COURSES OF STUDY FOR

M. TECH.

(Thermal Engineering)

IN

MECHANICAL ENGINEERING

National Institute of Technology Srinagar

Dean Acad

14.9.2021

Submitted by:
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Mechanical Engineering Department

Requirements for completion of M. Tech in Thermal Engineering (MTE)

(As per NIT academic statutes)

1. A student has to complete a minimum of 60 credits for the award of M. Tech Degree. The credit structure is as follows:
    a. Core: 13+11+3=27 credits
    b. Dissertation: 18 credits
    c. Electives: 15 credits (Minimum)
2. Full time student has to take 12 to 17 credits in each semester.
3. Part time student has to take 9 to 12 credits in each semester.
4. In addition to above a student can audit a total number of 3 courses during his/her entire programme of M. Tech, for which he/she will be awarded an AU grade, subject to the following:
    a. In 1st year: 1st semester, full time student is not allowed to audit a course whereas a part-time student can do so.
    b. A part-time or full-time student can audit only one course in one semester.

Eligibility criteria for admission to M. Tech in Thermal Engineering (MTE)

1. BE./B. Tech (4-year Programme) in Mechanical Engineering/Chemical Engineering from Accredited/Recognized University/ Institution having a valid GATE score.
2. Sponsored/Self-sponsored category shall be admitted as per Institute policy.

Seat Matrix

The category wise seat matrix for July 2022 session will be as follows:

Category	Intake capacity for proposed M. Tech (MTE)
Open	8
Open-PWD	1
Open-EWS	2
EWS-PWD	0
SC	2
SC-PWD	1
ST	1
ST-PWD	0
OBC	5
OBC-PWD	0
Sponsored/Self Sponsored	15
Total	35

Thermal Engineering First Semester

S. No.	Subject	C	L	T	P
MTE 101	Conduction and Radiation	3	3	0	0
MTE 102	Advanced Internal Combustion Engine	3	3	0	0
MTE 103	Instrumentation and Measurement Techniques	3	3	0	0
MTE 104	Compressible Fluid Flow	3	3	0	0
MTE 105	Advanced Heat and Fluid Flow Laboratory	1	0	0	2
	Elective--I	3	3	0	0
Total Credits & LTP		**16**	**15**	**0**	**2**

Thermal Engineering Second Semester

S. No.	Subject	C	L	T	P
MTE 106	Advanced Concepts in Thermodynamics	3	3	0	0
MTE 107	Viscous Flow Theory	3	3	0	0
ChMC23	Computational Fluid Dynamics	3	3	0	0
MTE 108	Seminar	1	0	0	6
MTE 109	Instrumentation and Measurements Laboratory	1	0	0	2
	Elective –II	3	3	0	0
	Elective -III	3	3	0	0
Total Credits & LTP		**17**	**15**	**0**	**8**

Thermal Engineering Third Semester

S. No.	Subject	C	L	T	P
MSD 104	Design Optimization	3	3	0	0
	Elective–IV	3	3	0	0
	Elective –V	3	3	0	0
MTE 110	Dissertation-I	6	0	0	6
Total Credits & LTP		**15**	**9**	**0**	**0**

Thermal Engineering Fourth Semester

S. No.	Subject	C	L	T	P
MTE 111	Dissertation-II	12	0	0	18
Total Credits & LTP		**12**	**0**	**0**	**18**

List of Electives (Elective--I, Elective--II, Elective--III, Elective--IV, Elective--V)

S.No	Course Code	Course Title	Credits	L	T	P
1.	MTE-112	Modeling and Simulation of Thermal Systems	3	3	0	0
2.	MTE-113	Research Methodologies and Techniques	3	3	0	0
3.	MTE-114	Refrigeration Engineering	3	3	0	0
4.	MTE-115	Convection Heat Transfer	3	3	0	0
5.	MTE-116	Advanced Characterization and Instrumentation Techniques for Thermal Systems	3	3	0	0
6.	MTE-117	Microscale and Nanoscale Heat Transfer	3	3	0	0
7.	MTE-118	Turbulent Flows	3	2	0	1
8.	MTE-119	Energy Management and Auditing	3	3	0	0
9.	MTE-120	Engine Modeling And Simulation	3	3	0	0
10.	MSD-102	Finite Element Method	3	3	0	0
11.	MSD-205	Advanced Control Systems	3	3	0	0
12.	MTME15	Advanced Numerical Methods	3	3	0	0
13.	PSPHY EL1	Renewable Energy Sources	3	3	0	0
14.	ChMC11	Advanced Transport Phenomena	3	3	0	0
15.	ChME26	Fundamentals of Fuel Cell Technology	3	3	0	0
16.	ChME25	Environmental Eng. and Waste Management	3	3	0	0
17.	EEM129	Hybrid Electric Vehicles	3	3	0	0
18.	EEM 108	Soft Computing	3	3	0	0

MTE 101 **CONDUCTION AND RADIATION**
C L T P 3 3 0 0

Introduction, Thermal energy equation in a solid medium, Fourier's law revisited, thermal conductivity tensor, Initial and boundary conditions, non-dimensionalization, fin equation, Steady state in one dimension, slab and circular geometries, heat conduction in fin, steady state in two dimension, heat conduction in square domain, heat conduction in cylindrical coordinates

Unsteady heat conduction in one and two dimensional regions, bonded one dimensional domain, transient response of linear systems, semi-infinite solids, time-dependent boundary conditions, time-dependent source terms, One dimensional phase change, Stefan condition, movement of phase front in super-cooled liquid, heat transfer in solid and liquid phases, Inverse heat Transfer, method of sensitivity coefficients, least squares approach, linear and nonlinear inverse problems

Planck's law, special form, radiation intensity, energy exchange between black surfaces, Energy exchange between diffuse-gray surfaces, Gas radiation, combined conduction and radiation, radiative exchange in a participating medium, exact solution of the radiative transport equation

Textbook and References:

1. Heat Conduction by N. Ozisik, John Wiley, John Wiley, 2012
2. Heat Conduction by Kakac, S., Yener, Y., Naveira-Cotta, C.P., CRC Press, 2018.
3. Conduction and Radiation by K. Muralidhar and J. Bannerjee, Narosa Publishers, 2009
4. Thermal Radiation Heat Transfer by Sigel and Howell, McGraw Hill, 2014

MTE 102 **ADVANCED INTERNAL COMBUSTION ENGINE**
C L T P 3 3 0 0

Basic design of internal combustion engines. Design techniques for engine manifolds. Introduction, methods for calculating the unsteady flow of a compressible gas in a pipe, design of engine gas flow systems, numerical simulation of unsteady flows in internal combustion engine silencers and prediction of tail pipe noise. Case studies further developments.

Main components of electronic fuel injection system. Design of electronic fuel injection system. Throttle body injection, port injection and direct fuel injection techniques. Pollution from internal combustion engines. Mechanism of pollution formation in internal combustion engines.

Design of catalytic converters and filters for pollution control from I C engines. Engine performance with alternative fuels like hydrogen, CNG, LPG, Non edible vegetable oils, bio-diesel etc. engine modifications for alternative fuels.

Textbook and References:

1. Advanced Engine Design by Hoag , *SAE Publication,2005.*
2. Fundamentals of IC Engines by J B Heywood, McGraw Hill.

MTE 103 INSTRUMENTATION AND MEASUREMENT TECHNIQUES

C L T P 3 3 0 0

Characteristics of Measurement Systems - Elements of Measuring Instruments Performance characteristics - static and dynamic characteristics. Calibration. Analysis of experimental data - Causes and types of experimental errors - Error & uncertainty analysis-statistical & graphical methods -probability distributions. Temperature measurements -Theory, Thermal expansion methods, Standards and Calibration. Thermoelectric sensors, Resistance thermometry, Junction semiconductor sensors, Pyrometry, Infrared imaging systems. Temperature measuring problems in flowing fluids, Dynamic Response & Dynamic compensation of Temperature sensor, Heat Flux measurements.

Fluid pressure measurement - Mechanical & Electrical types, High pressure & Low pressure measurements, Differential Pressure Transmitters. Laminar & Turbulent flow measurements - Determination of Reynolds stresses – Flow visualization techniques - Gross Volume flow measurements - Measurement of Liquid level, Density, Viscosity, Humidity & Moisture, Compressible flow measurements. Thermal Analysis Techniques - Measurements in combustion: Species concentration, Reaction rates, Flame visualization, charged species diagnostics, Particulate size measurements. Data Acquisition and Processing - General Data Acquisition system - Signal conditioning - Data transmission - A/D & D/A conversion - Data storage and Display - Computer aided experimentation.

Text Book and References:

1. Measurement Systems – E O Doeblin, D N Manik – 6/e, Mc Graw Hill, 2015.
2. Temperature, Pressure and Air Flow Measurements by R..P. Benedict, John Wiley
3. Fluid Mechanics Measurement by R.J.Goldstein, Taylor and Francis, 1996
4. Experimental Methods for Engineers by J.P.Holman, McGraw Hill, 2007

MTE 104 COMPRESSIBLE FLUID FLOWS

C L T P 3 3 0 0

Introduction, Concepts and applications of compressible flow, speed of sound and Mach number, Supersonic Flow: Normal Shocks - Governing equations, Rankine Huguenot, Prandtl and other relations, weak shocks, thickness of shocks, normal shocks in ducts, performance of convergent divergent nozzle with shocks, moving shock waves, shock problems in one dimensional supersonic diffuser, supersonic pitot tube. Flow in Constant Area Duct under different conditions: Flow in Constant Area Duct with Friction: Governing equations, working formulas and tables, choking due to friction, performance of long ducts, Isothermal flow in long ducts. Flow in Constant Area Duct with Heating and Cooling: Governing equations, working formula and tables, choice of end states, choking effects, shock waves with changes in stagnation temperature.

Generalized One-Dimensional Flow: Working equations, general method of solution, example of combined friction and area change, Example of combined friction and heat transfer. Oblique shock: Governing physical equations and general relations, shock polar diagram and auxiliary diagrams, strong and weak shocks, detached shock, interaction and reflection of shocks.

Method of characteristics flows & its applications: General principle of integration using method of characteristics, application to one dimensional isentropic progressive waves, application to steady two dimensional irrotational isentropic supersonic flows, Prandtl-Meyer expansion

Textbook and References:

1. Compressible Fluid Flow by M.A. Saad, Prentice-Hall, New Jersey, 1985
2. Gas Dynamics by E. Rathakrishnan, Prentice-Hall of India, New Delhi, 2002.
3. The Dynamics and Thermodynamics of Compressible Fluid Flow by A. H. Shapiro, The Ronald Press, New York, 1953.

MTE 105 ADVANCED HEAT AND FLUID FLOW LABORATORY

C L T P 1 0 0 2

1. Experimental Analysis of Heat Transfer Problems – Use of Data Acquisition System for: i) Forced convection, ii) Natural convection, iii) Heat pipe heat transfer, iv) Drop wise / Film wise condensation, v) Extended surface heat transfer
2. Determination of thermal conductivity of liquids using KD2Pro
3. Measurement of velocity profile in a boundary layer
4. Measurement of Lift and Drag over an airfoil
5. Performance Characteristics of Fan and Blowers
6. Measurement of detailed temperature field using Infrared Thermography

MTE 106 ADVANCED CONCEPTS IN THERMODYNAMICS

C L T P 3 3 0 0

Scope and methods of thermodynamics, Review of Thermodynamics, Basic relations and the First law, review of property evaluation and basic laws, first law for closed systems, allowed states, uncoupled and coupled systems, General Conservation of Energy Principle for a Control Volume, Transient flow analysis, Structured presentation of First law of Thermodynamics, The second law for closed systems, reversibility, entropy function, second law analysis for control volume, Entropy production in simple cyclic devices, Born-Caratheodory formulation of second law. Availability analysis, irreversibility, second law efficiency, availability analysis of cycles

Equation of state, characteristics of PvT behavior, compressibility factor, two-parameter cubic equation of state, corresponding states principle, three-parameter cubic equations of state, other equations of state, Thermodynamic property relations, fundamental relations for compressible systems, generalized relations for change in Entropy, Internal energy and enthalpy, relations of specific heats, residual property function, Joule-Thomson coefficient, Thermodynamic properties of homogeneous mixtures, fundamental property relationships for systems of variable composition, partial molal properties, fugacity, fugacity coefficient, ideal solutions

Text Book and References:

1. Advanced Thermodynamics for Engineers by Kenneth Wark, McGraw hill, 1995
2. Advanced Engineering Thermodynamics by Adrain Bejan, John Wiley, 2006
3. Concepts of Thermodynamics Edward F. Obert, McGraw Hill, 1960
4. A Course on Thermodynamics by Joseph Kestin, McGraw Hill, 1979

MTE 107 **VISCOUS FLOW THEORY**

C L T P 3 3 0 0

Historical Outline, Fundamentals equations of motion and continuity applied to fluid flow, General stress system in a deformable body, Stoke's hypothesis, The Navier-Stokes equations, Exact solutions of the Navier-Stokes equations, Parallel flow through a straight channel and Couette flow, The Hagen-Poiseuille theory of flow through a pipe, A general class of non-steady solutions, Laminar Boundary Layers, Boundary Layer Equations in Plane Flow, General properties and Exact solutions of the boundary-layer equations for Plane flows, Similar solutions of the Boundary-Layer Equations, Wake Behind bodies, Boundary Layer at Moving Wall, Momentum-Integral equations, Energy Integral equation, Moment-of-Momentum Integral Equations, Approximate Methods for the solution of the two- dimensional, steady boundary-layer equations, Laminar flow against pressure gradient

Boundary Layer Control (Suction/blowing), Continuous suction and Blowing, Similar solutions, Some Experimental results on the Laminar-turbulent Transition, Stability theory, General properties of the Orr-Sommerfield equation, Fundamentals of turbulent flow, Apparent turbulent stresses, Derivation of the stress tensor of apparent turbulent friction from the Navier-Stokes equations, Prandtl's mixing length theory, Von Karman's similarity hypothesis, Universal velocity distribution laws, Von Karman's velocity distribution law,

Textbook and References:

1. Boundary Layer Theory by Schlichting S., McGraw Hill, 2001.
2. Viscous Fluid Flow by White F.W.,McGraw Hill, 1990.
3. Advanced Engineering Fluid Mechanics by Muralidhar K.M., Biswas G, *Narosa, 2003.*
4. An Introduction to Fluid Dynamics by Batchelor,G.K., Cambridge University Press, 1990.

ChMC23 **COMPUTATIONAL FLUID DYNAMICS**

C L T P 3 3 0 0

Review of basic fluid mechanics and the governing (Navier-Stokes) equations; Techniques for solution of PDEs – finite difference method, finite element method and finite volume method; Finite volume (FV) method in one-dimension; Differencing schemes; Steady and unsteady calculations; Boundary conditions; FV discretization in two and three dimensions; SIMPLE algorithm and flow field calculations; variants of SIMPLE. Turbulence and turbulence modeling; illustrative flow computations; Commercial software's FLUENT and CFX – grid generation, flow prediction and postprocessing. Special Topics: Case studies using FDM and FVM: Flow and heat transfer in pipes and channels, square cavity flows, reactive flow, multiphase flow, rotary kiln reactors, packed and fluidized bed reactors, furnaces and fire systems.

Textbook and References:

1. Computational Techniques for Fluid Dynamics by C.A.J Fletcher,Springer- Verlag, 1998.
2. Computational Fluid Dynamics by J.D. Anderson, McGraw Hill, 1995.
3. Computer Simulation of Flow and Heat Transfer by P.S. Ghosh Dastidar, Tata McGraw Hill,
1998.
4. Numerical Heat Transfer and Fluid Flow by S.V. Patankar, Taylor and Francis, 2004.

MTE 108

SEMINAR

C L T P 1 0 0 6

The student shall independently do an exhaustive research work on a particular topic, under the supervision of a faculty member. The student will be examined on the basis of presentation, compressive report and viva voce.

MTE 109 **INSTRUMENTATION AND MEASUREMENT LABORATORY**

C L T P 1 0 0 2

1. Structural determination of powdered crystalline materials by XRD.
2. Surface morphology of the materials by SEM.
3. Synthesis of Nanofluids
4. Determination of chemical structure, phase, composition etc of thermal materials by Raman Spectroscopy
5. Determination of viscosity of Nanofluids using Rheometer
6. Use of Zeta potential for nanofluids

MSD 104

DESIGN OPTIMIZATION

C L T P 3 3 0 0

Motivating examples of calculus of variations, Fundamental lemmas of calculus of variation, Euler-Lagrange (E-L) equations, Applications of E-L equation, Extensions of E-L equation to multiple derivatives, independent variables, multiple state variables. Isoparimetric problems-global and local (finite subsidiary) constraints, Applications of optimizing functional subject to constraints, Applications in mechanics: strong and weak forms of governing equations, Variable end conditions--transversality conditions. Size optimization of a bar for maximum stiffness.

Optimization with side constraints (variable bounds), Worst load scenario for an axially loaded stiffest bar, Min-max type problem with stress constraints, Beam problems for stiffness and

strength, Optimization of a beam for given deflection, Variational formulations for the eigenvalue

problems: strings, bars, beams, and other elastic structures, Optimum design of a column, Variable-thickness optimization of plates, sufficient conditions for E-L optimum

Finite dimensional optimization- A summary and highlights of Numerical optimization techniques using the optimization tool-box in MATLAB, Gear design optimization.

Text Book and References:

1. Calculus of Variations with Applications to Physics and Engineering by Robert Weinstock, Dover publications, 1974.
2. Calculus of Variations with Applications by Gupta, A.S., Prentice-Hall of India Pvt. Ltd.,New Delhi, 2008.
3. Calculus of Variations by Gelfand, I.M., Fomin,S.V., Dover publications, 2000.

MTE 110 **DISSERTATION-I**
C L T P 6 0 0 6

MTE 111 **DISSERTATION-I**
C L T P 12 0 0 18

The dissertation will involve the following activities, review of related work, specification, design and implementation, evaluation and presentation. It will be assessed on the basis of skill demonstrated in the application of design and evaluation techniques, ingenuity, originality and mastery of the chosen field, volume of work achieved, enthusiasm and diligence in its conduct, quality of outcome as shown by effectiveness as system or quality of the experimental results, completeness, coherence, organization, readability, comprehensibility. The students will be encouraged to publish at least one paper in any international journal of repute, besides presenting their work in conferences/workshops.

LIST OF ELECTIVES
(ELECTIVE--I, ELECTIVE--II, ELECTIVE--III, ELECTIVE--IV, ELECTIVE--V)

MTE 112 **MODELING AND SIMULATION OF THERMAL SYSTEMS**
C L T P 3 3 0 0

Introduction, Design versus Analysis, Synthesis versus Design, Optimal and Nearly Optimal designs, Life Cycle Design, Thermal design aspects, Concept, creation and assessment, Thermal system (Basic Characteristics, Analysis), some typical examples, formulation of the design problem, Steps in design process, Material selection. Modelling of thermal systems, types of models, Mathematical modeling, General procedure (Transient/steady state, spatial dimensions, lumped mass approximation, simplification of boundary conditions, negligible effects, idealizations, material properties, conservation laws, simplification of governing equations), final model and validation, physical modeling and dimensional analysis, curve-fitting, Numerical modeling and simulation, Solution procedures, methods for numerical simulation,

Formulation of problem for optimization, optimized design, objective function, constraints, operating conditions versus hardware, optimization methods (Calculus methods, Search methods, etc.), Optimization of thermal systems, Considerations of Second law of Thermodynamics, Economic analysis, Estimation of total capital cost, principles of economic evaluation, Thermoeconomic analysis and evaluation. Applications with Thermodynamics, Heat and Fluid flow, Cogeneration system Exergy analysis, Thermal insulation, Fins, Electronic packages, Refrigeration, Power Generation, Energy Storage by Sensible heating.

Textbooks and References:

1. Thermal Design and Optimization by Bejan, A., Tsatsaronius, G., Moran, M., John Wiley, 2013.
2. Design of Thermal Systems by Stoecker, W.F, McGraw Hill, 2017.
3. Design of Fluid Thermal Systems by Janna, W.S., Cengage Learning, 2015.

MTE 113 **RESEARCH METHODOLOGIES AND TECHNIQUES**

C L T P 3 3 0 0

Definition and objectives of Research – Types of research, Various Steps in Research process, Mathematical tools for analysis, Developing a research question-Choice of a problem Literature review, Surveying, synthesizing, critical analysis, reading materials, reviewing, rethinking, critical evaluation, interpretation, Research Purposes, Ethics in research – APA Ethics code. Quantitative Methods for problem solving: Statistical Modeling and Analysis, Time Series

Analysis Probability Distributions, Fundamentals of Statistical Analysis and Inference, Multivariate methods, Concepts of Correlation and Regression, Fundamentals of Time Series Analysis and Spectral Analysis, Error Analysis, Applications of Spectral Analysis.

Tabular and graphical description of data: Tables and graphs of frequency data of one variable, Tables and graphs that show the relationship between two variables , Relation between frequency distributions and other graphs, preparing data for analysis Structure and Components of Research Report, Types of Report, Layout of Research Report, Mechanism of writing a research report, referencing in academic writing

Textbook and References:

1. Research Methodology Methods and Techniques by C.R. Kothari, ,New Age International Publishers, 2019.
2. Research Methods by Donald H.McBurney, Wadsworth Publishing Co Inc, 2006.

MTE 114 **REFRIGERATION ENGINEERING**

C L T P 3 3 0 0

Thermodynamics process pertaining to refrigeration and air conditioning. First and Second law applied to refrigerating machines, Carnot principles, COP, Reverse Carnot Cycle, Different methods of refrigeration, Refrigerants - Classification- designation of refrigerants – selection criterion – Thermodynamic requirements - Chemical-physical requirements - Secondary refrigerants –Environmental impact of Refrigerants Global warming, Alternate refrigerants, future refrigerants, Vapour compression systems, Actual vapour compression system - Complete vapour compression system.

Advanced vapor compression systems, multi pressure systems, Flash gas removal, Two evaporator and one compressor systems. One evaporator and two compressor systems, other combinations of compressors, evaporators and condensers, Low temperature refrigeration, cascade systems. Thermal compression against mechanical compression – Vapour absorption refrigeration systems -Maximum COP – Common refrigerant absorbent systems - Modification to simple vapour absorption systems - Using liquid-liquid heat exchanger – Using analyzer - Actual vapour absorption systems – and its representation on enthalpy composition diagram – Absorption system calculations - Lithium bromide water systems- Triple Fluid systems, Air Refrigeration Systems: Thermodynamic processes, priority criteria and suitability of air refrigeration system. Types of Air refrigeration system. Lubrication in refrigeration system – Non conventional refrigeration systems – Thermo electric - Pulse tube - Vortex tube refrigeration systems - Ejector compression systems

Textbook and References:

1. Refrigeration and Air conditioning by Wilbert F. Stoecker, McGraw Hill, Inc 1982.
2. Refrigeration and Air conditioning by C.P. Arora, Tata McGraw Hill, 2000.
3. Refrigeration and Air conditioning by Roy. J Dossat, Prentice Hall
4. ASHRAE Handbook—Refrigeration, ASHRAE

MTE 115 **CONVECTIVE HEAT TRANSFER**

C L T P 3 3 0 0

Transport equations and boundary conditions; Order of magnitude analysis, Reynolds analogy. Forced Convection: Convective heat transfer in external flows: Boundary layer Approximations to momentum and energy equations, Similarity solution techniques, Momentum and energy integral methods and their applications in flow over flat plates with low and high Prandtl number approximations. Convective heat transfer in Laminar internal flow: (a) Exact solutions to N-S equations for flow through channels and circular pipe, Fully developed forced convection in pipes with different wall boundary conditions, Forced convection in the thermal entrance region of ducts and channels (Graetz solution), heat transfer in the combined entrance region, (b) Integral method for internal flows with different wall boundary conditions. Elements of turbulent heat transfer.

Natural convection: Introduction to natural convection; Boussinesq approximation and scaling analysis; Similarity solution of natural convection equations for boundary layers; Laminar and turbulent free convection; Fundamentals of boiling and condensation; Deviations from continuum: wall slip and thermal creep, an introduction to convective transport of heat in micro-scales; Conjugate heat transfer problems.

Textbook and References:

1. Convective Heat and Mass Transfer by W. M. Kays, E. M. Crawford, and B. Weigand, Tata McGraw Hill, 4th Edition, 2012.
2. Convective Heat Transfer by Louis C Burmeister, John Wiley and Sons, 2nd Edition, 1993.
3. Convective Heat Transfer by Adrian Bejan, John Wiley and Sons, 4th Edition, 2013.

MTE 116 ADVANCED CHARACTERIZATION AND INSTRUMENTATION TECHNIQUES FOR THERMAL SYSTEMS

C L T P 3 3 0 0

Introduction: Need of materials characterization and available techniques. Optical Microscopy: Optical microscope - Basic principles and components, Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast, Polarised light, Hot stage, Interference techniques), Stereo microscopy, Photo microscopy, Colour metallography, Specimen preparation, Applications.

Electron Microscopy: Interaction of electrons with solids, Scanning electron microscopy, Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wavelength dispersive spectroscopy. Diffraction Methods: Fundamental crystallography, Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction.

Surface Analysis: Atomic force microscopy, scanning tunneling microscopy, X-ray photoelectron spectroscopy. Spectroscopy: Atomic absorption spectroscopy, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy. Thermal Analysis: Thermo gravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry, Thermo mechanical analysis and dilatometry.

Textbook and References:

1. Materials Characterization Techniques by Li, Lin, Ashok Kumar, CRC Press, (2008).
2. Elements of X-Ray Diffraction by Cullity, B.D., and Stock, R.S.,Prentice-Hall, (2001).
3. Advanced Techniques for Materials Characterization by Tyagi, A.K., Roy, Mainak, Kulshreshtha, S.K., and Banerjee, S., Materials Science Foundations (monograph series), Volumes 49 – 51, 2009.
4. Thermal Analysis by Wendlandt, W.W. John Wiley & Sons, 1986.

5. Characterization of Materials by Wachtman, J.B., Kalman, Z.H., Butterworth Heinemann, 1993.

MTE 117 MICROSCALE AND NANOSCALE HEAT TRANSFER
C L T P 3 3 0 0

Introduction & Overview of Microscopic Thermal Sciences, The Length Scales, Fundamentals of Thermodynamics, Heat Transfer Basics, Statistical Mechanics of Independent Particles, Thermodynamic Relations, Ideal Molecular Gases, Statistical Ensembles and Fluctuations, Basic Quantum Mechanics, Kinetic Description of Dilute Gases, Local Average and Flux, The Mean and Free path, Transport Equations and Properties of Ideal Gases, Shear Force and Viscosity, Heat Diffusion, Mass Diffusion, Intermolecular Forces, The Boltzman Transport Equation, Microfluidics and Heat Transfer, The Knudsen Number and Flow Regimes, Velocity Slip and Temperature Jump

Specific heat of solids, Lattice vibration in solids, The Debye Specific Heat Model, Quantum Size Effect on the Specific Heat, General Expressions of Lattice Specific Heat, Nanocrystals and Carbon Nanotubes, Electrical and Thermal Conductivity of Solids, Thermoelectricity, Onsager's Theorem and Irreversible Thermodynamics, Electron and Phonon Transport, The Hall Effect, General Classifications of Solids, Crystal Structures, The Bravais Lattices, Electronic Band Structures, Dispersion Relation for Real Crystals, Phonon Scattering, Electron Emission and Tunneling, Photoelectric effect, Electrical Transport in Semiconductor Devices, Optoelectronic applications

Nonequilibrium energy transfer in Nanostructures, Thermal Radiation Fundamentals, The wave equation, Propagating and evanescent waves, Black body Radiation, Radiative Properties of Semi-Infinite Media, Emissivity, Radiative properties of a single layer, Effect of Surface Scattering, Radiative properties of Multilayer structures, Radiative properties of Thin films on a thick substrate, Photonic crystals, Periodic Gratings, Bidirectional Reflectance Distribution Function, Waveguides and Optical Fibers, Surface plasmon and phonon polaritons, Radiation Transmission through nanostructures, Spectral and Directional Control of Thermal Radiation, Radiation Heat Transfer at Nanometer Distances

Textbook and References:

1. Nano/ Microscale Heat Transfer by Z.M.Zhang, McGraw Hill, 2020
2.Microscale Heat Transfer by Kakac, Vasiliev and Yener, Springer, NATO Science, 2004.

MTE 118

TURBULENT FLOWS
C L T P 3 3 0 0

The nature of turbulence, Length scales in turbulent flows, Reynolds decomposition, Reynolds stress, Turbulent transport of heat, Elements of the kinetic theory of gases, The mixing-length model, Turbulent heat transfer, Reynolds analogy, Turbulent shear flow near a rigid wall, Pure shear flow, Kinetic energy of the turbulence, Scale relations, Spectral energy transfer, Wind-tunnel turbulence, Vorticity dynamics, Two-dimensional mean flow, Approximate vorticity budget, Multiple length scales, The dynamics of temperature fluctuations

Parallel two dimensional flows, The cross-stream momentum equation, Turbulent wakes, Axisymmetric wakes, Turbulent jets and mixing layers, Turbulent flows in pipes and channels, Logarithmic friction law, The viscous sub-layer, Experimental data on the law of the wall, Experimental data on the velocity-defect law, Flow over rough surfaces, The potential flow, The pressure inside the boundary layer, The law of wall, The logarithmic friction law, The pressure-gradient parameter

The probability density, Fourier transforms and characteristics functions, Correlation functions and spectra, Erogodicity, Transport in stationary homogeneous turbulence, Stationarity, The probability density of the Lagrangian velocity, The diffusion equation, Uniform shear flow, joint statistics, Longitudinal dispersion in channel flow, Bulk velocity measurements in pipes, Transport at large scales, Turbulent transport in evolving flows, Thermal wake in grid turbulence, self preservation, One- and three- dimensional spectra, Aliasing in one dimensional spectra, The three-dimensional spectrum, Spectra of isotropic simple waves, Spectral energy transfer

Textbook and References:

1. A First Course in Turbulence by Tennekes and Limley, MIT Press
2. Turbulent Flows by Stephen B. Pope, Cambridge University Press
3. Turbulence by J.O.Hinze, McGraw Hill
4. Turbulent flows by Biswas and Eswaran, Narosa Publishers

MTE 119 **ENERGY MANAGEMENT AND AUDITING**

C L T P 3 3 0 0

General Philosophy and need of Energy Audit and Management, Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy, Energy Audit, Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution.

Data gathering, Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering. Analytical Techniques, Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation. Evaluation of saving opportunities, Energy Audit Reporting, The plant energy study report- Importance, contents, effective organization, report writing and presentation

Energy Policy Planning and Implementation, Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation. Format and Ratification, Organizing, Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning. Energy Balance, First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements, Energy Balance sheet and Management Information System (MIS), Energy Modeling and Optimization. Energy Audit Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy

Textbook and References:

1. Energy Management by W.R.Murphy, G.Mckay, Butterworths.
2. Energy Management Principles by C.B.Smith, Pergamon Press.
3. Efficient Use of Energy by I.G.C.Dryden, Butterworth Scientific.
4. Energy Economics by A.V.Desai, Wiley Eastern.
6. CRC Handbook of Energy Efficiency, CRC Press.

MTE 120 **ENGINE MODELING AND SIMULATION**

C L T P 3 3 0 0

Fundamentals, Basic principles, Homentropic flow, the solution of nonsteady flow equations by the method of characteristics, graphical solution of non steady flow problems with boundary conditions on the state diagram., graphical solution of non-steady flow problems: single cylinder engines with flow through valves and ports., numerical solution of non-steady flow problems

Non-homentropic flow, numerical solution of non steady flow problems with simple boundary conditions, boundary conditions with in pipe systems, turbine and centrifugal compressor boundary conditions. In-cylinder processes, calculation of non-steady flows using filling and emptying methods and quasi-steady flow models, flow processes in cylinders, heat transfer in the cylinder and porting, combustion and cycle calculations in compression ignition engines.

Unsteady reacting flows: numerical solution of non steady flows with variable specific heats and chemical reactions, pressure exchangers and pressure exchange engines, Completes engine simulation models, quasi-steady models, engine simulation models with filling and emptying methods, wave action simulation models, transient performance.

Textbook:

1.Thermodynamics and Gas Dynamics of Internal Combustion Engines Vol-I &II by R. Benson Horlock and Winenetrbone, Clarendon Press, 1998

MSD 102 **FINITE ELEMENT METHOD**

C L T P 3 3 0 0

Physical problems and finite element method (FEM), simulations and visualizations in FEM, Integral formulations for numerical solutions, Variational method, sub-domain method, collocation, Galerkin's method, least squares method, element matrices, Analysis of beams, trusses, one dimensional formulations, two dimensional formulations, Co-ordinate systems, local, global and natural, area coordinates and continuity, strong and weak forms, Hamilton's principle, domain discretization, properties of shape functions, shape functions for trusses.

Strain matrices and element matrices in local and global coordinates for trusses and beams, Rate of convergence and high-order one dimensional elements, Use of commercial code for specific problems on beams and trusses, FEM for frames, Case study of a typical frame e.g., a bicycle, FEM for 2-D solids, construction of shape functions for 2-D elements, strain matrix and element matrices for 2-D elements, linear rectangular element and shape function construction, Gauss integration, Linear quadrilateral elements and coordinate mapping .

Quadratic and cubic triangular elements, rectangular elements and Lagrange elements, Serendipity type of elements and elements with curved edges, FEM for plates and shells, Shape functions and element matrices for plates and shells, elements in local and global coordinate systems for plates and shells, some specific case study on plates and shells using a commercial code, FEM for 3-D solids, meshing and solution procedures.

Text Books and References:

1. Applied Finite Element Analysis by Segerlind L.J, John Wiley Publishers, 1976.
2. Numerical Methods in Finite Element Analysis by Bathe, K.J. and Wilson, E.L., Prentice Hall, 1976.

MSD 205 **ADVANCED CONTROL SYSTEM**

C L T P 3 3 0 0

Block diagram algebra of mechanical, electrical and electromechanical systems, their state space representation and relation between state variable & other system representations, Z-transform, the inverse z-transform.

State space equations and their solution. Methods of computing state transition matrix. Eigen values of system matrix. System stability, controllability & observability. Pole placement design.

Multivariable system. System response algebra and stability. Adaptive control systems: System parameters estimation and self-tuning control. Fuzzy logic control: fuzzy sets, fuzzy logic control algorithms. Examples and exercises on Mechanical system design for control.

Text Book and References:

1. Feedback control of Dynamic systems by Granklin, G.F., Powell, J.D., Addison Wesley, 1991.
2. Modern control systems by Dorf, R.C., Bishop, R.H.,Pearson education, 1999.

MTME15 **ADVANCED NUMERICAL METHODS**

C L T P 3 3 0 0

Interpolation: The difference operators, their properties and applications. Interpolation with equal intervals, Newton's advancing difference formula. Newtons's backward difference formula. Interpolation with unequal intervals. Newton's divided difference formula. Lagrange's interpolation formula. Spline functions. Gauss forward and backward interpolation formula, Sterlings, Bessel's, Laplace and Everetts formulae.

Numerical Solution of Algebraic and Transcendental Equations: Iterative method, Graphic

Method, Regula-Fast method, Balzano's Process of bisection of intervals, Newton-Raphson Method and its geometrical significance. Solution of Linear Systems: Matrix Inversion Method, Gauss Elimination, Gauss – Jordan Method, Modification of the Gausss Method to Compute the Inverse.

Numerical Differentiation and Integration: Numerical Integration, General Quadrature Formula, Simpson's one-third and three-eight rules, Weddles' rule, Hardy's rule, Trapezoidal rule.

Numerical Solution of Ordinary and Partial Differential Equations: Picard's method. Numerical solution of ordinary differential equations, Taylors series method, Euler's method, Runge-Kutta Method. Solution of Parabolic, elliptical and hyperbolic partial differential equations.

Textbook and References:

1. Introductory methods in Numerical Analysis by S.S. Sastry , Prentice Hall of India.
2. Numerical Methods for Scientific and Engineers by M.K.Jain, S.R.Iyengar and R.K. Jain, Wiley Eastern Ltd.
3. Mathematical Numerical Analysis by S.C. Scarborough, Oxford and IBH Publishing Company.

PSPHY EL 01 **RENEWABLE SOURCES OF ENERGY**

C L T P 3 3 0 0

Relevance of renewable energy in relation to depletion of fossil fuels and environmental considerations, Green Energy, Solar Energy, Sun as a source of energy, nature of solar radiation and sun-earth angles, Flat plate collectors, types of FPC, effects of various parameters on the performance of FPC, Overall heat loss coefficient and heat transfer correlations, collector efficiency factor, Solar thermal applications like solar cooker and solar water heaters solar dyers, solar stills, solar cooling. Solar refrigeration and Carnot's refrigeration cycle, thermal energy storage, active and passive heating of buildings.

Physics and Materials properties basic to photovoltaic conversion, Optical properties of solids, Direct and indirect transition semiconductors, interrelationship between absorption coefficient and band gap, recombination of carriers, Types of solar cells, pn junction solar cells, transport equation, current density, open circuit voltage and short circuit current, brief description of single crystal silicon and amorphous silicon solar cells, e.g. tandem solar cells, solid liquid junction solar cells, nature of semiconductor, electrolyte junction, photoelectrochemical solar cells

Solar Hydrogen through photo-electrolysis and photocatalytic process. Physics of material characteristics for production of solar hydrogen, Various factors relevant for safety, use of Hydrogen as fuel, use in vehicular transport, hydrogen for electricity generation, Fuel Cells, Energy Storage, Brief discussion of various storage processes, special feature of solid state hydrogen storage materials, structural and electronic characteristics of storage materials, new storage modes Wind Energy, Energy and power in Wind, Wind Turbines, Aerodynamics of Wind turbines, Environmental impacts, offshore wind energy, economics

Text Book and References:

1. Renewable Energy by Twidel and Weir, E& F N Spon ltd
2. Renewable Energy by Godfrey Boyle, Oxford
3. Solar engineering of thermal processes by Duffie, J.A. and W.A. Beckmann, John Wiley.
4.Principles of thermal collection and storage by Sukhatme S.P. Solar Energy, Tata McGraw Hill, 1997.

ChMC11 **ADVANCED TRANSPORT PHENOMENA**

C L T P 3 3 0 0

Isothermal systems: Equations of change, Velocity distributions in 2D and 3D for laminar and turbulent flow, Macroscopic balances. Non-Isothermal Systems: Temperature distributions in 2D and 3D for solids, laminar flow and turbulent flow, Macroscopic balances. Concentration distributions in 2D and 3D for solids, laminar flow and turbulent flow, Interphase transport in multi-component systems, Macroscopic balances for multi- component systems.

Text books and References:

1. Transport Phenomena by Bird R.B., Stewart W.E. and Light Foot E.N., Wiley International Edition, 2007.
2. Transport Processes and Unit Operations by Christie J. Geankopolis, Prentice Hall (India) Pvt. Ltd., New Delhi, 2004.
3. Transport Phenomena by William J. Thomson, Pearson Education, Asia, 2001.

ChME26 **FUNDAMENTALS OF FUEL CELL TECHNOLOGY**

C L T P 3 3 0 0

Overview of fuels cells: Low and high temperature fuel cells: Fuel cell thermodynamics – heat, work potentials, prediction of reversible voltage, fuel cell efficiency; Fuel cell reaction kinetics – electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro-catalyses – design, activation kinetics, Fuel cell charge and mass transport – flow field, transport in electrode and electrolyte; Fuel cell characterization: - in-situ and ex-situ characterization techniques, i-V curve, frequency response analyses; Fuel cell modeling and system integration: - 1D model – analytical solution and CFD models, Balance of plant; Hydrogen production and storage; safety issues, cost expectation and life cycle analysis of fuel cells.

Textbook and References:

1. Fuel Cells- From Fundamentals to Applications by Supramaniam Srinivasan, Springer.
2. Fuel Cell Fundamentals by Ryan O'Hayre, Suk-Won Cha , Whitney Colella , Fritz B. Prinz, John Wiley,2009.
3. Handbook of Fuel Cells: Fundamentals, Technology, Applications by Wolf Vielstich , Arnold Lamm , Hubert A. Gasteiger (Editors) , 4-Volume Set, John Wiley, 2013.

ChME25 ENVIRONMENTAL ENGINEERING AND WASTE MANAGEMENT

C L T P 3 3 0 0

Ecology and Environment. Sources of air, water and solid wastes. Air Pollution: Micrometeorology and dispersion of pollutants in environment. Fate of pollutants. Air pollution control technologies: centrifugal collectors, electrostatic precipitator, bag filter and wet scrubbers. Design and efficiencies. Combustion generated pollution, vehicles emission control. Case studies. Water Pollution: Water quality modelling for streams. Characterization of effluents, effluent standards. Treatment methods. Primary methods: settling, pH control, chemical treatment. Secondary method: Biological treatment, Tertiary treatments like ozonization, disinfection etc. Solid wastes collection, treatment and disposal, Waste recovery systems.

Textbook and References:

1. Air Pollution by Stern A. C.; Vol. I, II, & III, Academic Press, 1968.
2. Handbook of Air Pollution Prevention and Control by Cheremisinoff, Nicholas P., Butterworth- Heinemann, 2002.
3. Waste Water Engineering Treatment and Reuse by Metcalf and Eddy Inc.; Revised by G. Tchobanoglous, F.L. Burton, H,D. Stensel, Tata Mc Graw-Hill, 2003.

EEM 129 **HYBRID ELECTRIC VEHICLES**

C L T P 3 3 0 0

Introduction: Conventional vehicle and its components, propulsion load, drive cycles, Concept of electric vehicles and hybrid electric vehicles (HEVs), architectures of HEVs, series and parallel HEVs, complex HEVs.

HEVs Drive-train: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Plug-in Hybrid Electric Vehicles: PHEVs Architectures, equivalent electric range of PHEVs; Fuel economy of PHEVs, power management of PHEVs, PHEVs battery charging, end-of-life battery for electric power grid support, vehicle to grid technology.

Power Electronics in HEVs: Rectifiers used in HEVs, Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter, current

source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV

battery chargers.

Text Book and References:

1. Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives by Chris Mi and M. Abul Masrur, John Wiley & Sons.
2. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory and Design by Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, CRC Press.
3. Electric and Hybrid Vehicles: Design Fundamentals by Iqbal Husain, CRC Press.
4. Electric and Hybrid-electric Vehicles by Ronald K. Jurgen, SAE International.

EEM 108 **SOFT COMPUTING**

C L T P 3 3 0 0

Introduction to Soft Computing: Concept of computing systems, soft vs. hard computing, various types of soft computing techniques, Fuzzy Computing, Neural Computing, Genetic Algorithms, Adaptive Resonance Theory, Classification, Some applications of soft computing techniques.

Evolutionary Algorithm: Fundamentals of Genetic Algorithms, basic concepts of "Genetics" and "Evolution", working principle, encoding, fitness function, reproduction, genetic modeling. Basic GA framework and different GA architectures, GA operators: Crossover, Selection, Mutation, Solving single-objective optimization problems using GAs.

Fuzzy Set Theory & Fuzzy Systems: Fuzzy set theory, Fuzzy set versus crisp set, Crisp relation & fuzzy relations, introduction & features of membership functions, Extension Principle, Fuzzy If-Then Rules, Fuzzy Inference Systems, Sugeno Fuzzy Models, Fuzzification, Defuzzification, Applications.

Fundamentals of Artificial Neural Network (ANN): Introduction, model of artificial neuron, Architectures, Learning methods, Deep learning, Taxonomy of ANN Systems, Single layer ANN system, Supervised learning neural networks, Perceptron, Adeline, Back propagation, Multilayer perceptron, Applications of ANN in research.

Text Book and References:

1. Fuzzy Logic with Engineering Applications by Timothy J.Ross, McGraw-Hill, 1997.
2. Genetic Algorithms: Search, Optimization and Machine Learning by Davis E.Goldberg, Addison Wesley, N.Y., 1989.
3. Introduction to AI and Expert System by Dan W. Patterson, PHI, 2009.
4. Neuro-Fuzzy and Soft Computing by J.S.R.Jang, C.T.Sun and E.Mizutani, PHI, 2004.