M. TECH. IN THERMAL SCIENCES AND ENERGY SYSTEMS

Program Structure (Applicable to 2023 admission onwards)

YEAR	FIRST SEMESTER						SECOND SEMESTER					
	SUB CODE	**SUBJECT NAME**	**L**	**T**	**P**	**C**	**SUB CODE**	**SUBJECT NAME**	**L**	**T**	**P**	**C**
I	MIE 5111	Numerical Methods and Computer Programming	3	1	0	4	MIE 5215	Thermal Management of Electronic Devices	3	1	0	4
	MIE 5120	Advanced Thermodynamics and Combustion	3	1	0	4	MIE 5216	Applied Computational Fluid Dynamics	3	1	0	4
	MIE 5121	Design and Optimization of Thermal Systems	3	1	0	4	MIE ****	Program Elective-I	3	1	0	4
	MIE 5122	Theoretical and Computational Fluid Dynamics	3	1	0	4	MIE ****	Program Elective-II	3	1	0	4
	MIE 5123	Advanced Solar Energy Technologies	3	1	0	4	MIE ****	Program Elective-III	3	1	0	4
	HUM 5051	Research Methodology and Technical Communication*	1	0	3	-	*** ****	Open Elective	3	0	0	3
	MIE 5146	Programming and Simulation Lab	0	0	6	2	HUM 5051	Research Methodology and Technical Communication*	1	0	3	2
	MIE 5147	Thermal Instrumentation Lab	0	0	3	1	MIE 5244	Applied CFD Lab	0	0	3	1
							MIE 5245	Renewable Energy Lab	0	0	3	1
	Total		**16**	**5**	**12**	**23**			**19**	**5**	**9**	**27**
	THIRD AND FOURTH SEMESTER											
II	MIE 6091	PROJECT WORK & INDUSTRIAL TRAINING							**0**	**0**	**0**	**25**

*TAUGHT IN BOTH SEMESTERS AND EVALUATED AND CREDITED IN THE SECOND SEMESTER

PROGRAM ELECTIVES		OPEN ELECTIVES	
COURSE CODE	COURSE TITLE	COURSE CODE	COURSE TITLE
MIE 5423	Bio-Hydrogen and Fuel Cells	MIE 5301	Design and Analysis of Experiments
MIE 5424	Design of Heat Exchangers	MIE 5302	Design of Curves and Surfaces
MIE 5425	Energy Management & Storage	MIE 5303	Energy Storage Systems
MIE 5426	HVAC Systems & Cryogenics	MIE 5304	Mechanics of Polymers
MIE 5408	Machine Learning and Its Application to Mechanical Engineering	MIE 5305	Principles of Lean in Production Systems
MIE 5427	Measurements in Thermal Systems	MIE 5306	Product Design and Development
MIE 5428	Microfluidics	MIE 5307	Quality Control and Reliability
MIE 5429	Turbomachines for Energy & Jet Propulsion	MIE 5308	Renewable Energy Technology
MIE 5430	Two Phase Flow		

I SEMESTER – CORE COURSES

MIE 5111 NUMERICAL METHODS AND COMPUTER PROGRAMMING [3 1 0 4]

Introduction to Computer Programming: Environment, Mathematical Operations, Governing Equations, Approximations and Errors: Round-off Errors, Truncation Errors, Total Numerical Error, Model Errors. Solution to Nonlinear Equations Bracketing and Open methods, Roots in Engineering and Science, Newton-Raphson Method. Differential Equations: Initial and Boundary value problems, Euler's Method, Runge-Kutta Methods. Solution to Linear Algebraic Equations: Gauss elimination, LU factorization, Cholesky factorization, Jacobi Method, Gauss-Seidel method, Relaxation technique, FFT. Curve Fitting and Interpolation: Linear, polynomial and nonlinear Regression, Splines and piecewise interpolation. Numerical Differentiation and Integration: Richardson Extrapolation, Derivatives of unequally spaced data, Partial Derivatives, The trapezoidal rule, Simpson's Rules, Higher-Order Newton-Cotes formulas, Numerical Integration of Functions-Romberg integration, Gauss quadrature. Computer programming using relevant Case Studies.

References:

1. Rao, Singiresu S. *Applied numerical methods for engineers and scientists*. Prentice Hall Professional Technical Reference, 2001.
2. Bradie B., *A Friendly Introduction to Numerical Analysis*, Pearson Prentice Hall, 2006.
3. Ralston A. and Rabinowitz P., A First Course in Numerical Analysis, McGraw Hill, 2001
4. Mathews J. H. and Fink K. D., *Numerical methods using MATLAB*. Pearson Prentice Hall, 1999.
5. Chapra S. C., Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw Hill, 2017.
6. Chapra S. C. and Clough D, Applied Numerical Methods with Python for Engineers and Scientists, McGraw Hill, 2022.

MIE 5120 ADVANCED THERMODYNAMICS & COMBUSTION [3 1 0 4]

Review of basic thermodynamics: First & Second laws, Concept of entropy and entropy generation, Entropy balance for closed & open systems; Concept of exergy & irreversibility, Exergy analyses of open and closed system. Joule-Thompson experiment.

Thermodynamic property relations: Maxwell relations; Relations involving enthalpy, internal energy, and entropy; Mayer relation: **Phase Equilibrium:** Equilibrium between two phases of a pure substance, Clapeyron equation and Clausius-Clapeyron equation, Multi-component, and multiphase systems, Gibb's phase rule: **Thermodynamics of reactive systems:** Fuel and combustion, Theoretical and actual combustion process, Concepts of Enthalpy of combustion and formation, first law analysis of reactive systems for open and closed systems, second law analysis and entropy change of reacting systems, Adiabatic flame temperature: **Flames:** Types of flames, Simplified analyses of premixed & diffusion flames, Factors influencing flame velocity and thickness, Quenching, flammability and ignition, and Flame stabilization. Premixed combustion modelling using ANSYS: **Chemical Equilibrium:** Criteria for equilibrium, Concept of Chemical potential, evaluation of chemical potential for single-phase of a pure substance and ideal gas mixture, Equation for reaction equilibrium, extent of reaction, equilibrium constant for ideal gas mixture, Le chatlier principle. Computing the equilibrium composition for non-reacting and reacting ideal gas mixtures, Equilibrium constant for mixture and ideal solutions.

References:

1. Buekens, A.,Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation. International Journal of Environment & Pollution, 17(3), pp.291-291, 2002.
2. Winterbone, D. and Turan, A., 2015. Advanced thermodynamics for engineers. Butterworth-Heinemann.
3. Williams, F.A., Combustion theory. CRC Press, 2018.
4. Turns, S.R., Introduction to combustion (Vol. 287, p. 569). New York, NY, USA: McGrawHill Companies,1996.
5. Mukunda, H.S., Understanding combustion. Universities Press (India) Private Limited Publication, ISBN, 978(81), p.7371,1989.
6. Mishra, D.P.,Fundamentals of combustion. PHI Learning Pvt. Ltd . 2007.
7. Glassman, I., Yetter, R.A. and Glumac, N.G., Combustion. Academic press,2014.
8. Gaydon, A.G., Wolfhard, H.G. and Penner, S.S., Flames, their structure, radiation and temperature,1960.
9. Denbigh, K.G. and Denbigh, K.G., The principles of chemical equilibrium: with applications in chemistry and chemical engineering. Cambridge University Press,1981.

10. Annamalai, K., Puri, I.K. and Jog, M.A., Advanced thermodynamics engineering. CRC press,2010.

MIE 5121 DESIGN AND OPTIMISATION OF THERMAL SYSTEMS [3 1 0 4]

Modeling of Thermal Systems: Introduction, types of models, mathematical modeling, curve fitting (Lagrange interpolation, polynomial representations, Least square method, exponential forms): **Acceptable Design of a Thermal System:** Initial design, design strategies for heat exchangers including condensers and evaporators (LMTD, NTU etc): **Numerical model simulation**: System simulation basics, methods for numerical simulation (Newton Raphson's method and back substitution methods): **Economic Considerations**: Calculation of interest, worth of money as a function of time, series of payments, raising capital, taxes, economic factor in design, application to thermal systems: **Problem Formulation for Optimization:** Optimization methods, practical aspects in optimal design, optimization of constrained and unconstrained problems using Lagrange multiplier method, search methods: Single-variable problem, multivariable and constrained optimization, geometric programming technique, linear, and dynamic programming for optimization: **Use of optimization algorithms and software to solve optimization problems in thermal engineering:** Problem solving using MINITAB, Artificial Neural Networks, Response Surface methodology, Genetic algorithms etc.

References:

1. W F Stoecker, Design of Thermal Systems, McGraw Hill, 1971.
2. Y Jaluria, Design & Optimization of Thermal Systems, CRC Press, 2007
3. N V Suryanarayana, Design & Simulation of Thermal Systems, McGraw Hill, 2002
4. Thermal Design and Optimization by Adrian Bejan, George Tsatsaronis and Michael J. Moran, John Wiley & Sons, Technology & Engineering, 1995.
5. Thermal System Design and Simulation, P.L. DHAR, Academic Press, USA,2017

MIE 5122 THEORETICAL AND COMPUTATIONAL FLUID DYNAMICS [3 1 0 4]

Introduction to fluid dynamics: A brief recapitulation of fluid mechanics, Introduction to vector and tensor algebra, Flow kinematics (streamlines, pathlines, streaklines, vortex lines, stream function, velocity potential, flow net): **Navier Stokes Equation:** Continuum hypothesis, Lagrangian and Eulerian description of the flow, total derivative, Reynolds transport theorem, Conservation principles, continuity equation, Derivation of Navier Stokes and energy equations, Exact solutions of Navier Stokes equation: **Boundary layer theory:** Laminar boundary layer, Prandtl's boundary layer equations, Analysis of boundary layer over a flat plate, Von Karman momentum integral equation of boundary layer. Boundary layer separation, Description of flow past cylinders and spheres, Concept of drag and lift: **Convective heat transfer:** Internal and external thermal boundary layers, constant temperature and constant heat flux boundary conditions, Heat transfer through pipes of circular and non-circular crosssection: **Introduction to computational fluid dynamics**: Generalized forms of governing equations, finite volume discretization, Illustration through 1D and 2D diffusion problems, Interface diffusivity, Gradient computation methods: least square gradient, Green Gauss node-based and cell-based methods, Concept of non-orthogonality, Under-relaxation and over-relaxation factors, source term linearization.

References:

1. White, Frank M., and Majdalani Joseph, Viscous fluid flow, 4th ed, McGraw-Hill Education publications, 2021.
2. Kundu, Pijush K., Cohen, Ira M., and David Dowling R., Fluid mechanics, 6th ed, Academic press publications, 2015.
3. Currie, Iain G., Fundamental mechanics of fluids, 4th ed, CRC press publication, 2012.
4. Fox, Robert W., Alan McDonald T., and John Mitchell W., Fox and McDonald's introduction to fluid mechanics. Wiley publications, 2021.
5. Kays W., Crawford M., Weigand B., Convective Heat and Mass Transfer,4th ed, McGraw-Hill publications, 2017.
6. Bergman, Theodore L., Adrienne Lavine S., Frank Incropera P., and David DeWitt P., Introduction to heat transfer, 6th ed, John Wiley & Sons, 2011.
7. Ferziger, Joel H., Milovan Perić, Robert Street L., Computational Methods for Fluid Dynamics,4th ed, Springer publications,2020.
8. Patankar, Suhas V., Numerical heat transfer and fluid flow, special Indian ed, CRC press publications, 2018.
9. Versteeg, Kaarle H., and Malalasekera W., An introduction to computational fluid dynamics: the

finite volume method,2nd, Pearson education publications, 2008.

MIE 5123 ADVANCED SOLAR ENERGY TECHNOLOGIES [3 1 0 4]

Introduction to non-concentrating systems: Sun earth geometry, Empirical equations to predict irradiance, Thermal analysis of various systems: **Introduction to concentrating systems:** Need for concentration, Optimum operating condition, Significance of sCO_2 cycle, Power cycles for concentrating systems: **Line focusing concentrators:** *Parabolic trough collector*-Thermal losses and analysis, Layout of solar field, Second law analysis, SolTrace application, *Compound parabolic collector* Optical and thermal analysis, Second stage concentration, *Fresnel reflectors:* Performance analysis, Parametric study of collector performance: **Point focussing concentrators:** Optical and thermal analysis, Application of SolTrace, Beam down and solar pipe concept, Fresnel refractors: **Central receiver:** Configurations, Heliostats, Receiver, Analysis, Thermodynamic analysis of solar power tower plant, Receiver considerations, Beam down systems, Use of CPC as tertiaries: **Role of natural circulation systems in solar energy conversion:** Working principle, classification, challenges, review of applications in other commercial systems, analysis, Generalized flow equation, parametric effects and natural circulation performance, Introduction to instability, Coupled natural circulation systems, Introduction to thermosyphon heat transport devices and their analysis methods, Adequacy of NCL in solar thermal systems:**Energy storage:** Analysis of wellmixed two tank storage, Thermocline storage and packed-bed storage system, Suitability of PCM for concentrating power plants, Advances, Thermochemical Storage: **Status of flat and concentrated PV modules:** Performance analysis, Prediction of surface temperature, Thermal management.

References:

1. Lovegrove, K., & Stein, W. (Eds.). Concentrating solar power technology: principles, developments and applications. 2nd edition, Woodhead publishing, 2020.
2. Blanco, M., & Santigosa, L. R. (Eds.). Advances in concentrating solar thermal research and technology. Woodhead Publishing, 2016.
3. Goswami, D. Y., Kreith, F., & Kreider, J. F. Principles of solar engineering. 3rd edition, CRC Press, 2015.
4. Tiwari G. N. Solar Energy: Fundamentals, Design, Modelling and Applications. Narosa Publishing, 2013.
5. Kalogirou, S. A. Solar energy engineering: processes and systems. 2nd edition, Academic Press, 2014.
6. Sukhatme, S. P., & Nayak, J. K. Solar Energy. 4th edition, McGraw Hill Publishers, 2018.
7. Duffie, J. A., Beckman, W. A., & Blair, N. Solar engineering of thermal processes, photovoltaics and wind. John Wiley & Sons, 2020.
8. Tiwari, G. N., & Tiwari, A. Handbook of solar energy. Singapore: Springer, 2016.
9. Kanoğlu, M., Çengel, Y. A., & Cimbala, J. M. Fundamentals and applications of renewable energy. McGraw-Hill Education, 2020.
10. P.K. Vijayan, A.K. Nayak, N. Kumar, SinglePhase, Two-Phase and Supercritical Natural Circulation Systems, Woodhead Publishing - Elsevier, 2019.

MIE 5146 PROGRAMMING AND SIMULATION LAB [0 0 6 2]

PART 1

Basic MATLAB programming

1. Write a MATLAB program to find the root of a given non-linear equation using the bisection and Newton-Raphson methods.
2. Write a MATLAB program to solve a given system of linear algebraic equations using the Gauss elimination and Gauss Seidal method.

1-D Programming using MATLAB

3. Write a MATLAB program to solve the one-dimensional steady-state heat diffusion equation with and without heat generation using forward, backward and central difference schemes and compare the results with the analytical solutions.
4. Write a MATLAB program to solve the one-dimensional unsteady heat diffusion equation using the finite difference method and compare it with the analytical results. 1-D simulation using FLOWNEX & TRNSYS
5. 1-D simulation of Brayton cycle using FLOWNEX.

6. Simulate the effect of varying turbine inlet temperature on the performance of the organic Rankine cycle using FLOWNEX.
7. Dynamic simulation of the solar water heater using TRNSYS.
8. Transient simulation of the heat transfer rate and temperature variation in a room using TRNSYS.

2-D analysis using OpenFOAM

9. 2D steady state analysis of incompressible flow in a lid driven cavity using OpenFOAM.
10. 2D steady state analysis of flow over an airfoil using OpenFOAM.
11. 2D steady state analysis of heat conduction through a solid wall using OpenFOAM.

Introduction to ANSYS – Workbench and Meshing

12. Geometric modeling of 2D and 3D computational domains using ANSYS design modeler/space claim.
13. Mesh creation of 2D and 3D computational domain using ANSYS meshing.

PART 2

Multiple mini projects will be given to students, which will involve the applications of MATLAB/OpenFOAM/Flownex/TRNSYS.

References:

1. Chapra, Steven., Applied Numerical Methods with MATLAB for Engineers and Scientists,3rd ed, McGraw Hill publications, 2011.
2. Rudra, Pratap, Getting Started with MATLAB-A Quick Introduction for Scientists and Engineers, Oxford publishers, 2010.
3. Leader, Jeffery J., Numerical analysis and scientific computation, 1st ed, CRC Press publications, 2004.
4. Kiusalaas, Jaan, Numerical methods in engineering with Python 3, 3rd ed, Cambridge University Press, 2013.
5. OpenFOAM documentation on https://www.openfoam.com/documentation/overview
6. Francisco Bulnes, Jan Peter Hessling., Recent Advances in Numerical Simulations, IntechOpen, 2021.

MIE 5147 THERMAL INSTRUMENTATION LABORATORY [0 0 3 1]

Demonstration

- Data acquisition demonstrator
- Thermocouple bead making process & response time check
- Integration of thermostatic bath for the defined process

Calibration

- Pressure calibrator
- Temperature calibrator
- Flowmeter calibration

Testing

- Demonstration of various temperature sensors
- Establishing Nu and f correlation for plate heat exchanger
- Performance evaluation of packed bed heat exchanger and cooling tower
- Surface characterization using thermal imager
- Measurement of solar flux, air velocity and humidity • Uncertainty analysis
- Establishing Nu and f correlation for compact heat exchanger using wind tunnel
- Interfacing of automatic Bomb calorimeter

References:

1. Holman J. P: Experimental methods for Engineers, Mc Graw Hill. Inc, 1994.
2. E. O. Doeblin: Measurement systems: Applications and Design, Tata Mc Graw Hill, 2004.
3. Alan S. Morris: Principles of measurement and instrumentation, Prentice Hall of India, 2002.
4. Sadik Kakac: Heat exchangers: Selection, rating, and thermal design, CRC Press, 2012.
5. Beckwith: Mechanical Measurements, Peasrson Education, India, 2005

II SEMESTER

HUM 5051 RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 2]

Theory: (Handled by Humanities Dept.)

Research Methodology: Basic concepts: Types of research, Significance of research, Research framework. Sources of data, Methods of data collection. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, Characteristics and Types of hypothesis, Elements of research design, Introduction to various sampling methods Sources of data, Collection of data, Research reports, references styles, Effective Presentation techniques, Research Ethics.

Lab exercises: (Handled by the Mechanical Dept.)

Recap of basic concepts of Research Methodology, use of numerical computation tools for research, Presentation - 1 (Beginning level of research), Presentation - 2 (Intermediate level of research), Presentation - 3 (Analysis/Evaluate level of research), Report writing.

References:

1. Sekaran, U., & Bougie, R., Research methods for business: A skill building approach. John Wiley & Sons, 2016.
2. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M., Business research methods. Cengage Learning, 2013.
3. Creswell, J. W., & Creswell, J. D., Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications, 2017.
4. Donald R Cooper & Pamela S Schindler, Business Research Methods, McGraw Hill International, 2018.

MIE 5215 THERMAL MANAGEMENT OF ELECTRONIC SYSTEMS [3 1 0 4]

Introduction: importance of thermal management of electronics, temperature effects on different failure modes; Basics of conduction, convection, radiation heat transfer. thermal contact resistance in electronic equipment interfaces. Heat generation in active and passive electronic devices Cooling fluids; discrete heat source and thermal spreading, Convectional coolants, potential new coolants, Nano fluids: **Transient cooling for electronic system:** Heat cycle transient temperature raise, cooling cycle transient temperature change, method for decreasing hot spot temperature raise, transient analysis of an amplifier on a PCB: **Convection cooling:** Cooling by heat sinks– design aspects of heat sinks, forced air cooling for electronics, Selection of fan, Micro/mini channel cooling, Selection of cooling technique– ranges of cooling rates of different cooling methods, selection criteria; Experimental techniques used for thermal measurements; Reliability issues: importance, bathtub curve.**Special cooling applications**: Working principle, selection of heat pipe working fluid; direct and indirect liquid cooling, liquid immersion cooling, flow-through cooling of CCAs, cold-wall cooling, cold plates, jet impingement cooling, synthetic jet cooling, thermoelectric or solid-state coolers, cooling using phase change-PCM and boiling.

References:

1. Ralph Remsburg: Thermal deign of electronic equipment, CRC Press 2001
2. Dave S. Steinberg, Cooling Techniques for Electronic Equipment, Wiley, 1991.
3. Younes Shabany, Heat Transfer: Thermal Management of Electronics, CRC Press Inc, 2010.
4. Ravi Kandasamy and Arun S. Mujumdar, Thermal Management of Electronic Components, Lambert Academic Publishing, 2010.
5. Sung Jin Kim, Sang Woo Lee, Air Cooling Technology for Electronic Equipment, Taylor & Francis, 1996.
6. Yunus A. Cengel, Heat Transfer: A Practical Approach. McGraw-Hill, 2003.

MIE 5216 APPLIED COMPUTATIONAL FLUID DYNAMICS [3 1 0 4]

Discretization of convection-diffusion equation: Analytical solution of steady 1D convection-diffusion equation, numerical solutions and schemes: Central differencing scheme, First order and second order upwind schemes, power law scheme and QUICK schemes, Truncation error and stability analysis: **Discretization of unsteady terms:** Discretization of 1-D unsteady diffusion problems, Implicit and explicit schemes, Crank-Nicolson schemes, ADI method, Initial conditions, stability analysis of parabolic and hyperbolic equations: **Solution of Navier-Stokes Equation:** Concept of Collocated and Staggered grids, Checkerboard problems, SIMPLE algorithm on a Staggered grid: **Introduction to turbulence:** Characteristics of Turbulent flow, Mean and

fluctuating quantities, scales of Turbulence, Energy cascading, Kolmogorov scale, Vorticity transport equation, vortex stretching, Statistical distribution of turbulence: homogeneous, stationary and isotropic turbulence. Averaging techniques: time average, space average and ensemble average, Ergodic hypothesis: **Transportation equations in turbulent flow:** General properties of turbulent flows: Reynolds decomposition, Continuity equation and Reynolds average Navier Stoke equation (RANS), Reynolds stress and Boussinesq's eddy viscosity hypothesis approximation, Turbulent kinetic energy, dissipation rate and turbulent intensity: **External and internal turbulent flows:** Analysis of Flow over a flat plate under steady, and incompressible condition, modelling of turbulent viscosity, Prandtl's mixing length hypothesis, Universal turbulent velocity profile, concept of viscous sublayer, Buffer layer and fully turbulent layer, law of wall, Integral solutions for turbulent boundary layer, $1/7^{th}$ law of velocity profile. Internal turbulent flow: Concept of entry length and governing equations, Universal velocity profile and its limitations. Mean velocity: **Turbulence modelling:** Two equation turbulence models: Standard k-€ model, and $k-$□ model, SST $k-$□ model, Near-wall turbulence modelling: concept of wall function: standard wall functions, scalable wall function,
Enhanced wall function, difference between y^+ and y^*, Modelling near-wall heat transfer.

References:

1. Ferziger, Joel H., Milovan Perić, Robert Street L., Computational Methods for Fluid Dynamics, 4^{th} ed, Springer publications,2020.
2. Patankar, Suhas V., Numerical heat transfer and fluid flow, special Indian ed, CRC press publications, 2018.
3. Versteeg, Kaarle H., and Malalasekera W., An introduction to computational fluid dynamics: the finite volume method, 2^{nd}, Pearson education publications, 2008.
4. Chung T. J., Computational Fluid Dynamics, 2^{nd}, Cambridge University Press, 2010.
5. Anderson, John D., Computational fluid dynamics the basics with applications, McGraw Hill Education publications, 2017.

MIE 5244 APPLIED CFD LAB [0 0 3 1]

Cycle 1: Introduction to CFD simulations using ANSYS Fluent.

1. Steady-state analysis (2D and 3D) of flow and heat transfer over a flat plate.
2. Drag and lift analysis (2D) of flow over NACA aerofoil at various angle of attack.
3. Unsteady flow through a pipe with uniform heating (2D).

Cycle 2: Transient CFD simulations

1. Numerical Simulation of Viscous incompressible fluid flow in a Lid-driven cavity (2D).
2. Numerical Simulation of Melting and Solidification of PCM in a container (2D).
3. Species transport modeling of methane combustion (2D).

Cycle 3: Application-based simulations

1. Electronic component cooling simulation using ANSYS Fluent.
2. Numerical simulation of heat exchanger with porous medium.
3. Radiation-based CFD analysis of solar PV panels.
4. 3D steady-state CFD simulations to study the thermo-fluid dynamics of a receiving cavity for the CSP receiver.
5. Film cooling analysis in turbine blades.
6. Numerical Investigation of Pool Boiling Phenomena using ANSYS Fluent.

References:

1. ANSYS FLUENT 12.0 User's Guide.
2. Versteeg, W. Malalasekera., An Introduction to Computational Fluid Dynamics The Finite Volume Method, 2/e., 2007.
3. John D. Anderson, Computational Fluid Dynamics, McGraw Hill publications, 1995.
4. Atul Sharma, Introduction to Computational Fluid Dynamics: Development, Application and Analysis, Wiley publications, 2016.
5. Jiri Blazek, Computational Fluid Dynamics: Principles and Applications, Elsevier Science, 2005.

MIE 5245 RENEWABLE ENERGY LABORATORY [0 0 3 1]

Solar thermal energy:

- Performance of flat plate solar water heater under simulated irradiance
- Paraboloid dish with beam down technology
- Parabolic through collector with two axes tracking

Wind energy:

- Wind energy training system
- Wind emulator
- Performance analysis of hybrid system (vertical wind turbine + PV module)

Photovoltaics:

- Photovoltaic training system
- PV emulator
- PV grid tied system

Other systems:

- Fuel cell test rig
- Thermal energy storage system
- Green hydrogen plant demonstrator

References:

1. G. N. Tiwari: *Solar Energy*, Narosa Publications, 2014.
2. S. P. Sukhatme and J. K. Nayak: *Solar Energy*, Tata McGraw Hill, 2012.
3. James F. Manwell, Jon G. McGowan and Anthony L. Rogers, Wind Energy Explained: Theory, Design and Application, 2nd Ed., Wiley, 2009
4. Augustin McEvoy, Tom Markvart and Luis Castaner, Practical Handbook of Photovoltaics: Fundamentals and Applications, 2nd Ed., Academic Press, 2011.
5. R O Hayre, Fuel Cell Fundamentals, 3rd Ed., Wiley, 2016.

PROGRAM ELECTIVES

MIE 5423 BIOHYDROGEN AND FUEL CELLS [3 1 0 4]

Sustainable hydrogen production: Introduction, fundamentals of biohydrogen production, hydrogenase, Dark-fermentative biohydrogen production, thermophilic fermentation for enhanced biohydrogen production photo fermentative hydrogen production, microbial electrolysis cell for biohydrogen production: **Biohydrogen production, modeling and simulation:** Thermochemical route for biohydrogen production, biohydrogen production from algae, solid wastes, food wastes, renewable biomass resources, acidogenic biohydrogen production from wastewater. Modeling and simulation of the biohydrogen production processes:
Storage and Transportation of hydrogen: Hydrogen storage techniques and transportation, safety measures. Hydrogen as a fuel in heat engines, stationary and powering vehicles in road transport and aviation industry: **Fuel cell:** Basics, Fuel cell definition, Difference between batteries and fuel cells, Fuel cell history, Components of fuel cells, Principle of working of fuel cell, Performance characteristics of fuel cells, Efficiency of fuel cell, Fuel cell stack, Fuel cell power plant: Fuel processor, Fuel cell power section, Power conditioner, Advantages and disadvantages of fuel cell power plant: **Applications of fuel cells:** Co-generation, Fuel cell application in the automotive industry and future perspective. Fuel cells in power sector.

References:

1. Pandey A. S., Mohan V., Jo-Shu Chang, Patrick C. Hallenbeck, and Larroche C., eds. Biomass, biofuels, biochemicals: biohydrogen. Elsevier, 2019.
2. Demirbas, A. Biohydrogen: For Future Engine Fuel Demands, Springer Dordrecht Heidelberg London New York, 2009.
3. O'hayre, Ryan, Suk-Won Cha, Whitney Colella, and Fritz B. Prinz. Fuel cell fundamentals. John Wiley & Sons, 2016.
4. Basu, S. Recent Trends in Fuel Cell Science and Technology, Springer New York, NY, 2007.
5. Das, D., Khanna, N. and Dasgupta, C.N., Biohydrogen production: fundamentals and technology advances. CRC Press, 2017.

MIE 5424 DESIGN OF HEAT EXCHANGERS [3 1 0 4]

Introduction: Classification of heat exchangers, heat transfer mechanisms and flow arrangement, design methods and calculation, convection correlations, pressure drop and pumping power calculations, fouling of heat exchangers: **Micro and nano heat transfer**: Fundamentals of gas flow in micro channels, engineering applications of gas and liquid flow, convective heat transfer with nano fluids and analysis: **Double pipe heat exchangers**: Thermal and hydraulic analysis, bare and finned tube analysis, parallel – series arrangements: **Shell and tube heat exchangers**: Types, basic components, layout and geometry, stream allocation, design procedure, Kern and Bell-Delaware method: **Design of condensers and evaporators**: Laminar film condensation, forced convection, Condensation in horizontal and vertical tubes, Thermal design of shell and tube condensers, horizontal and vertical condensers with tube side and shell side condensation, flow boiling correlations, Thermal design of evaporators: **Compact heat exchangers**: Types, heat transfer and pressure drop calculations: **Plate heat exchangers**: Plate types, passes and flow arrangement, heat transfer and pressure drop calculations, Thermal performance: **Fired process heaters and furnaces**: Types, fundamentals of combustion, heat transfer and heat balance in fired heaters, furnace heat transfer: **Cooling towers**: Classification, concept of psychrometry, energy balance, design and analysis: Testing and experimental performance evaluation of heat exchangers.

References:

1. Sadik Kakac, Heat exchangers: Selection, rating, and thermal design, CRC Press, 2012.
2. Robert W Serth, Process Heat Transfer: Principles, Applications and Rules of Thumb, Academic Press, 2014.
3. Donald Q Kern, Process heat transfer, McGraw Hill Publication, 1997.
4. Kays W. M. and London A.L, Compact Heat Exchangers, McGraw-Hill, 1998.
5. Ramesh K Shah, Fundamentals of heat exchanger design, John Wiley and sons, 2003.
6. Standards of the TEMA, 1999.

MIE 5425 ENERGY MANAGEMENT AND STORAGE [3 1 0 4]

Energy Management & Audit: Present Energy Scenario, Energy Management Principles, Energy Action Plan, Energy Audit Methodologies, Common Energy Audit Instruments, Role of Energy Manager: **Energy conservation and performance Assessment:** Insulation- properties, critical thickness of insulation for cylinders, Economical thickness of insulation, Power factor improvement methods, Electrical lighting and energy conservation methods: **Energy conservation by Waste heat recovery devices and Cogeneration**: Waste heat recovery devices- recuperators -constructional features of Heat wheel, heat pump, heat pipe, Cogeneration principles, methods and types. Performance evaluation of boilers, furnaces, and cooling towers, energy conservation measures: **Need of energy storage**: Introduction and different modes of Energy Storage: **Mechanical and Thermal storage:** Pumped hydro storage, compressed air energy storage, Flywheel storage, and thermal energy storage mechanisms: **Electrical, Magnetic, and Chemical energy storage**: Capacitors, electromagnets, Thermo-chemical, photo-chemical, bio-chemical, electro-chemical energy systems, and Solar Ponds for energy storage: **Case studies**: Energy audit for the existing workshops, AC units, and other major buildings.

References:

1. W C Turner, Energy Management Handbook, Seventh Edition, Fairmont Press Inc., 2007
2. BEE (Bureau of Energy Efficiency) Study Material, Energy Management & Energy Audit, www.bee-india.com.
3. Johannes Jensen Bent Squrensen, Fundamentals of Energy Storage, John Wiley, NY 1984
4. P. D. Dunn, Renewable Energies. Peter Peregrinus Ltd, London, United Kingdom, First Edition, 1986.
5. V.K Mehta, Rohit Mehta, Principles of Electrical Machines, S. Chand and Company LTD, 2019.

MIE 5426 HVAC SYSTEMS AND CRYOGENICS [3 1 0 4]

Refrigeration systems: Vapour compression cycle, multistage compression, multi evaporator system, cascade system, gas cycle refrigeration, aircraft refrigeration: **Major components of the refrigeration Systems:** Estimation of thermal load, selection and matching of components compressors, evaporators, condensers, expansion devices, cyclic controls requirements of refrigerants, lubricants in refrigeration, Secondary refrigerants, mixed refrigerants: **Theory of mixtures**: enthalpy composition diagrams, absorption system calculation, aqua ammonia systems, LiBr water system, Three fluid absorption systems, solar refrigeration system: **Cryogenic Systems:** Cryogenic Systems**:** Introduction: Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction, Inversion Curve, Joule Thomson Effect: **Liquefaction Cycles**: Linde

Hampson Cycle, Pre-cooled Linde-Hampson Cycle, Claudes Cycle, Dual Cycle, Helium Refrigerated Hydrogen Liquefaction Systems. Critical components in Liquefaction Systems: **Applications**: Applications of Cryogenics in Space programs, Superconductivity, Cryo Metallurgy, Medical applications.

References:

1. W.F. Stocker and J. W. Jones, Refrigeration and Air-conditioning' McGraw Hill 2007.
2. Manohar Prasad, Refrigeration and Airconditioning, Wiley Eastern Ltd., 2009
3. Jordan and Priester,Refrigeration and Airconditioning, Prentice Hall of India, 1974.
4. K. D Timmerhaus and T. M. Flynn, Cryogenic Process Engineering, Plenum Press, 2006.
5. Mamata Mukhopadhyay, Fundamentals of Cryogenic Engineering PHI learning PVT LTD, New Delhi,2010

MIE 5408 MACHINE LEARNING AND ITS APPLICATION TO MECHANICAL ENGINEERING [3 1 0 4]

Module 1: Machine Learning

Introduction to Machine Learning: Resurgence of Machine Learning, Relation with Artificial Intelligence, Machine Learning Models (classification models, clustering models, prediction models), applications, modes of machine learning: **Supervised learning**: Introduction, Regression, logistic regression, Support vector machine, nearest neighbour, K-Nearest Neighbour, probabilistic learning, Naive Bayes, Decision tree and Random Forest: **Model performance improving and evaluation:** Dimensionality Reduction Technique, Feature Selection, Feature Scaling, gradient descent rule, regularization, Training, Testing, Cross validation, Confusion matrix, Under-fitting, Overfitting, Correct-fitting, Training accuracy, Testing accuracy, Loss determination-comparison: **Artificial neural network**: Neural Network as Oversimplified Brain, Visualizing Neural Network Equations, Neural Network Representation, SingleLayer Perceptron, Multi-Layer Perceptron, Training the Network, Gradient Computation through Backpropagation, Chain Rule, Updating Weights, Use of Neural Networks in Deep Learning: **Deep learning approaches**: Introduction, Convolutional neural network, Re-current neural network, long, long short-term memory, Transfer learning, Case studies dealing with vision/numeric inputs.

Module 2: Application of ML to Mechanical Engineering

Case studies and mini-project: Computer implementation (using MATLAB and/or PYTHON) of Machine Learning, applied to problems in design engineering, thermal engineering, manufacturing engineering, materials engineering, and tribology.

References:

1. Jo T., Machine Learning Foundations Supervised, Unsupervised, and Advanced Learning. In Machine Learning Foundations. Springer International Publishing, 2021.
2. Kramer, O., Machine learning for evolution strategies. Springer International Publishing, 2016.
3. Rebala, G., Ravi, A., & Churuwala, S., Introduction to Machine Learning. In Studies in Computational Intelligence (Vol. 975), 2021.
4. Manohar Swamynathan, Mastering Machine Learning with Python in Six Steps, A Practical Implementation Guide to Predictive Data Analytics Using Python, 2nd ed., A Press, 2019.
5. Rodrigo Fernandes de Mello and Moacir Antonelli Ponti, Machine Learning, A Practical Approach on the Statistical Learning Theory, Springer International Publishing AG, 2018.
6. Oliver Theobald, Machine Learning For Absolute Beginners: A Plain English Introduction, 3rd ed., 2021.

MIE 5427 MEASUREMENT IN THERMAL SYSTEMS [3 1 0 4]

Experimentation Planning: Planning of experiments, various stages in experimental investigations; preliminary, intermediate and final, steady state and transient techniques, selection of measuring devices based on static, dynamic characteristics and allowable uncertainties, basics of Taguchi method for design of experiments. **Instrumentation & Measurements:** Fundamental elements of a measuring instrument, static and dynamic characteristics, principles of temperature measurement, calibration of thermocouple, RTD, Orifice plate and Pressure gauge, design of temperature measuring instruments, thermo positive elements, thermocouples in series & parallel, pyrometry, steady state and transient methods of measuring heat flux, measurement of thermal radiation and associated parameters, measurement of turbulence, measurement of thermal conductivity of solids, liquids and gases, measurement of thermo-physical properties, measurement of solar radiation. **Advancement in measurements:** Data logging and acquisition, use of sensors for error reduction, elements of microcomputer interfacing, intelligent instruments and their use, Basics of P, PI, PID controllers, pneumatic and hydraulic controllers, electronic controllers. **Advanced measurement techniques and analysis:** Shadowgraph, Schlieren, Interferometer, Laser Doppler Anemometer, Hot wire Anemometer, Telemetry in measurement, Gas Analyzers, Smoke meters, gas chromatography, spectrometry. **Uncertainty in measurements:** Errors in instruments, Analysis of experimental data and determination of overall uncertainties in experimental investigation, uncertainties in measurement of measurable parameters like pressure, temperature, flow etc. under various conditions.

References:

1. Holman J. P: Experimental methods for Engineers, Mc Graw Hill. Inc, 1994.
2. E. O. Doeblin: Measurement systems: Applications and Design, Tata Mc Graw Hill, 2004.
3. Alan S. Morris: Principles of measurement and instrumentation, Prentice Hall of India, 2002.
4. S. P. Venkateshan: Mechanical measurements, Ane Books India, 2008.
5. Beckwith: Mechanical Measurements, Peasrson Education, India, 2005

MIE 5428 MICROFLUIDICS [3 0 0 3]

Flow visualization: Velocity vectors, streamlines, path lines, streak lines, circulation, vorticity, stream tubes, vortex tubes, traditional flow visualization techniques, fluorescence microscopy, particle image velocimetry (PIV): **Physics of micro-flows**: Pressure driven flows, Darcy friction factor, Surface tension driven flows, Young-Laplace equation, Capillary dynamics in micro-channels, modulating surface tension, electro-wetting, rotationally actuated microflows, non-Newtonian flows (viscoelastic, dilatant, power law fluid), blood rheology, blood properties: **Electro-kinetic flow**: Types of electrokinetic flows, electric double layer, electro-osmotic flows in microchannels, electrophoretic motion of particles in microchannels, electrohydrodynamic flow of dielectric liquids: **Micro-pumps**: Passive and active micro-pumps, micro-pump actuation mechanisms, electrokinetic pumps: **Microfluidics in biotechnology**: Detection and separation techniques, lab on a chip, lab on a CD, micro robots for drug delivery: **Micro-heat exchangers and thermal management**: single-phase gas flow and heat transfer, single-phase liquid flow and heat transfer, electronic cooling, thermal management of Li-ion batteries: **Microfabrication**: Top-down and bottom-up approach, photolithography, soft lithography, micromilling, paper based microfluidic devices, low-cost fabrication techniques: **Nano fluidics**: Applications of nanofluids, Van der walls interaction, orientation and dispersion forces, Lucas Washburn equation, concept

References:

1. George Em Karniadakis and Ali Beskok, Micro Flows – Fundamentals and Simulation, Springer-Verlag, 2002
2. S. Kandlikar, Heat transfer and fluid flow in minichannels and microchannels, 1st ed. Kidlington, Oxford, UK: Butterworth-Heinemann, 2006
3. Patrick Tabeling, Introduction to Microfluidics, Oxford University Press, 2005
4. Suman Chakraborty, Microfluidics and Microfabrication, Springer book, 2010.
5. Li Dongqing, Electrokinetics in Microfluidics, 1st ed., Elsevier Academic Press, 2004.
6. M. J. Madou, Fundamentals of Microfabrication, CRC press, 2002.
7. H. Bruus, Theoretical Microfluidics, Oxford University Press Inc., 2008.

MME 5429 TURBOMACHINES FOR ENERGY & JET PROPULSION [3 1 0 4]

Nozzles and diffusers: Introduction, Equation of continuity, Steady Flow Energy Equation in nozzles, Momentum equation, Entropy changes, Nozzle efficiency, Critical pressure, Parameters affecting the performance of nozzles: **Impulse steam turbines:** Types, Steam engines and turbines, Classifications of Steam turbine, Impulse turbine, Compounding of Impulse turbine, Impulse–Reaction turbine, Combination turbines, Stage efficiency, Efficiency of multistage impulse turbine: **Flow of Steam through Impulse-Reaction Turbine Blades:** Velocity diagram, Degree of reaction, Effect of working steam on the stage efficiency, Operation with varying heat drop or variable speed. State Point Locus Reheat Factor and design procedure: Introduction, stage efficiency of impulse turbines, State point locus of an impulse turbine, Reheat factor, Efficiencies, Correction for terminal velocity, Reheat factor for different work condition, Correction of reheat factor for finite number of stages, Design procedure of impulse and impulse- reaction turbines: **Axial Flow and Centrifugal Compressors:** Introduction, Compressibility effects, Factors affecting stage pressure ratio, Blockage in compressor annulus, Degree of reaction, 3-dimensional flow, Design process and blade design. Shaft power cycles and gas turbine cycles for air-craft propulsion: Ideal cycles, Design point performance calculations, Comparative performance of practical cycles, COGAS cycles and cogeneration schemes, Closed cycle gas turbines, Simple turbojet cycle, Turbo fan engine, Turbo prop engine, Thrust augmentation: **Axial and Radial Flow Gas Turbines and Prediction of Performance:** Elementary theory of axial flow turbine, Vortex theory, Choice of blade profile, Pitch and chord, Estimation of blade performance, Overall turbine performance, The cooled turbine, The radial flow turbine, Component characteristics, Off-design operation of the single-shaft gas turbine, Equilibrium running of a gas generator, Off-design operation of free turbine engine, Off-design operation of the jet engine, Methods of displacing the equilibrium running line, Incorporation of variable pressure losses: **Jet and Rocket Propulsion:** The ram jet engine, Pulse jet engine, Turbo prop engine, Turbo jet engine, Thrust equation, Specific thrust, Principles of rocket propulsion, Ideal chemical rocket, Advantages of liquid over solid propellants, Free radical propulsion, Nuclear propulsion, Electro dynamics propulsion, Photon propulsion.

References:

1. R. Yadav, Steam and Gas Turbines, 7th edition, Central Publishing House, Allahabad, 2004.
2. H.I.H. Saravanamuttoo, G.F.C. Rogers & H Cohen, Gas Turbine Theory, 5th Edition, Prentice Hall Publications, 2001.
3. V. Ganesan, Gas Turbines, 3rd Edition, Tata McGraw-Hill Publications, 2010.
4. V Kadambi, Prasad M, An Introduction to Energy Conversion (Vol. 3)-Turbomachinery, Kadambi, Prasad M., 2nd Edition, New Age International Publishers, 2011.
5. S.L. Dixon, Cesare Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, 7th Edition, Elsevier Publishers, 2013.

MIE 5430 TWO-PHASE FLOW [3 1 0 4]

Introduction to two-phase flow: Fundamentals of multiphase flows, areas of applications, different variations of two-phase flow, method of analysis of single and two-phase flow- a comparison: **Estimation of flow patterns:** Classification of flow pattern for gas-liquid, liquid-liquid, and fluid-solid flows in pipes and channels under different orientations, flow pattern map: **Definitions of common terminologies of multiphase flow**. **Modelling two-phase flow:**
Homogeneous flow regime: Pressure drop and volume fraction computation using empirical correlations and homogeneous flow model: **Segregated/separated flow regime:** Pressure drop and volume fraction computation using empirical correlations and separared flow model: **Two-phase Interactions:** Various interacting forces like Drag, lift, virtual mass force, Basset force, Different coupling approach one way, two way, three-way and four-way coupling and the corresponding mathematical formulations. Computational modelling of multiphase flow: Eulerian-Eulerian model (Two-fluid model), Mixture model, Eulerian-Lagrangian model. Two-phase flow with phase change.

References:

1. G.B. Wallis, One Dimensional Two-phase Flow. J.C. Collier, Convective Boiling and Condensation. L. Stong, Boiling Heat Transfer and Two-phase Flow.
2. G. Collier and J.R. Thome, Convective Boiling and Condensation, 3rd ed., Oxford University Press, 1996.
3. C. Kleinstreuer, Two-Phase Flow: Theory and Applications, Taylor & Francis, 2003.
4. G.B. Wallis, One-Dimensional Two-Phase Flow, McGraw-Hill, 1969.
5. P B Whalley, Boiling, Condensation and GasLiquid Flow. Oxford University Press, 1987.
6. L.S. Tong and Y.S. Tang, Boiling Heat Transfer and Two-Phase Flow, 2nd ed., Taylor and Francis, 1997.
7. M. Ishii and T. Hibiki, Thermo-Fluid Dynamics of Two-Phase Flow, Springer, 2006.

OPEN ELECTIVE COURSES

MIE 5301 DESIGN AND ANALYSIS OF EXPERIMENTS [3 0 0 3]

Understanding basic experimental design principles, Working in simple comparative experimental contexts, introduction to R language and its applications in DOE problems, Working with single factors or one-way ANOVA in completely randomized experimental design contexts, Implementing randomized blocks, Latin square designs and extensions of these, Understanding factorial design contexts, Working with two level, 2*k*, designs, Implementing confounding and blocking in 2*k* designs, Working with 2-level fractional factorial designs, Working with 3-level and mixed-level factorials and fractional factorial designs, Simple linear regression models, Understanding and implementing response surface methodologies, Understanding robust parameter designs, Working with random and mixed effects models, Design of computer experiments and the applications in industrial engineering problems.

References:

1. Montgomery, D. C. (2001), *Design and Analysis of Experiments,* John Wiley & Sons. Inc. ISBN: 0-471-31649-0.
2. Dean, A. M. and Voss, D. T. (1999), *Design and Analysis of Experiments (Springer text in Statistics),* Springer Science + Business Media, Inc. ISBN: 0-387-98561-1.
3. Box, G. E. P., Hunter, W. G., and Hunter, J. S. (1978), *Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building,* John Wiley & Sons. Inc. ISBN: 0-47109315-7.
4. Diamond, W. J. (2001), *Practical Experiment Designs for Engineers and Scientists,* John Wiley & Sons. Inc. ISBN: 0-471-39054-2.
5. Jeff Wu, C. E. and Hamada, M. I. (2000), *Experiments: Planning, Analysis, and Parameter Design Optimization,* John Wiley & Sons. Inc. ISBN: 0-471-39054-2.

MIE 5302 DESIGN OF CURVES AND SURFACES [3 0 0 3]

Hardware and software for Computer Aided Design (CAD), geometric modelling concepts of CAD; parametric representation of analytic curves (line, circle, ellipse and hyperbola), synthetic curves (Hermite cubic splines, Bezier curves, B-spline curves, NURBS), analytical surfaces (plane, ruled, tabulated, revolved), synthetic surfaces (Bi-cubic, Bezier, B-spline, NURBS, Coons, Ferguson’s and Bilinear surface patches); 3D transformation (translation, scaling, rotation and concatenation) of geometric entities and their projections.

References:

1. Michael E. Mortenson, GEOMETRIC MODELING, Wiley Computer Publishing, John Wiley and Sons, Inc. Second Edition), 1996.
2. Ibrahim K.Zeid, CAD/CAM Theory and Practice, Tata McGraw Hill, New Delhi, 1998.
3. David F. Rogers and J Alan Adams, Mathematical Elements for Computer Graphics, Tata McGraw Hill, New Delhi, 2002.
4. David F. Rogers and J Alan Adams, Procedural Elements for Computer Graphics, McGraw Hill, New York, 2001.
5. Donald Hearn and M Pauline Baker, Computer Graphics, Prentice Hall of India, New Delhi, 2000.
6. Mikell P. Groover and Emory W. Zimmers, Jr, CAD/CAM: Computer Aided Design and Computer Aided Manufacturing, Pearson Education India, 2013.

MIE 5303 ENERGY STORAGE SYSTEMS [3 0 0 3]

Introduction: Need for energy storage, Different modes of energy storage. **Potential energy**: Pumped hydro storage, Kinetic energy and compressed gas system, Flywheel storage, Compressed air energy storage, Electrical and magnetic energy storage, Capacitors, Electromagnets, Chemical energy storage, Thermo-chemical, photo-chemical, bio-chemical, electro-chemical, fossil fuels and synthetic fuels, Hydrogen for energy storage, Solar ponds for energy storage. **Electrochemical, Magnetic and Electric Energy Storage Systems**: Batteries, Primary, Secondary, Lithium, Solid-state and molten solvent batteries, Lead acid batteries, Nickel Cadmium Batteries, Advanced batteries, Superconducting Magnet Energy Storage (SMES) systems, Capacitor and Batteries, Comparison and application, Super capacitor, Electrochemical Double Layer Capacitor (EDLC.**Sensible and Latent Heat Storage**: SHS mediums, Stratified storage systems, Rock-bed storage systems, Thermal storage in buildings, Earth storage, Energy storage in aquifers, Heat storage in SHS systems, Aquifers storage, Phase Change Materials (PCMs),Selection criteria of PCMs, Solar thermal LHTES systems, Energy conservation through LHTES systems,LHTES systems in refrigeration and air-conditioning systems, Numerical heat transfer in melting and freezing process. **Application of Energy Storage:** Food preservation, Waste heat recovery, Solar energy storage, Green house heating, Power plant applications, Drying and heating for process industries.

References:

1. Johannes Jensen Bent Squrensen, *Fundamentals of Energy Storage*, John Wiley, NY , 1984.
2. *IEE Energy Series*, Electro-chemical Power Sources.
3. Baader, W., Dohne, E., Brenndorfer, *Bio-gas in Theory and Practice*.
4. P.D.Dunn, *Renewable Energies*. Peter Peregrinus Ltd, London, United Kingdom, First Edition, 1986.
5. Ibrahim Dincer, *Thermal Energy Storage: Systems and Applications*, Wiley Publications, 2010.

MIE 5304 MECHANICS OF POLYMERS [3 0 0 3]

Introduction, Overview of Polymeric Materials, Polymerization and Crosslinking, Crystallinity, Glass Transition Temperature, Molecular Orientation; Processing of polymers -Thermoplastics and thermosets processing techniques; Kinetic Theory of Rubber Elasticity, Linear elastic relations for rubber elasticity, Mechanics of Elastomers, thermomechanical behavior of polymers;
Viscoelasticity **-** Linear and fractional order models, Maxwell Models,Creep, Stress Relaxation, Dynamic Response; Mechanical response during plastic deformation and fracture -Yielding and Crazing,viscoplasticity, Linear Fracture Mechanics, Elastic-plastic Fracture, Brittle Fracture, Toughening.
Failure mechanisms in polymer matrix composites.

References

1. R.J. Young and P.A. Lovell, Introduction to Polymers: 3rd Edition, CRC Press, 2011
2. I.M. Ward, J. Sweeney, Mechanical Properties of Solid Polymers, 3rd ed. Wiley
3. R.S. Dave, A.C. Loos, Processing of Composites, Hanser, 2000.
4. Jorgen S Bergstrom, Mechanics of solid polymers: theory and computational modelling, Elsevier, 2015.

MIE 5305 PRINCIPLES OF LEAN IN PRODUCTION SYSTEMS [3 0 0 3]

Introduction: Evolution of Mass production – Traditional vs. Mass production – Evolution of Toyota Production System (TPS) – Business Dynamics of Lean production – Principles of Lean production: Value, Value Stream, Flow, Pull, Perfection. TPS – Tools & Techniques - 1: 3Ms: Muda, Mura, Muri – 7 Wastes in Manufacturing – Lean Tools to eliminate Muda – 5S –, Plan-Do-Check-Act (PDCA), Standardised work, TPM – SMED – Jidoka – Poka Yoke – JIT – Heijunka – Kanban – One piece production, Kaizen, Visual Management, Production smoothing, Shortening production lead time, Shortening setup time – concepts and techniques

References:

1. Monden Y., Toyota Production System: An Integrated Approach to Just-In-Time, (4e), CRC Press, U.S.A, 2011.
2. Rother and Shook, Learning to See: Value Stream Mapping to add Value and Eliminate Muda, The Lean Enterprise Institute, U.S.A., 1999.
3. Gross and McInnis, Kanban Made Simple: Demystifying and Applying Toyota's Legendary
4. Manufacturing Process, AMACOM Books, U.S.A., 2003.
5. Fled W., Lean Manufacturing: Tools, Techniques and How to Use Them, CRC Press, U.S.A., 2001.
6. Dailey K. W., The Lean Manufacturing Pocket Handbook, D.W. Publishing Co., 2003.

MIE 5306 PRODUCT DESIGN AND DEVELOPMENT [3 0 0 3]

Introduction: Characteristics, design, cost, duration and challenges of successful design and development of products. **Development Processes and Organizations:** A generic development process and concept of development process, the AMF development process, product development organizations, the AMF organization. **Product Planning:** The product planning process, Evaluate and prioritize projects, allocate resources and plan timing, complete pre project planning. **Identifying Customer Needs:** Gather raw data, interpret raw data, organize the needs into a hierarchy, establish the relative importance of the needs and reflect on the results and the process. **Product Specifications:** What are specifications, establishing target specifications, setting the final specifications. **Concept Generation:** The activity of concept generation, , search externally and internally, explore systematically, reflect on the results and the process. **Concept Selection:** concept screening, and concept scoring, **Concept Testing:** Define the purpose of concept test, choose a survey population, survey format, communicate the concept, measure customer response, interpret the result, reflect on the results and the process. **Product Architecture:** Product architecture, implications of the architecture, establishing the architecture, variety and supply chain considerations, platform planning, related system level design issues. **Industrial design:** need and impact of industrial design, industrial design process, managing the industrial design process, assessing the quality of industrial design. **Design for Manufacturing:** Definition, estimation of manufacturing cost, reducing the cost of components, assembly, supporting production, impact of DFM on other factors. **Prototyping:** Prototyping basics, principles of prototyping, technologies, planning for prototypes. **Product Development Economics:** Elements of economic analysis, base case financial mode, Sensitive analysis, project trade-offs, influence of qualitative factors on project success, qualitative analysis.

References:

1. Karl.T.Ulrich, Steven D Eppinger - Product Design and Development - Irwin McGrawHill - 2000.
2. A C Chitale and R C Gupta, Product Design and Manufacturing - PH1, - 3rd Edition, 2003.
3. Timjones. Butterworth Heinmann -New Product Development -Oxford. UCI -1997
4. George E Deiter, Engineering Design, 5th Edition, McGraw-Hill , 2012 .
5. Boothroyd G, Dewhurst P and Knight W, Product Design for Manufacture and Assembly, 2nd Edition, Marcel Dekker, New York, 2002.
6. G Altshuller, H Altov, Lev Shulyak, And Suddenly the Inventor Appeared: TRIZ, The theory of Inventive Problem Solving, Technical Innovation Centre, 2nd Edition, May 1996.
7. Vladimir Petrov, Theory of Inventive Problem Solving, Level 1, Springer Series, 2019, ISBN: 978-3-030-04253-0.

MIE 5307 QUALITY CONTROL AND RELIABILITY [3 0 0 3]

Definitions of the term quality, Inspection and quality control, Causes of variation, Patterns of variation, Frequency distribution, Measures of central tendency and dispersion, The Normal distribution curve,
Inequality theorems, Shewhart's bowl drawing experiments, Control charts for variables ($\bar{X}$, R and s charts), Type I and Type II Errors, Process capability analysis, Process capability indexes, Control charts for attributes (p, np, c and u charts), Importance of Acceptance sampling, Single and Double sampling plans, Operating characteristic curve, Acceptable quality level, Lot tolerance percent defective, Average outgoing quality, Average total inspection, Average fraction inspected, Producers risk, Consumers risk, Introduction to life testing and reliability, Equipment failure pattern, Failure rate, Mean Time Between Failure (MTBF), Mean Time To Failure (MTTF),
Product rule, Parallel connection, System reliability.

References:

1. Grant E. L and Levenworth R., *Statistical Quality Control*, McGraw Hill Publications, New York, 2005.
2. Mahajan M.S., *Statistical Quality Control*, Dhanpat Rai and Co. Pvt. Ltd., Delhi, 2012.
3. Montgomery D.C., *Introduction to Statistical Quality Control*, John Wieley and Sons, New York, 2005.
4. Juran J.M. and Gryna F.M., *Quality Planning and Analysis*, Tata McGraw Hill Publications, Delhi, 1995.
5. Bertrand L. Hansen, *Quality Control- Theory and Applications*, Prentice Hall India, Delhi, 1987.

MIE 5308 RENEWABLE ENERGY TECHNOLOGY [3 0 0 3]

Solar energy –Production and transfer of solar energy – Sun-Earth angles –Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation. Applications of Solar energy, Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels, Aerobic and anaerobic bio-conversion – Properties of biomass, Biogas plants– Design and operation, Wind energy – Principles of wind energy conversion – Site selection considerations –Wind power plant design – Types of wind power conversion systems – Operation, maintenance and economics, fuel cells, fuel cell power plant, Geothermal fields- Hot dry rock, Energy conversion technologies, Ocean thermal energy conversion, Wave and tidal energy: Scope and economics – Introduction to integrated energy systems.

References:

1. J.A. Duffie and W.A. Beckman: *Solar Energy Thermal Processes*, J. Wiley, 1994.
2. A.A.M. Saigh (Ed): *Solar Energy Engineering*, Academic Press, 1977
3. F. Kreith and J.F. Kreider: *Principles of Solar Engineering*, McGraw Hill, 1978

4. G.N. Tiwari: *Solar Energy-Fundamentals, Design, Modelling and Applications*, Narosa Publishers, 2002
5. H.P. Garg, S.C. Mullick and A.K. Bhargava: *Solar Thermal Energy Storage*, 1985
6. K.M. Mittal: *Non-conventional Energy SystemsPrinciples, Progress and Prospects*, Wheeler Publications, 1997.

THIRD AND FOURTH SEMESTER

MIE 6091 PROJECT WORK & INDUSTRIAL TRAINING [0 0 0 25]

Students are required to undertake innovative and research oriented projects, which not only reflect their knowledge gained in the previous two semesters but also reflects additional knowledge gained from their own effort. The project work can be carried out in the institution / industry /research laboratory or any other competent institutions. The duration of project work should be a minimum of 36 weeks. There will be a mid-term evaluation of the project work done after about 18 weeks. An interim project report is to be submitted to the department during the mid- term evaluation. After completing the project work, each student has to submit a project report in prescribed format, to the department / institution. The final project evaluation and viva-voice will be conducted only after submission of the report approved by both internal and external guides. Each student has to make a presentation on the project work carried out, before the departmental M. Tech. project evaluation panel for the project evaluation. The mid-term & end semester project evaluation will be done by the departmental project evaluation panel including the internal as well as external guides.

The students carrying out their project work within the institution need to mandatorily undergo an industrial training for a minimum period of 4 weeks. For the students carrying out their project work in an industry/research laboratory/organization, the industrial training is not mandatory.