Annexure-5

CURRICULUM

FOR

Integrated Dual Degree Programme

(M.Tech-PhD Thermal Engineering)

चरैवेति चरैवेति

महात्मा ज्योतिबा फुले
रुहेलखण्ड विश्वविद्यालय, बरेली

DEPARTMENT OF MECHANICAL ENGINEERING
FACULTY OF ENGINEERING AND TECHNOLOGY
M. J. P. ROHILKHAND UNIVERSITY,
BAREILLY-243006 (U.P.) INDIA

Integrated Dual Degree Programme in

M.Tech-PhD
Year-1

Semester-I (Common)

Sr. No.	Subject Code	Subjects	Teaching Schedule			Credits
			L	T	P	
1		Advanced Engineering Mathematics	3	1	0	4
2	MME-1003C 55552	Statistics for Decision Making	3	1	0	4
3	MME-1005C 55553	Research Methodology	3	1	0	4
4	MME-1007C 55554	Experimental Design Techniques	3	1	0	4
5	MME-1009E 55555/ MME-1011E 55556	Advance Heat Transfer (Elective-I) Advanced Manufacturing Process (Elective-I)	3	1	0	4
6	MME-1001P 65551	Industrial Engineering Lab-I	0	0	2	2
7	MME-1013P 65552 MME-1009P 65553	Simulation Lab/ Heat Transfer Lab	0	0	2	2
		Total				**24**

Semester-II (Even Semester)

Sr. No.	Subject Code	Subjects	Teaching Schedule			Credits
			L	T	P	
1	MME-1002C 55561	Advance Fluid Mechanics	3	1	0	4
2	MME-1004C 55562	Air Conditioning System Design	3	1	0	4
3	MME-1006C 55563	Advance Heat Exchanger Design	3	1	0	4
4	MME-1008C 55564	Combustion in IC Engine	3	1	0	4
5	MME-1010E 55565/ MME-1012E 55566/ MME-1014E 55567	Steam and Gas Turbine (Elective-II) Gas Dynamics (Elective-II) Advance Power Generation System (Elective-II)	3	1	0	4
6	MME-1004P 65561	Air Conditioning System Lab	0	0	2	2

7	MME-1008P 65562	IC Engine Lab	0	0	2	2
		Total				**24**

Electives-I

	Subject Code	Paper Code	Subject
•	MME-1009E	55555	Advance Heat Transfer
•	MME-1011E	55556	Advanced Manufacturing Process

Year-2

Semester-III (Odd Semester)

Sr. No.	Subject Code	Subjects	Teaching Schedule			Credits
			L	T	P	
1	MME-1107P 65563	Dissertation-I*	0	0	20	18
2	MME-1109P 65564	Seminar	0	0	2	4
		Total				**22**

Semester-IV (Even Semester)

Sr. No.	Subject Code	Subjects	Teaching Schedule			Credits
			L	T	P	
1	MME-1104P 65565	Dissertation-II*	0	0	22	22
		Total				**22**

It is desirable that candidate should publish at least 02 papers in national/International Journal/ conferences.

Electives-II

	Subject Code	Paper Code	Subject
•	MME-1010E	55565	Steam and Gas Turbine
•	MME-1012E	55566	Gas Dynamics
•	MME-1014E	55567	Advance Power Generation System

Sub. Code **Advanced Engineering Mathematics** **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Develop the ability to analyze boundary value problems and apply solution techniques like separation of variables, the method of characteristics, and Fourier series to solve PDEs.
CO 2: Develop a deep understanding of vector calculus concepts like divergence, curl, gradient, and line, surface, and volume integrals, and apply these concepts to problems in electromagnetism, fluid mechanics, and continuum mechanics.
CO 3: Students will be able to apply numerical methods (e.g., finite difference, finite element, and Runge-Kutta methods) to solve ordinary and partial differential equations where analytical solutions are difficult or impossible to obtain.
CO 4: Enhance problem-solving skills, critical thinking, and analytical techniques to break down complex engineering problems into solvable components using advanced mathematical concepts.

Unit-01: Linear Algebra: Introduction to vector space, linear independence, solution of simultaneous linear systems, uniqueness and existence, Algebraic eigenvalue problem, similarity transformation, Introduction of linear transformation, Calculus: Differential geometry, parametric representation, Grad, Div and Curl, introduction to tensor algebra, equation of line, plane, surface, Line integral, path independence, Divergence theorem, Stokes theorem, Green's theorem in a plane.

Unit-02: Ordinary Differential Equation: First order equations, integrating factor, orthogonal trajectories, Existence and uniqueness, Second order equations with constant coefficients, The Cauchy-Euler equation, Method of undetermined coefficients, variation of parameters, matrix method, Sturm-Liouville problems, trigonometric Fourier series.

Unit-03: Integral Transform: Fourier series, Fourier integral, Fourier and Laplace transform, standard rules, Dirac-delta and Heaviside function, convolution, solution of ODEs.

Unit-04: Partial differential equation: Linear equations, superposition, separation of variable, Second order wave equation, Unsteady heat conduction equation, Laplace equation.

Text Books and Reference Books:

1. David Kincaid and Ward Cheney, "Numerical Analysis: Mathematics of Scientific Computing'', AMS, 2009.
2. Richard L. Burden and J. Douglas Faires, Numerical Analysis, Cengage Learning India Private Ltd.
3. M. K. Jain, S.R.K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications, 2008.
4. K. E. Atkinson, "An Introduction to Numerical Analysis", Wiley, 2nd Edition, 1989.
5. S.D. Conte, Carl de Boor, "Elementary Numerical Analysis: An Algorithmic Approach'', SIAM, 2018.

Subject Code MME-1003C | **Statistics for Decision Making** | **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will develop a strong foundation in basic statistical concepts, including types of data, data types, scales of measurement, and the role of statistics in decision-making processes.
CO 2: Understand the fundamentals of probability theory, including basic probability rules, conditional probability, and Bayes' theorem.
CO 3: Understand and apply techniques for estimation, point estimation, and interval estimation to make data-driven decisions and evaluate the uncertainty associated with those decisions.
CO 4: Understand how to interpret test results, make decisions based on statistical significance, and communicate findings effectively in the context of decision-making.
CO 5: Apply correlation analysis to measure the strength and direction of relationships between variables, and learn how to assess causality versus correlation in decision-making contexts.

Unit 1: Fundamentals of Probability Theory and Descriptive Statistics:

- Descriptive Statistics: Mean, median, mode, variance, standard deviation, and data visualization.
- Probability Theory: Basics of probability, probability models, random variables, probability mass function (PMF), probability density function (PDF).
- Conditional Probability & Bayes' Theorem: Concepts of conditional probability, independence, and Bayes' Theorem.

Unit 2: Probability Models and Random Variables:

- Discrete and Continuous Distributions: Properties of common distributions like Binomial, Poisson, Normal, Exponential, etc.
- Expectations and Moments: Mean, variance, and higher moments; moment generating functions and their properties.
- Law of Large Numbers & Central Limit Theorem: Their importance in probability and statistical applications.

Unit 3: Statistical Inference and Estimation Techniques:

- Point Estimation: Methods of moments, maximum likelihood estimation.
- Confidence Intervals: Construction and interpretation for population parameters.
- Case Studies: Applications of estimation methods in real-world engineering and applied sciences problems.

Unit 4: Hypothesis Testing and Goodness of Fit:

- Concept of Null Hypothesis & Alternative Hypothesis: Types of errors (Type I & II), significance level, p-value.
- Testing of Hypotheses: Z-test, t-test, chi-square tests.
- Goodness of Fit Tests: Chi-square test for distributions.
- Non-Parametric Tests: Wilcoxon test, Mann-Whitney U test.

Unit 5: Regression, Curve Fitting, and Software Applications:

- Linear Regression: Simple and multiple regression analysis, interpretation of coefficients.
- Curve Fitting and Estimation Techniques: Least squares method and other curve fitting approaches.
- Software in Statistics: Introduction to statistical software like R, Python (Numpy, Pandas) and others for data analysis and modeling.
- Industrial Applications: Quality control, reliability analysis, and simulation.

Recommended Books:

Subject Code MME-1005C | **Research Methodology** | **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Develop the ability to choose suitable data collection techniques (e.g., surveys, interviews, focus groups, observations) based on the research objectives.
CO 2: Understand how to interpret research data, draw conclusions, and validate findings, ensuring they are consistent with the research objectives and questions.
CO 3: Understand the distinction between qualitative and quantitative research methods, and be able to identify when to apply each approach depending on the research objectives and data types.
CO 4: Understand how to assess the credibility and reliability of sources and use academic databases to gather relevant research material.
CO 5: Learn how to identify research gaps and propose new areas for exploration or future studies based on existing research limitations or emerging trends.

Unit 1: Research Methodology: An introduction; meaning of research; objective of research; motivation in research; types of research, research approaches; significance of research, research methods v/s methodology; research and scientific method.

Defining the Research Problem: What is problem; selecting the problem; necessity of defining the problem, Hypothesis: Types and their formulation, Uses of Internet resources in selecting problem research.

Unit 2: Research Design: Meaning of the research design; need for research design; feature of a good design; important concept relating to research design; different research design; basic principles of experimental designs; important experimental Designs; developing a research plan.

Sampling Design: Census and sample survey; Implication of sample design; Steps in sampling design; Criteria for selecting a sampling procedure, Sampling & Non-sampling error, Sample size calculation.

Unit 3: Methods of Data Collection: Selection for appropriate method for data collection; collection of primary data; online data collection tools; collection of data through questionnaires/schedules/other methods; collection of secondary data;

Unit 4: Processing and Analysis of Data: Processing operations; Elements/types of analysis; Univariate Analysis (measures of central tendency; measures of dispersion; measures of asymmetry (Skewness& Kurtosis); Bi-variate Analysis (measures of relationship; simple regression analysis); Multiple correlation and regression; partial correlation; Association in the case of attributes; Introduction to Multivariate analysis: Confirmatory Factor Analysis (CFA) , Structural Equation Modeling (SEM)

Unit 5: Interpretation and Report Writing: Meaning of interpretation; why interpretation? Analysis Writing, Discussion Writing, Techniques of interpretation, precautions in interpretation; Significance of Report Writing; Bibliography and References, Online Referencing using Internet Resources.

Recommended Books:

Subject Code MME-1007C **Experimental Design Techniques** **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will gain foundational knowledge of experimental design concepts, including variables, controls, and different types of experimental setups.
CO 2: Students will learn specific techniques such as Randomized Block Designs, Latin Square Designs, and Factorial Designs, and understand their applications and limitations.
CO 3: Students will develop skills in statistical methods for analysing experimental data, including ANOVA (Analysis of Variance), regression analysis, and hypothesis testing.
CO 4: Students will be able to apply factorial design methods and response surface methodology (RSM) to optimize processes and improve outcomes.

Unit 1: Introduction to Designed Experiments, Importance and Need for Experimental Design, Basic statistics (ii) ANOVA (iii) Regression

Unit 2: Experimental Designs-
(i) RCBD (ii) Latin square (iii) BIBD (iv) CCD (iv) Regression Modelling (v)Taguchi Approach.

Unit 3: Factorial Designs-
(i) Full factorial designs (ii) 2 k factorial designs (iii) Blocking and confounding in 2 k factorial designs (iv) 2 k - p factorial designs.

Unit 4: Response Surface Methodology-
(i) Method of steepest ascent (ii) Analysis of second order responses (iii) Multiple responses

Unit 5: **Robust Design-**
(i) Crossed array design (ii) Combined array design.

Textbook: Montgomery, Design and Analysis of Experiments, 7th Edition.

Reference Books:

1. Roy, Ranjit K, Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement, John Wiley & Sons, Inc 2001.
2. G. Casella, S. Fienberg, and I. Olkin, Statistical Analysis of Designed Experiments, Third Edition, Springer Science Business Media, LLC, 2009.
3. Klaus Hinkelmann and Oscar Kempthorne, Design and Analysis of Experiments (Volume 2: Advanced Experimental Design), John Wiley & Sons, Inc, 2005.
4. J. Antony, Design of Experiments for Engineers and Scientists, Elsevier Science & Technology Books, 2003.
5. G. E. P. Box and N. R. Draper, Response Surfaces, Mixtures, and Ridge Analyses, John Wiley & Sons, Inc, 2007.

Subject Code MME-1009E	Advance Heat Transfer (Elective-I)	LTP (310)

Course Outcomes (COs)

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

CO 1: Students will gain advanced knowledge of conduction, convection, and radiation, including the mathematical models that describe these processes.

CO 2: Students will develop the ability to analyze systems involving combined modes of heat transfer, including conduction-convection, convection-radiation, and phase-change phenomena.

CO 3: Students will understand the design and optimization of heat exchangers, including shell-and-tube, plate, and microchannel heat exchangers, and will apply various models to assess their performance.

CO 4: Students will apply advanced heat transfer principles to solve real-world engineering problems, such as in thermal management of electronics, energy systems, aerospace, and manufacturing processes.

Unit 1: Understand the basic modes of heat transfer, Analysis of steady state situation in conduction for plane wall, cylinder and sphere. Study the transient (time dependent) conduction and solving problems of 1-d with explicit and implicit scheme, Understand the basic of radiation.

Unit 2: Derivation of governing equation for three-dimensional transient heat conduction problems. Two-dimensional steady state heat conduction. Transient one-dimensional heat conduction in finite length bodies

Unit 3: Newton's law of cooling-Derivation of energy equation- Self-similar solution for laminar boundary flow over a flat plate – energy integral method for laminar boundary layer flow over a flat surface-Laminar internal flows-thermally fully developed flows Gratz problem - Natural convection over a vertical flat plate: similarity solutions and energy integral method- natural convection in enclosures-mixed convection-Turbulent flow and heat transfer: Reynolds averaged equations-Turbulent boundary layer flows – The law of wall-integral solutions. Convective mass transfer.

Unit 4: Convection with phase change: Pool boiling regimes- Condensation: drop-wise condensation-Laminar film condensation over a vertical surface.

Unit 5: Radiative heat transfer: Black body radiation-radiative properties of non-black bodies surface radiation heat transfer in enclosures with grey diffused walls and non-grey surfaces. Calculation of radiation exchange between black and grey body and concept of gas radiation.

Reference Books:

1. Fundamentals of engineering Heat and mass transfer - R.C. SACHDEVA – New Age International
2. Heat transfer – Ghoshdastidar – oxford university Press – IInd edition.
3. Heat and mass transfer – R.K. Rajput
4. Fundamental of heat transfer and mass transfer – Incropera and Dewitt – John Wiley. Publication.
5. Fundamentals of Heat and Mass Transfer, Incropera and Dewitt, Sixth Edition, John Wiley.

6. Convection Heat Transfer, A Bejan, John Wiley.
7. Convective Heat and Mass Transfer, W M Kays and M E Crawford, McGraw-Hill publishing Company.
8. Thermal Radiation Heat Transfer, J Siegel and R Howell, Elsevier.

Subject Code MME-1011E | **Advanced Manufacturing Process (Elective-I)** | **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will gain a comprehensive understanding of advanced manufacturing techniques, including additive manufacturing, precision machining, advanced welding, and non-traditional machining (e.g., EDM, ECM, and laser cutting).

CO 2: Gain proficiency in advanced non-traditional manufacturing processes like Electrical Discharge Machining (EDM), Electrochemical Machining (ECM), Laser Beam Machining (LBM), and Ultrasonic Machining (USM).

Unit 1: USM and AJM

Ultrasonic Machining (USM): Basics, mechanics, Shaw's model, Process parameters; Abrasive Jet Machining (AJM): Basics, process parameters, MRR, Components

Unit 2: Electrochemical Machining (ECM)

ECM Basics: Electrochemistry, Debye-Huckel theory, ECM process, MRR estimation, electrode potential; ECM Dynamics: Kinematics, tool shape, electrolyte flow design, Insulation design, defects in ECM; Electrochemical Grinding and Drilling: Basics and process parameters

Unit 3: Thermal Processes (EDM, EBM)

Electro-Discharge Machining (EDM): Process parameters, mechanics, MRR, crater volume; EDM Surface Finishing: Machining accuracy, Surface hardness, electrode, dielectric fluid; Electron Beam Machining (EBM): Mechanics, power requirements

Unit 4: Laser and Plasma Arc Machining

Laser Beam Machining (LBM): Basics, types of lasers, mechanics of material removal, Heat conduction, cutting speed; Plasma Arc Machining: Overview and applications; Micro-Fabrication: Silicon/glass processes, soft lithograph

Unit 5: Advanced Finishing Processes

Abrasive Flow Finishing (AFF) and Magnetorheological Abrasive Flow Machining (MRAF): Basics, process parameters.

Reference Books:

1. **V. K. Jain**, Advanced Machining Processes, Khanna Publishers, 2009.
2. **B. K. Parekh**, Non-Traditional Machining Processes, A. H. Wheeler & Co, 2007.
3. **Serope Kalpakjian and Steven R. Schmid**, Manufacturing Engineering and Technology, Pearson Education, 7th Edition, 2014.
4. **J. R. Davis,** Electrochemical Machining, ASM Handbook, Vol. 16, 1996.
5. **S. C. Mishra and R. K. Gupta,** Non-Conventional Machining Processes, Wiley, 2018.
6. **B. L. Juneja**, Advanced Machining Processes, New Age International, 2007.

Subject Code MME-1001P **Industrial Engineering Lab-I** **LTP (002)**

<u>List of Experiments of Industrial Engineering Lab:</u>

1. P-chart for fraction defectives
2. C- chart for number of defectives (constant sample size)
3. Operating characteristic curve of single sampling Attributes plan
4. Test for normality of sample means (normal distribution)
5. Test for normality of sample means (universal distribution Rectangular)
6. X, R – charts & process capability
7. Pin board study experiment

Reference Books:

Subject Code MME-1013P **Subject Code MME-1009P**	**Simulation Lab/** **Heat Transfer Lab**	**LTP (002)**

<u>List of Experiments of Simulation Lab:</u>

1. Forecasting methods
2. Inventory management
3. MRR Modeling
4. Simulate analog and digital function blocks
5. PDCA cycle
6. 5S
7. Kaizen

<u>List of Experiments of Heat Transfer Lab:</u>

1. To determine temperature distribution and heat transfer in pool boiling conditions.
2. To determine temperature distribution of a solid slab
3. Analysis of fin using MATLAB.
4. To determine the heat transfer in film wise and drop wise condensation process.
5. To determine the emissivity of grey surface.
6. To study and analysis of compact heat exchanger.
7. To study of heat pipe.
8. To find thermal conductivity of powders/ liquids.

Reference Books:

Second Semester

Subject Code MME-1002C | **Advance Fluid Mechanics** | **LTP (310)**

Course Outcomes (COs)

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

CO 1: Students will gain expertise in boundary layer theory, analyzing boundary layer formation, separation, and transition from laminar to turbulent flow.

CO 2: Students will learn to analyze complex flow phenomena, such as compressible flows, unsteady flows, and non-Newtonian fluids, and understand their applications in engineering.

CO 3: Proficiency in using CFD software (such as ANSYS Fluent, OpenFOAM, or COMSOL Multiphysics) for simulating and analyzing fluid flows in complex systems.

CO 4: Students will gain skills in using dimensional analysis and similitude for designing experiments, scaling models, and interpreting complex flow problems.

Unit 1: Introduction. Field theory, tensor algebra and calculus.

Unit 2: Reynolds transport theorem. Derivation of mass, momentum and energy equations.

Unit 3: Constitutive relations and the Naiver Stokes equation for Newtonian fluids.

Unit 4: Inviscid flows, applications of Bernoulli/Euler equations, irrotational incompressible flows using complex variables

Unit 5: Analytical solutions of the transient and steady Navier Stokes equations for incompressible viscous flows: e.g. Stokes first problem or Rayleigh problem, Stokes second problem, pulsatile Poiseuille flow, steady flow through pipes of various cross-sections, Hiemenz's solution to stagnation point flow, Oseen vortices.

Unit 6: Boundary layer theory (zero/non-zero pressure gradient) and its applications to laminar boundary layers, jets, wakes and stagnation regions in external (e.g. aerofoil) and internal flows (e.g. nozzles, developing flows).

Unit 7: Stability and transition to turbulence, Derivation of RANS equations; turbulent shear flows.

Unit 8: Special topics: topics from lubrication theory, flows with surface tension, zero Reynolds number flow, compressible flow, introduction to non-Newtonian flows.

Reference Books:

1. Fluid mechanics: F.M. White McGraw Hill
2. Fluid mechanics: Som and Biswas, T.M.H. Reference
3. Fluid mechanics: P.K. Kundu & Ira M. Cohen 2. Fluid mechanics: G.K. Batchelor

Subject Code MME-1004C | **Air Conditioning System Design** | **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will understand the fundamental principles of air conditioning, including thermodynamics, psychrometrics, and heat transfer processes related to HVAC (Heating, Ventilation, and Air Conditioning) systems.

CO 2: Students will learn the design process for various HVAC systems, such as split, packaged, and central systems, and understand their components, such as compressors, evaporators, condensers, and fans.

CO 3: Students will learn the importance of indoor air quality, including ventilation standards and filtration techniques, and how to design systems that ensure adequate air quality.

CO 4: Proficiency in using HVAC design software (such as Carrier HAP, Trane TRACE, or Revit) for modeling, simulating, and analyzing air conditioning systems.

Unit 1: Cooling and heating load calculation – I: Estimation of solar radiation. Introduction, solar radiation, constant and irradiation geometry and various related basic and derived angle, angle of incident for horizontal, vertical and tilted surfaces, calculation of direct, diffuse and reflected radiation using ASHRAE solar radiation model including effect of clouds.

Unit 2: Cooling and heating load calculation – II: Solar radiation fenestration, ventilation and infiltration. Fenestration, need, effect on air conditioning systems, estimation, concepts, SHGF, shading coefficient, external shading, calculation of shaded area, windows with overhang, infiltration and ventilation, causes, estimation of heat transfer rate.

Unit 3: Cooling and heating load calculation – III: Heat transfer through building, fabric heat gain/loss. Heat transfer through buildings, 1-D, steady state and unsteady state heat transfer through homogeneous, non-homogeneous walls, air spaces, composite walls, opaque walls, roofs. The analytical and in brief numerical methods used to solve the 1-D transient heat transfer problem,

Unit 4: Selection of air conditioning systems. Introduction to thermal distribution systems, there functions, selection criteria and their classification of air conditioning systems, working principal, advantages, disadvantages and its application for various air/water flow systems.

Unit 5: Transmission of air in air conditioning ducts. Describe an air handling unit (AHU) its functions, need for studying transmission, air flow through ducts, Bernoulli and modified Bernoulli equation, static, dynamic, datum and total head, fan total pressure (FTP) and power input to fan, estimation of pressure loss through ducts, estimation of dynamic pressure drop in various types of heating.

Text Books:

1. Refrigeration and air conditioning by Stooker W.F.
2. Refrigeration and air conditioning by C.P. Arora, Tata McGraw Hill.

Reference Books:

1. Refrigeration and air conditioning by Ahmad ul Ameen, PHI publication.
2. Handbook of air conditioning and Refrigeration by Shan K. Wang, Tata McGraw Hill.

Subject Code MME-1006C **Advance Heat Exchanger Design** **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will develop a strong foundation in heat exchanger types, mechanisms, and applications across various industries, including chemical, HVAC, automotive, and power generation.

CO 2: Students will acquire skills to design shell and tube heat exchangers, considering factors such as tube layouts, baffle spacing, shell-side film coefficients, pressure drops, and enhanced flow arrangements for improved heat recovery.

CO 3: Students will study heat pipe operation, design principles, and limitations, including fluid selection, wick structures, and capillary and thermal constraints for various applications.

Unit 1: Thermal Performance Analysis of Heat Exchangers: Compact, cross flow, liquid to gas, and double pipe heat exchangers, film coefficients for tubes and annuli, equivalent diameter of annuli, fouling factors, caloric or average fluid temperature, true temperature difference; Design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangements.

Unit 2: Shell and Tube Heat Exchangers: Tube layouts, baffle spacing, classification of shell and tube exchangers, Design calculation of shell and tube heat exchangers, shell-side film coefficients, shell-side equivalent diameter, true temperature difference in a 1-2 heat exchanger, influence of approach temperature on correction factor, shell and tube sides pressure drop; performance analysis of 1-2 heat exchangers, design calculation of shell and tube heat exchangers; flow arrangements for increased heat recovery.

Unit 3: Direct Contact Heat Transfer: Classification of cooling towers, wet-bulb and dew point temperatures, Lewis number, cooling-tower internals, heat balance, heat transfer by simultaneous diffusion and convection;

Unit 4: Heat Pipes: Types and applications, operating principles, working fluids, wick structures, control techniques, pressure balance, maximum capillary pressure, liquid and vapor pressure drops, effective thermal conductivity of wick structures, capillary limitation on heat transport capability, sonic, entrainment, and boiling limitations, determination of operating conditions;

Reference Books:

1. Kern, D. Q., Process Heat Transfer, Tata McGraw-Hill, 2000.
2. Chi, S. W., Heat Pipe Theory and Practice- A Source Book, McGraw-Hill, 1976
3. Fraas, A. P., Heat Exchanger Design, Second Edition, John Wiley & Sons, 1989
4. Dunn, P. D. and Reay, D. A., Heat Pipes, Fourth Edition, Pergamon Press, 1994

Subject Code MME-1008C **Combustion in IC Engine** **LTP (310)**

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will gain a foundational understanding of combustion chemistry and physics, including fuel properties, chemical reactions, stoichiometry, and energy release mechanisms.
CO 2: Students will learn about combustion processes specific to IC engines, such as premixed and diffusion flames, flame propagation, and auto-ignition, and their applications in gasoline and diesel engines.
CO 3: Students will explore the differences in combustion processes in various engine types, including spark-ignition (SI), compression-ignition (CI), and homogeneous charge compression ignition (HCCI) engines.
CO 4: Students will study ignition systems in IC engines (e.g., spark ignition, compression ignition) and diagnostic methods for analyzing combustion, such as pressure measurement, thermocouples, and laser diagnostics.

Unit 1: **Introduction:** importance of combustion. Applications and role of combustion engineer. Premixed and non-premixed combustion. Solid, liquid and gaseous fuel combustion. Heterogeneous and homogeneous combustion. d^2 law.

Unit 2: **Chemical thermodynamics:** stoichiometry, enthalpy of formation, enthalpy and heat of combustion, adiabatic flame temperature, chemical equilibrium.

Unit 3: **Chemical kinetics:** elementary and global reactions, law of mass action, reaction order, rate expressions. Opposing, concurrent and consecutive reactions, steady state and partial equilibrium assumptions, mechanism of H2-O2, CO-oxidation, hydrocarbon oxidation and NOx formation.

Unit 4: Constant volume reactor, constant pressure reactor, well-stirred reactor, plug flow reactor

Unit 5: **Conservation equations:** Mass, momentum, energy and species conservation equations, Shvab-Zeldovich formulation. Detonation and deflagration: Rankine-Huguenot relation, calculation of detonation velocity,

Unit 6: **Combustion of solids:** mechanisms of solid fuel combustion - drying, devolatilization and char combustion. Simplified analysis of particle combustion to calculate char burning time under diffusion and kinetic control.

Reference Books:

1. Turns, Stephen R, An Introduction to Combustion, McGraw-Hill, 2012.
2. Kuo, Kenneth K, Principles of Combustion, John Wiley, 2000.
3. Poinsot, T and Veynante, D Theoretical and Numerical Combustion, RT Edwards, 2005.
4. Crouse William, Automotive Emission Control, Gregg Division /McGraw-Hill. 1980
5. Ernest, S., Starkman, Combustion Generated Air Pollutions, Plenum Press, 1980.

6. George, Springer and Donald Patterson, Engine emissions, Pollutant Formation and Measurement, Plenum press, 1972.
7. Obert, E.F., Internal Combustion Engines and Air Pollution, Intext Educational Publishers, 1980.
8. Combustion / Sarkar / Mc. Graw Hill.
9. An Introduction to Combustion / Stephen R. Turns/ Mc. Graw Hill International Edition.
10. Combustion Engineering / Gary L. Berman & Kenneth W. Ragland/ Mc. Graw Hill International Edition.

Subject Code MME-1004P **Air Conditioning System Lab** **LTP (002)**

List of experiments:

1. Performance test of a vapor compression test rig.
2. Performance test of a vapor absorption test rig
3. Performance evaluation of a mechanical heat pump
4. Study of different Psychrometric processes.
5. Performance evaluation of air-conditioning test rig.
6. Study of cut models of different components of a vapor compression refrigeration unit.
7. Performance test ice plant test rig

Reference Books:

Subject Code MME-1008P | **IC Engine Lab** | **LTP (002)**

<u>List of experiments:</u>

1. Performance test on Spark Ignition engines using petrol/Alternate fuels
2. Emission measurement in Spark Ignition and Compression Ignition Engines.
3. Performance test using pressure transducers in S.I. Engines.
4. Performance test using pressure transducers in C.I. Engines.
5. Performance test on variable compression ratio petrol and diesel engines.
6. Simulation studies of Petrol and Diesel Engine Cycles.
7. Simulation of Gas Turbine Cycles

Reference Books:

Subject Code MME-1010E | **Steam and Gas Turbine** | **LTP (310)**

Electives-II

Course Outcomes (COs)

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

CO 1: Students will learn the fundamental thermodynamics that govern steam and gas turbine cycles, including the Rankine and Brayton cycles, and their application to power generation.

CO 2: Students will gain an understanding of turbine components, such as compressors, combustion chambers, rotors, nozzles, blades, and condensers, and how these interact within the turbine system.

CO 3: Students will learn methods to analyze and calculate thermal efficiency, work output, and performance parameters of steam and gas turbines, identifying ways to optimize the cycles.

CO 4: Students will explore combined cycle systems that integrate steam and gas turbines to improve overall efficiency in power generation applications.

Unit 1: Steam nozzles: Types of nozzles, velocity of steam, discharge through nozzle, critical pressure ratio and condition for maximum discharge, physical significance of critical pressure ratio, nozzle efficiency and gas turbines.

Unit 2: Steam turbine: Principle of operation, types of steam turbines, compounding of steam turbines, impulse turbine – velocity diagram, calculation of work, power and efficiency, condition for maximum efficiency, Reaction turbines – velocity diagram, degree of reaction, reheat factor, governing of steam turbine – throttle, nozzle and bypass governing, Methods of attachment of blades to turbine rotor, Labyrinth packing, Losses in steam turbine, Special types of steam turbine- back pressure, pass out and mixed pressure turbine.

Unit 3: Gas turbine: Classification, open and closed cycle, gas turbine fuels, actual Brayton cycle, optimum pressure ratio for maximum thermal efficiency, work ratio, air rate, effect of operating variables on the thermal efficiency and work ratio, and air rate, simple open cycle turbine with regeneration, reheating and Intercooling, Combined steam and gas turbine plant, requirements of combustion chamber, types of combustion chambers.

Unit4: Jet propulsion: Fundamental of propulsion technology, Turbojet Engine, thrust, thrust power, propulsive efficiency, thermal efficiency, and Turboprop, Ramjet and Pulsejet engines.

Reference Books:

1. Power Plant Engineering P.K. Nag McGraw-Hill Education
2. Power Plant Engineering R. K. Hegde Pearson India Education
3. Gas Turbines V. Ganeshan McGraw Hill Education
4. Thermal Engineering R.K. Rajput, Laxmi Publication
5. Steam Turbine Theory and Practice William J. Kearton CBS Publication

Subject Code MME-1012E	Gas Dynamics Electives-II	LTP (310)

Course Outcomes (COs)
At the end of the course, the student will be able to:

CO 1: Students will learn the basic principles of gas dynamics, including compressible flow, thermodynamics, and conservation laws (mass, momentum, and energy).
CO 2: Students will learn to analyze one-dimensional flow processes, including isentropic flows, shock waves, expansion waves, and nozzle flows, using governing equations and tables.
CO 3: Students will gain proficiency in calculating Mach numbers and understanding different flow regimes (subsonic, transonic, supersonic, and hypersonic) and their impact on flow properties.
CO 4: Students will explore basics of multi-dimensional compressible flow, including applications of potential flow and linearized flow theory in aerodynamic applications.

Unit 1: **Review of fundamentals**: Types of flows, concepts of continuum and control volume, generalized continuity, momentum and energy equations, velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, three reference speeds, dimensionless velocity M*, concepts of static and stagnation parameters.
One dimensional isentropic flow: General features, working equations, choking in Isentropic flow, operation of nozzles and diffusers under varying pressure ratios, performance of real nozzles, applications of isentropic flow.

Unit 2: **Normal shocks**: Introductory remarks, governing equations, Rankine–Huguenot, Prandtl's and other relations, weak shocks, thickness of shocks, normal shocks in ducts, performance of convergent-divergent nozzle with shocks, moving shock waves, shocks problems in one dimensional supersonics diffuser, supersonic pilot tube.

Unit 3: **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.

Unit 4: **Multidimensional flow**: Equation of continuity, Naiver stock equation, potential flow, Method of characteristics.

Unit 5: **Dimensional analysis and similitude**: Buckingham- pai theorem, Van driest theorem, Dimensional analysis, model study, compressible flow of viscous fluids.

Unit 6: **Rarefied gas dynamics**: Knudsen number, sleep flow, transition and free molecular flow.

Reference Books:

1. Fundamentals of Compressible Flow by S.M. Yahya, New Age
2. Gas Dynamics by Ali Campbell & Lenning
3. Gas Dynamics by Radha Krishnan, PHI

Subject Code MME-1014E | **Advance Power Generation System** | **LTP (310)**

Electives-II

Course Outcomes (COs)

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

CO 1: Students will learn to apply thermodynamic principles and perform energy and exergy analyses to evaluate the efficiency and performance of power generation systems.

CO 2: Students will understand combined cycle power plants and cogeneration systems, including their design, operation, and advantages in terms of energy efficiency and environmental impact.

CO 3: Students will gain insights into smart grid technology, microgrids, and distributed generation, including their impact on grid stability, demand response, and resilience.

CO 4: Students will enhance their ability to communicate power generation analyses and design solutions through technical reports, presentations, and data visualizations.

Unit 1: General Introduction to current power generation technologies. Thermodynamics of supercritical cycles.

Unit 2: Advanced and ultra-supercritical power systems. Thermo-fluid design of super critical steam generators. Design and analysis of turbines for super critical steam.

Unit 3: Thermodynamics of organic working fluids. Analysis of organic Rankine cycles Simulation of cycles using mixtures. Development of solar thermal, geothermal and Bio-thermal ORCs

Unit 4: Thermofluidic analysis of solar PV systems and Hybrid systems. Advance hydro power systems. Special designs for micro & Pico power systems.

Reference Books:

1. Power System Engineering by Kothari D. P Nagrath I. J ·
2. Electrical Power Systems by Wadhawa C. L
3. Power System Analysis by Grainger J. J., Stevenson Jr W. D.
4. Papers collected from international journals.
5. Technical reports by DoE and other international organizations.