Bharatiya Vidya Bhavan's

SARDAR PATEL COLLEGE OF ENGINEERING

(Government Aided Autonomous Institute under Mumbai University)

Andheri (W) Mumbai - 400058

COURSE CONTENTS

(M.Tech. in Thermal Engineering)

Year: 2017-18

Sardar Patel College of Engineering, Andheri (West), Mumbai 400058
Year: 2017-18

List of Courses

MTTH101 Transport Phenomena

Course Pre-requisite: UG Course - Fluid Mechanics

Course Objective:

- How to use fundamental principles of fluid mechanics to solve thermal problem.
- How to use basic principles of thermodynamics to solve thermal problem.
- How to use basic principles of heat transfer to solve thermal problem.
- How to use basic principles of mass transfer to solve thermal problem.

Course Outcome:

Upon successful completion of the course, students should be able to

1. have knowledge of advanced features of fluid mechanics, thermodynamics, heat and momentum transfer pertaining to thermo-fluid problem,
2. Understand the significance of course content for thermo-fluid problems,
3. Apply knowledge in analysis and interpretation of thermo-fluid problem
4. Analyze and evaluate an existing thermal system and recommend their ideas.

Course Content

Module No.	Description	Hrs.
1.	Introduction to transport phenomena: Basic transport quantities in thermal system; Conservation principle of mass, momentum, energy and species; **Thermodynamics:** Thermodynamic terms; laws; energy, entropy and exergy analysis;	6
2.	**Fluid Mechanics:** Types of flow, Integral and differential form of governing equation. Navier-Stokes equation, Dimensionless form of conservation equation and their use. Common flow boundary conditions. Boundary layer	6
3.	**Turbulence:** Laminar and turbulent transport of fluid. Characteristics, RANS Equation, Turbulence models.	5
4	**Momentum Transport: Internal** Internal incompressible viscous flow –Developing and developed flow. Estimating laminar velocity profile of flow between infinite parallel plates Fully developed laminar pipe flow. Turbulent velocity profile. Head loss estimation, Flow through Non-circular ducts.	6
5	**Momentum Transport: External** External incompressible viscous flow –Blasius solution of flow over plates, Von-Karmon's momentum integral equation. Flow separation, lift and drag. Flow over cylinders and spheres.	6
6	**Energy Transport:** Thermal boundary conditions. Diffusion transport: Energy equation, conduction through plane and cylindrical surfaces, Fins, Transient conduction – lumped and distributed model.	6

	Convective transport: Energy equation, heat transfer coefficient, non-dimensional numbers, Nu correlations –external flow over flat plate, cylinders and spheres, Internal flow -developing and developed for isothermal and constant heat flux boundary conditions.	
7	**Mass Transport:** Diffusivity and the mechanism of mass transport –Fick's law of diffusion, mass diffusivity, Mass transfer in non-stationary media, Stationary medium approximation, conservation of species for a stationary medium, boundary condition and discontinuous concentration at interfaces, Mass diffusion with homogeneous chemical reaction	5

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics:	**Hrs.**
1. Thermal Analysis	4
2. Fluid Dynamics	4
3. Turbulence:	4
4. Momentum Transport: Internal	4
5. Momentum Transport: External	4
6. Energy Transport:	4
7. Mass Transport:	4

Recommended books:

1. White, F. M. *Fluid Mechanics*, McGraw-Hill, New York, 1986.
2. Ozisik, M. Necati. *Heat transfer: a basic approach*. (1985).
3. Moran, Michael J., Howard N. Shapiro, Daisie D. Boettner, and Margaret B. Bailey. *Fundamentals of engineering thermodynamics*. John Wiley & Sons, 2010.
4. Incropera, F.P. and Dewitt, D.P. *Fundamentals of Heat and Mass Transfer*, Wiley
5. Fox, Robert W., Alan T. McDonald, and Philip J. Pritchard. *Introduction to fluid mechanics*. Vol. 7. New York: John Wiley & Sons, 1985.
6. Cengel, Yunus A., and Michael A. Boles. "*Thermodynamics: an engineering approach*." *Sea* 1000 (1994): 8862.
7. Eckert, Ernst Rudolf Georg, and Robert M. Drake Jr. "*Analysis of heat and mass transfer*." (1987).

MTTH102 Energy Resources, Conversion and Management
Course Pre-requisite: UG Courses - Thermodynamics, Thermal Engineering

Course Objective:

- To know the different energy resources
- Understand thermodynamic power cycles and the associated processes and fuels
- Understand the basic principles of nuclear energy, solar energy, fuel cells, and wind energy
- Understand the economics of energy conversion

Course Outcomes:

Upon successful completion of the course, students should be able to

1. Develop knowledge to identify, explain and compare competing energy resources, conversion technologies on an economic and efficiency basis
2. Understand the significance of course contents and develop capability to apply different tools to assess the validity of energy conversion claims
3. Analyze different energy systems and related economics.
4. Evaluate different energy resources, their conversion and management.

Course Content

Module No.	Description	Hrs.
1.	**Energy Resources** – Efficient use of Solid Fuels, Manufactured Fuels, Agro Fuels, Indian coals, Petroleum, Refining and Other Conversion Processes, Nature of Indian Crudes & Petroleum Refining in India	5
2.	**Fuels Through Non-Thermal Route** - Biogas, Refinery Gas, LPG	5
3.	**Renewable Energy Sources** - Solar Energy, Nuclear Power, Energy from Biomass, Wind Power, Tidal Power, Geothermal Energy, Energy Survey of India	6
4.	**Basic principles of energy conversion**. Analyzing tools - energy, entropy, exergy and pinch analysis.	6
5.	**Conventional Energy Conversion** – Fluidized Bed combustion boiler – Advantages – waste heat Recovery boilers – Co generation Power Plant, Combined Power cycle Plants – Advantages and Limitations, Gas turbine – Steam turbine Power Plant And MHD – Steam Power Plant. Methods for utilization of Solar, wind, biomass, geothermal energy.	6
6.	**Energy Storage** – hydrogen, flow batteries, compressed gas, flywheels, fuel cells	6
7.	**Energy Economics and Auditing** -Economic analysis for cogeneration and waste heat recovery systems-Investment cost – economic concepts – measures of economic performance – procedure for economic analysis – examples – procedure for optimized system selection and design – load curves - sensitivity analysis –regulatory and financial frame work for cogeneration and waste heat recovery systems	6

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Energy resources	4
2. Fuels Through Non-Thermal Route	4
3. Renewable energy sources	4
4. Basic principles of energy conversion	4
5. Conventional energy conversion	4
6. Energy storage	4
7. Energy economics and its auditing	4

Recommended Books:

1. Weston, Kenneth C. "*Energy conversion–the ebook*." University of Tulsa(2000).
2. A Culp, Jr ,Principles of Energy Conversion, 2nd ed., McGraw-Hill, Inc., 1991.
3. Smith, Craig B., and Kelly E. Parmenter. *Energy, Management, Principles: Applications, Benefits, Savings*. Elsevier, 2013.
4. Hamies, *Energy Auditing and Conservation; Methods, Measurements, Management and Case study*, Hemisphere, Washington, 1980.
5. Witte, Larry C, *Industrial Energy Management and Utilization*, Hemisphere Publishers, Washington, 1988.

MTTH103 Design and Analysis of Thermal Systems
Course Pre-requisite: UG Course - Machine Design

Course Objective:

- To learn overall design requirement and methodology of a thermal system.
- To learn tools and techniques of analysis of a thermal system.
- How to do modeling of a thermal system.
- To techniques of economic analysis of thermal system.
- How to do optimization of a thermal system

Course Outcome:

Upon successful completion of the course, students should be able to

1. have knowledge of different aspects of designing of a thermal system,
2. Identify and examine a design problem associated to a thermal system,
3. Understand basics of modeling and their associated techniques,
4. Explain economic aspect of designing and able to apply different techniques of optimization applicable to thermal system.

Course Content

Module No.	Description	Hrs.
1.	Requirement of engineering design, Other similar terms: Analysis, Synthesis, Selection and Optimization. Characteristics of a thermal system, types and analysis.	6
2.	Formulation of the Design Problem, Conceptual Design, Steps in the Design Process, Computer-Aided Design, Material Selection	6
3.	**Modelling Basics:** Importance of Modelling in Design, basic features of modelling, Types of Models- Analogue, Mathematical, Physical and Numerical. Mathematical modelling – general procedure, final model and validation.	6
4.	**Modelling Techniques:** Physical modelling and dimensional analysis, Curve fitting – exact and best fit. Synthesis of Different Design Steps – Initial design, Design strategies- commonly used design approach and Iterative design procedure.	6
5.	**Economic Considerations:** Calculation of interest- simple, compound, continuous compounding and effective. Worth of money as function of time. Types of payments. Bonds and stocks, Taxes and depreciations. Cost comparison and rate of return. Application to thermal system.	5
6.	**Optimization- Introduction:** Need of optimization, Basic concepts- Objective function, constraints, mathematical formulation for optimization.	5
7.	**Methods of Optimization:** Calculus method, Search method and Geometrical programming Practical aspect of Optimal design – choice of variables, sensitivity analysis, dependence on objective function, multi-objective optimization.	6

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Fundamentals of engineering design	4
2. Formulation of the Design Problem	4
3. Modelling Basics	4
4. Modelling Techniques	4
5. Economic Considerations of design	4
6. Introduction to Optimization	4
7. Methods of Optimization	4

Recommended books:

1. Jaluria, Yogesh. *Design and optimization of thermal systems*. CRC press, 2007.Stoecker, W.F. Design of Thermal Systems, McGraw-Hill, New York.
2. Dieter, G.E.,*Engineering Design: A Materials and Processing Approach*, McGraw-Hill, 2008.
3. Janna, William S. *Design of Fluid Thermal Systems-SI Version*. Cengage learning, 2010.
4. Rieder, W.G. and Busby, H.R. Introductory Engineering Modelling Emphasizing differential Models and Computer Simulation, Wiley, 1986.
5. Collier, Courtland A., and William Burl Ledbetter. *Engineering economic and cost analysis*. Harpercollins College Division, 1988.
6. Fox, R.L. *Optimization Methods for Engineering Design*, Addison-Wesley, 1971.
7. Rao, Singiresu S., and S. S. Rao. *Engineering optimization: theory and practice*. John Wiley & Sons, 2009.

MTTH111 Refrigeration System Design (Elective I)

Course Pre-requisite: UG Course - Refrigeration and Air-conditioning

Course Objective:

- To know about the different refrigeration cycles
- Understand the hardware related to the refrigeration systems
- Understand how the different components harmonize together
- Understand the importance of the auxiliary systems.

Course Outcomes:

Upon successful completion of the course, students should be able to

1. have a review of refrigeration cycles and alternate refrigeration system to enhance their knowledge of refrigeration, and will be able to explain them,
2. Understand and solve the problem of component selection, refrigerant related issues and system balancing and control
3. Apply their knowledge to appraise different refrigeration system components and environmental issues caused by refrigerant.
4. Analyze a refrigeration problem to carryout necessary calculation.

Course Content

Module No	Description	Hrs.
1	**Refrigeration Cycles – Analysis** Evolving vapour compression cycle from basic Carnot cycle - analysis of multi- pressure systems – cascade systems	05
2	**System Components and Selection** Compressors, condensers-evaporators- expansion devices- types, performance, and their selection, **condensers:** estimation of heat transfer coefficient – fouling factor – friction factor – design procedures – Wilson plots – designing different types of condensers – bis standards – optimization studies – design of evaporative condensers. **evaporators:** design procedure – thermal stress calculations – matching of components	07
3	**Refrigerants**- Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact- ODP, GWP, TEWI Montreal/Kyoto protocols, Paris Agreement, Phase out plans, -eco-friendly Refrigerants, Natural Refrigerants	05
4	**System balancing & controls** Estimation of cooling load – system equilibrium, balancing and matching of components – cycling controls – different defrosting and capacity control methods – electronic controls in refrigerators	05
5	**Refrigeration System Components** System Capacity control – piping – Oil return – Oil separators – Different types- Refrigerant driers- strainers – Receivers – Accumulators – Low pressure receivers – Refrigerant Pumps. Cooling Tower components-Air Washers – Spray ponds. Compressor Motor protection devices – Oil equalizing in multiple evaporators –Testing of Air conditioners, Refrigerators, Visi-coolers, Cold Rooms	08

6	**Alternate Refrigeration Systems**– Aqua Ammonia & Li-Br Systems – Steam Jet refrigeration –Thermo-Electric Refrigeration-Solar vapour absorption refrigeration system – Pulse tube refrigeration.	06
7	**Tools**-Different Types of Refrigeration Tools – Evacuation and Charging Unit – Recovery and Recycling Unit.	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Refrigeration cycles - analysis	4
2. Alternate refrigeration systems	4
3. System components and selection	4
4. Refrigerants	4
5. System balancing & controls	4
6. Different Types of Refrigeration Tools	4
7. Refrigeration system components	4

Recommended books:

1Dossat, Roy J. *Principles of refrigeration*. No. 621.56 D68 1978. 1978.

2. Stoecker, Wilbert F. *Refrigeration and air conditioning*. Vol. 3. London: McGraw-Hill, 1958.

3. Ananthanarayanan, P. N. *Basic refrigeration and air conditioning*. Tata McGraw-Hill Education, 2013.

4. Goshnay W.B., Principles and Refrigeration, Cambridge, University Press, 1982.

5. Langley, Billy C., Solid state electronic controls for HVACR, Prentice-Hall 1989.

MTTH112 Advanced Combustion Techniques (Elective I)
Course Pre-requisite: UG Course - I. C. Engines

Course Objectives:
The objective of this course to make student aware of-

- the fundamental of combustion phenomena in general,
- the different combustion process, its thermodynamics and kinetics,
- the combustion mechanism in different types of combustion,
- the burner design for efficient combustion,
- different combustion models.

Course Outcomes:
Upon successful completion of the course, students should be able to

1. have knowledge of fundamentals of combustion, thermodynamics of combustion, different combustion processes,
2. understand the significance of contents of the course for combustion technology,
3. be able to apply knowledge to solve simple/advance numerical problem of a combustion system,
4. be able to analyze and design a combustion system such as furnace and burner

Course Content

Module No.	Details	Hrs.
01	**Stoichiometry** Combustion Reactions, Gravimetric & Volumetric Analysis, Stoichiometric Relations, Theoretical air required for complete combustion of solid, liquid and gaseous fuels	06
02	**Combustion Process (Stoichiometry)** Combustion Stoichiometry: Application of General Methods, Rapid Methods (Use of Fundamental Formulae) and Empirical Co-Relations for solution of combustion problems, Combustion problems involving Loss of Combustibles with flue gases and ash, Air Ratio, Combustion calculations involving humid air in place of dry air for combustion.	06
03	**Combustion Process (Thermodynamics)** Heat of Combustion, Hess's Law, Combustion Efficiency, Enthalpy of Combustion System & calculations using these concepts, Equilibrium Constants of Combustion Reactions, Phenomenon of Dissociation, Degree of Dissociation, Enthalpy-Temperature (h-t) Diagrams, Concepts of Theoretical, Adiabatic, Actual& Maximum Adiabatic Flame Temperature, Combustion problems based on these concepts.	06
04	**Combustion Process (Kinetics)** Nature of Combustion Process, Types of Combustion Processes: Combustion with Stationary Flames, Surface Combustion, Submerged Combustion, Combustion with Explosion flame, Pulsating Combustion, Slow Combustion, Combustion of Solid Fuels on grate, Mechanism of Combustion Reactions:- Chain Reaction, Thermal Mechanism, Hydrogen-Oxygen Reaction, Combustion of Elementary Carbon.	06

05	**Ignition** Concept of Ignition, Spontaneous Ignition Temperature (SIT):- Influencing factors, Methods of determination, Flame Propagation, Velocity of Flame Propagation:- Influencing Factors, Methods of measuring, Limits of Inflammability:-Influencing Factors, Methods of determination, Combustion Problems to determine Limits of Inflammability, Structure & Nomenclature of Flames, Types of Flames, Flame Stability:- Influencing Factors, Methods.	06
06	**Burners for Combustion Process** Detailed Classification of Gas Burner & Oil Burners with constructional features, design considerations, Advantages, Limitations & Applications, Coal Burning Equipment, Pulverized Coal Firing, Cyclone Firing, Fluidized bed Combustor, Recuperative & Regenerative Burners.	06
07	**Combustion Models and Modeling** Classification, zero-dimensional modeling, quasi-dimensional modeling, multidimensional, comparison of different combustion systems, combustion efficiency, applications Different standard Combustion Models	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Fundamental of Stoichiometry	4
2. Combustion Process	4
3. Thermodynamics of Combustion	4
4. Kinetics Combustion	4
5. Ignition	4
6. Burners for Combustion Process	4
7. Combustion Models and Modeling	4

Recommended Books:-

1. Sarkar, Samir. *Fuels and combustion*. Universities Press, 1974.
2. Mishra, D. P. *Fundamentals of combustion*. PHI Learning Pvt. Ltd., 2007.
3. Bhatt, B. I., and S. M. Vora. *Stoichiometry:(si units)*. Tata McGraw-Hill Pub. Co., 1996.
4. Oppenheim, A. K. *Advanced combustion methods*: Felix J. Weinberg, Editor, Academic Press, New York, 1986, (1988)
5. Kuo, Kenneth K. "Principles of combustion." (1986).

MTTH113 Fuel Cells (Elective-I)

Course Pre-requisite: UG Course - Basic Electrical and Electronics, Thermodynamics, Heat and Mass Transfer

Course Objectives:

- To understand the basics of Fuel Cell operation
- To know how the fuels are prepared to be used in fuel cells
- Know about different applications

Course Outcomes:

Upon successful completion of the course, students should be able to

1. have good knowledge and understanding of Fuel cells,
2. Describe working principle and process of a fuel cell storage system,
3. Express different methods to preparing and processing fuel for fuel cell,
4. Use and identify application of fuel cell with knowledge to new generation fuel cells.

Course Content

Module No.	Description	Hrs.
1	**Introduction**- Fuel Cell Basic- Physics, Power Generation , Loss Mechanism, Equivalent Circuit , Power Conditioning, Fuel Cell Systems Storage System	05
2.	**Voltage Regulation-** DC/DC and DC/AC Converters., Power Transistors DC/DC,DC/AC. Small Scale Systems, Increased Available Power, Size and Weight Reduction	06
3	**Solid Oxide Fuel Cells-** Materials, SOFC stack, Micro-tubular SOFC, PEM Fuel Cells, Components and Their Properties, Stack Design Principles, System Design .	06
4	**Fuel Cell Applications**- Residential Application, Power Plant and Grid Support , Auxiliary Power Unit Automotive Applications, Stationary Power Applications, Portable Power Applications	05
5	**Fuels and Fuel Processing** - Feedstocks for H_2 Production - Natural Gas- Liquid Petroleum Gas, Liquid Hydrocarbon Fuels: Gasoline and Diesel Alcohols: Methanol and Ethanol Ammonia Biomass Fuel Processing for Fuel Cell Application Desulfurization Fuel Reforming.	06
6	New Generation of Catalyst Layers for PEMFCs Based on Carbon Aerogel Supported Pt Catalyst (CASPC)	06
7.	**Microbial Fuel Cells** Introduction- Historical Perspective -MFC Performance -MFC Applications Microbiology Overview-Bacterial Structure Nutrient Transport	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Introduction to Fuel Cell	4
2. Voltage Regulation	4
3. Solid Oxide Fuel Cells	4
4. Fuel Cell Applications	4
5. Fuels and Fuel Processing	4

6. New Generation of Catalyst Layers 4
7. Microbial Fuel Cells 4

Recommended books:

1. Sammes, Nigel, ed. *Fuel cell technology: reaching towards commercialization*. Springer Science & Business Media, 2006.
2. Handbook of Fuel Cells, Wiley on line library
3. Viswanathan, Balasubramanian, and M. AuliceScibioh. *Fuel cells: principles and applications*. CRC PressILlc, 2007.
4. Fuel Cell Systems Explained (Second Edition) by James Larminie, Wiley,2003
5. Kordesch, Karl, and Günter R. Simader. *Fuel cells and their applications*. (1996).

MTTH114 Energy Storage Systems (Elective-II)
Course Pre-requisite: UG Course - Thermodynamics, Heat and Mass Transfer

Course Objectives:

- To understand the different types of storage for load leveling
- Know about portable energy storage devices
- Understand storage in batteries

Course Outcomes:

Upon successful completion of the course, students should be able to

1. have good knowledge and understanding of energy storage system
2. Explain the meaning and importance of load leveling
3. Apply the concepts of thermodynamics to understand energy storage system
4. Compare and select a correct type of storage for a given application

Course Content

Module No.	Description	Hrs.
1.	Introduction - Storage in the Fuel Distribution System - Periodic Storage Long-Term, or Seasonal, Storage- Daily and Weekly Storage -The Problem of Load Leveling , Methods That Can Be Used to Reduce the Magnitude of the Variations in Energy Demand Short-Term Transients	05
2.	Portable Applications That Require Energy Storage - Storage Methods for Use with Portable Electronic Devices, Energy Use and Storage in Vehicles Hydrogen Propulsion of Vehicles . .	06
3.	General Concepts- The First Law of Thermodynamics – Thermal Entropy, Configurational Entropy- The Energy Available to Do Work - The Temperature Dependence of G, H and S , The Carnot Limitation , Energy Quality	05
4	Thermal Energy Storage Introduction Sensible Heat ,Latent Heat, Inorganic Phase Change Materials ,Organic Phase Change Materials, Quasi-Latent Heat Energy Storage in Organic Fuels	06
5.	Storage of Energy in Living Biomass Storage via Animals, Hard Biomass Synthetic Liquid Fuels Gaseous Fuels Stored as Liquids The Energy Content of Various Materials Used as Fuels	06
6.	Mechanical Energy Storage, Electromagnetic Energy Storage, Hydrogen Storage	06
7.	Electrochemical Energy Storage Simple Chemical and Electrochemical Reactions Major Types of Reaction Mechanisms in Electrochemical Cells. Lead-Acid Batteries, Negative Electrodes in Other Rechargeable Aqueous Systems. Positive Electrodes in Other Aqueous Systems, Negative Electrodes in Lithium Systems, Positive Electrodes in Lithium Systems, Primary, Non-rechargeable Batteries, Energy Storage for Medium-to-Large Scale Applications	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Storage in the Fuel Distribution System	4
2. Portable Applications	4
3. General Concepts	4
4. Thermal Energy Storage Introduction	4
5. Storage of Energy in Living Biomass	4
6. Mechanical Energy Storage	4
7. Electrochemical Energy Storage	4

Recommended books:

1. Huggins, Robert Alan. *Energy storage*. Vol. 406. New York: Springer, 2010.
2. Dincer, Ibrahim, and Marc Rosen. *Thermal energy storage: systems and applications*. John Wiley & Sons, 2002.
3. Beckmann G., Gilli,P.V., *Thermal energy storage:Basics-design-applications to power generation and heat supply*, Springer Verlag , 1984

MTTH115 Hydraulic and Pneumatic control systems (Elective-II)
Course Pre-requisite: UG Course -Fluid Mechanics, Hydraulic Machinery, Mechatronics

Course Objectives:

- To understand fundamental principles of hydraulic and pneumatic machines
- Know about design and operation of hydraulic and pneumatic machines
- Know different components used in hydraulic and pneumatic machines

Course Outcomes:

Upon successful completion of the course, students should be able to

1. Have good knowledge and understanding of hydraulic and pneumatic machines
2. Identify hydraulic and pneumatic components
3. Ability to design hydraulic circuits
4. Ability to design pneumatic circuits.

Course Content

Module No.	Description	Hrs.
1.	Introduction: - Introduction to Fluid power- Advantages and Applications- Fluid power systems – Types of fluids- Properties of fluids Basics of Hydraulics – Pascal's Law- Principles of flow – Work, Power and Torque. Properties of air– Perfect Gas Laws.	05
2.	Sources of Hydraulic power: Pumping Theory – Pump Classification- Construction, Working, Design, Advantages, Disadvantages, Performance, Selection criterion of Linear, Rotary- Fixed and Variable displacement pumps, Hydraulic Actuators: Cylinders – Types and construction.	06
3.	Hydraulic motors Control Components: Direction control, Flow control and Pressure control valves- Types, Construction and Operation- Applications – Types of actuation. Accessories: Rese rvoirs, Accumulators, Intensifiers, Pressure Switches- Applications- Fluid Power ANSI Symbol.	06
4	Industrial hydraulic circuits- Regenerative, Pump Unloading, Double-pump, Pressure Intensifier, Air-over oil, Sequence, Reciprocation, Synchronization, Fail-safe, Speed control, Hydrostatic transmission, Accumulators, Electro hydraulic circuits, Mechanical Hydraulic servo systems.	06
5.	Pneumatic Systems: Compressors, Filter, Regulator, Lubricator, Muffler, Air control Valves, Quick Exhaust valves, Pneumatic actuators, Servo systems. Introduction to Fluidics, Pneumatic logic circuits.	06
6.	Design of Hydraulic Circuits: Design of circuits using the components of hydraulic system for Drilling, Planning, Shaping, Punching, Press. – Selection, fault finding and maintenance of hydraulic components- Sequential circuit design for simple application using cascade method	06

7.	Design of pneumatic circuits: Electro pneumatic circuits. Selection criteria of pneumatic components – Installation fault finding and maintenance of pneumatic components. Microprocessor and PLC- Applications in Hydraulic and Pneumatics- Low cost Automation – Hydraulic and Pneumatic power packs.	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Hydraulic Power	4
2. Hydraulic Motor Control	4
3. Industrial Hydraulic Circuits	4
4. Pneumatic Systems	4
5. Design of Hydraulic Circuits	4
6. Design of pneumatic circuits	4

Recommended books:

1. Anthony Esposito," Fluid Power with Applications", PHI / Pearson Education, 2005..
2. Shanmugasundaram.K, "Hydraulic and Pneumatic controls", Chand & Co, 2006.
3. Majumdar, S.R., "Oil Hydraulics Systems- Principles and Maintenance", Tata McGraw Hill, 2001
4. Majumdar, S.R., "Pneumatic Systems – Principles and Maintenance", Tata McGraw Hill, 2007.
5. Micheal J, Pinches and Ashby, J.G., "Power Hydraulics", Prentice Hall, 1989.
6. Dudelyt, A Pease and John J Pippenger, "Basic Fluid Power", Prentice Hall, 1987.
7. Srinivasan. R, "Hydraulic and Pneumatic Control", IInd Edition, Tata McGraw - Hill Education,

MTTH116 Fundamentals of Gas Dynamics (Elective-II)
Course Pre-requisite: UG Course - Thermodynamics, Fluid Mechanics, Thermal Systems

Course Objectives:

- To understand fundamental of gas dynamics
- To know types of compressors and turbines used in aircrafts
- Know different jet propulsion cycles.

Course Outcomes:

Upon successful completion of the course, students should be able to

1. Understand fundamental of gas dynamics
2. Understand working of compressors, turbines etc.
3. Understand working of jet propulsion cycles.
4. Able to do analysis of jet propulsion systems.

Course Content

Module No.	Description	Hrs.
1.	Introduction, Cycles, Performance characteristics and improvement, Gas dynamics	05
2.	Centrifugal, axial and mixed flow compressor, principles and characteristics	05
3.	Turbine construction, Blade materials, manufacturing techniques, blade fixing, problems of high temperature operation, blade cooling	06
4	Practical air cooled blades Combustion Systems, various fuels and fuel systems	05
5.	Jet propulsion cycles and their analysis, parameters affecting performance,	05
6	Thrust augmentation, environmental considerations	05
7	Applications of gas dynamics in aeroplanes.	05

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Different Cycles	4
2. Types of Compressors	4
3. Turbine Construction	4
4. Practical Air Cooled Blades Combustion System	4
5. Jet propulsion cycles	4
6. Thrust augmentation	4

Recommended books:

1. H Cohen, GFC Rogers and HIH Saravanamuttoo, "Gas Turbine Theory", Pearson Education,2000.
2. V. Ganesan, "Gas Turbines", Tata McGraw Hill, 2003.
3. S.M.Yahya "Turbines, Compressors and Fans", Tata McGraw Hill, 1992.
4. Vincent "The theory and design of Gas Turbine and Jet Engines", McGraw Hill, 1950.
5. W W Bathic, "Fundamentals of Gas Turbines", John Wiley and Sons.

MTTH199/MTTH189 Seminar I/Mini Project
Course Pre-requisite: Nil

Course Objective:

The course intends to provide opportunity to student for self-learning to beyond syllabus contents related to thrust area of engineering and technology. This will inculcate the habit of lifelong learning.

Course Outcomes:

1. Student will be able to apply the skill of presentation and communication techniques.
2. Student will be able to use the knowledge of the fundamentals of subjects to search the related literature.
3. Student will be able to analyze the available resources and select most appropriate one.
4. Students will be able to apply a multidisciplinary strategy to address current, real-world issues.

Course Content (Seminar-I):

Sr. No.	Description	Hrs
1	Student shall prepare a report on a topic related to his/her area of specialization outlining objective of the report, importance of the study, review of literature published in the relevant field and possible areas for further work. The student shall present seminar based on chosen topic.	**42**

Course Content (Mini Project):

Sr. No.	Description	
1	Student shall select the project topic in consultation with mentor to his/her area of specialization and work on it. Student will prepare a report outlining objective of the project work, importance of the study, review of literature published in the relevant field and possible areas for further work. The student shall present seminar on this report.	**42**

MTTH104 Thermal Laboratory
Course Pre-requisite: UG Courses - Thermodynamics, Fluid Mechanics

Course Objective:
The course intends to provide opportunity to student for performing actual experiments on heat transfer mechanism and related phenomenon.

Course Outcomes:
1. Student will be able to apply the skill learnt in theory subjects to do hands on experiments.
2. Students will be able to analyze and do basic calculations on thermos-fluid related problems.
3. Students will be able to collect, analyze and interpret the data.
4. Student will be able to analyze and evaluate different thermal equipment's.

Course Content:
Laboratory experiments on topics such as:
1. Transient heat transfer
2. Convective heat conduction
3. Plate heat exchanger
4. Shell and Tube type heat exchanger
5. Fluidized bed combustion system
6. Performance on cooling tower

MTTH201 Design of Heat Exchanger
Course Prerequisite: UG Course - Heat and mass transfer PG - MTTH102

Course objectives:

- It provides exposure to different kind of heat exchanger, their working and selection for a given application.
- Students will come to know about different techniques of heat exchanger analysis.
- Student will be able to learn construction and thermal design methodology of shell and tube, Plate and compact heat exchanger

Course outcomes:

Upon successful completion of the course, students should be able to

1. have knowledge of different techniques of heat exchanger analysis and be aware of common heat exchangers with their constructions, working principles and performance parameters,
2. Understand the significance of contents of the course for the design and development of heat exchangers.
3. Apply their knowledge for thermal design of a heat exchanger such as shell and tubes, compact and plate heat exchanger,
4. Analyze an existing heat exchanger with reference to rating and sizing.

.

Course Content

Module No.	Description	Hrs.
1	**Introduction to Heat Exchangers:** Mechanism of heat exchange, Classification, Geometrical construction of Tubular, plat and compact heat exchanger, Applications and Selection.	05
2	**Basic Design Methods of Heat Exchanger:** Basic equations in design, overall heat transfer coefficient, LMTD, NTU Method for parallel and counter flow heat exchangers, multi-pass and cross flow heat exchangers, Heat exchanger design calculation- heat transfer and pressure drop calculation, Heat exchangers design methodology- rating and sizing.	06
3	**Fouling Of Heat Exchangers:** Effect of fouling, Categories of fouling, Process of Fouling, Prediction of fouling, Design of heat exchanger courseed to fouling, Operation of heat exchanger under fouling, Control of fouling.	06
4	**Shell And Tube Heat Exchanger:** Basic components, TEMA and other standards, Basic design methodology – heat transfer and pressure drop calculation, Shell side calculation- KERN'S and Bell-Delaware Method.	06
5	**Compact Heat Exchanger:** Plate fin and tube fin heat exchanger- application, construction and heat transfer and pressure drop calculation..	06
6	**Plate Heat Exchanger:** Application, mechanical features, operational characteristics, flow arrangement, heat transfer and pressure drop calculation..	06

7	**Condensers and Evaporators:** Features, types, construction, working, design and operational considerations, and thermal analysis.	05

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Introduction to Heat Exchangers	4
2. Basic Design Methods of Heat Exchanger	4
3. Fouling Of Heat Exchangers	4
4. Shell And Tube Heat Exchanger	4
5. Compact Heat Exchanger	4
6. Plate Heat Exchanger	4
7. Condensers and Evaporators	4

Recommended books:

1. Kakac, Sadik, Hongtan Liu, and Anchasa Pramuanjaroenkij. *Heat exchangers: selection, rating, and thermal design*. CRC press, 2012.R K Shah, Fundamental of Heat Exchanger Design
2. Kays and London, *Compact heat exchanger*, Krieger Pub Co,., 1998
3. Hesselgreaves, John E. *Compact heat exchangers: selection, design and operation*. Gulf Professional Publishing, 2001.T. Taborek, G.F. Hewitt and N. Afgan, Heat Exchangers, Theory and Practice, McGraw Hill Book Co., 1980
4. Taborek, Jerry. "Industrial Heat Exchangers: A Basic Guide By G. Walker, Hemisphere Pub L. Corp. Washington Dc, 1982, $41.50, 408 Pg." *AIChE Journal* 29, no. 2 (1983): 349-350.
5. Fraas, Arthur P. *Heat exchanger design*. John Wiley & Sons, 1989.

MTTH202 Experimental Analysis and Instrumentation
Course Pre-requisite: UG course - Mechanical Engineering Measurement

Course objectives:

- To learn different techniques of instrumentation involved in thermal quantity measurement.
- To understand the static and dynamic behavior of a measuring system.
- To learn different kind of errors involved in experimentation and their analysis.
- To know about the transducers for different types of thermo-physical quantities.

Course outcomes:

Upon successful completion of the course, students should be able to

1. have good knowledge and understanding of experimental analysis and Instrumentation related to thermal system,
2. Apply general concept of measurement, statistical analysis of experimental data and performance analysis of a measuring system
3. Examine a given experimental requirement and recommend a correct measurement procedure and device pertaining to kinetic and thermo-physical measurement
4. Understand the integration of digital to analog way of measurement

Details Syllabus:

Module No.	Details	Hrs.
01	**General Concepts and Statistical Analysis** General Concepts:- Types of Instruments, Functional Elements & Input-Output configuration of Measurement System / Instrument, Desired, Modifying & Interfering Inputs, Methods of correction for Interfering & Modifying Inputs. Statistical Analysis:- Gross, Systematic & Random, Causes and methods of elimination, Limiting Errors, Mean value, Deviation, Mean Deviation, Standard Deviation , Variance, Probable Errors, Probable Errors of Combination of Components, Uncertainty Analysis & Propagation of Uncertainties.	06
02	**Performance Characteristics** Static Characteristics: Important parameters. Dynamic Characteristics:-Standard inputs, Mathematical Model of Linear & Non Linear systems, Electrical Networks, Mechanical Systems, Thermal Systems, Liquid Level Systems & Pneumatic Systems, Transfer Function, Zero, First & Second order systems, First Order Electrical, Thermal & Liquid Level Systems, Differential Equation of a General First Order System, Time Domain Analysis:-Response of First and Second order system to Step, Ramp &Impulse Input, Frequency Domain Analysis:-Frequency Response of First and Second order system.	06
03	**Displacement, Velocity and Acceleration Measurement:** Classification & Characteristics of Transducers, Choice of Transducers, Displacement Measurement:-Resistive (Potentiometric), Resistance Strain Gauge, Inductive, LVDT, Capacitive, Piezo-Electric type devices, Shaft Encoder, Optical Encoder. Velocity Measurement: Doppler Effect, Mechanical, Electrical & Digital Tachometers, Non Contacting Methods, Stroboscope. Acceleration: Seismic Transducers, Resistive (Potentiometric), Resistance Strain Gauge, LVDT, Variable Reluctance, Piezo-Electric	06

	type	
04	**Pressure, Temperature and Flow Measurement** Pressure Measurement: Pressure Transducers- Potentiometric, Resistance Strain Gauge, Inductive, LVDT, Capacitive, Piezo-Electric, Photoelectric type, High Pressure Measurement: Bridgman Gauge, Vacuum Measurement:- McLeod Gauge, Knudsen Gauge, Viscosity Gauge, Thermal Conductivity Gauge, Ionization Gauge. Temperature Measurement: Electrical Methods - RTD, Thermistor, Thermocouples, Pyrometry: Total Radiation and Optical Pyrometers, Quartz Crystal Thermometer, Liquid Crystal Thermography. Flow Measurement: Orifice, Flow Nozzles, Pitot Tube, Rotameter, Vortex Meter, Hot Wire Anemometer, Turbine Flow Meter, Ultrasonic Flow Meter, Laser Doppler Anemometer,	06
05	**Measurement of Thermo-Physical Properties** Thermal Conductivity Measurement:-Steady State Methods- Guarded Hot Plate Apparatus for Solid and Liquid Samples, Radial Heat Conduction Apparatus for Liquids and Gases, Thermal Conductivity Comparators, Transient Methods: Laser Flash Method. Measurement of Heat Capacity: Solid & Liquid Samples. Measurement of Heat Transfer Coefficient: Film Coefficient Transducer, Cylindrical Heat Transfer Coefficient probe.	06
06	**Strain , Viscosity and Humidity Measurement** Strain Measurement:Theoryand Types of Strain Gauges, Gauge Factor, Gauge Sensitivity, Temperature compensation: Need & Methods. Measurement of Viscosity: Rotating cylinder, Capillary Tube, Saybolt& Redwood Viscometers. Measurement of Humidity:Terms used, Galvanometric and Electrical Hygrometers, Sling Psychrometer, Use of Dew Point Temperature.	06
07	**Instrumentation** Bridge Circuits: Wheatstone Bridge Types, Filters: Types, Operational Amplifiers: Various modes, Analog to Digital & Digital to Analog Convertors, Types of Recorders, Devices indicating & recording Voltage, Data acquisition & processing.	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. General Concepts & Statistical Analysis	4
2. Performance Characteristics	4
3. Pressure, Temperature and Flow Measurement	4
4. Measurement of Thermo-Physical Properties	4
5. Strain , Viscosity and Humidity Measurement	4
6. Instrumentation	4
7. General Concepts & Statistical Analysis	4

Recommended Books:-

1. Dobelin E.O , *Measurement Systems, Application & Design*,., McGraw Hill, New York, 2001.
2. Holman, J. P. J. P. *Experimental methods for engineers*. 2001.

3. Beckwith T.N. Buck L., Roy M.,*Mechanical Engineering Measurement*, Narosa Publishing House, .
4. Venkateshan, S. P. *Mechanical measurements*. John Wiley & Sons, 2015.
5. Rangan, C. S., Garimella R. Sarma, and V. S. V. Mani. *Instrumentation: devices and systems*. Tata McGraw-Hill, 1983.
6. Sawhney, A. K., and PuneetSawhney. "A Course on Mechanical Measurements, Instrumentation and Control." *Dhanpath Rai and Co* (2004).
7. Nakra, B. C., and K. K. Chaudhry. *Instrumentation, measurement and analysis*. Tata McGraw-Hill Education, 2003.
8. Thaval A.K., *Instrumentation and Mechanical Measurements*.
9. Anderson, Norman A. *Instrumentation for Process Measurement and Control, Third Editon*. Crc Press, 1997.
10Morris, Alan S. *Principles of measurement and instrumentation*. Prentice-Hall, Inc., 1994.

MTTH203 Computational Fluid Dynamics
Course Prerequisite: UG courses - Fluid Mechanics and Heat and Mass Transfer PG - MTTH101

Course Objective:

- To learn the methodology of numerical analysis of heat and fluid flow problems.
- To learn methods of direct and iterative methods of solving linear equations.
- To learn methods of domain discretization – FDM and FVM.
- To learn about the numerical treatment of diffusive, convective and transient heat transfer.
- To learn about the numerical treatment of fluid flow problem.

Course Outcome:

Upon successful completion of the course, students should be able to

1. have good knowledge and understanding of computational aspects of fluid dynamics,
2. Describe need of modeling and simulation and its overall methodology of execution,
3. Apply their knowledge to solve a system of linear algebraic equation using standard direct and iterative technique,
4. Examine, analyze and formulate a thermal and fluid flow problem using techniques of computational fluid dynamics

Course Content

Module No.	Description	Hrs.
1.	**Introduction to Modeling and Simulation:** Experimental and Analytical approach, Physical, Mathematical and Numerical modeling, Model validation, Simulation. Introduction and Methodology of Numerical simulation. Computational fluid dynamics and its application, merits and limitations	**06**
2.	**Solution of Linear Algebraic Equation:** Direct methods: Gauss Elimination, LU decomposition, TDMA etc. Iterative methods: Jordon method and Gauss Seidel Method, SOR and SUR, ill-conditioned system, condition number.	**06**
3.	**Mathematical Modeling:** Integral and differential form of governing equation of steady and unsteady incompressible flow and heat transfer system. Mathematical nature of PDE, Initial condition and boundary conditions (thermal and flow).	**06**
4	**Discretization Schemes:** Introduction to Finite difference method, Finite Element Method and Finite Volume Method. Developing descretized form of partial derivative terms of different order by FDM and FVM techniques. Central, Forward, Backward difference,Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.	06
5	**Numerical Modeling of Diffusive Heat Transfer:** Steady one-dimensional conduction, Two and Three dimensional steady state problems, Transient one- dimensional problem, Two-dimensional Transient Problems. Stability condition under different condition.	**06**

6	**Numerical Modeling of Convective Heat Transfer:** Steady One-Dimensional and Two-Dimensional Convection - Diffusion, Unsteady one-dimensional convection - Diffusion, Unsteady two-dimensional convection - Diffusion Upwind Schemes- Central Difference, First order, second order, QUICK and Power law scheme.	**06**
7	**Numerical Modeling of Fluid Flow:** Complexities in numerical modeling of fluid flow. Common flow modeling technique- MAC, SIMPLE, SIMPLEC and PISO. Turbulence models: Algebraic Models - One equation model, K-ε Models, K-ω Models, SST Model, Standard and High and Low Reynolds number models.	**06**

Recommended books:

1. Muralidhar, K., Sundararajan,T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House ,New Delhi1995.
2. Ghoshdastidar, ParthaSarathi. *Computer Simulation of flow and heat transfer*. Tata McGraw-Hill Publishing Company Limited, 1998.
3. Patankar, Suhas. *Numerical heat transfer and fluid flow*. CRC press, 1980.
4. Taylor, Cedric, and T. G. Hughes. *Finite element programming of the Navier-Stokes equations*. PineridgePressLtd, 1981.
5. Anderson, Dale Arden, John C. Tannehill, and Richard H. Pletcher. "Computational fluid mechanics and heat transfer." (1984).
6. Fletcher, Clive. *Computational techniques for fluid dynamics 2: Specific techniques for different flow categories*. Springer Science & Business Media, 2012.
7. Bose,T.K.,*Numerical Fluid Dynamics*,Narosa Publishing House, 1997

MTTH211 Air-Conditioning System Design (Elective III)

Course Pre-requisite: UG Course - Refrigeration and Air Conditioning.

Course Objectives:

- Understand basics of air conditioning
- Estimate the capacity of an air conditioning system
- Select the equipment for the system

Course Outcomes:

Upon successful completion of the course, students should be able to

1. Develop knowledge and understanding of air conditioning system design,
2. Describe the fundamental of psychometrics and different air condition system
3. Analyze an air conditioning system, carryout related calculation and select appropriate components
4. Apply knowledge their knowledge to solve many real life problems of air conditioning system

Course Content

Module No.	Description	Hrs.
1.	**Psychometrics:** Introduction, properties of air and water vapour mixture, psychrometric chart and its use in air-conditioning, air and human comfort.	**06**
2.	**Design of Equipment:** Analysis of air-conditioning load, load calculation.	**05**
3.	**Equipment selection:** Balancing, piping system, valves, receivers, oil trap, oil regenerators, driers and strainers	**06**
4.	**Air-conditioning system:** Window type, package type, split type, central units-direct and indirect, construction details, specification and testing, evaporative cooling system.	**06**
5.	**Air distribution**: air distribution devices-air circuits-design of supply system, noise consideration	**06**
6	**Air-conditioning controls:** Control system of temperature, pressure, oil flow, compressor motor-protection devices.	**06**
7	**Application:** Air-conditioning in automobiles, railway wagons, marine vessels, air craft and other commercial application.	**05**

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Psychometrics	4
2. Design of Equipment	4
3. Equipment selection	4
4. Air-conditioning system	4
5. Air distribution	4
6. Air-conditioning controls	4
7. Application	4

Recommended books:

1.Edward Pita, *Air-conditioning-An Energy Approach*, Pearson Press, 2002

2. Wang, Shan Kuo, and Shan K. Wang. "Handbook of air conditioning and refrigeration." (2000).
3 Carrier Air Conditioning Co., Handbook of Air Conditioning Systems design, McGraw Hill.
4. Langley, Billy C. Refrigeration and Air Conditioning Ed. 3, Engle wood Cliffs (N.J) Prentice Hall, 1995.
5. ASHRAE, Handbooks. All volumes
6. Jones, William Peter. Air conditioning engineering. Routledge, 2007.

MTTH212 Advanced Turbo machinery (Elective III)
Course Pre-requisite: MTTH101, MTTH102

Course Objective:

- To make students familiar with different type of common turbo machinery involving gas.
- To impart knowledge about construction, working and performance of centrifugal, axial and radial turbo machines.
- To understand the blade theory and apply it to develop understanding of turbo machines.

Course Outcome:

Upon successful completion of the course, students should be able to

1. Develop an advance knowledge and understanding of turbomachinery,
2. Explain the working principle and different terminology used in turbo machinery
3. Compare different system and select an appropriate turbo machines for a given application
4. Organize his understanding and apply for the analysis a given turbo system

Course Content

Module No.	Description	Hrs.
1	**Introduction:** Introduction to turbo machinery, Classification and Selection, Dimensional analysis, Model testing, Prototype and model efficiency	**06**
2	**Energy transfer in turbo-machines:** Basic thermodynamics and fluid mechanics for turbo machines. Different efficiency terms, Energy transfer in turbo machines, Euler Turbine Equation, Component of energy transfer. Specific speed	**06**
3	**Blade theory:** Aero-foil Section, Drag and lift, Energy transfer in terms of lift and drag, Blade terminology, Cascade Nomenclature, Turbine Cascade Nomenclature, Cascade testing and curves, Cascade lift and drag coefficient, Losses in cascade.	**06**
4	**Centrifugal compressor and fans:** Construction, working, velocity diagram, slip factor, energy transfer, Stage pressure rise and loading coefficient, pressure coefficient, Diffuser, Degree of reaction, Effect of blade shape on performance, Pre-whirl, Centrifugal compressor characteristics-Surging, Stall and choking, characteristic curves, losses	**06**
5	**Axial compressor and fans:** Advantages of axial flow turbo system, Construction and working principle, Stage work, pressure rise, Range of operation, efficiency, Pressure coefficient and Reaction ratio, characteristic curves, Multistage compression	**06**
6	**Axial flow and radial flow gas turbines:** Construction and working, Velocity triangle and work output, Blade loading coefficient, degree of reaction, stator and rotor losses. Efficiency	**06**

7.	**Power transmitting turbo-machines:** Introduction, Hydraulic coupling, working principle, efficiency, slip, Torque converter, Characteristics of fluid coupling and converter.	**06**

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Introduction to turbo machinery	4
2. Energy transfer in turbo-machines	4
3. Blade theory	4
4. Centrifugal compressor and fans	4
5. Axial compressor and fans	4
6. Axial flow and radial flow gas turbines	4
7. Power transmitting turbo-machines	4

Recommended books:

1. Stepanoff A.J. Turboblowers, John Wiley & sons, 1970.
2. Gorla, Rama SR, and Aijaz A. Khan. *Turbomachinery: design and theory*. CRC Press, 2003.
3. Austin, H. Chruch. "Centrifugal pumps and blowers." (1980).
4. Dixon, S. Larry, and Cesare Hall. *Fluid mechanics and thermodynamics of turbomachinery*. Butterworth-Heinemann, 2013.

MTTH213 Research Methodology (Elective III)

Prerequisite: Nil

Course Objectives:

1. To develop an ability to identify, formulate research problem.
2. To develop an ability to apply knowledge of research methodology to engineering problems.
3. To carry out research on engineering problems.
4. To develop an ability to investigate the phenomenon in a critical manner.
5. Develop critical thinking to find business opportunities and to solve questions related to industries.
6. To get knowledge on various kinds of research questions and research designs

Course Outcomes:

1. To carry out literature survey, formulate the problem statement using various research considerations
2. Demonstrate knowledge and understanding of data analysis and interpretation in relation to the research process

Course Content:

Module No.	Description	Hrs.
1	**Introduction** Definition of Research: Research Definition; Concept of Construct, Postulate, Proposition, Thesis, Hypothesis, Law, Principle. Definition and Dimension of a Theory, Functions and Characteristics; Types of Theory: General Theory and Particular / Empirical Theory. Cases and their Limitations; Causal Relations. Philosophy and validity of research. Objectives of research.	**8**
2	**Characteristics of research** Various functions that describe characteristics of research such as systematic, valid, verifiable, empirical and critical approach.	**4**
3	**Types of research** Pure and applied research. Descriptive and explanatory research. Qualitative and quantitative approaches.	**4**
4	**Research Procedure** Formulating the Research Problem, Literature Review, Developing the objectives, preparing the research design including sample Design, Sample size.	**4**
5	**Considerations in selecting research problem** Relevance, interest, available data, choice of data, Analysis of data, Generalization and interpretation of analysis	**4**
6	**Outcome of research** Preparation of the Report on conclusions reached. Testing validity of research outcomes .Suggestions and recommendations, identifying future scope.	**4**
7	**Computer application in research** Introduction to spreadsheet application, features and functions, using formulas and functions, data storing, features for statistical data analysis,	**8**

	generating charts/ graph and other features. Tools used may be Microsoft Excel, Open office or similar tool. Introduction to presentation tool, features and functions, creating presentation, customizing presentation, showing presentation. Tools used may be Microsoft Power Point, Open Office or similar tool. Introduction to Internet based searches, use of advanced search techniques.	

Tutorial work consists on class room tutorial session based on above course content.

Description of Tutorial Topics	Hrs.
1. Definition and characteristics of research	4
2. Types of research	4
3. Research procedure	4
4. Considerations of research	4
5. Outcome of research	4
6. Computer applications in research	4

Recommended books:

1. Dawson, Catherine, 2002, *Practical Research Methods,* New Delhi, UBS Publishers' Distributors.
2. Kothari, C.R.,1985, *Research Methodology-Methods and Techniques,* New Delhi, Wiley Eastern Limited.
3. Kumar, Ranjit, 2005, *Research Methodology-A Step-by-Step Guide for Beginners*, (2nd.ed), Singapore, Pearson Education.

MTTH214 Piping Engineering (Elective IV)

Course Pre-requisite: UG Courses - Thermodynamics, Hydraulic Machinery

Course Objectives

The piping engineering forms the backbone of industrial development & growth. Transportation of raw materials, basic energy inputs, finished products, utilities, wastes, etc. are utmost important to almost every industry. Even a small failure or malfunctioning of piping systems may bring industries to halt. Therefore, ensuring reliable, safe & cost effective pipeline & piping system is crucially important.

Course Outcomes

Upon successful completion of the course, students should be able to

1. Discuss needs and requirements of a piping system
2. Explain the fundamental of piping such as reading pipe layout, materials for construction-fabrication, fittings and supports, and different codes associated to piping
3. Select and analyze a pipe network for specified application
4. Calculate pressure dropin piping system using fluid mechanics fundamentals

Course Content:

Module No.	Description	Hrs.
1	**Introduction** Overview of Industry and role of piping engineering in various fields. Inputs received & outputs given by piping engineering department. Role of piping designer, engineer, analyst, etc. Preparation of fundamental drawings/diagrams such as PFD, P& ID, Plot plans, Layouts, Isometrics, etc.	**4**
2	**Materials of Construction and Fabrication** Material classification &selection of material for various processes, Preparation of Material Specification Sheets. Metallurgy of piping materials. Review of fabrication methods; their precautions, preparations & requirements relevant to pipes & piping system.	**6**
3	**Codes and Standards** Brief study of various codes/standards & rules/regulations relevant to piping engineering such as ASME B 31.1 & 31.3, IBR, Indian Explosives Act, Factories Act, NFPA rules, etc.	**6**
4	**Design of Pipes and Pipe Fittings** Pipe specification, Line designation list, Calculations for piping and pipeline sizing, Pressure drop in pipelines, piping and pipeline pressure integrity regarding thickness, including straight pipe, curved pipe, and intersections. Design of branch pipe & miter bends. Stress Intensification Factors& Flexibility Factors for pipe fittings.	**6**
5	**Valves and allied Fittings** Study & selection of various types of valves for various services such as On-Off, Throttling, Non-return, Safety, etc. Preparation of Valve data Sheets. Use of vendor data in design. Study & selection of various types of steam traps, expansion devices, etc.	**6**

6	**Pipe Supports** Study & selection of various types of pipe supports. Design considerations, supporting span of overhead pipelines. Calculations for occasional loadings such as wind and earthquake. Piping flexibility, reactions, for sustained, thermal and occasional loading. Calculations for high frequency vibration as opposed to low frequency slug flow and fluid transients.	**8**
7	**Standard Piping Arrangements and Software** Various standard piping arrangements such as Pump piping, Compressor piping, Heat exchanger piping, Tank farm piping, Storage vessel piping, Reactor piping, Distillation Column piping, etc. Relevant software hands on training.	**6**

Tutorial work consists on class room tutorial session based on above course content.

Description of Tutorial Topics	Hrs.
1. Introduction to piping -fundamentals	4
2. Materials of construction & fabrication	4
3. Codes & standards	4
4. Design of pipes & pipe fittings	4
5. Valves & allied fittings	4
6. Pipe supports	4
7. Standard piping arrangements & software	4

Recommended books:

1. MW Kellogg Co. *Design of Piping Systems*. Wiley, 1961.
2. Silowash, Brian. *Piping systems manual*. McGraw Hill Professional, 2009.
3. Peng, Liang-Chuan, and Tsen-Loong Peng. *Pipe stress engineering*. ASME press, 2009.
4. Menon, Shashi. *Piping calculations manual*. McGraw Hill Professional, 2004.
5. Wilson, B. *Detail engineering and layout of piping systems*, 2011.

MTTH215 Nuclear Engineering (Elective IV)
Course Pre-requisite: UG Courses - Thermodynamics, Fluid Mechanics, Heat and Mass Transfer PG Courses – MTTH102

Course Objectives

- General awareness of fundamentals of Nuclear energy
- Learn about effects of nuclear radiation on materials of construction
- Know about the positive and negative aspects of Nuclear Energy

Course Outcomes:

Upon successful completion of the course, students should be able to

1. Develop knowledge and understanding of nuclear engineering
2. Describe the mechanism of nuclear reaction, different type of nuclear reactors, nuclear materials and their processing and reprocessing etc.
3. Assess the significance of nuclear waste disposal and will be able to understand the need of safety and pollution control in nuclear power station
4. Discuss international safety standard practiced by the world

Course Content

Module No.	Description	Hrs.
1.	**Nuclear reactions** :Mechanism of nuclear fission - nuclides - radioactivity – decay chains - neutron reactions - the fission process	06
2.	**Nuclear reactors** - types - design and construction of nuclear reactors - fast breeder reactors- heat transfer techniques in nuclear reactors - reactor shielding	06
3.	**Reactor materials nuclear fuel cycles** - characteristics of nuclear fuels - Uranium - production and purification of Uranium - conversion to UF4 and UF6 - other fuels like Zirconium, Thorium - Beryllium.	06
4.	**Reprocessing: Nuclear fuel cycles - spent fuel characteristics** - role of solvent extraction in reprocessing - solvent extraction equipment.	06
5.	**Separation of reactor products :** Processes to be considered - 'Fuel Element' dissolution - precipitation process – ion exchange - redox - purex - TTA - chelation -U235 - Hexone - TBP and thorax Processes - oxidative slaging and electro - refining - Isotopes - principles of Isotope separation.	06
6.	**Waste disposal and radiation protection** Types of nuclear wastes - safety control and pollution control and abatement	06
7.	**International conventions**- on safety aspects - radiation hazards and prevention	06

Tutorial work consists on class room tutorial session based on above syllabus

Description of Tutorial Topics	Hrs.
1. Nuclear reactions	4
2. Nuclear reactors	4
3. Reactor materials nuclear fuel cycles	4

4.	Reprocessing: Nuclear fuel cycles - spent fuel characteristics	4
5.	Separation of reactor products	4
6.	Waste disposal and radiation protection	4
7.	International conventions	4

Recommended books:

1. Glasstone, Samuel, and Alexander Sesonske. *Nuclear reactor engineering: reactor systems engineering*. Springer Science & Business Media, 2012.
2. Duderstadt, James J., and Louis J. Hamilton. "Nuclear reactor analysis." (1976).
3. Lamarsh, J.R., Introduction to Nuclear Reactor Theory, Wesley, 1996.
4. Waltar, Alan Edward, and Albert Barnett Reynolds. *Fast breeder reactors*. Alan E. Waltar, 1981.
5. Winterton, Richard HS. *Thermal design of nuclear reactors*. Elsevier, 2014.

MTTH216 Intellectual Property Rights (Elective IV)

Course Pre-requisite: Nil

Course Objectives

- To learn about intellectual property.
- To learn about types of patents
- To learn about copyrights and trademarks
- To know about new plant varieties

Course Outcomes

Upon successful completion of the course, students should be able to

1. Know about intellectual property right and patent
2. Able to prepare patent document
3. Know about patent enforcing agencies
4. Know about commercializing intellectual property rights

Course Content:

Module No.	Description	Hrs.
1	**Overview of Intellectual Property** introduction and the need for intellectual property right (IPR), IPR in India – Genesis and Development, IPR in abroad, Some important examples of IPR	**4**
2	**Patents** Macro economic impact of the patent system, Patent and kind of inventions protected by a patent, Patent document, How to protect your inventions? Granting of patent, Rights of a patent, How extensive is patent protection? Why protect inventions by patents? Searching a patent Drafting of a patent, Filing of a patent, The different layers of the international patent system (national, regional and international options)	**8**
3	**Utility Models and Copyright** Utility models: Differences between a utility model and a patent? Trade secrets and know-how agreements Copyright: What is copyright? What is covered by copyright? How long does copyright last? Why protect copyright? RELATED RIGHTS What are related rights? Distinction between related rights and copyright? Rights covered by copyright?	**4**
4	**Trademarks** What is a trademark? Rights of trademark? What kind of signs can be used as trademarks? types of trademark, function does a trademark perform, How is a trademark protected? How is a trademark registered? How long is a registered trademark protected for ? How extensive is trademark protection? What are well-known marks and how are they protected? Domain name and how does it relate to trademarks?	**4**

5	**Geographical Indicators:** What is a geographical indication? How is a geographical indication protected? Why protect geographical indications? **Industrial Design:** What is an industrial design? How can industrial designs be protected? What kind of protection is provided by industrial designs? How long does the protection last? Why protect industrial designs? **New Plant Varieties:** Why protect new varieties of plants? How can new plants be protected? What protection does the breeder get? How long do the breeder's rights last? How extensive is plant variety protection?	**6**
6	**Unfair Competition:** What is unfair competition? relationship between unfair competition and intellectual property laws? **Enforcement of Intellectual Property Rights**: Infringement of intellectual property rights, Enforcement Measures, EMERGING ISSUES IN	**4**
7	**Intellectual Property:** Overview of intellectual property, Licensing and enforcing intellectual property, Commercializing IPR, case studies of patents.	**6**

Tutorial work consists on class room tutorial session based on above course content.

Description of Tutorial Topics	Hrs.
1. Overview of IPR	4
2. Patents	4
3. Utility Models	4
4. Trademarks	4
5. Industrial Design and New plant varieties	4
6. Enforcement of Property rights	4
7. Case study on IPR	4

Recommended books:

1. T. M Murray and M.J. Mehlman, Encyclopedia of Ethical, Legal and Policy issues in Biotechnology, John Wiley & Sons 2000
2. P.N. Cheremisinoff, R.P. Ouellette and R.M. Bartholomew, Biotechnology Applications and Research, Technomic Publishing Co., Inc. USA, 1985
3. Ajit Parulekar and Sarita D' Souza, Indian Patents Law – Legal & Business Implications; Macmillan India ltd , 2006
4. B.L.Wadehra; Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India 2000
5. P. Narayanan; Law of Copyright and Industrial Designs; Eastern law House, Delhi ,2010

MTTH299/MTTH289 Seminar II/Mini Project-II
Course Pre-requisite: Nil

Course Objective:

The course intends to provide opportunity to the student for self-learning to beyond syllabus contents related to thrust area of engineering and technology. This will inculcate the habit of lifelong learning.

Course Outcomes:

1. Student will be able to apply the skill of presentation and communication techniques.
2. Student will be able to use the knowledge of the fundamentals of subjects to search the related literature.
3. Student will be able to analyze and evaluate the available resources and to select/design/create most appropriate one.

Course Content (Seminar-II):

Sr. No.	Description	Hrs
1.	Student shall prepare a report on a topic related to his/her area of specialization outlining objective of the report, importance of the study, review of literature published in the relevant field and possible areas for further work. The student shall present seminar on this report.	**48**

Course Content (Mini Project-II):

Sr. No.	Description	Hrs
1.	Student shall select the project topic in consultation with mentor to his/her area of interest and work on it. Student will prepare a report outlining objective of the project work, importance of the study, review of literature published in the relevant field and possible areas for further work. The student shall present seminar on this report.	**48**

MTTH204 Computational Fluid Dynamics Laboratory
Course Pre-requisite: MTTH203

Course Objective:

- To learn hand on simulation of fluid flow problems.
- To learn 2-D and 3-D modelling and meshing.
- Derive results from numerical simulation

Course Outcomes:

1. Student will be able to apply the skill learnt in theory subjects to do hands on simulations.
2. Students will be able to 2-D and 3-D modelling and meshing.
3. Students will be able to analyze results of numerical simulation of thermal and fluid flow problems.

Course Content:

Laboratory experiments on topics such as:

1. 2-D Modelling and meshing
2. 3-D Modelling and meshing
3. Internal flow simulation
4. External flow simulation
5. Simulation of conductive heat transfer
6. Simulation of convective heat transfer

MTTH396 Seminar on Literature Review
Course Pre-requisite: MTTH189 / MTTH199 / MTTH289 / MTTH299

Course Objective:

To inculcate self learning and research aptitude among students to handle and investigate a real life problem.

Course Outcomes:

1. Student will be able to apply principles of ethics and standards, skill of presentation and communication techniques.
2. Student will be able to integrate the knowledge of the fundamentals of subjects to search the related literature and devise solution.
3. Student will be able to use knowledge for formulation / fabrication of the desired project.
4. Student will be able to analyze the available resources and to select most appropriate one.

Course Content:

Sr. No.	Description	Hrs
1	The project work extends through the third and fourth semester. The project work is defined based on the interest of the students to specialize in a particular area. Students are expected to carry out independent research work on the chosen topic and submit a thesis for evaluation.The work at this stage may involve review of literature, laboratory experimental work, development of software, development of model, case study, field data collection and analysis etc. On completion of the work the student shall prepare a report and will give a Seminar on the report.	48

MTTH397 Dissertation Seminars Stage I
Course Pre-requisite: MTTH189 / MTTH199 / MTTH289 / MTTH299

Course Objective:
To inculcate self learning and research aptitude among students to handle and investigate a real life problem.

Course Outcomes:
1. Student will be able to apply principles of ethics and standards, skill of presentation and communication techniques.
2. Student will be able to integrate the knowledge of the fundamentals of subjects to search the related literature and devise solution.
3. Student will be able to use knowledge for formulation / fabrication of the desired project.
4. Student will be able to analyze the available resources and to select most appropriate one.

Course Content:

Sr. No.	Description	Hrs
1	Student shall finalize a theme, related to his/her area of specialization for the dissertation work. Student shall prepare a report on the theme outlining importance of the theme of the study, objective, scope of work, methodology, and a review of literature published in the relevant area. The student shall present seminars on this report.	48

MTTH498 Dissertation Seminars Stage II Seminar (Pre-Synopsis)
Course Pre-requisite: MTTH396 / MTTH397

Course Objective:

To inculcate self learning and research aptitude among students to handle and investigate a real life problem.

Course Outcomes:

1. Student will be able to apply principles of ethics and standards, skill of presentation and communication techniques.
2. Student will be able to integrate the knowledge of the fundamentals of subjects to search the related literature and devise solution.
3. Student will be able to use knowledge for formulation / fabrication of the desired project.
4. Student will be able to analyze the available resources and to select most appropriate one.

Course Content:

Sr. No.	Description	Hrs
1	Student shall study the problem of dissertation in the light of outcome of Stage I and Stage II seminars. On completion of data collection, analysis, and inference the student shall prepare an interim report and shall present a seminar on the work done, before the submission of Synopsis.	48

MTTH499 Dissertation and Viva Voce

Course Pre-requisite: MTTH498

Course Outcomes:

1. Student will be able to apply principles of ethics and standards, skill of presentation and communication techniques.
2. Student will be able to integrate the knowledge of the fundamentals of subjects to search the related literature and devise solution.
3. Student will be able to use knowledge for formulation / fabrication of the desired project.
4. Student will be able to analyze the available resources and to select most appropriate one.

Course Content:

Sr. No.	Description
1	On finalization of the dissertation student shall submit the dissertation report. The student shall have to appear for a Viva-voce examination for the dissertation.

Guidelines for Assessment of Dissertation II

Dissertation II should be assessed based on following points

1. Quality of Literature survey and Novelty in the problem
2. Clarity of Problem definition and Feasibility of problem solution
3. Relevance to the specialization or current Research / Industrial trends
4. Clarity of objective and scope
5. Quality of work attempted
6. Validation of results
7. Quality of Written and Oral Presentation

Dissertation II should be assessed through a presentation jointly by Internal and External Examiners

Students should publish at least one paper based on the work in reputed International / National Conference (desirably in Refereed Journal)