Motion, generalized form of Bernoulli Equation, potential flows, Principle of superposition.
Low Reynolds number approximation of Navier Stokes equation: creeping flow over sphere, Stokes and Oseen approximation, Hydrodynamic Theory of Lubrication.
High Reynolds number approximation: Prandtl's Boundary Layer Equations, Laminar Boundary Layer over a flat plate, Blausius solution, Falkner-Skan solution, Approximate method for solution of B.L. Equation, Momentum Integral methods, Holstein and Bohlen method, Thermal Boundary layer, Reynolds Analogy.
Transition to turbulence: introduction to Theory of Hydrodynamic Stability, OrrSommerfield equation, results from transition studies, factor affecting transition and its control.
Fundamental of turbulent flows: Reynolds stress tensor, Phenomenolgoical theories of turbulence, Prandtl's Mixing Length and Eddy Viscosity concepts, Universal Velocity distribution, Laws of the Wall and the Wake.
Turbulent flows in two dimensional channel and pipes: velocity field. Smooth and rough pipes, drag reduction in pipes, turbulent boundary layer over a flat plate, laws of drag over flat plates, effect of pressure gradient, boundary layer control, Reynolds analogy for turbulent flow.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self study contents.

References:

1. Yunus Cengel and John Cimbala , Fluid Mechanics, Tata McGraw Hill Publishing Co. Ltd.
2. F. M. White, Viscous Fluid Flow, McGraw Hill Book Co.
3. H. Schlichting, Boundary Layer Theory, McGraw Hill Book Co.
4. F.M. White, Fluid Mechanics, McGraw Hill Book Co.
5. Fox, Pritchard and McDonald, Introduction to Fluid Mechanics, John Wiley & Sons.

3ME2108 **Advanced Heat Transfer** **[3 0 2 5]**

Course Learning Outcome:

After successful completion of the course, student will be able to

- analyse steady state and transient heat conduction in thermal systems
- analyse extended surface heat transfer, phase change heat transfer and radiation heat transfer principles.
- appreciate the basic concepts of micro-scale heat transfer and numerical methods for conduction heat transfer.

Syllabus

Transient heat conduction: Exact solution, Use of Heisler and Grober chart, integrated method.

Heat conduction with heat generation: plane wall and cylinder with uniform heat generation, applications. Two-dimensional steady state conduction.

Extended surfaces: Steady state analysis and optimization, Radial fins of rectangular and hyperbolic profiles-longitudinal fin of rectangular profile radiating to free space.

Thermal boundary layers: Momentum and energy equations, Internal and external flows, Forced convection over cylinders, spheres and bank of tubes.

Heat transfer with phase change: condensation and boiling heat transfer, Heat transfer in condensation, Effect of non-condensable gases in condensing equipments, film boiling correlations.

Radiation heat transfer: Review of radiation principles, Hottel's method of successive reflections, Gebhart's unified method, Poljak's method. Radiation exchange with emitting and absorbing gases. Radiative exchange and overall heat transfer in furnaces.

Numerical methods in heat conduction.

Micro-scale heat transfer- basics with applications.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

Laboratory Work:

It will consists of experiments based on above syllabus.

References:

1. Incropera, P.P. and Dewitt, D.P., Fundamentals of Heat and Mass Transfer, Wiley Eastern
2. Eckert and Drake, Analysis of Heat and Mass Transfer, McGraw Hill.
3. Adrian Bejan, Convective Heat Transfer, Wiley India.
4. Kays, Crawford and Weigand, Convective Heat and Mass Transfer, McGraw Hill.
5. Siegel and Howell, Thermal Radiation, McGraw Hill.
6. Kraus, A.D., Aziz, A., and Welty, J, Extended Surface Heat Transfer, McGraw Hill
7. Adrian Bejan, Allan D. Krams, Heat Transfer Handbook, John Wiley & Sons

3ME2109 **Seminar** **[0 0 2 2]**

Course Learning Outcome:
After successful completion of the course, student will be able to

- conduct a literature review on a topic allotted for detailed study
- apply modern search engines and internet facility for subject preparation
- develop oral and written presentation skills.

The aim of the Seminar is to prepare the students for literature survey for their major M Tech project. The student will prepare a seminar report on relevant topics and will present the same.

3ME2115 **Refrigeration Engineering** **[3 0 0 3]**

Course Learning Outcome:

After successful completion of the course, student will be able to

- analyse vapor compression and absorption refrigeration systems and related components.
- analyse air cycle and alternate refrigeration systems such as steam jet and thermo-electric refrigeration.
- comprehend the design for various applications of refrigeration such as food preservation, transport and cold storages.

Syllabus:

Refrigerants: Eco-friendly refrigerants and their properties, secondary refrigerants, mixture of refrigerants.
Compound compression systems: Analysis of cycles with flash chamber, water cooler and flash inter cooler.
Multiple evaporator systems: Analysis of evaporators with individual expansion valve with and without flash inter cooling, analysis of various types of cascade systems.
Absorption refrigeration: Analysis of ammonia-water and LiBr–water vapour absorption refrigeration systems with h-x charts and mass concentration equilibrium charts, two stage vapour absorption refrigeration systems.
Air cycle refrigeration: Analysis of various cycles and their applications.
Steam jet refrigeration: Analysis on h-s diagram, performance, control, various applications.
Thermo–electric refrigeration: Thermoelectric effects, analysis of thermoelectric cooling.

Preservation and processing of foods by use of refrigeration, design of refrigeration systems for transport refrigeration, walk in coolers and cold storages for different applications.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

References:

1. Stoecker and Jones, Refrigeration and Air-conditioning, TMH Publication
2. Manohar Prasad, Refrigeration and Air-conditioning, New Age Publication
3. Jordan and Priester, Refrigeration and Air-conditioning, McGraw Hill
4. ASHRAE Hand Book: Refrigeration, ASHRAE
5. Stoecker, Industrial Refrigeration Hand Book, McGraw Hill
6. C P Arora, Refrigeration and Air-conditioning, TMH Publication
7. Threlked, Thermal Environmental Engineering, Wiley Eastern

L	T	P	C
3	0	0	3

Course Code	3ME2111
Course Title	Advanced Thermodynamics

Course Outcomes (CO):

After successful completion of the course, student will be able to-

1. analyze various thermodynamic systems based on first law, second law, entropy and exergy concepts
2. utilize the principles of real gas behavior and multicomponent system for industrial problems
3. assess the combustion phenomenon using thermo chemistry principles
4. evaluate thermodynamic system applying fundamentals of statistical thermodynamics.

Syllabus **Teaching hours: 45**

UNIT-I

15 hours

Entropy and Exergy: Clausius theorem, concept of entropy, Inequality of Clausius, entropy principle and its applications, entropy change for closed and open system, exergy and its types, exergy concepts for control volume and closed system, irreversibility, second law efficiency, exergy analysis of processes and cycles, pictorial representation of exergy balance, exergy based property diagram, exergy costing, exergoeconomic analysis.

UNIT-II

12 hours

Real gas behaviour and multi-component systems: Equations of State (mention three equations), Fugacity, Compressibility, Principle of Corresponding States, Use of generalized charts for enthalpy and entropy departure, fugacity coefficient, Lee-Kesler generalized three parameter tables. Fundamental property relations for systems of variable composition, partial molar properties, Real gas mixtures, Ideal solution of real gases and liquids, Equilibrium in multi-phase systems, Gibbs phase rule for non-reactive components. Phase transition, types of equilibrium and stability, multi-component and multiphase systems, equations of state for multicomponent system.

UNIT-III

06 hours

Thermo chemistry: First law analysis of reactive mixtures, Equilibrium combustion products, Low temperature combustion products, High temperature combustion products, and problems.

UNIT-IV

12 hours

Kinetic theory of gases and statistical thermodynamics: Basic assumption, molecular flux, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity, intermolecular forces, collision cross section, mean free path, energy states and energy levels, macro and micro-scales, thermodynamic probability, thermo statistics, statistical interpretation of entropy, distribution function, application of statistics to gases-mono-atomic ideal gas, distribution of molecular velocities.

Self-Study: The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

References:

1. Adrian Bejan, Advanced Engineering Thermodynamics, John Wiley and Sons.
2. T. J Kotas, The Exergy Method of Thermal Plant Analysis, Krieger Publishing Company
3. Adrian Bejan, George Tsatsaronis, Michael Moran, J, Thermal Design and Optimization, John Wiley and Sons.
4. Wark, Advanced Thermodynamics, McGraw Hill
5. Winterbone, Advance Thermodynamics for Engineers, Butterworth-Heinemann
6. Nellis and Klein, Thermodynamics by Nellis and Klein, Cambridge University Press
7. Francis W Sears and Gerhard L Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa Publishing House, New Delhi.

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
3	0	0	3

Course Code	**3ME2112**
Course Title	**Advanced Fluid Mechanics**

Course Outcomes (CO):
After successful completion of the course, student will be able to-

1. apply the fundamentals of kinematics and conservation laws to fluid flow systems,
2. apply the principles of potential and creeping flows to fluid flow systems,
3. analyse the concepts of boundary layer flow,
4. analyse and apply the fundamentals of turbulent flow.

Syllabus **Teaching hours: 45**

UNIT-I

07 hours

Introduction: Review of basic concepts and fluid properties, vorticity, circulation, stream function, velocity potential function, types of motion of fluid element, strain rate tensor, free and forced vortex flows.

UNIT-II

10 hours

Governing equations of fluid flow in differential form: Mass conservation equation, Navier-Stokes equation, energy equation, dimensionless form of governing equations, flow through pipe and annulus, flow between parallel plates with thermal effects.

UNIT-III

10 hours

Potential flow theory: Euler's equation for inviscid flow, Bernoulli's equation, potential flow, basic flows like uniform flow, source, sink, irrotational vortex, superposition of various flows, Kelvin theorem, design of an airfoil.

Creeping flow: Creeping flow over sphere, Stokes and Oseen approximation, hydrodynamic theory of lubrication.

UNIT-IV

10 hours

Laminar boundary layer: Prandtl's boundary layer equation, laminar boundary layer over a flat plate, Blasius solution, Falkner-Skan solution, Von-Karman integral solution, approximate method for solution of boundary layer equation, momentum integral methods, Holstein and Bohlen method.

UNIT-V

08 hours

Turbulent flow: Characteristics of turbulent flow, transition to turbulent flow, Orr-Sommerfeld analysis, time mean motion and fluctuations, Reynolds equation for turbulent flow, Reynolds stresses, Boussinesq hypothesis, Prandtl's mixing length theory, law of wall, turbulent flow in pipes, turbulent boundary layer on flat plate.

Self-Study:

The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

References:

1. Muralidhar K. and Biswas G., Advanced Engineering Fluid Mechanics, Alpha Science International Ltd.
2. Kakac S., Yener Y. and Pramuanjaroenkij A., Convective Heat Transfer, CRC Press
3. Fox R.W., McDonald A.T , Introduction to Fluid Mechanics, John Wiley and Sons Inc.
4. Kundu P.K., Kohen I.M. and Dawaling D.R., Fluid Mechanics, Elsevier Science Publishing Co Inc.
5. Schlichting H., Boundary Layer Theory, Springer Book Co.
6. Yuan S.W., Fundamentals of Fluid Mechanics, Prentice Hall
7. White F.M., Viscous Fluid Flow, McGraw Hill Book Co.

L = Lecture, T = Tutorial, P = Practical, C = Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
3	0	0	3

Course Code	3ME2113
Course Title	Heat Transfer Processes

Course Outcomes (CO):
After successful completion of the course, student will be able to-

1. analyze steady state and transient heat conduction in thermal systems,
2. analyze extended surface heat transfer, phase change heat transfer and radiation heat transfer principles,
3. appreciate the basic concepts of micro-scale heat transfer.

Syllabus **Teaching hours: 45**

UNIT-I

10 hours

Heat conduction: Transient heat conduction: Exact solution, Use of Heisler and Grober charts. Heat conduction with heat generation: plane wall and cylinder with uniform heat generation, applications. Multi dimensional system. Moving boundary problems. Multi dimensional transient systems. Heat conduction in anisotropic materials.

UNIT-II

06 hours

Extended surfaces: Steady state analysis and optimization, Radial fins of rectangular and hyperbolic profiles- longitudinal fin of rectangular profile radiating to free space.

UNIT-III

09 hours

Convection heat transfer: Thermal boundary layers, Momentum and energy equations, Internal and external flows, Forced convection over cylinders, spheres and bank of tubes. Natural circulation loops, convection in high speed flow.

UNIT-IV

06 hours

Heat transfer with phase change: condensation and boiling heat transfer, Heat transfer in condensation, Effect of non-condensable gases in condensing equipments, film boiling correlations. Flow boiling. Phase change heat transfer during melting/solidification. Stefan and Neumann solutions.

UNIT-V

10 hours

Radiation heat transfer: Review of laws and principles of thermal radiation, Shape factors calculation and estimation, Radiation shields, radiation properties of a participating medium, Radiation exchange with emitting and absorbing gases. Radiative exchange and overall heat transfer in furnaces, cryogenics and space applications.

UNIT-VI

04 hours

Micro-scale heat transfer- basics with applications.

Self-Study:

The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

References:

1. Incropera, P.P. and Dewitt, D.P., Fundamentals of Heat and Mass Transfer, Wiley Eastern
2. Eckert and Drake, Analysis of Heat and Mass Transfer, McGraw Hill.
3. Adrian Bejan, Convective Heat Transfer, Wiley India.
4. Kays, Crawford and Weigand, Convective Heat and Mass Transfer, McGraw Hill.
5. Siegel and Howell, Thermal Radiation, McGraw Hill.
6. Kraus, A.D., Aziz, A., and Welty, J, Extended Surface Heat Transfer, McGraw Hill
7. Tien, Majumdar and Gerner, Microscale Energy Transport, Taylor & Francis
8. Nellis and Klein, Heat Transfer, Cambridge University Press

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
2	1	0	3

Course Code	**3ME2114**
Course Title	**Modelling and Optimization of Thermal Systems**

Course Outcomes (CO):

After successful completion of the course, student will be able to-

1. explain the basic concepts of optimization and its use as a tool for decision making,
2. apply various optimization methods to thermal engineering problems based on linear programming, non-linear programming and stochastic programming,
3. simulate engineering problems which are interdisciplinary in nature using unconventional optimization techniques.

Syllabus **Teaching hours: 30**

UNIT-I

04 hours

Introduction: Design analysis through a flow chart, Optimization, Analysis and Design, Workable system and Optimum system.

UNIT-II

05 hours

System Simulation: Some uses of simulation, Different classes of simulation, Information flow diagram, Techniques for system simulation, System simulation for thermal engineering problems.

UNIT-III

05 hours

Quantitative Techniques: Interpolation-polynomial, Langrangian, curve fitting – Exact fit and its types, Best fit, Strategies for best fit, regression analysis, solution of transcendental equations.

UNIT-IV

09 hours

Optimization: Objectives/constraints, problem formulation. Unconstrained problems- Necessary & Sufficiency conditions, Constrained Optimization-langrange multipliers, constrained variations, Kuhn-Tucker conditions, Linear Programming - Simplex tableau, pivoting, sensitivity analysis, search techniques-Univariate/Multivariate. Case studies of optimization in Thermal systems problems.

UNIT-V

07 hours

Non-traditional Optmization Techniques: Genetic Algorithm (GA)- basics features, principle and robustness of GA, Particle swarm optimization, Simulated Annealing, Artificial Neural Networks.

Self-Study:

The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

References:

1. C Balaji, Essentials of Thermal System Design and Optimization, Ane Books Pvt Ltd.
2. W.F. Stoecker, Design of Thermal Systems, McGraw Hill
3. S S Rao, Optimization Theory and Applications, Wiley Eastern
4. S S Sastry, Introductory Methods of Numerical Analysis, Prentice Hall
5. P. Meier, Energy Systems Analysis for Developing Countries, Springer Verlag
6. Yogesh Jaluria, Design and Optimization of Thermal Systems, CRC Press

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
0	0	4	2

Course Code	**3ME2116**
Course Title	**Thermo-Fluid Engineering Laboratory**

Course Outcomes (CO):

After successful completion of the course, student will be able to-

1. apply the principles of uncertainty analysis to experiments conducted.
2. evaluate the fundamental concepts of thermo-fluid systems through experimentation.
3. identify the effect of relevant parameters on various thermo-fluid systems and able to correlate the same.

Syllabus **Teaching hours: 60**

Experimentation based on thermal and fluid engineering topics such as Advanced Thermodynamics, Advanced Fluid Mechanics and Advanced Heat Transfer, errors in experimental data, uncertainty analysis.

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
0	0	4	2

Course Code	**3ME2117**
Course Title	**Computational Laboratory-I**

Course Outcomes (CO):

After successful completion of the course, student will be able to-

1. apply the principles of programming skills for engineering problem solving
2. make use of software skills to solve problems related to thermo-fluid engineering.

Syllabus **Teaching hours: 60**

Basic concepts in programming skills, computational exercises based on thermal and fluid engineering topics such as Advanced Thermodynamics, Advanced Fluid Mechanics and Advanced Heat Transfer.

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
2	1	0	3

Course Code	**3ME2118**
Course Title	**Energy Conservation and Management**

Course Learning Outcome:
After successful completion of the course, student will be able to

1. understand the overall energy scenario of country and the world
2. prepare energy planning
3. comprehend and apply various models for resource availability predictions
4. demonstrate various energy conservation techniques for effective energy utilization
5. evaluate the viability of energy conservation options through various energy economic indices.

Syllabus **Teaching hours: 30**

UNIT-I

03 hours

Energy Economics: Overview of World Energy Scenario, Overview of India`s Energy Scenario,

UNIT-II

09 hours

Energy Management: Importance of energy management, Country Energy Balance Construction – Examples, Trends in energy use patterns, Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation, Energy Chain, Primary energy analysis Life Cycle Assessment, Net Energy Analysis.

UNIT-III

08 hours

Energy Systems: Boiler -efficiency testing, excess air control, Steam distribution & use- steam traps, condensate recovery, flash steam utilization, Thermal Insulation. Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & Air conditioning systems.

UNIT-IV

05 hours

Waste heat recovery: Recuperators, heat pipes, heat pumps, Cogeneration - concept, options (steam / gas turbines / diesel engine based), selection criteria, control strategy.

UNIT-V

05 hours

Heat exchanger networking: concept of pinch, target setting, problem table approach, composite curves. Demand side management. Financing energy conservation.

Self Study:
The self study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self study contents.

References:

1. Witte. L.C., Schmidt, P.S., Brown,.R., Industrial Energy Management and Utilisation Hemisphere Publication, Washington
2. Industrial Energy Conservation Manuals, MIT Press
3. Frank Kreith and D Yogi Goswami, Energy Management and Conservation Handbook, CRC Press
4. TERI hand book on Energy Conservation
5. Fowler, J.M., Energy and the Environment, McGraw Hill
6. Guide Book for National Certification Examination for Energy Managers and Energy Auditors, Bureau of Energy Efficiencies.

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

3ME2201 Gas Dynamics [3 1 0 4]

Course Learning Outcome:

After successful completion of the course, student will be able to

- apply the fundamentals of the compressible flow and rarefied gas dynamics.
- apply the fundamentals of one dimensional isentropic flow to variable area duct.
- analyse the principles of normal shock formation and its effects.
- apply the principles of compressible flow to constant area duct subjected to friction or heat transfer.
- analyse the forces acting on submerged bodies

Syllabus

Review of fundamentals: Types of flows, concepts of continuum and control volume, generalized continuity, momentum and energy equations, velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, three reference speeds, dimensionless velocity M*, concepts of static and stagnation parameters
One dimensional isentropic flow: General features, working equations, choking in Isentropic flow, operation of nozzles and diffusers under varying pressure ratios, performance of real nozzles, applications of isentropic flow
Normal shocks: Introductory remarks, governing equations, Rankine–Hugonout, Prandtl and other relations, weak shocks, thickness of shocks, normal shocks in ducts, performance of convergent-divergent nozzle with shocks, moving shock waves, shocks problems in one dimensional supersonics diffuser, supersonic pilot tube
Flow in constant area duct with friction: Governing equations, working formulas and tables, choking due to friction, performance of long ducts, isothermal flow in long ducts, flow in constant area duct with heating and cooling
Generalized one dimensional flow: Working equations, general method of solution, example of combined friction and area change, example of combined friction and heat transfer, Multidimensional flow: Equation of continuity, Navier stock equation, potential flow, Method of characteristics
Dimensional analysis and similitude: Buckingham π theorem, Van driest theorem, Dimensional analysis, model study, compressible flow of viscous fluids
Rarefied gas dynamics: Knudsen number, sleep flow, transition and free molecular flow
Forces on submerged bodies: Forces exerted by flowing fluid on a stationary body, drag, lift for different objects like sphere, cylinder, development of lift on a circular cylinder, development of lift on aerofoil

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self study contents.

Tutorial Work:

Tutorial work will be based on above syllabus with minimum 10 tutorials to be incorporated.

References:

1. Zucker & Biblarz, Fundamentals of Gas Dynamics, John Wiley & Sons, Inc.
2. James John and Theo Keith , Gas Dynamics, Pearson Prentice Hall
3. D.S. Kumar., Fluid Mechanics and Fluid Power Engineering, S. K. Kataria & sons
4. S. M. Yahya , Fundamentals of Compressible Flow, New Age International Publishers
5. J D Anderson, Computational Fluid Dynamics, Tata-Mcgraw Hill Publisher

3ME2255 **Thermal Insulation and Design** **[3 0 0 3]**

Course Learning Outcome:

After successful completion of the course, student will be able to

- understand role of thermal insulation in energy conservation
- comprehend classification, characteristics, properties and testing of thermal insulation
- apply heat transfer fundamentals to thermal insulation systems
- analyze selection, design and optimization of thermal insulation
- evaluate energy saving using thermal insulation through case studies

Syllabus

Role of insulation in saving of energy

Thermal insulation: Classification of insulation based on different criteria, salient features of different insulation, important properties of insulation, factors affecting thermal conductivity of insulations, weather barriers and vapour barriers, testing of insulation for determining important properties of insulation.

Concept of thermal resistance, total thermal resistance, over all heat transfer coefficient for composite slab, pipes, critical radius of insulation - criteria for selection of insulation for different application, optimization of insulation, design of insulation for different application.

Thermal insulation in buildings: case studies of energy saving by the use of insulation, study of insulation system of different application – cold storage power plants, dairy, chemical plants, refineries, petrochemical industries, LNG storage, cryocontainers, cryogen transfer lines.

Different methods for determining thermal conductivity of insulations, their relative merits.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self study contents.

References:

1. Paul Dunham Close, Thermal Insulations of buildings, Reinhol Publication Corporation.
2. R. M. E. Diamant, Thermal and Accoustic Insulations, Butter Worth Publications
3. Edwin F. Strother and William C. Turner, Thermal Insulation Building Guide, Robert E. Krieger Publishing Company
4. Richard T. Bynum Jr., Insulation Handbook, Mc Graw Hill Professional
5. William C. Turner, John F. Mallory, Handbook of Thermal Insulation Design Economics for Pipes and Equipment, Mc Graw hill Companies
6. Harry Hardenbrook, Walker's Insulation Techniques and Estimating Handbook: A Reference Book Setting Forth Detailed Procedures and Cost Guidelines for Those Involved in, Frank R Walker Company

3ME2295 Cryogenics Technology [3 0 0 3]

Course Learning Outcomes (CLO):
After successful completion of the course, students will be able to-

5. explain low temperature properties and describe various methods to produce low temperature for cryogenic systems,
6. analyze different cryogenic refrigeration, liquification, gas separation and purification systems,
7. design cryogenic fluid storage and transfer devices,
8. illustrate the use of instrumentation applied to the cryogenic technology and relate applications of cryogenic systems..

Low Temperature Properties – Mechanical, thermal, electrical and magnetic properties of engineering materials, properties of cryogenic fluids.
Gas Liquefaction Systems – Thermodynamically ideal system, Joule Thomson effect adiabatic expansion, simple, pre-cooled and dual pressure Linde Hampson systems, Claude system, comparison of liquefaction systems, liquefaction systems for hydrogen and helium
Gas Separation and Purification Systems - Thermodynamically Ideal separation system, general characteristics of mixtures, principles of gas separation, theoretical plate calculations for columns, types of rectification columns , Air separation and purification systems: Linde single column, double column, argon, hydrogen and helium gas separation system, Gas purification methods
Cryogenic Refrigeration Systems – Ideal isothermal and isobaric source systems, Joule Thomson systems, pre-cooled Joule Thomson system, expansion engine system, Philips refrigerator, G M refrigerator, Pulse Tube refrigerator.
Cryogenic Fluid Storage – Basic storage vessel, construction of storage vessels for oxygen, hydrogen, nitrogen, helium, safe devices, design of the vessel.
Insulation – Gas filled powder and fibrous, vacuum, evacuated powder and fibrous, multilayer insulation, mechanism of thermal insulation, apparent thermal conductivity, selection of insulation
Cryogenic Fluid Transfer Systems – Different types of transfer lines, process of cryogenic transfer, components of transfer lines.
Measurement Systems for Low Temperatures – Temperature, pressure flow rate and liquid level measurement at low temperatures.
Application of Cryogenic Systems – Super-conducting magnets, space technology, blood and tissue preservation, cryo probes used in cryo surgery.

Self-Study:

The self-study contents will be declared at the commencement of semester. Around 10% of the questions will be asked from self-study contents.

Suggested Reading:

1. Barron, R. F., Cryogenic Systems, Clarendon Press.
2. Flynn, T. M., Cryogenic Engineering., CRC Press.
3. Hands, B. A., Cryogenic Engineering. Academic Press, London
4. Vance, R. W., Adelberg, M., & Buchhold, T. A., Cryogenic Technology, Wiley.
5. Scott, R. B., Cryogenic Engineering, D. VanNostrand Co. Inc.

L	T	P	C
3	0	2	4

Course Code	**3ME2209**
Course Title	**Computational Fluid Dynamics and Heat Transfer**

Course Outcomes (COs):
After successful completion of the course, students will be able to-

- develop an understanding of major theories, approaches and methodologies used in CFD,
- apply CFD concepts for solution of diffusion type problems,
- make use of CFD concepts for solution of convection diffusion problems,
- apply the concepts of turbulence and multiphase modelling for thermo-fluid systems.

Syllabus **Teaching hours: 45**

UNIT-I **08 hours**

Introduction to Computational Fluid Dynamics and Heat Transfer: Continuity Equation, Navier Stokes Equation, Energy Equation and General Structure of Conservation Equations. Classification of Partial Differential Equations and Physical Behaviour. Solution of Systems of Linear Algebraic Equations**:** Elimination Methods, Iterative Methods, Gradient Search Methods.

UNIT-II **08 hours**

Fundamentals of Discretization: Variational Principles and Weighted Residual Approach, Error Minimization Principles, Finite Element Method, Finite Difference and Finite Volume Method. Conceptual basics and illustration of Finite Volume Method through 1-D Steady State Diffusion Problems, Boundary Condition Implementation and Discretization of Unsteady State Problems.

UNIT-III **10 hours**

Discretization of Time Dependent Diffusion Type Problems: Consistency, Stability and Convergence, LAX Equivalence theorem, Grid independent and time independent study, Stability analysis of parabolic equations (1-D unsteady state diffusion problems): FTCS (Forward time central space) scheme, Stability analysis of parabolic equations (1-D unsteady state diffusion problems): CTCS scheme (Leap frog scheme) Dufort-Frankel scheme, Stability analysis of hyperbolic equations: FTCS, FTFS, FTBS and CTCS Schemes.
Finite Volume Discretization of 2-D unsteady State Diffusion type Problems.

UNIT-IV **10 hours**

Discretization of Convection-Diffusion Equations: Grid generation, body fitted grid, orthogonal grid, staggered and collocated grid, structured and unstructured grid. Discretization of Navier-Stokes Equations: Stream Function- Vorticity approach and Primitive variable approach. Pressure correction methods- SIMPLE, SIMPLER, SIMPLEC, PISO Algorithm. Pressure projection method. Unstructured Grid Formulation.

UNIT-V **09 hours**

Turbulence and multiphase modelling: scales of turbulence, eddy viscosity models, k-ε, k-ω and RANS models, introduction to LES and DNS. Interface tracking during solidification and melting. Enthalpy formulation, Level Set/VOF method.

Self Study:

The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

Laboratory work: The Laboratory work will be based on the above syllabus and include development of codes and use of commercial CFD software for numerical simulation of thermo-fluid systems.

Suggested Readings:

1. John D. Anderson, Computational Fluid Dynamics: The Basics with Application, McGraw Hill Book Company.
2. Suhas V. Patankar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Co.
3. J. C. Tannehill, J. D. Anderson and R. H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor & Francis.
4. H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Addison Wesley – Longman.
5. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press.
6. Charles Hirsch, Numerical Computation of Internal and External Flows, Butterworth-Heinemann

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

L	T	P	C
3	0	2	4

Course Code	**3ME22D101**
Course Title	**Design of Heat Exchangers**

Course Outcomes (COs):
After successful completion of the course, students will be able to-

1. develop an understanding of the basic thermal design principles for heat exchangers,
2. apply principles of thermo-hydraulic design for double-pipe and shell and tube heat exchangers,
3. design compact heat exchanger for various thermal applications,
4. make use of computerized methods for the design and analysis of heat exchangers.

Syllabus **Teaching hours: 45**

UNIT-I **03 hours**

Heat Exchangers Classification: According to transfer process, number of fluids, surface compactness, and construction features. Tubular heat exchanger, plate type heat exchangers, extended surface heat exchangers, heat pipe, Regenerators. Classification according to flow arrangement: counter flow, parallel flow, cross flow exchanger.

UNIT-II **13 hours**

Heat exchanger design methodology: Assumption for heat transfer analysis, problem formulation, e-NTU method, *P*-NTU method, Mean temperature difference method, correction factor charts, basic design methodology, fouling of heat exchanger, effects of fouling, categories of fouling, fundamental processes of fouling, prediction of fouling, techniques to control fouling, effect of fouling on design, TEMA code.
Correlations for different flow regimes through different geometries under natural and forced convection, Tube side pressure drop, non-circular cross section pipes, pressure drop in tube bundles in cross flow, pressure drop in helical and spiral coils, and pressure drop in fittings.

UNIT-III **05 hours**

Double Pipe Heat Exchangers: Thermal and hydraulic design of inner tube, Thermal and hydraulic analysis of annulus, total pressure drop, design methodology for with extended surface, design requirement for series, parallel and combination of series and parallel combination.

UNIT-IV **15 hours**

Shell and tube type heat exchanger: Basic components, standards, Tinker's, Kern and Bell Delaware method of thermal and hydraulic design of shell and tube heat exchanger, pressure drop estimation.

Condensers and evaporators: Construction of different types of condensers and evaporators, film and drop wise condensation, use of equations for determination of heat transfer coefficients for laminar and turbulent film condensation on vertical surfaces, simple rod and bank of tubes, nucleate and film boiling, calculation of heat transfer coefficients. thermal design of shell and tube condensers for power plants, process industries and refrigeration and air conditioning system.

UNIT-V **05 hours**

Compact heat exchangers: Geometry construction, heat transfer enhancement, thermal and hydraulic design, pressure drop.

UNIT-VI **04 hours**

Mechanical Design, Testing, Maintenance, Simulation and Optimization: Codes for mechanical design of heat exchangers, testing, evaluation and maintenance of heat exchangers. Introduction to simulation and optimization of heat exchangers, flow induced vibrations.

Self-Study:
The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

Laboratory work: The Laboratory work will be based on the above syllabus and include development of codes and use of commercial software for design of various heat exchangers.

Suggested Readings:

1. Sadik Kakac, Heat Exchanger Selection, Rating and Thermal Design, CRC Press
2. Ramesh K. Shah and Dusan P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley
3. W. M. Kays and A. L. London, Compact Heat Exchangers, McGraw Hill
4. D. Q. Kern, Process Heat transfer, McGraw Hill
5. G. F. Hewitt and G. L. Shires, Process Heat Transfer, CRC Press
6. T. Kuppan, Hand Book of Heat Exchanger Design, CRC Press

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w.e.f. academic year 2019-20 and onwards

L	T	P	C
3	0	0	3

Course Code	**3ME22D201**
Course Title	**Refrigeration and Cryogenics**

Course Outcomes (COs):
After successful completion of the course, students will be able to-

1. analyze vapour compression systems and related components,
2. appraise vapour absorption systems, air cycle and non-conventional refrigeration systems,
3. apply principles of refrigeration for food preservation, transport and cold storages,
4. analyze properties at cryogenic temperatures and various gas liquefaction systems.

Syllabus **Teaching hours: 45**

UNIT-I **10 hours**
Vapour compression refrigeration: Actual cycle, second law efficiency, Multistage compression with inter-cooling, Multi-evaporator systems, Cascade systems
Refrigerants: Refrigerant properties, alternative refrigerants, CFC/HCFC phase-out regulations

UNIT-II **07 hours**
VCR Cycle component design and selection: Performance characteristics and capacity control of reciprocating and centrifugal compressors, screw compressor and scroll compressor, Design & selection of evaporators, condensers, control systems, motor selection.

UNIT-III **06 hours**
Absorption refrigeration: Analysis of ammonia-water and LiBr–water vapour absorption refrigeration systems with h-x charts and mass concentration equilibrium charts, two stage vapour absorption refrigeration systems.

UNIT-IV **07 hours**
Air cycle refrigeration: Analysis of various cycles and their applications.
Non-conventional Refrigeration System: Steam jet refrigeration, Thermo-electric refrigeration, etc.

UNIT-V **05 hours**
Refrigeration Applications: Preservation and processing of foods by use of refrigeration, design of refrigeration systems for transport refrigeration, walk in coolers and cold storages for different applications.

UNIT-VI **10 hours**
Properties at Cryogenic Temperature: Mechanical, thermal, electrical and magnetic properties of engineering materials, properties of cryogenic fluids.
Gas Liquefaction Systems: Thermodynamically ideal system, Joule Thomson effect adiabatic expansion, simple, pre-cooled and dual pressure Linde Hampson systems, Claude system

Self-Study:
The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

Suggested Readings:

1. C. P. Arora, Refrigeration and Air-conditioning, McGraw Hill.
2. R. J. Dossat, Principle of Refrigeration, Pearson Education.
3. W. F. Stoecker, J.W. Jones, Refrigeration and Air-conditioning, McGraw Hill.
4. ASHRAE Hand Book: Refrigeration, ASHRAE.
5. ASHRAE Hand Book: Fundamentals, ASHRAE.
6. W. Stoecker, Industrial Refrigeration Hand Book, McGraw Hill.
7. R. F. Barron, Cryogenic Systems, Oxford University Press.

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w.e.f. academic year 2019-20 and onwards

L	T	P	C
3	0	0	3

Course Code	**3ME22D301**
Course Title	**Air-conditioning System Design**

Course Outcomes (COs):
After successful completion of the course, students will be able to-

1. utilize the principles of applied psychrometry and thermal comfort for air conditioning system design,
2. estimate the cooling load for air conditioning applications,
3. design the air distribution and air handling systems,
4. analyse the performance of various air conditioning systems, cooling towers and evaporative coolers,
5. analyse noise in air conditioning systems and its control methods.

Syllabus **Teaching hours: 45**

UNIT-I **10 hours**

Applied psychrometry: summer and winter air conditioning.
Thermal comfort: Human thermo-regulation, environmental indices, IAQ, human comfort.

UNIT-II **12 hours**

Cooling load calculation: design condition, Calculation of transmission load, fenestration load, infiltration and ventilation load, internal load using CLTD method

UNIT-III **10 hours**

Duct design: static and dynamic loss, duct design using equal friction method, velocity reduction and static regain methods in brief
Air distribution: factors affecting grille performance, selection of outlets using nomographs, tables and line charts
Air handling systems: fan laws, testing of fans as per various standards, selection of fans

UNIT-IV **09 hours**

Air conditioning systems: features of air conditioning systems and selection of appropriate air conditioning system for different applications
Cooling towers: construction, working, performance, testing.
Evaporative cooler: Performance of desert cooler and air washer, testing as per BIS

UNIT-V **04 hours**

Air conditioning controls: Characteristics of HVAC noise, acoustical rating systems and different criteria for noise rating, noise control methods

Self-Study:
The self study contents will be declared at the commencement of semester. Around 10% of the questions in the examination will be asked from self study contents.

Suggested Readings:

1. C. P. Arora, Refrigeration and Air-conditioning, McGraw Hill.
2. ASHRAE Handbook, Systems and Equipments, ASHRAE.
3. R. H. Howell, Principles of Heating Ventilating and Air Conditioning, ASHRAE.
4. J. L. Threlkeld, Thermal Environmental Engineering, Wiley Eastern.
5. Hand Book of Air Conditioning Systems Design, Carrier Corporation, McGraw Hill.
6. S. K. Wang, Handbook of Air Conditioning and Refrigeration, McGraw Hill.
7. W. P. Jones, Air Conditioning Applications and Design, Routledge.

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w.e.f. academic year 2019-20 and onwards

L	T	P	C
0	0	10	5

Course Code	**3ME2211**
Course Title	**Minor Project**

Course Outcomes (COs):

After successful completion of the course, students will be able to-

1. practice acquired knowledge within the chosen area of technology for project development,
2. identify, discuss and justify the technical aspects of the chosen project with a comprehensive and systematic approach,
3. reproduce, improve and refine technical aspects for engineering projects,
4. work as an individual or in a team in development of technical projects,
5. report project related activities effectively to peers and mentors.

The minor project shall be based on the recent trends in technology, system/process analysis, construction/fabrication/production techniques, design methodologies etc. The student(s) shall carry out a comprehensive project at relevant Academic/R&D/Industrial organisation based on one or more of the aspects such as prototype design, product preparations, working models, fabrication of set-ups, laboratory experiments, process modification/development, simulation, software development, integration of software and hardware, data analysis, survey etc.

The student is required to submit comprehensive project report based on the work.

L=Lecture, T= Tutorial, P=Practical, C=Credit

w.e.f. academic year 2019-20 and onwards

3ME2301 Major Project Part I – Full Time [0 0 0 15]

Course Learning Outcome

The course provides an opportunity to the student to explore their knowledge in the area of their interest. Student will apply idea into application through experiments/ simulation. It will also help them to decide the project area / topic for further research work in their life. . As an outcome of the course, student will be able to develop:

- Problem formulation techniques.
- Analysis techniques of published data.
- Identification of scope and objectives of research work.
- Techniques for the design of experiments.
- Associated administration for project work.
- Development of compilation skill.
- Writing skill.
- Presentation skill.
- Technical Paper writing.
- Report preparation techniques.
- Fundamentals, information, reviews and in-depth knowledge in the desired area.

Syllabus

The Major Part I is aimed at training the students to analyze independently any problem in the field of Thermal Engineering. The project may be analytical or computational or experimental or combination of them based on the latest developments in the said area. At the end of the semester, the students will be required to submit detailed report. The Major Project Part I should consists of objectives of study, scope of work, critical literature review of the Major Project and preliminary work pertaining to the said work.

3ME2401 Major Project Part II – Full Time [0 0 0 15]

Course Learning Outcome

The course provides an opportunity to the student to explore their knowledge in the area of their interest. Student will apply idea into application through experiments/ simulation. It will also help them to decide the project area / topic for further research work in their life. . As an outcome of the course, student will be able to develop:

- Problem formulation techniques.
- Analysis techniques of published data.
- Identification of scope and objectives of research work.
- Techniques for the design of experiments.
- Associated administration for project work.
- Development of compilation skill.
- Writing skill.
- Presentation skill.
- Technical Paper writing.
- Report preparation techniques.
- Fundamentals, information, reviews and in-depth knowledge in the desired area.

Syllabus

Major Project Part II is a continuation of the work done by the student during semester III. The student is required to submit thesis as a partial fulfillment of the M. Tech degree. The thesis should consist of detailed study of the problem under taken, concluding remarks and scope of future work, if any. The project report (thesis) is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical, computational and experimental aptitude of the student.