M.TECH. DEGREE
in
THERMAL POWER ENGINEERING

SYLLABUS FOR CREDIT BASED CURRICULUM
(For Students Admitted in 2018 – 2019)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015
INDIA

JULY 2018

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY: TIRUCHIRAPPALLI

M.TECH. THERMAL POWER ENGINEERING

The total minimum credits required for completing the M.Tech. Programme in Thermal Power Engineering is 64.

SEMESTER I

CODE	COURSE OF STUDY	L	T	P	C
ME 601	Fuels Combustion and Emission Control	3	0	0	3
ME 603	Advanced Fluid Mechanics	3	0	0	3
ME 605	Advanced Heat Transfer	3	0	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
ME 609	Advanced Thermal Engineering Lab	0	0	3	2
	Total	**18**	**0**	**3**	**20**

SEMESTER II

CODE	COURSE OF STUDY	L	T	P	C
ME 604	Heat Transfer Equipment Design	3	0	0	3
ME 607	Analysis and Design of Pressure Vessels	3	0	0	3
ME 635	Analysis of Thermal Power Cycles	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
	Elective VI	3	0	0	3
ME 610	Advanced Engineering Simulation Lab	0	0	3	2
	Total	**18**	**0**	**3**	**20**

SEMESTER III

CODE	COURSE OF STUDY	L	T	P	C
ME 747	Project Work – Phase I	0	0	0	12

SEMESTER IV

CODE	COURSE OF STUDY	L	T	P	C
ME 748	Project Work – Phase II	0	0	0	12

Total Credits **64**

LIST OF ELECTIVES

Code	Course of Study	Credit
ME 602	Fluid Mechanics of Turbomachines	3
ME 606	Computational Fluid Dynamics	3
ME 631	Energy Conservation, Management, and Audit	3
ME 632	Boiler Auxiliaries and Performance Evaluation	3
ME 634	Finite Element Method in Heat Transfer Analysis	3
ME 636	Safety in Thermal and Nuclear Power Plants	3
ME 637	Installation, Testing and Operation of Boilers	3
ME 639	Boiler Production Technology	3
ME 640	Thermal Piping Analysis and Design	3
ME 642	Cogeneration and waste Heat Recovery Systems	3
ME 643	Advanced IC Engines	3
ME 644	Mechanical Vibration And Shock: Theory & Measurements	3
ME 646	Power Plant Instrumentation	3

LIST OF OPEN ELECTIVES

Code	Course of Study	Credit
ME 641	Design and Optimization of Thermal Energy Systems	3
ME 645	Pollution: Sources, Effects and Control	3

SEMESTER I

ME 601 FUELS, COMBUSTION, AND EMISSION CONTROL (3 – 0 – 0) 3

Course Learning Objective:

1. To study fuels and their properties combustion chemistry and stoichiometry.
2. To solve simplified conservation equations for reacting flows and to compare different types of FBCs.
3. To distinguish the factors influencing flame velocity and thickness flame stabilization.
4. To understand the emission norms and standards

Course Content:

Types of fuels and their properties - Coal characterization - Combustion chemistry - Stoichiometry Heat of reaction - Calorific value - Adiabatic flame temperature - Equilibrium - Mass transfer.

Chemical kinetics - Important chemical mechanisms - Simplified conservation equations for reacting flows - Laminar premixed flames - Simplified analysis.

Factors influencing flame velocity and thickness flame stabilization - Diffusion flames - Introduction to turbulent flames.

Coal combustion systems – Liquid fuel atomizers - FBC - Different types of FBCs - Models for droplet and Carbon particle combustion.

Emissions - Emission index - Corrected concentrations - Control of emissions for premixed and non-premixed combustion.

References:

1. Sharma, S.P. and Mohan, C., *Fuels and Combustion,* Tata McGraw-Hill, 1987.
2. Sarkar. S., *Fuels and Combustion,* Orient Longman, 2005.
3. John B. Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill Book, 2018.
4. Obert, E.F., *Internal Combustion Engine and Air Pollution*, International Text Book Publishers, 1983.

Course Outcome:

At the end of the course student will be able to
1. Recall fuels and their properties combustion chemistry and stoichiometry.
2. Construct simplified conservation equations for reacting flows.
3. Choose the factors influencing flame velocity and thickness flame stabilization.
4. Discuss emissions, emission index and control of emissions for premixed and no premixed combustion.

ME 603 ADVANCED FLUID MECHANICS (3 – 0 – 0) 3

Course Learning Objective:

1. To familiarize with the properties of fluids and the applications of fluid mechanics.
2. To formulate and analyze problems related to calculation of forces in fluid structure interaction.
3. To classify flows and to understand and apply the conservation principles for fluid flows.
4. To understand the principles of dimensional analysis.

Course Content:

Review of Basic concepts- Reynold's transport theorem, Fluid kinematics –

Physical conservation laws - Integral and differential formulations. Navier-Stokes and energy equations - Dimensionless forms and dimensionless numbers - Solution of Navier-Stokes equations.

Two-dimensional Potential flows - Different types of flow patterns, complex potential conformal mapping.

Momentum integral approach. Turbulent flows - Reynolds equation and closure problems, free and wall bounded shear flows- Prandtl and von Karman hypothesis- Universal velocity profile near a wall- flow through pipes Boundary layer concept.

Boundary layer thickness- Prandtl's equations - Blasius solution-skin friction coefficient.

References:

1. Currie, LG., *Fundamental Mechanics of Fluids, 3rd* ed., CRC Press, 2002.
2. White, P.M., *Viscous Fluid Flow, 2nd* ed., McGraw-Hill, 1991.
3. Ockendon, H. and Ockendon, J., *Viscous Flow,* Cambridge Uni. Press, 1995.
4. Tennekesse, H. and Lumley, JL., *A first course in turbulence*, MIT Press, 1971.
5. Kundu, P.K., Ira Cohen, M., Dowling, DR., *Fluid mechanics*, Elsevier, 1990.

Course Outcome:

At the end of the course student will be able to

1. Identify and obtain the values of fluid properties and relationship between them and understand the principles of continuity, momentum, and energy as applied to fluid motions.
2. Recognize these principles written in form of mathematical equations.
3. Apply dimensional analysis to predict physical parameters that influence the flow in fluid mechanics.

ME 605 **ADVANCED HEAT TRANSFER** **(3 – 0 – 0) 3**

Course Learning Objective:

1. To use Heisler and Grober charts and to discuss about transient heat conduction
2. To compare and optimization of longitudinal fin of rectangular, triangular and parabolic profiles
3. To understand boundary layers and to formulate pool and flow boiling correlations
4. To discuss thermal radiation, view factor, gas radiation, radiation effect on temperature measurement.

Course Content:

Transient heat conduction – Exact solution – Use of Heisler and Grober charts–Semi-infinite solids – Multidimensional systems.

Extended surfaces – Steady state analysis and optimization – Longitudinal fin of rectangular, triangular and parabolic profile radiating to free space – Radial fins.

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

Heat transfer with phase change – Condensation and boiling heat transfer – Heat transfer in condensation, Effect of non-condensable gases in condensing equipment – Pool and flow boiling correlations.

Thermal radiation – View factor – Gas radiation – Transmitting, reflecting and absorbing media

– Flame radiation in furnaces – Radiation effect on temperature measurement.

References:

1. Ozisik, M.N., *Heat Transfer - A Basic Approach*, McGraw-Hill, 1987.
2. Incropera, P.P. and Dewitt, D.P., *Fundamentals of Heat and Mass Transfer*, 5th ed., John Wiley, 2002.
3. Bejan, A., *Heat Transfer*, John Wiley & Sons Inc., 1993.
4. Kakac, S. and Yener, Y., *Convective Heat Transfer*, CRC Press, 1995.
5. Kraus, A.D., Aziz, A., and Welty, J., *Extended Surface Heat Transfer*, John Wiley, 2001.

Course outcome:

At the end of the course student will be able to

1. Discuss about transient heat conduction and to use Heisler and Grober charts
2. Analyze and optimize various fins like rectangular, triangular and parabolic profiles for heat transfer applications.
3. Understand thermal boundary layers, momentum and energy equations
4. Describe condensation and boiling heat transfer and estimate pool and flow boiling heat transfer
5. Analyze thermal and gas radiation in heat transfer equipment.

ME609 ADVANCED THERMAL ENGINEERING LAB (0 – 0 – 3) 2

Course Learning Objectives

1. To study the performance and emission characteristics of IC engine
2. To impart the knowledge of various alternate fuels for IC engines
3. To understand the thermodynamic relations of thermal engineering devices
4. To understand the working principle of different heat transfer equipments

List of Experiments

1. Simulation of IC engine processes
2. Performance and emission characteristics of SI and CI engines
3. Production, optimization and characterization studies of alternate fuels
4. Thermal property measurements of liquids
5. Melting and solidification studies of medium temperature phase change materials
6. Studies on HVAC system
7. Unsteady state heat transfer equipment
8. Radiation errors in temperature measurement
9. Pool boiling heat transfer

Course Outcome:

At the end of the course student will be able to
1. Understand the performance and emission characteristics of IC engine
2. Know the various alternate fuels and production methods
3. Understand the thermodynamic relations of thermal engineering devices
4. Understand the working characteristics of different heat transfer equipments

SEMESTER II

ME 604 HEAT TRANSFER EQUIPMENT DESIGN (3 – 0 – 0) 3

Course Learning Objective:

1. To discuss the types of heat transfer equipment and various flow patterns.
2. To study shell and tube heat exchanger and other types of heat exchangers for special services
3. To understand the design procedure of air pre-heaters, economizers, super heaters, condensers and cooling towers for thermal power plants
4. To design plate and compact heat exchangers for industrial applications

Course Content:

Classification of heat transfer equipment - Design of shell and tube heat exchanger - Finned surface heat exchanger –Heat exchangers for special services – Fired heaters

Plate and spiral plate heat exchanger – plate heat exchanger for Dairy industry – Heat Pipes

Thermal design of heat exchange equipments such as Air pre-heaters , Economizer – Super heater and condensers.

Selection of compact heat exchangers.

Analysis and design of cooling towers.

References:

1. Ganapathy, V., *Applied Heat Transfer,* Pennwell Books, 1982.
2. Kays, W.M. and London, A.L., *Compact Heat Exchangers,* McGraw-Hill, 1998.
3. Dunn, P. and Reay, D.A., *Heat Pipes,* Pergamon, 1994.
4. Kakac, S. and Liu, H., *Heat Exchangers,* CRC Press, 2002.
5. Arthur P. Frass, Heat Exchanger Design, John Wiley & Sons, 1988.
6. Hewitt G.F., Shires G.L. and Bott T.R., Process Heat Transfer, CRC Press, 1994.
7. Nicholas Cheremisioff, Cooling Tower, Ann Arbor Science Pub 1981.
8. Sekulic D.P., Fundamentals of Heat Exchanger Design, John Wiley, 2003.
9. TaborekT., Hewitt.G.F. and Afgan N., Heat Exchangers, Theory and Practice, McGraw-Hill Book Co. 1980.
10. Walker, Industrial Heat Exchangers - A Basic Guide, McGraw Hill Book Co., 1980.
11. Coulson and Richardson, Chemical Engineering Design, Volume 6, Elsevier Butterworth – Heinemann, 2005.

Course Outcome:

At the end of the course student will be able to

1. Classify the various heat transfer equipment
2. Design various heat exchangers viz. shell and tube, finned surface & special purposes for thermal engineering industries.
3. Analyze the performance of air pre-heaters, economizers, super heaters and condensers for power plants.
4. Design compact heat exchangers and cooling towers.

5. Select a suitable heat exchanger for any given application.

ME 607 ANALYSIS AND DESIGN OF PRESSURE VESSELS (3 – 0 – 0) 3

Course Learning Objective:

1. To impart basic knowledge of design of pressure vessels and piping system.
2. To introduce use of various standards used for the pressure vessel design.
3. To analyze the general applications of pressure vessels
4. To understand the development of cracks, fracture mechanism and corrosion
5. To perform finite element analysis on high pressure and temperature components

Course Content:

Establishment of design conditions – Fracture Mechanics – Heads, Basic shell thickness - Reinforcement of openings – Special components like flange, tube plate, supports.

Cylindrical shells – Thick cylinders- Lame's solution - Theories of breakdown of elastic action – Unrestrained solution – Lateral loading – General loading. Axisymmetric loading - Membrane solutions - Edge bending solutions - Flexibility matrix.

Application of general analysis – Flat closure plates –conical heads and reducers – hemispherical and torispherical, ellipsoidal heads.

Development of cracks - Fracture mechanics - Corrosion - Selection of working stress for ductile and brittle materials.

Finite element analysis for high pressure and high temperature components.

References:

1. Bickell, M.B. and Ruiz, c., *Pressure Vessel Design and Analysis*, MacMillan, London, 1967.
2. Den Hartog, J.P., *Advanced Strength of Materials*, McGraw-Hill, 1949.
3. Timoshenko, S., *Strength of Materials*, Van Nostrand, 1986.

Course Outcome:

At the end of the course student will be able to
1. Analyze thin plates and shells for various types of stresses.
2. Design shells, end closures and nozzles of pressure vessels using ASME codes.
3. Analyze the general applications of pressure vessel
4. Understand the fracture and corrosion mechanism
5. Analyze the FEM models on high pressure and temperature components

ME 635 ANALYSIS OF THERMAL POWER CYCLES (3 – 0 – 0) 3

Course Learning Objective:

1. To describe sources of energy and types of power plants.
2. To analyze different types of steam cycles and estimate efficiencies in a steam power plant.
3. To define the performance characteristics and components of power plants.
4. To study and analyse various refrigeration cycles

Course Content:

Steam power plant cycle - Rankine cycle - Reheat cycle - Regenerative cycle with one and more feed heaters - Types of feed heaters - Open and closed types - Steam traps types.

Cogeneration - Condensing turbines - Combined heat and power - Combined cycles - Brayton cycle Rankine cycle combinations - Binary vapour cycle.

Air standard cycles - Cycles with variable specific heat - fuel air cycle - Deviation from actual cycle.

Brayton cycle - Open cycle gas turbine - Closed cycle gas turbine - Regeneration - Inter cooling and reheating between stages.

Refrigeration Cycles - Vapour compression cycles - Cascade system - Vapour absorption cycles - GAX Cycle.

References:

1. Culp, R., *Principles of Energy Conversion*, McGraw-Hill, 2000.
2. Nag. P.K., *Power Plant Engineering, 2nd* Tata McGraw-Hill, 2002.
3. Nag. P.K., *Engineering Thermodynamics, 3rd* ed., Tata McGraw-Hill, 2005.
4. Arora, C.P., *Refrigeration and Air Conditioning, 2nd* ed., Tata McGraw-Hill, 2004.

Course Outcome:

At the end of the course student will be able to
1. Understand various energy resources and conversion methods and equipments
2. Derive efficiency calculation for various power cycles.
3. Understand different refrigeration cycles.

ME 610 ADVANCED ENGINEERING SIMULATION LAB (0 – 0 – 3) 2

Course Learning Objective:

1. To learn the modeling of various thermal systems
2. To impact the knowledge of simulation software
3. To understand the applications of different thermal systems
4. To employ processing of materials using CFD package

List of experiments:

Heat transfer & fluid flow analysis in pipes, cascades, ducts, heat exchanger, heat transfer equipment, Materials processing using CFD package.

Course Outcome:

At the end of the course student will be able to

1. Acquire knowledge in various heat transfer simulation
2. Acquire the knowledge of simulation software
3. Understand the applications of different thermal systems
4. Employ processing of materials using CFD package

ELECTIVE COURSES

ME 602 FLUID MECHANICS OF TURBOMACHINES (3 – 0 – 0) 3

Course Learning Objective:

1. To understand the basic concepts and flow equations of turbomachines
2. To compare and choose machines for various operations.
3. To understand the operating principles of various turbomachines and analyze their use for various engineering applications.
4. To formulate optimum design of turbomachines

Course content:

Introduction and cascades - Two-dimensional cascades - Analysis of cascade forces – Energy losses – Cascade correlation – Off design performance.

Power generating machine I - Axial flow turbines- Stage losses and efficiency – Soderberg"s correlation – Turbine flow characteristics

Power generating machine II - Radial flow turbines, Loss coefficients – off design operating condition – clearance and windage losses 90 deg IFR turbines.

Power absorbing machine I - Axial flow compressors, pumps, and fans – Three dimensional flow in axial turbo machines – theory of radial equilibrium – actuator disc approach – Secondary flows

Power absorbing machine II - Centrifugal pumps, fans, and compressors – slip factor – optimum design of centrifugal compressor inlet choking in a compressor stage.

References:

1. Dixon, S.L., *Fluid Mechanics and Thermodynamics of Turbomachinery, 5th* ed., Butterworths Heinemann, 2005.
2. William W, Peng, *Fundamentals of Turbomachinery*, John Wiley & Sons, 2007
3. Lakshminarayana, B., *Fluid Dynamics and Heat Transfer of Turbomachinery*, Wiley, 1995.
4. Yahya, S.M., *Turbines, Compressor and Fans*, 3rd Edition, Tata McGraw Hill, 2005.
5. Earl Logan, *Turbomachinery – Basic Theory and Applications*, Marcel Dekker Inc. 1993.
6. Csanady, G.T., *Theory of Turbomachines*, McGraw Hill, 1964.

Course outcome:

At the end of the course student will be able to

1. Explain basic concepts and flow equations of turbomachines.
2. Select and comparison of turbomachine for various operations
3. Discuss the operation of various turbomachine and their utilization for various engineering applications
4. Associate the optimal design of turbomachines

ME 606 COMPUTATIONAL FLUID DYNAMICS (3-0-0) 3

Course Learning Objective:

1. To introduce numerical modeling and its role in the field of heat transfer and fluid flow.
2. To enable the students to understand the various discretization methods and solving methodologies.
3. To create confidence to solve complex problems in the field of heat transfer and fluid dynamics by using high speed computers

Course Content:

Computational Fluid Dynamics: What, When, and Why?, CFD Advantages and Applications, Fundamental principles of conservation, Reynolds transport theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of Energy, General scalar transport equation. Approximate Solutions of Differential Equations: Error Minimization Principles, Functional involving higher order derivatives, Essential and natural boundary conditions,

Discretization methods - Finite Element Method and Finite difference methods: Well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM), Illustrative examples and Some Conceptual Basics and Implementation of boundary conditions. Discretization of Unsteady State Problems: 1-D unsteady state diffusion problems: implicit, fully explicit and Crank-Nicholson scheme

Important Consequences of Discretization of Time Dependent Diffusion Type Problems: Consistency, Stability, Convergence, Grid independent and time independent study, Stability analysis of parabolic and hyperbolic equations. Finite Volume Discretization of 2-D unsteady State Diffusion type Problems: FVM for 2-D unsteady state diffusion problems

Solution of Systems of Linear Algebraic Equations: Criteria for unique solution, infinite number of solutions and no solution, Solution techniques for systems of linear algebraic equations: Elimination, Iteration and Gradient Search methods with examples. Norm of a vector, Norm of a matrix, Some important properties of matrix norm, Error analysis of elimination methods.

Finite volume discretization of Convection-Diffusion Equations: Schemes. The concept of false diffusion, QUICK scheme. Discretization of Navier Stokes Equations: Discretization of the Momentum Equation, Staggered grid and Collocated grid, SIMPLE Algorithm, SIMPLER Algorithm. What is there in implementing a CFD code?: The basic structure of a CFD code: Pre-processor, Solver and Postprocessor, User-defined subroutines.

References:

1. Tannehill, J.E., Anderson, D.A., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, 2^{nd} ed., Taylor & Francis, 1997.
2. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics for Engineers, Engineering Education Systems, 2000.
3. Anderson J.D., Computational Fluid Dynamics – The basics with Applications, Mc Graw-Hill, 1995.

4. Versteeg, H.K. and Malalasekera, W., *An Introduction to Computational Fluid Dynamics – The finite volume method*, Longman Scientific & Technical, 1995.
5. Patankar, S.V., Numerical Heat Transfer & Fluid Flow, Hemisphere, 1980.
6. Date A.W., *Introduction to Computational Fluid Dynamics*, Cambridge University Press, 2005.

Course Outcome:

At the end of the course student will be able to

1. Express numerical modeling and its role in the field of fluid flow and heat transfer.
2. Estimate the various errors and approximations associated with numerical techniques
3. Apply the various discretization methods, solution procedures and turbulence modeling to solve flow and heat transfer problems.
4. Interpret the knowledge, capability of analyzing and solving any concept or problem associated with heat energy dynamics and utilization.
5. Illustrate the working concepts of thermal engineering devices.

ME 631 ENERGY CONSERVATION, MANAGEMENT, AND AUDIT (3 – 0 – 0) 3

Course Learning Objective:

1. To learn energy audit and management practices.
2. Learn to analyze various heat conversion system
3. To learn the instruments suitable for energy auditing, various measures for energy conservation and financial implications for various thermal utilities.

Course Content:

Energy Scenario - Basics of Energy and its various forms - Energy Management and -Audit - Material and Energy Balance -Energy Action Planning-Financial Management -Project Management -Energy Monitoring and Targeting -Global Environmental Concerns

Energy Efficiency in Thermal Utilities - Fuels and Combustion-Boilers-Steam System-Furnaces - Insulation and Refractory -FBC Boilers -Cogeneration -Waste heat recovery

Energy Efficiency in Electrical Utilities-Electrical Systems-Electric Motors-Compressed Air System-HVAC and Refrigeration System-Fans and Blowers-Pumps and Pumping System-Cooling Tower-Lighting System-Diesel Generating System-Energy Efficient Technologies in Electrical Systems

Energy Performance Assessment for Equipment and Utility systems -Boilers-Furnaces-Cogeneration, Turbines (Gas, Steam)- Heat Exchangers-Electric Motors and Variable Speed Drives-Fans and Blowers-Water Pumps-Compressors

HVAC Systems-Lighting Systems-Performing Financial Analysis-Applications of Non-Conventional and Renewable Energy Sources-Waste Minimization and Resource Conservation

References:

1. *Guide book for National Certification Examination for Energy Managers and Energy Auditors*, Bureau of energy efficiencies, 2005.

2. Eastop T.D & Croft D.R, *Energy Efficiency for Engineers and Technologists*, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
3. Reay D.A, *Industrial Energy Conservation*, 1st edition, Pergamon Press, 1977.
4. Witte, LC., Schmidt, P.S., and Brown, DR., *Industrial Energy Management & Utilization*, United States, 1988.

Course Outcome:

At the end of the course student will be able to
1. Apply energy audit and management practices
2. Analyze the various heat conversion systems
3. Understand the instruments applicable for energy auditing, measuring energy conservation and financial implications for various thermal utilities

ME 632 BOILER AUXILIARIES AND PERFORMANCE EVALUATION (3 – 0 – 0) 3

Course Learning Objective:

1. To understand the concepts of boiler types, circulation system and desuperheaters
2. To understand the types of fuel and ash handling equipment
3. To learn feed pumps and air draft system
4. To familiarize with the working principal of electrostatic precipitator
5. To learn soot blowers selection, operation and maintenance

Course content:

Boiler types – Specification – Circulating systems - Efficiency calculation - Balance diagram – Drum Internals – Desuperheaters.

Fuel and Ash handling Equipment – Mills - Specification – Selection – Operation – Maintenance.

Feed pumps – Different types, Specifications, Operation and maintenance aspects - Fans, blowers – Applications – Performance requirements, Selection, Operation and maintenance.

Dust cleaning equipment – Selection criteria – Design, operation and maintenance of electro static precipitators, Bag filters.

Soot blowers – Various types and their constructional features – Specifications – Selection – Operation and Maintenance.

References:

1. *Modern Power Station Practice*, CEGB London, Pergamon Press, 1991.
2. Eck, B., *Fans*, Pergamon Press, 1973.
3. Shields, C.D., *Boilers, Types Characteristics and Functions*, McGraw-Hill, 1961.

Course Outcome:

At the end of the course student will be able to
1. Understand the concepts of boiler types, circulation systems and desuperheaters

2. Understand the types of fuel and ash handling equipment
3. Describe the feed pumps and air draft system
4. Familiarize with the working principal of electrostatic precipitator
5. Explain soot blowers selection, operation and maintenance

ME 634 FINITE ELEMENT METHOD IN HEAT TRANSFER ANALYSIS (3 – 0 – 0) 4

Course Learning Objective:

1. To Understand the concepts behind variational methods and weighted residual methods in FEM.
2. To Identify the application and characteristics of FEA elements such as bars, beams, plane and isoparametric elements, and 3-D element.
3. To learn the theory and characteristics of finite elements that represent engineering structures.
4. To apply Suitable boundary conditions to a global structural equation, and reduce it to a solvable form.
5. To identify how the finite element method expands beyond the structural domain, for problems involving dynamics, heat transfer, and fluid flow.

Course Content:

Introduction, Weighted Residual Methods, Shape functions, Coordinate systems, Numerical Integration.

Modeling of Heat Conduction, Variational Formulation, Galerkin‟s Approach for one dimensional and two dimensional problems

One dimensional Problem solved using a single element – Linear element, Quadratic element, the use of numerical integration. A one dimensional problem solved using an assembly of elements.

Time stepping methods for Heat Transfer – Galerkin‟s approach in Non-linear transient heat conduction problems.

Basic Equations, Galerkin‟s Methods for steady Convection – Diffusion problems, Upwind Finite Elements in One Dimension, Heat Transfer in fluid flow between parallel planes, Convection on melting and solidification.

References:

2. Thomas, HR., Seetharamu, KN., Morgan, KR., and Lewis, W., *The Finite Element Method in Heat Transfer Analysis*, John Wiley & Sons Inc, 1996.
3. Lewis, RW., Nithiarasu P., and Seetharamu KN., *Fundamentals of the Finite Element Method for Heat and Fluid Flow*, Wiley; 1st edition, 2004.
4. Reddy, JN., and Gartling DK., *The Finite Element Method in Heat Transfer and Fluid Dynamics*, CRC Press; 2nd edition, 2000.
5. Taylor, C., and Hughes, JB., *Finite Element Programming of the Navier-Stokes Equation*, Pineridge Press Limited, U.K., 1981.

Course Outcomes

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

1. Understand the concepts behind variational methods and weighted residual methods in FEM.
2. Identify the application and characteristics of FEA elements such as bars, beams, plane and isoparametric elements, and 3-D element.
3. Develop element characteristic equation procedure and generation of global stiffness equation will be applied.
4. Apply Suitable boundary conditions to a global structural equation, and reduce it to a solvable form.
5. Identify how the finite element method expands beyond the structural domain, for problems involving dynamics, heat transfer, and fluid flow.

ME 636 SAFETY IN THERMAL AND NUCLEAR POWER PLANTS (3 – 0 – 0) 3

Course Learning Objective:

1. To learn the general safety consideration in handling of materials in thermal power plant
2. To identify the explosions and implosions of furnace
3. To understand the chemical and fuel handling systems
4. To discuss safety in nuclear power plants, safety features and radioactive waste disposal atomic energy act.

Course Content:

General safety considerations to be followed in material handling - Access requirements and welding. Safety in Commissioning of Thermal Power Plant Equipment - Steam blowing safety valve floating - Commissioning of rotary equipment.

Furnace explosions and implosions - Fire and other emergencies in boiler house - Mill bay - Air preheater bay - Cable racks and transformers - Pressure and nonpressure parts - Controls and protection logics.

Hydrogen plant - Cooling water system - Chemical handling - Fuel handling systems for coal, oil and gas - Electrostatic precipitator and H.V. rectifier.

Pressure parts - underground piping - Piping with a medium such as inflammable gas or vapour - Air pre-heaters and fans - Burner system - Closed vessels - Turbo generators - Switch-gears and transformers.

Safety in Nuclear Power Plants - Basic concepts - Radiation hazards and control practices - Reactor design safety features - Radioactive waste disposal Atomic Energy act - Radiation protection rules.

References:

1. Sterman, LS., *Thermal and Nuclear Power Stations*, MIR Publications, 1986.
2. El. Vakil, MM., *Nuclear Power Technology*, McGraw Hill, 1992.
3. Loffness, RL., *Nuclear Power Plant*, Van Nostrand, 1987.
4. Lish, KC., *Nuclear Power Plants Systems and Equipment*, Industrial Press, New York, 1972.
5. *Fossil Power Systems*, Combustion Engineering, 1990.

Course Outcome:

At the end of the course student will be able to
1. Explain the general safety consideration in handling of materials
2. Identify the explosions and implosions of furnace
3. Understand the chemical and fuel handling systems
4. Understand the safety procedures to be followed in nuclear power plants

ME 637 INSTALLATION TESTING AND OPERATION OF BOILERS (3 – 0 – 0) 3

Course Learning Objective:

1. To familiarize with the procedure and techniques of installing supporting structures
2. To choose modern boilers by using material characteristics
3. To explain commissioning and pre-commissioning activities of boilers
4. To predict life estimation for very old boilers and illustrate the thermal performance tests and capacity restoration

Course Content:

Methods and procedure of installation supporting structure - Civil foundations - sequence of Erection - HSFC Bolts. Pressure parts erection and alignment. - Provision for expansion.

Mountings - Seal boxes & seal welding, Erection of ESP, Rotary APH and fans - alignment and grouting of fans. Erection of ducks and dampers - „Cold Pull‟.

Lining and Insulation - Material characteristics and selection, Arrangements of refractory/insulation in modern boilers - methods of application.

Commissioning activities - Objectives - Pre commissioning checks - chemical cleaning Initial operation - Boiler turning and performance optimization.

Special commissioning checks - Preventive maintenance of boilers and auxiliaries, tube failures - causes and prevention - life estimation for very old boilers - Thermal performance tests and capacity restoration.

References:

1. *Erection of Boilers and Auxiliary Equipment,* Manuals Prepared by B.H.E.L., Tiruchirappalli, 1990.

Course Outcome:

At the end of the course student will able to:
1. Familiarize with the installation of supporting structures
2. Know the boiler mountings, insulation and linings
3. Analyze the commissioning activities
4. Understand the thermal performance and capacity restoration

ME 639 BOILER PRODUCTION TECHNOLOGY (3 – 0 - 0) 3

Course Learning Objective:

1. To illustrate stresses in pipes due to fluid pressure and to review code formulae for pipe wall thickness and to compute losses in piping systems
2. To distinguish stable and unstable deformations and to analyze failure and plastic instability
3. To discuss loadings, design limits, allowable stresses, and evaluation of stresses
4. To explain failure theories involved in piping
5. To distinguish in-plane bending moment and out of plane moment and to discuss occasional loads, creep, fatigue and stress analysis

Course Content:

Mechanics of metal working, Effect of temperature, stain rate and metallurgical structure on metal working. Workability, Residual stresses. Casting of Valves components, coal compartment assembly. Forging - Open die forging and closed die forging, different types of dished ends, Cold bending - Explosive and hydrodynamic forming of dished ends.

Types of rolling - rolling of bars and shapes, forces and geometrical relationship in rolling, rolling defects. Edge preparation: Beveling of tubes for headers, drums, stubs. Tube Expanders.

Welding and allied processes an overview – SMAW – GTAW, GMAW, Resistance welding, Electron beam welding, ultrasonic welding, Laser welding, Friction welding, Plasma arc welding,

Welding metallurgy – Thermal effects – heat treatment associated with welding, testing and inspection – Destructive and Non-Destructive welding. Welding Joint design – location- symbol.

Manufacture of pressure vessel components – manufacture of boiler drums, headers, structures, water walls, super heaters, mills, fans. Manufacture of heat exchangers and nuclear components.

References:

1. *ASM Metals Handbook, Forming and Forging*, Vol.14, Metals Park, Ohio, USA, 1990.
2. Dieter, G.E., *Mechanical Metallurgy*, McGraw-Hill Co. 1995.
3. Lange, K., *Hand book of Metal Forming*, McGraw Hill Book Company, 1985.
4. *AWS Welding Hand Books*, Section 1 to VIII, American Welding Society, 1996.
5. Jeffus, LF., *Welding: principles and applications*, 5th edition, Delmer Publishers, 2004

Course Outcome:

At the end of course the student will be able to

1. To illustrate stresses in pipes due to fluid pressure and to review code formulae for pipe wall thickness and to compute losses in piping systems
2. To distinguish stable and unstable deformations and to analyze failure and plastic instability
3. To discuss loadings, design limits, allowable stresses, and evaluation of stresses.
4. To explain failure theories involved in piping
5. To distinguish in-plane bending moment and out of plane moment and to discuss occasional loads, creep, fatigue and stress analysis

ME 640 THERMAL PIPING ANALYSIS AND DESIGN (3 – 0 – 0) 3

Course Learning Objective:

1. To understand the various stresses applied in pipes due to fluid pressure
2. To learn the stable and unstable deformations
3. To familiarize with code and standards
4. To analyze the failure theories
5. To understand the structural loading

Course Content:

Stresses in pipes due to fluid pressure – Collapsing pressure – Thin and thick walled cylinders – Code formulae for pipe wall thickness – Losses in piping systems – Effect of curvature on resistance of bends.

Stable and unstable deformations – Plastic deformation under uniaxial stress – Tri-axial stress – Yield condition – Plastic stress - strain relationship for tri-axial stress – Failure and Plastic Instability – Creep – Brittle and ductile fracture – Fatigue.

Codes and standards – Design considerations: Loadings – Design limits, Allowable stresses and Allowable stress ranges – Stress Evaluation – Combination of Stresses: Stress Intensification and Flexibility Factors – Evaluation of Deflections and Reactions.

Introduction – Failure theories: Maximum principal stress theory and Maximum shear stress theory – stress categories – stress limits – fatigue – Classification of loads – service limits – code requirements.

Structural loading: In-plane bending moment (closing and opening), Out of plane moment – Internal and External pressure – Combined loading – Occasional loads – Creep – Fatigue – Stress analysis – Shakedown –Limit analysis – Calculation of Collapse and Instability loads – Corrosion and Erosion Effects – Case studies using Finite Element Method.

References:

1. The American Society of Mechanical Engineers, "*ASME Boiler and Pressure Vessel code*", New York, ASME, 2004.
2. King R.C., "*Piping Handbook*", 5th edition, McGraw Hill Book Company, 1973.
3. Nayyar, Mohinder L, "*Piping Handbook*",7th edition, McGraw Hill, 2000.
4. John F. Harvey, "*Theory and Design of Pressure Vessels*", CBS Publishers, 2001.
5. The M.W. Kellogg Company, *Design of Piping Systems*", 2nd edition, John Wiley & Sons, 1956.

Web references:

Springer Verlag"s Link URL: http://www.springerlink.com/
Elsevier's Science Direct URL: http://www.sciencedirect.com/
ASME Journals URL: http://scitation.aip.org/publications/myBrowsePub.jsp

Course Outcome:

At the end of the course student will be able to
1. Understand the various stresses applied in pipes due to fluid pressure
2. Explain the stable and unstable deformations
3. Familiarize with code and standards
4. Analyze the failure theories
5. Describe the structural loading

ME 642 COGENERATION AND WASTE HEAT RECOVERY SYSTEMS (3 – 0 - 0) 3

Course Learning Objective:

1. To analyze the basic energy generation cycles.
2. To detail about the concept of cogeneration, its types and probable areas of applications.
3. To learn the waste heat recovery
4. To study the significance of waste heat recovery systems and carry out its economic analysis.
5. To understand the environmental consideration waste heat recovery and cogeneration

Course Content:

Cogeneration - Introduction - Principles of Thermodynamics - Combined Cycles-Topping - Bottoming - Organic Rankine Cycles - Advantages of Cogeneration Technology

Cogeneration Application. Sizing of waste heat boilers - Performance calculations, Part load characteristics - selection of Cogeneration Technologies – Financial considerations.

Waste heat recovery - Introduction - Principles of Thermodynamics and Second Law - sources of Waste Heat recovery - Power Plant.

Waste heat recovery systems - Design Considerations - fluidized bed heat exchangers - heat pipe exchangers - heat pumps -thermic fluid heaters - selection of waste heat recovery technologies

Environmental considerations for cogeneration and waste heat recovery - Pollution.

References:

1. Butler, CH., *Cogeneration*, McGraw Hill Book Co., 1984.
2. Horlock JH., *Cogeneration - Heat and Power, Thermodynamics and Economics*, Oxford,1987.
3. Institute of Fuel, *Waste Heat Recovery*, Chapman & Hall Publishers, London, 1963.
4. Subrata, S., Lee, SS., *EDS, Waste Heat Utilization and Management*, Hemisphere, Washington, 1983.
5. Nevers, D., Noel, *Air Polllution Control Engineering*, McGrawHill, New York,1995.

Course Outcomes:

At the end of the course student will able to
1. Understand the principles of cogeneration systems, waste heat recovery systems,
2. Explain the applications of cogeneration
3. Describe the economic analysis of waste heat recovery systems.
4. Describe the significance of waste heat recovery systems and carry out its economic analysis.
5. Understand the environmental consideration waste heat recovery and cogeneration

ME 643 **ADVANCED IC ENGINES** **(3 – 0 – 0) 3**

Course Learning Objective:

1. Learn to classify different types of internal combustion engines and their applications.
2. Apply principles of thermodynamics, fluid mechanics, and heat transfer to the design and analysis of engines and engine components.
3. Become aware of the relevance of environmental and social issues on the design process of internal combustion engines.
4. Develop mathematical methods for designing components and systems
5. Apply numerical methods to perform design calculations.
6. Advance proficiency in professional communications and interactions.

Course Content:

Combustion process in SI and CI engines, Combustion chambers and abnormal combustion.

Composition and effect of Fossil and Alternative Fuels in IC Engine.

IC Engine Modelling – Zero dimensional, Two zone and Multi zone modelling.

Instrumentation to study the combustion process in engines such as Particle image velocimetry Holographic PIV, Spray visualization, Phase Doppler interferometry for spray characterization.

Pollutant formation in SI and CI engines and Control measures such as DOC, DPF, SCR and LNT

References:

1. Heywood, JB., *Internal Combustion Engine Fundamentals*, McGraw-Hill, 1988.
2. Gill, PWS., Smith, JR., and Ziurys, J., *Fundamentals of internal combustion engines*, Oxford and IBH, New Delhi, 1959.
3. Taylor, CF., *The Internal combustion Engine in theory and practice*, MIT Press, Cambridge, 1985.
4. Obert, EF., *Internal Combustion Engines and Air Pollution*, Intext Educational Publishers, New York, 1973.
5. Bechtold, RL., *Alternative Fuels Guidebook, Properties, Storage, Dispensing, and Vehicle Facility Modifications*, SAE Publications, 1997.
6. Patterson DJ., and Henein NA., *Emission from Combustion engines and their control*, Ann Arbor science publishers, 1981.
7. Heisler, H., Advanced Engine Technology, ISBN 0340568224, SAE Publications, 1995.
8. Lumley, JL., *Engines: An Introduction*, Cambridge University Press, 1999.

Course Outcome:

At the end of the course student will be able to
1. Understand the combustion phenomena in SI and CI engines.
2. Study the characteristics of fossil and alternative fuels and their effect on the performance of IC engines.
3. Explain the recent technologies to tradeoff engine performance and emission characterization.
4. Explain the advanced imaging techniques to study the combustion and spray characteristics of the fuel.
5. Identify the exhaust pollutants and measurement techniques.

ME 644 MECHANICAL VIBRATION AND SHOCK: THEORY & MEASUREMENTS (3-0-0-3)

Course Learning Objectives:

1. Classify the characteristics of Vibration and shock.
2. Estimate the natural frequency of structural and Continuous system.
3. Introduced to various Instruments for vibration measurement and its measuring technique.
4. Demonstrated with various frequency analysis of vibration and shock.
5. Illustrate the need of vibration Isolation and control.
6. Introduced to shock and vibration analysis using Finite element analysis.

Course Content:

Characteristics of vibration & shock - Periodic vibration-Stationary random vibration-Transient phenomena and shocks-Non Stationary random vibrations, Response of mechanical system due to vibration - Response of linear and nonlinear system for vibrations-rotational & torsional vibrations-Response of mechanical system due to random vibration-Shock response & shock spectra-Vibration in structures- Shock and vibration analysis using FEA-Statistical energy analysis

Effects of vibration and shock on mechanical system - Damaging effects of vibration-Damaging effects of shock & transients, Effects of vibration and shock on man - Whole body vibration-Hand & arm vibration

Vibration measuring instrumentation and techniques - General measurement consideration-Selection of accelerometer-Selection of accelerometer pre amplifier-Calibration & system perfectness check-Force & impedance transducers-Mounting of accelerometers-Lab oriented instrumentation

Frequency analysis of vibration and shock - Introduction- Serial analysis of stationary signals-Real time analysis of transient and stationary signals-Analysis of non-stationary signals, Vibration measurement for machine health monitoring - Basic consideration- Force vibration relationships-Frequency range, dynamic range parameters-Use of vibration measurements for maintenance

Vibration and shock testing - Vibration testing-Shock testing, Fundamentals of shock and vibration control - Isolation of vibration and shock-Dynamic vibration control- Vibration damping.

Reference Books

1. Broch, JT., *Mechanical Vibration and Shock Measurements*, Bruel & Kjaer, Denmark, 2nd Edison, 1984.
2. Dossing, O., *Structural Testing Part I & Part II*, Bruel &Kjaer, Denmark, 1988.

Course Outcome:

At the end of the course, the students will be able to:

1. Enumerated with the effect of damping
2. Able to select the appropriate vibration measuring instrument.
3. Able to formulate the frequency for linear and nonlinear vibration
4. Able to extend his ideas to predict the merits and demerits of vibration measuring system.

5. Able to understand the need for measuring human vibration.
6. Identify the source of vibration in mechanical system.

ME 646 POWER PLANT INSTRUMENTATION (3 – 0 – 0) 3

Course Learning Objective:

1. To provide knowledge on various measuring instruments for thermal engineering.
2. To familiarize with static and dynamic features of instruments
3. To understand the various steps involved in error analysis and uncertainty analysis.
4. To provide knowledge on advance measurement techniques.
5. To impart knowledge on different control systems

Course Content:

Generalized instrumentation system – Error theory – Calibration of instruments – Range – resolution – Span – Linearity, Sensitivity- Signal conditioning systems.

Static and dynamic characteristics of instruments zero order, first order, second order instruments.

Error analysis - Uncertainty propagation – Oscilloscope for analysis of dynamic and transient events.

Principles and analysis of measurement systems used for measurement of flow, power, pressure, and temperature.

Basics of control system - Types of control – proportional control, Derivative control, Integral control, PID control-Programmable logic controllers.

References:

1. Doebelin, EO., *Measurement Systems* - *Application and Design*, *5th* ed., McGraw-Hill, 2004.
2. Beckwith, TG., Buck, L., and Marangoni, RD., *Mechanical Measurements*, Narosa Pub. House,1987.
3. Hewlett Packard, *Practical Temperature Measurements* - Application Note 290, 1995.
4. Barnery, Intelligent Instrumentation, Prentice Hall of India, 1988.
5. Bolton, W, Industrial Control & Instrumentation, Universities Press, Second Edition, 2001.
6. Holman JP., Experimental methods for engineers, McGraw-Hill, 2012.
7. Webster, JG., The measurement, Instrumentation and sensors Handbook, CRC and IEE Press, 1999.
8. Morris, AS, Principles of Measurements and Instrumentation Prentice Hall of India, 1998.
9. Nakra, BC., Choudhry KK., Instrumentation, Measurements and Analysis Tata McGraw Hill, New Delhi, 2nd Edition 2003.

Course Outcome:

At the end of the course student will be able to

1. Employ knowledge on various measuring instruments for thermal engineering.
2. Familiarize with static and dynamic features of instruments
3. Understand the various steps involved in error analysis and uncertainty analysis.
4. Analyze on advance measurement techniques.
5. Explain on different control systems

OPEN ELECTIVES

ME 641 DESIGN AND OPTIMISATION OF THERMAL ENERGY SYSTEMS (3 – 0 - 0) 3

Course Learning Objective:

1. To describe energy system design and recall regression analysis and equation fitting
2. To design thermal equipment like heat exchangers, evaporators, condensers, turbomachines, distillation equipment, absorber, generator, GAX.
3. To apply the successive method and Newton Raphson method in energy systems
4. To construct mathematical representation for optimization problems in energy systems
5. To analyze the cost involved in energy system by present worth-annual cost method

Course Content:

Introduction to Energy System Design - Modeling of thermal equipment - heat exchangers, evaporators, condensers, turbomachines, distillation equipment. Absorber, generator, GAX.

System simulation - Application of successive method and Newton Raphson Method to Energy Systems.

Regression analysis and Equation fitting, best fit - Least Square Regression, Exact fit - Lagrange interpolation.

Mathematical Representation for Optimization Problems in Energy Systems-Applications of various search methods to Energy Systems - Waste Heat Recovery System - design of energy recovery systems-Genetic Algorithm.

Thermoeconomic analysis-Exergy analysis-Estimation of cost of investment, cost of fuel, cost balance, cost of product-Thermoeconomic optimization.

References:

1. Hodge, BK. and Taylor, RP., *Analysis and Design of Energy Systems, 3rd Edition,* Prentice Hall, 1999.
2. Stoecker, WF., *Design of Thermal Systems*, McGraw-Hill, 1989,
3. Burmeister, LC., *Elements of Thermal-Fluid System Design*, Prentice Hall, 1998.
4. Jaluria, Y., *Design and Optimisation of Thermal Systems*, McGraw-Hill, 1998.
5. Janna, WS., *Design of Fluid Thermal Systems*, PWS-Kent Publishing, 1993.
6. Balaji, C., *Essentials of Thermal system Design and Optimization*, Ane Book pvt. Ltd., 2011.
7. Bejan, A., Tsatsaronis, G., and Moran, M., *Thermal Design and Optimization*, Wiley-IndiaEdition, 2013.

Course Outcome:

At the end of the course student will be able to

1. Describe energy system design and recall regression analysis and equation fitting
2. Design thermal equipment like heat exchangers, evaporators, condensers, turbomachines, distillation equipment, absorber, generator, GAX.
3. Apply the successive method and Newton Raphson method in energy systems
4. Construct mathematical representation for optimization problems in energy systems
5. Analyze the cost involved in energy system by present worth-annual cost method

ME 645 POLLUTION: SOURCES, EFFECTS AND CONTROL (3 – 0 – 0) 3

Course Learning Objective:

1. To impart knowledge on the atmosphere and ecolegislations.
2. To classify air, water and land pollutants and sources
3. To learn about pollutant sampling and analysis
4. To understand hazardous waste management
5. To study the various methods of controlling pollution in industries

Course Content:

Pollution control philosophy- chemical pollution of the aquatic environment-regulation of direct discharge-regulation. Chemistry and pollution of marine environment-sources, movement and behavior of pollutants.

Water pollution biology - chemical contaminants - drinking water quality and health-sources of contamination-drinking water standards-microbiological quality.

Sewage treatment processes - Sludge treatment and disposal. Sources and types of toxic wastes-treatment of toxic waste-disposal of toxic wastes.

Air pollution – sources, concentration and measurements, Air quality management-indoor air quality. Effects of air pollution on health, crops, trees and ecosystems. Control of air pollution-emission standards. Chemistry and climate change in Troposphere, Stratosphere. Atmospheric dispersal of pollutants and Modelling of air pollution.

Soil Pollution and Land contamination-sources-properties-consequences of soil pollution-case studies-Solid waste management.

Radioactivity in the environment-types of radiation-effects of radiation-radioactive waste treatments and disposal.

Noise pollution – sources and effects - standards and control.

Clean technologies and industrial ecology-environmental behavior of persistent organic pollutants. Integrated pollution prevention and control-design for the environment. Pollution prevention planning- Legal control of pollution-National Law-trends and issues in pollution legislation.

References:

1. Harrison, RM., *Pollution causes, effects and control*, 4th Edition, Royal Society of Chemistry, 2001.
2. Bishop, P., *Pollution Prevention: Fundamentals and Practice*, McGraw-Hill International Edition, McGraw-Hill book Co, Singapore, 2000.
3. Sincero AP., and Sincero, GA., *Environmental Engineering – A Design Approach*, Prentice Hall of India Pvt Ltd, New Delhi, 2002.
4. Rao, CS., *Environmental pollution engineering*, Wiley Eastern Limited, New Delhi, 1992.
5. Mahajan, SP., *Pollution control in process industries*, Tata McGraw Hill Publishing Company, New Delhi, 1993.
6. Masters G., *Introduction to Environmental Engineering and Science*, Prentice Hall of India Pvt Ltd, New Delhi, 2003.

Course Outcome:

At the end of the course student will be able to

1. Understand the atmospheric pollutants and ecolegislations.
2. Classify air, water and land pollutants and sources
3. Analyse various pollutants from industries
4. Manage hazardous wastes in industries
5. Understand various methods of controlling pollution in industries