Department of Mechanical Engineering

Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

To educate students at Undergraduate, Post Graduate, Doctoral, and Post Doctoral levels to perform challenging engineering and managerial jobs in industry.

- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

To become an internationally recognized centre of excellence in academics, research and technological services in the area of ***Mechanical Engineering*** and related inter-disciplinary fields.

Department Mission

- Imparting strong fundamental concepts to students and motivate them to find innovative solutions to engineering problems independently.
- Developing engineers with managerial attributes capable of applying appropriate technology with responsibility.
- Creation of congenial atmosphere and ample research facilities for undertaking quality research to achieve national and international recognition by faculty and students.
- To strive for internationally recognized publication of research papers, books and to obtain patent and copyrights.
- To provide excellent technological services to industry for the benefit of society.

Programme Educational Objectives (PEOs) – Heat Power Engineering

PEO 1: To develop capability to understand the fundamentals of Science and Heat Power Engineering for analyzing the engineering problems with futuristic approach.

PEO 2: To foster a confident and competent post graduate capable to solve real life practical engineering problems fulfilling the obligation towards society.

PEO 3: To inculcate an attitude for identifying and undertaking developmental work both in industry as well as in academic environment with emphasis on continuous learning enabling to excel in competitive participations at global level.

PEO 4: To nurture and nourish effective communication and interpersonal skill to work in a team with a sense of ethics and moral responsibility for achieving goal.

PROGRAM OUTCOMES (POs)
M. Tech. in Mechanical Engineering (Heat Power Engineering)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4: Clear insight to appreciate the multidisciplinary nature of the technological field in heat power engineering.

PO5: Develop an ability to work in team, apart from having awareness of social needs and professional code of conduct, ethics and behavior.

COURSE INFORMATION SHEET

Course code: ME561
Course title: Classical and Statistical Thermodynamics
Pre-requisite(s): B.E. /B. Tech. Thermodynamics
Co- requisite(s): Partial Differential Equations
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of classical thermodynamics while retaining an engineering perspective.
2.	Lay the groundwork for subsequent studies in such fields as heat transfer and energy conversion systems and to prepare the students to effectively use thermodynamics in the practice of engineering.
3.	Develop an intuitive understanding of thermodynamics by emphasizing the engineering and engineering arguments.
4.	Present a wealth of real world engineering examples to give students a feel for how thermodynamics is applied in engineering practice.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Review and Apply the concepts of I and II law of thermodynamics.
CO2	Analyse and evaluate the concept of exergy in different thermodynamic cycles
CO3	Analyze the concept of Real Gases and Mixtures and to apply the thermodynamic relations of gas mixtures.
CO4	Evaluate the Thermodynamic properties of homogeneous mixtures.
CO5	Analyze the concept of statistical thermodynamics.

SYLLABUS

Module 1:

Review of I and II Laws of Thermodynamics: Transient flow analysis, entropy balance for flow and non- flow systems, entropy generation. properties of pure substance, PVT surface, Third law of thermodynamics, Nerst heat theorem. (8L)

Module 2:

Exergy Analysis: Concepts, exergy balance analysis for flow, non-flow and transient systems, exergy transfer, exergetic/ Second Law efficiency, Second Law analysis of different thermal systems. (8L)

Module 3:

Real Gases and Mixtures: Equations of state- vander wall's equation of state and other equation of state, virial expansion, Law of corresponding state, compressibility factor, reduced coordinate system and generalized compressibility chart.

Thermodynamic Relationships: First order phase transition and Clapeyron's equation, second order phase transition and Ehrenfest's equations, Maxwell's equations: equations for internal energy, enthalpy, entropy, specific heat, and Joule-Thomson coefficient. (8L)

Module 4:

Chemical Thermodynamics: Gibb's theorem, Gibb's function of mixture of inert ideal gases. Chemical equilibrium, Thermodynamics equation for phase, degree of Reaction, equation of reaction equilibrium, Law of Mass Action, Heat of Reaction and Vant hoff Isobar, Saha's equation for standard Gibb's function change, affinity. (8L)

Module 5:

Statistical Thermodynamics: Importance of statistical anlysis, Stirling's approximation, Bose-Einstein statistics and Fermi-Dirac statistics, classical Maxwell-Boltzman model, equilibrium distribution, microscopic interpretation of heat and work, entropy, second law of thermodynamics, partition function and its properties. (8L)

Text Books

1. P.K. Nag, Basic and Applied Thermodynamics, Tata McGraw-Hill Publishing Co. Ltd., 2010.
2. Yonus A Cengel and Michale A Boles, Thermodynamics: An Engineering Approach, McGraw Hill, 2002.
3. A. Bejan, Advanced Engineering Thermodynamics, John Wiley & Sons, 2006.

Reference Books

1. M. J. Moran and H. N. Shapiro, Fundamentals of Engineering Thermodynamics, John Wiley and Sons, 1999.
2. J. B. Jones and R. E. Duggan, Engineering Thermodynamics, Prentice-Hall of India, 1996.

Course Evaluation:

Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

Detailed analysis of different transient thermodynamics systems using software EES

POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:

Irreversible thermodynamics.

POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 & PO4**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	3	1
CO3	3	3	3	3	1
CO4	3	3	3	3	1
CO5	3	3	3	3	1

$< 34\% = 1$, $34\text{-}66\% = 2$, $> 66\% = 3$

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME562
Course title: Advanced Incompressible Fluid Flow
Pre-requisite(s): B.E. /B. Tech. Fluid Mechanics
Co- requisite(s): Partial Differential Equation
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of classical incompressible fluid mechanics while retaining an engineering perspective.
2.	Lay the groundwork for subsequent studies in such fields as analysis of various incompressible fluid flows and to prepare the students to effectively use incompressible fluid mechanics theory in the practice of engineering.
3.	Develop an intuitive understanding of incompressible fluid mechanics by emphasizing the engineering and engineering arguments.
4.	Present a wealth of real world engineering examples to give students a feel for how incompressible Fluid mechanics is applied in engineering practice.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Outline the concepts of continuum, system of control volume, incompressible fluid and flow properties.
CO2	Apply the appropriate fundamental laws of incompressible fluid dynamics to various flow passages and over the bodies.
CO3	Analyse various incompressible fluid dynamics problems.
CO4	Evaluate the applicability governing equations of incompressible fluid mechanics where an exact solution of the problem is possible.
CO5	Create optimum design of simple(2D)/complex(3D) fluid flow geometry using conventional methods and modern tools.

SYLLABUS

Module 1:

Definition and properties of fluids, fluid as continuum, Lagragian and Eulerian description of fluid flow, velocity and stress field, fluid statics, fluid kinematics. stream and velocity potential function, circulation, irrotational vortex.

Potential flows: Uniform stream, source and sink, vortex flow, doublet, superposition of basic plane potential flows, flow past a half body, flow past a Rankine Oval body, flow past a circular cylinder, concept of lift and drag. (8L)

Module 2:

Reynolds transport theorem, Integral and differential forms of governing equations, mass, momentum and energy conservation equations, Navier Stokes equations and its formulation, solution of Navier Stokes equations like Couette flow, Poiseuille flow, Hagen Poiseuille flow, flow between two concentric rotating cylinders, theory of Hydrodynamic lubrication, flow around a sphere, Stokes first and second problem. (8L)

Module 3:

Boundary layer equations, boundary layer thickness, boundary layer on a flat plate, similarity solutions, integral form of boundary layer equations, approximate methods, flow separation, developing flow in a duct. (8L)

Module 4:

Introduction to Hydrodynamic Stability, Why do instabilities occur ?,Concept of small-disturbance stability,Linear stability theory, Rayleigh–Taylor instability, Kelvin-Helmholtz instability, Orr-Sommerfeld and Squire equations, Squire's transformation and Squire's theorem, inviscid stability theory, capillary Instability of a Jet, asymmetric instability of a liquid jet ,instability due to shear, stability of parallel shear flows, boundary layer stability, thermal instability, mechanics of boundary layer transition. (8L)

Module 5:

Characteristics of turbulent flow, general equations of turbulent flow, turbulent boundary layer equation, flat plate turbulent boundary layer, turbulent pipe flow, Prandtl mixing hypothesis. Turbulence modeling - Zero equation model: mixing length model, One equation model: Spalart-Almaras, Two equation models: k- ε models (standard, RNG, realizable), k- ω model, and ASM, Seven equation model: Reynolds stress model, free turbulent flows. Numerical examples. Basic concepts on flow simulation using softwares. (8L)

Text Books

1. Advanced Engineering Fluid Mechanics, Muralidhar K. and Biswas G., Narosa, 2016.
2. Fluid Mechanics, Pijush K. Kundu and Ira M. Cohen, Academic Press ELSEVIER, 2011.
3. Introduction to Fluid Mechanics and Fluid Machines, Som S. K. Biswas G, Chakraborty S , Tata McGraw Hill, 2017.

Reference Books

1. Fluid Mechanics, Frank M. White, Tata McGraw-Hill, 2017.
2. Boundary Layer Theory, Schlichting H., Springer Verlag, 2014.
3. Turbulence: An Introduction for Scientists and Engineers, Davidson P.A., Oxford Publication, 2015.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Detailed analysis of different transient fluid flow systems/devices. Outline of various CFD software used in industries.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Turbulence and Multiphase flow, Simple fluid flow simulation methods.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	3	2	1
CO3	3	2	3	3	1
CO4	3	2	2	2	1
CO5	3	3	3	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME563
Course title: Conduction and Radiation Heat Transfer
Pre-requisite(s): B.E. /B. Tech. Heat Transfer
Co- requisite(s): Partial Differential Equations
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of conductive and radiative heat transfer while retaining an engineering perspective.
2.	Lay the groundwork for subsequent studies in such fields as heat transfer systems and to prepare the students to effectively use of conductive and radiation heat transfer analysis in the practice of engineering.
3.	Develop an intuitive understanding of conductive and radiative heat transfer by emphasizing the engineering and engineering arguments.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Identify modes of heat transfer and model basic heat transfer processes.
CO2	Apply different methods for solution of multi-dimensional engineering problems of conductive heat transfer.
CO3	Apply different methods for solution of radiative heat transfer problems in non-participating medium.
CO4	Analyse gray and non-gray problems in the field radiative heat transfer in participating medium.
CO5	Evaluate the solution for one dimensional gray medium.

SYLLABUS

Module 1:

Multidimensional conduction-I: Introduction, integral form of governing equation, differential form of governing equation, simplified form of energy equation, thermal diffusivity, one-dimensional transient conduction: transient in a semi-infinite solid, approximate integral method due to Goodman, one dimensional transient problem: space domain finite, steady conduction in two dimensions: steady conduction in rectangle, steady conduction in a rectangle with heat generation, steady two-dimensional conduction in cylindrical co-ordinates, shape factors for some useful configurations, solution to Laplace equation in cylinder, solution to a practical problem, solution to Laplace equation in spherical co-ordinates. (8L)

Module 2:

Multidimensional conduction-II: Introduction, basic problem in Cartesian coordinates, basic problem in cylindrical coordinates, basic problem in spherical co-ordinates, one term approximation and Heisler charts: one term approximation of the slab transient, one term approximation of the cylinder transient, one term approximation of the sphere transient, transient conduction in more than one dimension: Introduction, transient conduction in an infinitely long rectangular bar, transient heat conduction in a rectangular block in the form of a brick, transient heat conduction in a circular cylinder of finite length. (8L)

Module 3:

Thermal radiation: the physics of radiation, thermodynamics of black body radiation, Planck distribution, properties of the Planck distribution functions, shape factor of complicated geometry, use of graphs for finding shape factors, radiation irradiation method of enclosure analysis, Enclosure containing diffuse non-gray surfaces, gray enclosures containing diffuse and specular surfaces. (8L)

Module 4:

Radiation in participating media: Introduction, definitions, equation of transfer, absorption of radiation in different media: transmittance of a solid slab, absorption of radiation by liquids, absorption of radiation by gases, radiation in an isothermal gray gas slab and the concept of mean beam length, modeling of gas radiation: basics of gas radiation modeling, band models, radiation in a non-isothermal participating medium: radiation transfer in a gray slab, radiation equilibrium, solution of integral equation, enclosure analysis in the presence of an absorbing and emitting gas: zone method, example of zone analysis. (8L)

Module 5:

Exact solution for one-dimensional gray media: Introduction, general formulation for a plane parallel Medium, radiative equilibrium of a non-scattering medium, radiative equilibrium of a scattering medium, plane medium with specified temperature field, radiative transfer in spherical media, radiative transfer in cylindrical media, numerical solution of the governing integral equations. (8L)

Text Books

1. Heat Transfer, S. P. Venketeshan, Ane books Pvt. Ltd, 2016.
2. Radiative Heat Transfer, M. F. Modest, McGraw-Hill, Inc, 2013.

Reference Books

1. Heat and Mass transfer, P. K. Nag, McGraw-Hill Publications, 2011.
2. Heat transfer, A. F. Mills and V. Ganeshan, Pearson Education, 2009.
3. Fundamental of heat and mass transfer by Sarit k das , Narosa publication, 2010.
4. Heat and Mass transfer by Domkundwar and Arora, Dhanpat rai & sons, 2007.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Analysis of radiation and conduction problems related to industries.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Multi-dimensional radiative heat transfer in participating medium and its different approximations.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	2	1
CO2	3	3	3	1	1
CO3	3	3	3	2	2
CO4	3	3	3	3	2
CO5	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME564
Course title: Renewable Energy Technology
Pre-requisite(s): Nil
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Identify renewable energy sources and their utilization.
2.	Provide basic knowledge of different renewable energy conversion principle.
3.	Harness the environment friendly RE sources and to enhance their contribution to the socio-economic development.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Outline the principles of energy conversion from solar energy sources.
CO2	Understand the application of wind energy conversion system.
CO3	Develop capability to do basic design of bio gas plant.
CO4	Understand the applications of different renewable energy sources like ocean thermal, hydro, geothermal energy etc.
CO5	Perform energy and exergy analysis of renewable energy systems.

SYLLABUS

Module 1:

Introduction, Solar Radiation, Sun path diagram, Basic Sun-Earth Angles, Solar Radiation Geometry and its relation, Measurement of Solar Radiation on horizontal and tilted surfaces, Principle of Conversion of Solar Radiation into Heat, Collectors, Collector efficiency, Selective surfaces, Solar Water Heating system, Solar Cookers, Solar driers, Solar Still, Solar Furnaces, Solar Green Houses. Solar Photovoltaic, Solar Cell fundamentals, Characteristics, Classification, Construction of module, panel and array. Solar PV Systems (stand-alone and grid connected), Solar PV Applications. Government schemes and policies. (8L)

Module 2:

Introduction, History of Wind Energy, Wind Energy Scenario of World and India. Basic principles of Wind Energy Conversion Systems (WECS), Types and Classification of WECS, Parts of WECS, Power, torque and speed characteristics, Electrical Power Output and Capacity Factor of WECS, Stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, Site selection criteria, Wind farm, Wind rose diagram. (8L)

Module 3:

Introduction, Biomass energy, Photosynthesis process, Biomass fuels, Biomass energy conversion technologies and applications, Urban waste to Energy Conversion, Biomass Gasification, Types and application of gasifiers, Biomass to Ethanol Production, Biogas production from waste biomass, Types of biogas plants, Factors affecting biogas generation, Energy plantation, Environmental impacts and benefits, Future role of biomass, Biomass programs in India. (8L)

Module 4:

Hydropower: Introduction, Capacity and Potential, Small hydro, Environmental and social impacts. Tidal Energy: Introduction, Capacity and Potential, Principle of Tidal Power, Components of Tidal Power Plant, Classification of Tidal Power Plants. Ocean Thermal Energy: Introduction, Ocean Thermal Energy Conversion (OTEC), Principle of OTEC system, Methods of OTEC power generation. Geothermal Energy: Introduction, Capacity and Potential, Resources of geothermal energy. (8L)

Module 5:

Energy and Exergy Analysis: Energy Matrices, Embodied Energy, Embodied Energy and Annual Output of Renewable Energy Technologies, Exergy Analysis, CO_2 Emissions, Earned Carbon Credit. (8L)

Text Books

1. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, 2000.
2. Non-Conventional Energy Resources, B. H. Khan, The McGraw Hill, 2017.
3. G N Tiwari, R K Mishra, Advanced renewable energy sources, RSC Publishing, 2012
4. Renewable Energy Sources, Twidell, J.W. & Weir, A., EFN Spon Ltd., UK, 2006.
5. Solar Energy – Principles of Thermal Collection and Storage, S. P. Sukhatme and J.K. Nayak, Tata McGraw-Hill, New Delhi, 2008.
6. Solar Energy, Fundamentals and Applications, Garg, Prakash, Tata McGraw Hill, 2017.

Reference Books

1. Solar Energy, Sukhatme. S.P., Tata McGraw Hill Publishing Company Ltd., 1997.
2. Renewable Energy, Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, U.K., 1996.
3. Biogas Technology – A Practical Handbook, Khandelwal, K.C., Mahdi, S.S., Tata McGraw-Hill, 1986.
4. Solar Energy – Fundamentals Design, Modelling & Applications, Tiwari. G.N., Narosa Publishing House, New Delhi, 2002.
5. Wind Energy Conversion Systems, Freris. L.L., Prentice Hall, 1990.
6. Principles of Solar Energy, Frank Krieth & John F Kreider, John Wiley, New York, 1987.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Application of solar energy to automobiles field.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Design aspects of solar vehicles and power plants
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	2	1
CO2	3	3	3	3	2
CO3	3	3	3	3	2
CO4	1	2	3	-	2
CO5	3	1	3	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME565
Course title: Theory and Design of I.C. Engines
Pre-requisite(s): B.E. /B. Tech. I.C. Engine
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Explore the knowledge of performance parameters and its characteristics, variables effects the performance of engine and methods of improving engine performance of internal combustion engine.
2.	Examination and selection of different alternative fuel and its emissions and control.
3.	Explore principle of different electronic fuel injection system, supercharging and its effect on performance of internal combustion engine.
4.	Design and recommend low cost and high performance engine components, which finds applications in modern internal combustion engines.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Explain performance parameters and characteristics; and calculation of performance parameters.
CO2	Interpret different alternative fuels and its emissions, then the method to control these emissions.
CO3	Analyze different electronic fuel injection system, supercharging and its effect on performance of SI and CI engine.
CO4	Specify and interpret data of alternative fuels and its emission which effect the environment.
CO5	Design low cost and high performance cylinder, cylinder head, crank case piston, connecting rod, crank shaft and radiator of Internal combustion engine.

SYLLABUS

Module 1:

Performance Parameters and Characteristics: Indicated and brake mean effective pressure, IP &BP, air standard, indicated and brake thermal, mechanical, relative, volumetric, scavenging, charge and combustion efficiencies, effect of spark timing, mixture composition ,load, speed, and compression ratio on engine performance and efficiency .Performance characteristics and variables affecting the performance characteristics, Methods of improving Engine performance, Performance maps. (8L)

Module 2:
Alternate Fuels: Solid, Liquid and gaseous fuels, Liquid fuels- Alcohol, methanol, ethanol, reformulated gasoline, water gasoline mixture, Gaseous fuels- Hydrogen, natural gas, CNG,LPG, their advantages and disadvantages, Biogas, dual fuel operation. Emission from alternative fuels, status of alternative fuels in India. (8L)

Module 3:
Air Capacity of Four-Stroke Engines and Supercharging: Ideal air capacity, volumetric efficiency, effect of engine variables on volumetric efficiency, supercharging for S.I. and C.I. engines, types of superchargers and their characteristics, exhaust supercharging, performance of supercharged engines. Multi-Point Fuel Injection (MPFI) system, Electronic Diesel Injection System, CRDI system and its advantages and disadvantages. (8L)

Module 4:
Engine Emissions and their control: Air pollution due to IC engines, Exhaust and non-exhaust emissions, HC, CO and NOx emissions and their causes, Photochemical smog, Particulates, Aldehyde, sulphur, lead, phosphorous emissions, Emission control methods. (8L)

Module 5:
Engine Design: General design concept of IC engine, design of principal parts of IC engine cylinder head, pistons, connecting rod, crank shaft, radiator and fin. (8L)

Text Books

1. Internal Combustion Engine, Ganesan,V., McGraw Higher Ed., 2012.
2. Internal Combustion Engines, Obert,E.F., International Textbook Co., 1968.
3. The Internal Combustion Engines in Theory and practice, Taylor,C.F., MIT Press, 1985.

Reference Books

1. Internal Combustion Engines, Mathur,R.P. & Sharma,M.L., Dhanpat Rai Publication, 2014.
2. Diesel Engine Design, Purdey,H.F.P., Nabu Press, 2010.
3. Internal Combustion Engines, Maleev,V.L., McGraw-Hill Book Company, 1945.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Performance parameters of IC engine, Air pollution of IC engine and design of IC parts.
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Air pollution of IC engine.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	1	1	1	2	2
CO2	2	2	1	2	1
CO3	1	1	1	2	2
CO4	1	2	1	2	2
CO5	2	2	1	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME566
Course title: Computational Methods in Thermal Engineering
Pre-requisite(s): B.E. /B. Tech. Fluid Mechanics and Heat Transfer
Co- requisite(s): Partial differential equation
Credits: 3 L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Students of thermal engineering make an increasing use of modelling and computational tools to predict system behaviour and performance.
2.	Develop the knowledge to model thermal systems and processes, including the mathematical representation of their components and the numerical solution of the resulting equations,
3.	Students learn the finite differences methods with application to distributed systems involving heat transfer and fluid mechanics.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Understand different methods for finding roots of Complex algebraic and transcendental equations.
CO2	Understand different integration methods to compute area, volume and view factor.
CO3	Apply different methods for solution of linear, nonlinear equations using initial value and boundary value problems.
CO4	Apply different methods for solution of thermal engineering problems.
CO5	Analyse thermal and fluid problems using finite difference methods.

SYLLABUS

Module 1:

Root finding: Complex algebraic and transcendental equations. Solution of linear equations by LU decomposition and Newton Raphson method, Root finding used in integration, evaluation of areas, surface of revolution, length of curve and volumes. (8L)

Module 2:

Evaluation of centroid of regular geometric bodies, Double integration to compute areas, triple integration to compute volumes and quadruple integration to compute view factors, Interpolation and its use in thermal engineering. (8L)

Module 3:

Solution of ordinary differential equations, Runge-Kutta method and Euler method, Solution of non-linear equations of any order and any degree, Solution of initial value problems and boundary value problems, Solution of boundary value problem through initial value problems, shooting method, optimization of objective functions to determine the solution of boundary value problems. (8L)

Module 4:

Application of shooting method or the optimization method to solve thermal engineering problems like: boundary layer flow on a flat plate, thermal boundary layer on a vertical and flat plate, flow near a rotating disk, Falkner-Skan wedge flow, travel of projectile in air with drag, temperature distribution in a circular fin, triangular fin and general solution to steady 1D heat conduction in any shape. (8L)

Module 5:

Introduction to finite difference (FD) method, Forward, Backward, CD and upwind schemes, Solution of ODE by FD method, Introduction to stability, numerical errors and accuracy, Application of finite difference method to thermal engineering problems, Solution of hydrodynamic and thermal boundary layer equations by FD method, Solution of Falkner-Skan problem by FD method, Extensive Application to transient heat transfer by FD method. FD method used for 2D and 3D problems. Demonstration and use of software such as EES to apply different methods and solve system of equations (linear or nonlinear) mentioned above. (8L)

Text Books

1. Iyenger, Jain, Numerical Methods Numerical Methods for Scientific & Engineering Computation, New age international Pvt. Ltd., 2003.
2. Dennis Zill, Warren Wright, Advanced Engineering Mathematics, Jones and Bartlett Publishers, 2010.
3. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley & Sons, 1989.

Reference Books

1. John D Anderson Jr, Computational Fluid Dynamics, McGraw Hill, 2017.
2. Hoffman Klaus, Computational Fluid Dynamics, Vol-1 & 2, 2000.
3. Sukanta K Dash, Engineering Equation Solver: Application Engineering and thermal engineering problems, Alpha Science International Ltd., 2013.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Optimisation of industrial related problems
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Finite volume method and its applications.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	3	1
CO3	3	3	3	3	2
CO4	3	3	3	3	2
CO5	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME567
Course title: Safety Aspects of Nuclear Power Plants
Pre-requisite(s): B.E. /B. Tech. Energy conversion system
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech.
Semester / Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives:

This course enables the students to:

1.	Familiarize the students on the future benifits of Nuclear power plants.
2.	Develop an intuitive understanding of safety of Nuclear power plants
3.	Study the regulatory approaches adopted, which assures the safety of NPP.

Course Outcomes:

At the end of the course, a student should be able to:

CO1	Outline the basic concept of Nuclear reactors.
CO2	Analyse the various Radiation sources and Protection of NPP
CO3	Analyze the safety principles.
CO4	Evaluate and Analyze some events in NPP and Sitings of Nuclear plants
CO5	Analyze the safety regulations in india.

SYLLABUS

Module 1:

Introduction: Energy sources, Nuclear Power Production, medical and Societal applications of radiation, Nuclear fuel cycle.
Basic Physics of Nuclear Reactors: Atomic Structure, isotopes, Radioactivity, half life, Basics of fission reaction, Moderation, Criticality, Decay heat, Reactivity and Feedback, Breeding. (8L)

Module 2:
Nuclear Reactor Types: Components of Nuclear Reactor, Present Reactor Types, Generation IV Concepts.
Radiation sources and Protection: Radiation and its units, Natural background and manmade Radiation, Biological Effects, Exposure limits and protection, Sources of radiation, shielding. (8L)

Module 3:
Safety Principles and approach: Safety objectives, Defence in depth philosophy, Multiple barriers, Rad-waste management, Levels of defence, Redundancy, Diversity Principles, Event analysis, core inventory, emergency response.
Deterministic approach- Design Basis Events & Beyond Design Basis Events, Acceptance Criteria, Probabilistic approach- Fault tree, event tree, failure rates.
Engineered Safety Systems: Shutdown systems in PWR, BWR,PHWR, Reactivity Worth of shutdown system, Trip Signals, Safety Logic, Operating Environment, Grouping of safety systems, Heat Removal systems, Emergency Core Cooling, Containment and subsystems.
(8L)

Module 4:
Analysis of Some Events in NPP: Heat transfer and Fluid flow prediction, validation, Safety set points, Safety actions for events, Spurious opening of Pressuriser valve in a PWR, LOCA analysis Indian PHWR, Station Blackout without Reactor Trip, FBTR.
Siting of Nuclear plants: Site evaluation Stages, Site Rejection Criteria, Earthquake, Geological criteria, Meteorological considerations, Flooding, Tsunami, Shoreline erosion, chemical explosion, Radiological impact study, Radioactivity pathways to humans, environmental Impact study. (8L)

Module 5:
Safety Regulation In India: Atomic Energy Regulatory Board, functions, safety Documents, Safety Review of site, design, regulatory inspections, safety review for PFBR, Koodankulam, Regulatory review of operating plants, Licensing stages, licensing of operating personnel, Training simulator, safety up-gradation Review after TMI Chernobyl, Review after Fukushima, safety review for decommissioning, Safety Review of Radiation Facilities, medical X-ray units, Gamma irradiators. (8L)

Text Books

1. G. Vaidyanathan, Nuclear reactor Safety- principles and concept, Yes Dee Publishing, 2017.

Reference Books

1. Samuel Glasstone, Nuclear Reactor Engineering, CBS Publishers & Distributors, 2004.
2. John R. Lamarsh, Introduction to Nuclear Engineering, Pearson Education India, 2014.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Various accidental studies of Indian NPP
POs met through Gaps in the Syllabus: **PO4 & PO5**

Topics beyond syllabus/Advanced topics/Design:
Design of Nuclear power plants.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO4 & PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	1	1
CO2	3	3	3	1	1
CO3	3	3	2	1	3
CO4	3	3	2	1	1
CO5	3	3	2	1	3

$< 34\% = 1$, $34\text{-}66\% = 2$, $> 66\% = 3$

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME568
Course title: Advanced Fluid Mechanics Lab
Pre-requisite(s): Fluid Mechanics
Co-requisite(s): Nil
Credits: 2 L: 0 T: 0 P:4
Class schedule per week: 04
Class: M. Tech
Semester/Level: I/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Be familiar with various types fluid flow measurement systems.
2.	Be confident on how to perform experiments related Fluid mechanics, different measurement systems.
3.	Study in detail the flow field around and through complex passages to enable students to calculate the characteristics of those systems.

Course Outcomes

After the completion of this course, a student should be able to:

CO1	Understand the procedure to conduct experiments related to fluid mechanics devices and components using different measurement systems and equipments.
CO2	Interpret various parameters influence the performance of the fluid mechanics devices and components.
CO3	Analyze the observations made through experiments.
CO4	Apply the experimental knowledge how to perform the experiments in different manner.
CO5	Predicting the sources of errors and minimizing them in the experiments.

List of experiments:

Experiment 1: Performance study on calibration of a wind tunnel.

Experiment 2: Performance study on flow field behind a circular cylinder using wind tunnel.

Experiment 3: Performance study on flow field behind a square cylinder using wind tunnel.

Experiment 4: Performance study on effect of circular cylinder in tandem on the flow field behind the rear cylinder using wind tunnel.

Experiment 5: Flow visualization using woollen turf to find out the position of point of separation on a circular cylinder.

Experiment 6: Performance study on calibration the pressure sensors used in pressure transducer.

Experiment 7: Performance study on pressure distribution at different location on a conical/circular body.

Experiment 8: Schlieren and shadowgraph flow visualization at supersonic speed.

Experiment 9: Flow visualization over a cylinder using water tunnel.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	-
CO2	2	1	2	1	-
CO3	2	1	2	1	-
CO4	3	1	2	1	1
CO5	3	1	2	1	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD3,CD6
CO2	CD1,CD3,CD6
CO3	CD1,CD3,CD6
CO4	CD1,CD3,CD6
CO5	CD1,CD3,CD6

COURSE INFORMATION SHEET

Course code: ME571
Course title: Convective Heat and Mass Transfer
Pre-requisite(s): UG courses of Fluid Mechanics, Heat and Mass Transfer
Co- requisite(s): Nil
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Investigate innumerable cases under convection heat and mass transfer process in terms of similarity parameters.
2.	Cover various applications, mathematical relations, analysis, heat transfer and flow & concentration parameters.
3.	Perform performance studies and thermal design at industry level.

Course Outcomes

At the end of this course, a student should be able to:

CO1	Extend the similarity concept in velocity and thermal boundary layer for isothermal and non-isothermal cases.
CO2	Examine the basics of turbulence model and analogy between flow field and heat transfer.
CO3	Apply the boundary layer concept in pipe and duct flow for CHF and CWT conditions.
CO4	Formulate and estimate free convection heat transfer for CHF and CWT conditions.
CO5	Explain and estimate convective mass transfer and simultaneous heat and mass transfer

SYLLABUS

Module1:

Similarity concepts in heat transfer for laminar and turbulent flows; Boundary layer equations; Boundary layer integral equation; similarity and integral solutions of flow over isothermal and non-isothermal flat plate, Numerical solution of the laminar boundary layer flow over a flat plate and viscous dissipation effects on flow over a flat plate. (8L)

Module 2:

Introduction to Turbulent Flows: governing equations, mixing length turbulence models, analogy solutions for heat transfer in turbulent flows, near walls region, transition from laminar to turbulent flow, analogy solution for boundary layer flows, numerical solution of turbulent boundary layer equations, viscous dissipation effects on turbulent boundary layer flow over a flat plate. (8L)

Module3:

Fully developed pipe and plane duct flow under constant heat flux and constant wall temperature; Pipe flow with developing temperature field; Fully developed laminar flow in ducts with other cross-sectional shapes. (8L)

Module 4:

Concept of free convection for vertical, horizontal and inclined plate and cylinders at constant heat flux and constant wall temperature; free convection in finned surfaces and PCBs; free convection in horizontal, inclined and vertical plane enclosures and in horizontal, inclined and vertical concentric cylindrical enclosures. (8L)

Module 5:

Significant parameters in convective mass transfer, application of dimensional analysis to Mass Transfer, Analogies among mass, heat, and momentum transfer, Convective mass transfer correlations, Mass transfer between phases, Simultaneous heat and mass transfer.

(8L)

Text Books:

1. Y. A. Cengel and A. J. Ghajar, Heat and Mass Transfer, McGraw-Hill Education, 2014.
2. P. H. Oosthuizen and D. Naylor, An Introduction to convective Heat Transfer Analysis, 1999.

References Books:

1. Frank P. Incropera, David P. Dewitt, Principles of Heat and Mass transferr, John Wiley & Sons, 2011.
2. William M. Kays & Michael E Crawford, Convective Heat and Mass Transfer, McGraw-Hill Science/Engineering/Math, 1993.

3. Frank Kreith and Mark S. Bohn, Principles of Heat Transfer, West Publishing Company, 1993.
4. D.Q. Kern, Heat Exchange Design, McGraw-Hill Book Co., Inc., New York, 1950.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Programming based problems are not focused.
POs met through Gaps in the Syllabus: **PO1 to PO4**

Topics beyond syllabus/Advanced topics/Design
Programming based numerical problems.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO4**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

Mapping of Course Outcomes onto Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	3
CO2	3	3	3	3	3
CO3	3	3	3	3	2
CO4	3	3	2	2	2
CO5	3	3	2	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME572
Course title: Modern Power Plant Engineering
Pre-requisite(s): Power Plant Engineering (UG)
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of power plant and its component.
2.	Lay the foundation of Non-conventional power plant system and its component to prepare the student to effectively use it in the practice of engineering.
3.	Develop intuitive understanding of combined cycle power plant and its component.
4.	Develop and explore intuitive understanding of nuclear power plant and its component.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Explain and analyse the working principle of various components and improvement of efficiency in a steam power plant
CO2	Explain and analyse the nuclear power plant and its safety measures.
CO3	Analyse and evaluate the performance of combined cycle and its exergy analysis for further improvement.
CO4	Explain the working principle of non-conventional power plant. Understand the mechanism of nuclear fission reaction and working principle of various nuclear power plants.
CO5	Explain different electrical components, operating characteristics of power plant and its improvements.

SYLLABUS

Module 1

Steam powerplant: site selection, coal to electricity, general layout of thermal powerplant, high pressure boilers, waste heat boilers, boiler circulation theory, working principle of ESP, construction and working principles of main oil pumps, starting of oil pumps, AC, DC oil pumps, oil coolers, working principle and constructional detail of LP heaters, deaerators, HP heaters, HP/LP bypass circuit and its utility, various interlocks for operation, oil circuits in HP and LP bypass system, steam piping, design of steam piping, steam piping materials, insulation of steam piping. (10L)

Module 2

Nuclear powerplant: general components of nuclear reactor, heavy water reactors, breeder reactors, reactor containment design, cladding and structural materials, moderating and reflecting materials, control rod materials, shielding materials, Control and safety measures adopted in nuclear powerplant, types of nuclear wastes, radioactive wastes disposal systems, gas disposal systems. (5L)

Module 3

Combined cycle powerplant: introduction, classification of combined gas/ steam, mixed and cogeneration cycle, combined cycle powerplant in India, Various configurations of combined cycle powerplant, mixed cycle, thermodynamic analysis of combined cycle and cogeneration plant, advantage of combined-cycle power generation, exergy analysis of combined cycle. (9L)

Module 4

Non-conventional power generation: magneto hydro-dynamic power, thermo-ionic power generation, thermoelectric power generation, fuel cells, geo thermal energy, hydrogen energy system, solar power plant. (6L)

Module 5

Layout of electrical equipment, generator and exciter, switch gear installations, circuit breaker, relays, earthing of power system, protective devices and control systems used in powerplants, voltage regulation, selection of generating equipment, performance and operating characteristics of powerplants, load division, Definitions and different tariffs for domestic, commercial, industrial application, power factors and its effects, methods of improving powerplants. (10L)

Text Books

1. P. K. Nag, Power Plant Engineering, McGraw Hill publication, 2002.
2. M. M. EiWakil, Power Plant Technology, McGraw Hill publication, 2016.
3. F.T. Mores, Power Plant Engineering, D. Van Nostrand Company inc., 1953.

Reference Books

1. P. C. Sharma, A Textbook of Power Plant Engineering, Kataria publication, 2013.
2. Arora and Domkundwar, Power Plant Engineering, Dhanpat Rai and Co., 2016.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Steam, Gas turbine and Nuclear power plant; Combined power plant
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design:
Combined power plant and Non-conventional power plant
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	1	2	2
CO2	1	1	1	2	1
CO3	2	2	2	2	2
CO4	2	2	2	2	2
CO5	1	1	1	1	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME573
Course title: Design of Thermal Systems
Pre-requisite(s): Fluid Mechanics and Heat Transfer
Co- requisite(s): Nil
Credits: 3 L:3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Design concepts and fundamental aspects of industrial thermal system simulation and optimization
2.	Examine optimum design criteria.
3.	Apply and scrutinise engineering decision.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Outline the thermal and material characteristics for selection of materials for thermal systems.
CO2	Select suitable mathematical and physical model for different thermal equipment.
CO3	Analyse numerical model for system simulation for accuracy and validation.
CO4	Evaluate performance of thermal systems using optimization technique.
CO5	Testing the thermal systems performance using neural network, fuzzy logic and genetic algorithm.

SYLLABUS

Module 1: FORMULATION OF DESIGN PROBLEM

Engineering design, Design variables, Constraint or Limitation, Requirement and specifications, Conceptual design, Steps in design process, Material properties and thermal characteristics for thermal systems, Selection and substitution of materials. (9L)

Module 2: MODELLING OF THERMAL SYSTEMS

Basic features of modelling, Types of Models, Mathematical modelling, Physical modelling, Modelling Thermal equipment. (8L)

Module 3: NUMERICAL MODELING AND SIMULATION

Development of a numerical model, Modeling of individual components, Merging of different models, Accuracy and validation, System simulation, Dynamic simulation of lumped system and large system. (9L)

Module 4: ACCEPTABLE DESIGN OF THERMAL SYSTEM

Initial design, Design strategies, Application illustrations with suitable examples, Optimization of thermal systems. (7L)

Module 5: USE OF ARTIFICIAL INTELLIGENCE TECHNIQUES

Neural network, Fuzzy logic and genetic algorithm in thermal systems design and optimization with examples, Introducing idea of knowledge-based design in thermal systems. (7L)

Text Books

1. Design and Optimization of Thermal Systems, Y. Jaluria, R.C Press, 2007.
2. Optimization in Engineering Design, K. Deb, Prentice Hall, 2002.
3. Design of Thermal Systems, W.F Stoecker, McGraw-Hill, 1971.

Reference Books

1. Thermal Design and Optimization, Bejan, G. Tsatsaronis, M.J Moran, Wiley, 1996.
2. Design and Simulation of Thermal Systems, N.V. Suryanarayana, McGraw Hill, 2002.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Cost effective design
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design
Advance design
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	3	2
CO2	3	2	3	3	2
CO3	3	3	3	2	2
CO4	3	3	3	3	2
CO5	3	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 574
Course title: Advanced Turbo-Machines
Pre-requisite(s): B.E. /B. Tech. Fluid Mechanics, Hydraulic Machines, Thermodynamics
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of classical turbomachinery while retaining an engineering perspective.
2.	Lay the groundwork for subsequent studies in such fields as analysis of various turbomachines and energy conversion systems and to prepare the students to effectively use Fluid mechanics and thermodynamics theory in the practice of turbomachinery in engineering.
3.	Develop an intuitive understanding of turbomachinery by emphasizing the engineering and engineering arguments.
4.	Present a wealth of real world engineering examples to give students a feel for how turbomachinery theories are applied in engineering practice.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Outline the fluid mechanics, thermodynamics concepts, system of control volume, to turbomachines
CO2.	Apply the appropriate fundamental laws of fluid dynamics, thermodynamics to various turbomachines
CO3.	Analyse various turbomachines for energy transfer
CO4.	Evaluate the performance of various turbomachines components
CO5.	Create optimum aerodynamic design/geometrical dimension of simple, complex turbomachines components using conventional methods and modern tools.

SYLLABUS

Module 1

Introduction to turbomachines, classification of turbomachines, momentum, and moment of momentum theory applied to moving blades, change in total enthalpy and total pressure, velocity triangles for radial and axial flow turbomachines. Basic aerofoil theory applied to turbomachines, free, forced vortex and mean streamline theory, non-dimensional performance parameters, specific speed, flow coefficient and head coefficient. Concept of turbomachines design using modern tools like (T-AXI®, AxSTREAM®, CAESES®, VISTA®) as a design tools. (8 L)

Module 2

Steam and gas turbines: Steam flow through nozzles, critical pressure ratio, and choking of nozzles, throat and exit areas for optimum discharge, impulse and reaction stage, flow of steam through turbine blades, velocity diagrams, stage and other efficiencies, condition for maximum efficiency of a single stage turbine, compounding of steam turbines. Axial flow gas turbines, stage losses, Soderbergs correlation, choice of reaction, pitch controlled blades, stress in turbine rotor blades, turbine characteristics and performance. (8L)

Module 3

Rotary Fans, Blowers and Compressors : Introduction,, centrifugal blower , types of vane shape , size and speed of machine, vane shape and efficiency, vane shape and stresses, vane shape and characteristics, actual performance characteristics, slip coefficient. Fan laws and characteristics, Centrifugal compressor, Performance of centrifugal compressors, compressibility and prewhirl, Axial flow compressor: compressor cascade, performance, axial-flow compressor performance, preheat in compressors, application of reversible rotary fan for ventilation and its performance. (8L)

Module 4

Hydraulic Turbines, hydraulic power utilization, hydrograph and water power, classification of water turbines, The Pelton wheel, velocity triangles, turbine efficiency and volumetric efficiency, working proportions of Pelton wheels , Francis and Deriaz turbines, velocity triangles and efficiencies, draft tube theory, cavitation, Propeller and Kaplan turbines, characteristics, application of aerofoil theory to propeller blades, design of Pelton, Francis and Kaplan turbine components. (8L)

Module 5

Centrifugal, Axial-Flow and Mixed flow pumps : Basic performance parameters, differential equations of the flow in a pump, flow kinematics in pumps, losses in pumps. Similarity laws of pumps, affinity laws, specific speed of a pumps, suction capability of pumps, cavitation in pumps, modeling of pumps, axial thrust and its balancing, radial thrust and its consequences, adjustment of pumps' work by changing of rotation speed and by swiveling of impeller's blades, Hydraulic design of a centrifugal, axial and mixed flow pumps, main dimensions' calculation, calculations of meridional cut and blade cuts of an impeller. (8L)

Text Books:

1. S. M. Yahya, Turbines, Compressors & Fans, Tata-McGraw Hill Co., 1983.
2. V. Kadambi and Manohar Prasad, An Introduction to energy conversion, Volume III - Turbo machinery, New Age International Publishers (P) Ltd., 2011.
3. D. G. Shepherd, Principles of Turbo Machinery, The Macmillan Company, 1956.

Reference Books:

1. S. L. Dixon and C. Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier, 1966.
2. William W Peng, Fundamentals of Turbomachinery, John Wiley & Sons, Inc., 2008.
3. M.S.Govindgouda & A.M.Nagaraj, A Text book of Turbomechanics-, -M.M.Publications.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Detailed discussion on different testing procedure as per standards.
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design:
Use of CFD software to design turbomachine components.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	3	2	1
CO3	3	2	3	3	1
CO4	3	2	2	2	1
CO5	3	3	3	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 575
Course title: Computational Fluid Dynamics
Pre-requisite(s): Fluid Mechanics and Heat Transfer, ME 562-Advanced Incompressible Fluid Flow
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Equip students with the knowledge base essential for application of computational fluid dynamics to engineering flow problems
2.	Provide the essential numerical background for solving the partial differential equations governing the fluid flow
3.	Develop students' skills of writing the CFD codes and use of commercial software package to solve practical and theoretical problems

Course Outcomes

After the end of the course, a student should be able to:

CO1	Understand the basic equations of fluid flow and heat transfer.
CO2	Apply different methods of discretisation for solution of governing equation.
CO3	Analyze convergence criteria used in multi-dimensional problem.
CO4	Explain different schemes for convergence of convection diffusion problems.
CO5	Evaluate Navier-Stokes equation by different algorithm.

SYLLABUS

Module 1:

Computational approach to Fluid Dynamics and its comparison with experimental and analytical methods, A brief overview of the basic conservation equations for fluid flow and heat transfer, conservative and non-conservative forms of equation, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. (7L)

Module 2:

Common methods of discretization: an overview of finite difference, finite element and finite volume methods. Numerical solution of parabolic partial differential equations using finite-difference and finite volume methods: explicit and implicit schemes, consistency, stability and convergence. Numerical solution of systems of linear algebraic equations: general concepts of elimination and iterative methods, Gaussian elimination, LU decomposition, tridiagonal matrix algorithm. (9L)

Module 3: Jacobi and Gauss-Seidel iterations, necessary and sufficient conditions for convergence of iterative schemes, gradient search methods, steepest descent and conjugate gradient methods. The finite volume method of discretization for diffusion problems: one dimensional steady diffusion problems, specification of interface diffusivity, source-term linearization. Discretization of transient one-dimensional diffusion problems. (8L)

Module 4: Discretization for multi-dimensional diffusion problems. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods. Convection diffusion problems: Central difference, upwind, exponential, hybrid and power law schemes, concept of false diffusion, QUICK scheme. (8L)

Module 5: Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity and artificial compressibility methods, requirement of a staggered grid. MAC, SIMPLE, SIMPLEC and SIMPLER algorithms. An introduction to unstructured grid finite volume methods. Special topics: Turbulence and its modeling, interface/free-surface tracking methods. (8L)

Text Books

1. John A. Anderson, Jr., Computational Fluid Dynamics, The Basic with applications by
1. McGraw Hill International editions, Mechanical Engineering series, 2017.
2. Suhas Patankar, Numerical Methods in Fluid Flow & Heat Transfer, 1980.
3. H.K. Versteeg & W.Malalasekera, An Introduction to Computational Fluid Flow (Finite Volume Method), Printice Hall, 2008.

Reference Books

1. Ferziger and Peric, Computational Methods for Fluid Dynamic, Springer Publication, 1996.
2. Chuen-Yen Chow, An Introduction to Computational Fluid Mechanics, Wiley
1. Publication, 2011.
2. Murlidhar and Sundarrajan, Computational Fluid Flow & Heat Transfer, Narosa
3. Publication, 2009.
4. J. Blazek, Computational Fluid Dynamics by principles and applications, Elsevier Science Ltd, 2001.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Numerical approach to compressible and two phase flow
POs met through Gaps in the Syllabus: **PO1 to PO3**

Topics beyond syllabus/Advanced topics/Design:
Combustion related topics
POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	1	1
CO2	3	2	3	1	1
CO3	3	3	3	2	2
CO4	3	3	3	2	2
CO5	3	3	3	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 576
Course title: Advanced Energy Technology
Pre-requisite(s): Thermodynamics
Co- requisite(s): Nil
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Provide basic knowledge of combined and cogeneration power cycle used for integrated power generation.
2.	Gain knowledge and understanding of the principles involved in modern, developing and emerging forms of energy conversion and storage systems.
3.	Gain knowledge about efficient systems which can results in significant reductions in energy consumption.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Understand the working principle of combined and cogeneration power cycle used for integrated power generation.
CO2	Understand different advanced energy storage systems.
CO3	Apply different methods for production and applications of hydrogen energy and coal gas.
CO4	Analyse economic and environmental aspects of energy conservation in power plants and waste heat recovery.
CO5	Evaluating the performance characteristics and relative efficiency of fuel cells.

SYLLABUS

Module 1:

Total energy system for industry, Integrated gasification combined cycle plant, combined cycle power plant with cogeneration, fuels for combined cycle power plants. Natural gas cycles, Integrated power generation. Cogeneration principles. (10L)

Module 2:

Advanced energy storage systems – Mechanical energy storage, chemical energy storage, Electromagnetic energy storage, electrostatic energy storage, Thermal energy storage and biological storage. (7L)

Module 3:

Hydrogen Energy – Properties of hydrogen; hydrogen production – Thermo-chemical methods, Electrolysis of water, thermolysis of water and biophotolysis; Storage of hydrogen, delivery, conversion, applications and safety issues, present status. (7L)

Module 4:

Clean Coal technologies – Coal washing, gasification etc., application of coal gas in heat engines and gas turbines, Pressurized fluidized bed combustion. Coal bed methane. Energy conservation opportunities in power plants, economic and environmental aspects of energy conservation in power plants, economic load sharing of power plants, waste heat utilization. (10L)

Module 5:
Fuel Cell – Principles, classification of fuel cells, working of different types of fuel cells, fuels for fuel cells, Development stages and relative performances of various fuel cells, efficiency, V-I Characteristics of fuel cell, fuel cell power plant, environmental effects. (6L)

Text Books

1. M.M. EL-Halwagi, Biogas Technology- Transfer and diffusion, Elsevier Applied science Publisher, New York, 1984.
2. D.O Hall and R.P. Overeed, Biomass – regenerable energy, John Willy and Sons Ltd. New York. 1987.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Sec. Ed.2000.

Reference Books

1. G. Rai, Non-Conventional Energy Sources, Khanna Publishers.
2. Fuel Cells, by W. Vielstich, translated by D. J. G. Ives, Willey Interscience, 1965.
3. Microbial Fuel Cells, by B. E. Logan, John Willey & Sons, 2008.
4. I. Boustead and G. F. Hancock, Handbook of Industrial Energy Analysis, Ellis Horwood Ltd., A division of John Wiley and Sons, 1979.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements)
Advanced applications of hydrogen fuel and fuel cell in industry, load sharing analysis to solar power plant.
POs met through Gaps in the Syllabus: **PO1 TO PO5**

Topics beyond syllabus/Advanced topics/Design:
Advanced applications of hydrogen energy and fuel cells.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 TO PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	3	2
CO3	3	3	3	3	1
CO4	3	3	3	3	1
CO5	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 577
Course title: Advanced Heat Transfer Lab
Co- requisite(s): Nil
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M. Tech
Semester / Level: II/05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Demonstrate the basic phenomenon of heat transfer.
2.	Develop innovative methodologies of solving heat transfer problems
3.	Compose precautionary measures while dealing with heat transfer equipment and problems.

Course Outcomes

After the completion of this course, students will be able to:

CO1.	Apply and demonstrate the basic laws of heat transfer under different modes.
CO2.	Analyze problems involving steady state heat transfer.
CO3.	Evaluate heat transfer coefficients under difference modes.
CO4.	Analyze heat exchanger performance under different conditions.
CO5.	Assess the importance of heat transfer coefficients and transferring medium.

List of experiments

Experiment 1: To determine the heat transfer coefficient on the internal surface of the pipe and compare it with respect to theoretical values (i) for different air flow rates (ii) for heat input

Experiment 2: To determine the efficiency and effectiveness of circular fin (i) for different air flow rates (ii) for different heat of the base.

Experiment 3: To verify the Stefan's Boltzmann law and to determine the emissivity of a gray body.

Experiment 4: To determine:

(i) the characteristic curve of Peltier element and to find out its cooling and heating capacity.

(ii) the coefficient of performance of Peltier device

Experiment 5: To determine the cooling rate of a heated rod within a bank of rods in a cross-flow heat exchanger and to find the average heat transfer coefficient over it.

Experiment 6: To demonstrate:

(i) the effect of constant current source and constant voltage source on temperature measurement.

(ii) Effect of two, three and four wire connection on temperature measurement in PRT.

Experiment 7: To demonstrate the super thermal conductivity of heat pipe made of stainless steel and to compare it with stainless steel and copper pipes for the same heat input.

Experiment 8: To demonstrate the effect of the air flow rate in the humidity measurement under humidifying and dehumidifying processes.

Experiment 9: To determination thermal contact resistance in a compound bar.

Experiment 10: To determine the thermal conductivity of a liquid by air calibration method.

Experiment 11: To determine the effect of the cross-section shape in the heat transfer from a fin.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	2
CO2	3	3	3	2	2
CO3	3	3	3	2	2
CO4	3	3	3	2	2
CO5	3	3	3	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 578
Course title: CFD Lab
Pre-requisite(s): Fluid Mechanics and Heat Transfer
Co- requisite(s): Nil
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M.Tech
Semester / Level: II/05
Branch: Mechanical Engineering (Heat Power Engineering)
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Provide exposure to different types of discretization techniques namely FDM and FVM
2.	Apply computational methods for solving complex engineering problems.
3.	Expose towards the different ways of time and space discretization techniques for solving different types of P.D.E’s
4.	Expose towards available postprocessing software (like Tecplot, gnuplot, etc) for postprocessing simulated results.
5.	Be capable of solving problems of engineering interest using available application software.

Course Outcomes

At the end of the course, a student should be able to:

CO1	Recognize the importance of CFD in Heat and Fluid flow
CO2	Identify different types of boundary conditions
CO3	Solve computational problems related to fluid flows and heat transfer
CO4	Analyse how to apply different prebuilt Models in CFD
CO5	Evaluate forced convection heat transfer coefficient over regular bodies like cylinder

List of Experiments

Experiment 1: To simulate a Simple Conduction Problem.

Experiment 2: To simulate a Mixed Boundary Problem (Conduction/ Convection/ Insulated).

Experiment 3: To simulate a Transient Thermal Conduction Problem.

Experiment 4: To do a Coupled Structural/Thermal Analysis.

Experiment 5: To simulate a Conjugate Heat Transfer Problem.

Experiment 6: To prepare a Computational Thermal Model of fluid flow in an elbow.

Experiment 7: To simulate fluid flow across a staggered uniformly-spaced tube arrangement.

Experiment 8: Understanding the simulation using Surface-to-Surface (S2S) Radiation Model.

Experiment 9: Simulation using the Discrete Ordinates Radiation Model.

Experiment 10: To simulate flow around an airfoil.

Experiment 11: To solve 1-D steady state conduction equation in Cartesian coordinate system (with and without source term).

Experiment 12: To solve Blasius Zero pressure gradient boundary layer equation using RK4 and shooting method.

Experiment 13: To solve 2-D steady state conduction equation using gauss seidel and Jacobi iteration methods.

Experiment 14: To solve 2-D steady state conduction equation using gauss seidel and Jacobi iteration methods.

Experiment 15: To solve 1-D steady state conduction equation using FTCS and Crank Nisholson scheme in time.

Experiment 16: To solve 1-D convection equation using Lax wendroff and Lax Friedrich scheme, compare and analysze the results obtained.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	2
CO2	3	3	3	3	2
CO3	3	3	3	3	2
CO4	3	3	3	3	2
CO5	3	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1, CD6, CD7
CO2	CD1, CD6, CD7
CO3	CD1, CD6 ,CD7
CO4	CD1, CD6, CD7
CO5	CD1, CD6, CD7

COURSE INFORMATION SHEET

Course code: ME600
Course title: Thesis Part I
Pre-requisite(s): Nil
Co- requisite(s): Nil
Credits: 8 L: T: P:
Class schedule per week:
Class: M.Tech.
Semester / Level: III/06
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Solve real world problems and challenges.
2.	Solve the various research challenges in the field of Heat Power Engineering.
3.	Create awareness among the students of the characteristics of several domain areas where their project ideas could help humanity.
4.	Improve the team building, communication and management skills of the students

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Demonstrate a sound technical knowledge of their selected project topic.
CO2.	Undertake problem identification, formulation and solution.
CO3.	Design engineering solutions to complex problems utilizing a systems approach.
CO4.	Communicate with engineers and the community at large in written and oral forms.
CO5.	Demonstrate the knowledge, skills and attitudes of a professional engineer.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	2
CO2	3		3	3	2
CO3	3		3	3	2
CO4	1	3	3	3	2
CO5	3	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

COURSE INFORMATION SHEET

Course code: ME 642
Course title: Advanced Refrigeration and Air conditioning
Pre-requisite(s): Refrigeration and Air Conditioning
Co- requisite(s):
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: III/06
Branch: Mechanical Engineering)
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Explore the knowledge of solar geometry and heating load calculation of building for air conditioning purpose through different arrangements of building.
2.	Examine and select different air conditioning system and their performance
3.	Explore principle of design an air conditioning system and evaluate its components for their performance.
4.	Design and recommend low cost and high-performance air conditioning duct, which finds applications in modern industries, homes and offices.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Explain fundamental of solar geometry and heating load calculation by direct and diffuse radiations
CO2	Interpret different heating sources of building and its calculations.
CO3	Analyse different air conditioning systems and economic application.
CO4	Specify, interpret data and design an air-conditioning system and its equipment in all aspect.
CO5	Design and recommend low cost and high-performance air conditioning duct which finds applications in modern industries, homes and offices; recognize the need to learn, to engage and to adapt in a world of constantly changing in air conditioning industry.

SYLLABUS

Module 1:

Cooling and Heating Load Calculations - I: Estimation of Solar Radiation : Introduction to cooling and heating load calculations, Refrigeration loads due to Solar radiation and Solar geometry, Air mass system, Calculation of direct, diffuse and reflected radiation using ASHRAE solar radiation model and Air mass system, Effect of clouds. (8L)

Module 2:

Cooling and Heating Load Calculations –II: Solar Radiation Through Fenestration Ventilation And Infiltration Need for fenestration in buildings and effects of fenestration on air conditioning systems, concepts of Solar Heat Gain Factor (SHGF) and Shading Coefficient, calculation of shaded area of fenestrations, Need for ventilation and recommended ventilation rates, Infiltration and causes for infiltration, Estimation of heat transfer rate due to infiltration and ventilation, comparison between natural ventilation and mechanical ventilation, characteristics of natural ventilation and estimation of airflow rate due to wind and stack effects, general guidelines for natural ventilation and forced ventilation using electric fans, interior air movement using interior fans. (8L)

Module 3:

Cooling and Heating Load Calculations - III: Heat Transfer Through Buildings - Fabric Heat Gain/Loss General aspects of heat transfer through buildings, steady state heat transfer through homogeneous, non-homogeneous walls, opaque walls and roofs with suitable initial and boundary conditions, semi-empirical methods based on Effective Temperature Difference or Cooling Load Temperature Difference, discuss the physical significance of decrement and time lag factors and present typical tables of CLTD for walls and roof. (8L)

Module 4:

Selection of Air Conditioning Systems: Introduction to thermal distribution systems and their functions, Selection criteria for air conditioning systems, Classification of air conditioning systems, Working principle, advantages, disadvantages and applications of all air systems, e.g. single duct, constant volume, and single/multiple zone system, single duct, dual duct, constant & variable air volume (VAV) systems, outdoor air control in all air systems, advantages/disadvantages & applications of all air systems, working principle, advantages, disadvantages and applications of all water systems, air-water systems, working principle, advantages, disadvantages and applications of unitary refrigerant based systems. (9L)

Module 5:

Transmission of Air in Air Conditioning Ducts: Air Handling Unit (AHU) and its functions, need for transmission aspects of air in air conditioning, airflow through air conditioning ducts, Bernoulli and modified Bernoulli equations, Static, dynamic, datum and total head, Fan Total Pressure (FTP) and power input to fan, estimation of pressure loss through air conditioning ducts,, Estimation of frictional pressure drop of circular and rectangular ducts using friction charts and equations, Estimation of dynamic pressure drop in various types of fittings, Static regain, Important requirements of an air conditioning duct, General rules for duct design, Classification of duct systems, Commonly used duct design methods, Principle of velocity method, Principle of equal friction method, Principle of static regain method. (9L)

Text books

1. Arora, C.P., Refrigeration and Air Conditioning, 3rd ed., Tata McGraw-Hill, 2010.

Reference books

1. W.F. Stoecker and J. W. Jones, Refrigeration and Air Conditioning, McGraw Hill, New Delhi,1986.
2. R. D. Dossat, Principle of Refrigeration, 4th ed., Prentice-Hall, 1997.
3. Manohar Prasad, Refrigeration and Air Conditioning, New Age International, 2004.
4. W. P. Jones, Air conditioning engineering. 5th edition, Elsevier Butterworth-Heinemann, 2001.
5. Hand Book of Air conditioning and Refrigeration by Shan k. Wang, Tata McGraw-Hill

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Designing of refrigeration and air conditioning duct system
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design
Air mass system, Cooling and Heating Load Calculations through sun radiation
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

Mapping of Course Outcomes onto Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5
CO1	1	2	1	2	2
CO2	2	2	1	2	2
CO3	2	2	2	2	2
CO4	2	2	1	2	2
CO5	2	2	2	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 643
Course title: Dynamics of Compressible Fluid Flow
Pre-requisite(s): Fluid Mechanics, Thermodynamics, ME 562-Advanced Incompressible Fluid Flow
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: III/06
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Present a comprehensive and rigorous treatment of classical compressible fluid dynamics while retaining an engineering perspective.
2.	Give base for studies in fields such as analysis of compressible flow and to prepare the students to effectively use Compressible flow theory in the practice of engineering.
3.	Develop an intuitive understanding of Compressible flow by emphasizing the engineering and engineering arguments.
4.	Present a wealth of real world engineering examples to give students a feel for how Compressible flow is applied in engineering practice.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Outline the concepts of continuum, system of control volume, compressible fluid and its flow properties.
CO2	Apply the appropriate fundamental laws of fluid dynamics and thermodynamics to Compressible flow dynamics and various fluid flow devices.
CO3	Analyse various Compressible fluid flow problems.
CO4	Evaluate the performance of various fluid flow geometry where fluid flow is compressible in nature.
CO5	Create design of simple(2D), complex(2D) compressible fluid flow geometries using conventional methods and modern tools

SYLLABUS

Module 1:

Fundamentals of compressible flow, concepts from fluid mechanics, compressibility, thermodynamic concepts, conservation equations, stagnation state pressure waves in gases, differential equations for 1d flow isentropic flow with area variations, numerical examples. (8L)

Module 2:

Normal Shock Concept, development of a shock wave, governing equations for normal Shock, mach number downstream of normal shock, static pressure ratio across the shock, temperature ratio across the shock, density ratio across the shock, stagnation pressure ratio across the shock, change in entropy across the shock, strength of a shock wave, moving shock waves, numerical examples. (8L)

Module 3:

Concept and theory of oblique shock, oblique Shock relations, property variations across oblique shock, detached shocks, shock-shock interactions,shock reflections, 1-D expansion wave, expansion fan, Prandtl Meyer function ,smooth expansions and compressions, numerical examples. (8L)

Module 4:

Flow in Constant Area Duct with Friction - Fanno curves, Fanno flow equations, solution of Fanno flow equations, variation of flow properties, change of entropy, variation' of mach number with duct length, isothermal flow in a constant area duct with friction, isothermal flow equations, variation of flow properties, numerical examples. (8L)

Module 5:

Flow in constant area ducts with heat transfer and without friction(Rayleigh flow)- Rayleigh line, constant entropy lines, constant enthalpy lines, general equations in Rayleigh flow process, Rayleigh flow relations, variation of flow properties, maximum heat transfer, numerical examples. Case study on capturing of shock using softwares. (8L)

Text Books

1. S. M. Yahya, Fundamentals of Compressible Flow, New Age International Publishers, 2018.
2. V. Babu, Fundamentals of Gas Dynamics, Ane Books India, 2014
3. A. H. Shapiro, The Dynamics and Thermodynamics of Compressible Flow, McGraw-Hill Publishing Co., 2017.

Reference Books

1. H. W. Liepmann and A. Roshko, Elements of Gas Dynamics, Dover Publications, New York, 2002.
2. Youns A. Cengel and John M. Cimbala, Fluid Mechanics, Fundamentals and Applications (S I Unit), Tata Mc-Graw Hills Education Pvt. Ltd., 2017.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Outline of various CFD softwares used in industries for compressible fluid flow analysis and related devices.
POs met through Gaps in the Syllabus: **PO1 to PO4**

Topics beyond syllabus/Advanced topics/Design
Analysis of different compressible fluid flow systems/devices for aerospace applications.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO4**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	3	2	1
CO3	3	2	3	3	1
CO4	3	2	2	2	1
CO5	3	3	3	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 644
Course title: Design and Analysis of Heat Exchangers
Pre-requisite(s): Heat and Mass Transfer.
Co- requisite(s): Nil
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: III/06
Branch: Mechanical Engineering

Course Objectives

This course enables the students to:

1.	Familiarize with the various applications of heat exchangers.
2.	Lay the groundwork for subsequent studies in construction, design, performance and testing of Heat Exchangers.

Course Outcomes

After the end of the course, a student should be able to:

CO1	Outline the physics of the Heat Exchangers.
CO2	Analyze the mathematical treatment of typical heat exchangers.
CO 3	Apply LMTD methods in the design of heat exchangers and analyze the importance of LMTD approach over AMTD approach.
CO 4	Evaluate the Effectiveness of the heat exchangers and analyze the performance of double-pipe counter flow (hair-pin) heat exchangers.
CO5	Design and analyze the shell and tube heat exchanger and classify cooling towers and explain their technical features.

SYLLABUS

Module 1

Introduction to Heat Exchangers: Definition, Applications, Various methods of classification of heat exchangers with examples. (7L)

Module 2

General Back-bone Equation for heat exchangers: Derivation from steady-state steady-flow considerations.

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Effects of fouling. (8L)

Module 3

Logarithmic Mean Temperature Difference: Expression for the same for single pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger. (9L)

Module 4

Hair-Pin Heat Exchangers: Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers.

Effectiveness: Effectiveness-Number of Transfer Units Approach, Derivations of expressions for effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays and London pertaining to Effectiveness-NTU approach.
(9L)

Module 5

Optimum Design: Criteria for optimisation of heat exchangers, constraints, feasible and optimum design, optimization based on volume, weight, cost, entropy generation and thermoeconomics; Brief introduction to some traditional and non-traditional optimisation techniques. (7L)

Text books:

1. Donald Q. Kern, Process Heat Transfer, McGraw – Hill, New York (1983).
2. F. P. Incropera and D. P De Witt, Fundamentals of Heat and Mass Transfer John Wiley and Sons, New York (2012).

Reference books:

1. W. M. Kays and A. L. London, Compact Heat Exchangers McGraw – Hill, New York (1964).
2. W. M. Rosenhow, J. P. Hartnett and Y. I. Cho, Handbook of Heat Transfer by McGraw Hill (1997).

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Micro-channel heat exchangers
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design:
Design and application of Micro-channel Heat exchangers
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	3	1
CO3	3	3	3	3	1
CO4	3	3	3	3	1
CO5	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 645
Course title: Steam Engineering
Pre-requisite(s): Thermodynamics.
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: III/06
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Familiarize with the applications of steam engineering in different thermal systems.
B.	Lay the groundwork for subsequent studies in construction, design, performance and testing of different thermal systems.

Course Outcomes

After the end of the course, a student should be able to:

1.	Familiarize with the working of different boilers and significance of mountings and accessories.
2.	Design a steam piping system, its components for a process and also design economical and effective insulation
3.	Analyze the different thermal systems for energy conservation
4.	Use techniques, skills, and modern engineering tools necessary for boiler performance assessment
5.	Design and develop controls and instrumentation for effective monitoring of the process.

SYLLABUS

Module 1

Introduction: Fundamentals of steam generation, Quality of steam, Use of steam table, Mollier Chart, Boilers Types, Mountings and Accessories, Combustion in boilers, Determination of adiabatic flame temperature, quantity of flue gases, Feed Water and its quality, Blow down; IBR, Boiler standards. (9L)

Module 2

Piping & Insulation: Water Line, Steam line design and insulation; Insulation-types and application, Economic thickness of insulation, Heat savings and application criteria, Refractory-types, selection and application of refractory, Heat loss. (8L)

Module 3

Steam Systems: Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system, Steam Engineering Practices; Steam Based Equipments / Systems. (7L)

Module 4

Boiler Performance Assessment: Performance Test codes and procedure, Boiler Efficiency, Analysis of losses; performance evaluation of accessories; factors affecting boiler performance, Boiler terminology. (8L)

Module 5

Instrumentation & Control: Process instrumentation; control and monitoring. Flow, pressure and temperature measuring and controlling instruments, its selection. (8L)

Text Books

1. T. D. Eastop and A. McConkey, Applied Thermodynamics, Parson Publication, 2009.
2. Yunus A. Cengel and Boles, Engineering Thermodynamics Tata McGraw-Hill Publishing Co. Ltd., 2005,
3. Energy Efficiency in Thermal Utilities; Bureau of Energy Efficiency.(http://www.em-ea.org/gbook1.asp)

Reference Books

1. Energy Performance Assessment for Equipment & Utility Systems; Bureau of Energy Efficiency.(http://www.em-ea.org/gbook1.asp)
2. J. B. Kitto and S C Stultz, Steam: Its Generation and Use, The Babcock and Wilcox Company, 2005.
3. P. Chatopadhyay, Boiler Operation Engineering: Questions and Answers, Tata McGrawHill Education Pvt Ltd, N Delhi, 2001.

4. Alan A. Morris, Measurement and Instruments principles Butterworth and Heinmann, Oxford. 2001.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Boiler Design aspects
POs met through Gaps in the Syllabus: **PO1 to PO5**

Topics beyond syllabus/Advanced topics/Design
Design of steam engineering systems
POs met through Topics beyond syllabus/Advanced topics/Design: **PO1 to PO5**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	3	1
CO3	3	3	3	3	1
CO4	3	3	3	3	1
CO5	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME 646
Course title: Thermal Engineering Lab
Pre-requisite(s): I.C Engines, refrigeration and solar energy
Co- requisite(s):
Credits: 2 L: 0 T:0 P: 4
Class schedule per week: 04
Class: M. Tech
Semester / Level: III/06
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Be familiar with various types Internal Combustion Engines, different measurement systems, refrigeration system and solar radiation equipment.
2	Be confident on how to perform experiments related Internal Combustion Engines, different measurement systems, refrigeration system and solar radiation equipment.
3.	Study performance characteristics of various I.C. Engines, refrigeration systems and solar radiation equipment.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Understand the procedure to conduct experiments related to Internal Combustion Engines, different measurement systems, refrigeration system and solar radiation equipment.
CO2.	Interpreting various parameters influence the performance of the Internal Combustion Engines, refrigeration and solar energy equipment
CO3.	Analyze the observations made through experiments
CO4.	Apply the experimental knowledge how to perform the experiments in different manner.
CO5.	Predicting the sources of errors and minimising them in the experiments

List of experiments:

Experiment 1: Performance study and analysis of Combustion characteristics (P-θ) diagram of 3-cylinder, 4-stroke M.P.F.I. petrol engine.

Experiment 2: Performance study with bended fuel on Mahindra 4-cylinder, 4-stroke Diesel engine.

Experiment 3: Analysis of exhaust gas emission on Diesel and Petrol Engine using AVL gas analysis.

Experiment 4: Performance evaluation of vapour absorption refrigeration system.

Experiment 5: Performance evaluation of variable load refrigeration rig at different flow rate of refrigerant and evaporator temperature.

Experiment 6: Performance evaluation of Peltier element at different flow rate of water in cooling and heating side of heat exchanger

Experiment 7: To study the working principle of different types of pyranometer and measurement of intensity of solar radiation.

Experiment 8: To demonstrate the I-V and P-V characteristics of PV module with varying radiation and temperature level.

Experiment 9: To demonstrate the I-V and P-V characteristics of series and parallel combination of PV module.

Experiment 10: Performance study of thermos siphon type solar water heater.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	1	2
CO2	2	2	2	1	2
CO3	3	2	3	2	2
CO4	3	3	3	2	1
CO5	3	2	3	1	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD3,CD6
CO2	CD1,CD3,CD6
CO3	CD1,CD3,CD6
CO4	CD1,CD3,CD6
CO5	CD1,CD3,CD6

COURSE INFORMATION SHEET

Course code: ME650
Course title: Thesis Part II
Pre-requisite(s): Nil
Co- requisite(s): Nil
Credits: 16 L: T: P:
Class schedule per week:
Class: M.Tech.
Semester / Level: IV/06
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Solve real world problems and challenges.
2.	Solve the various research challenges in the field of Energy Technology.
3.	Create awareness among the students of the characteristics of several domain areas where their project ideas could help humanity.
4.	Improve the team building, communication and management skills of the students

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Demonstrate a sound technical knowledge of their selected project topic.
CO2.	Undertake problem identification, formulation and solution.
CO3.	Design engineering solutions to complex problems utilizing a systems approach.
CO4.	Communicate with engineers and the community at large in written and oral forms.
CO5.	Demonstrate the knowledge, skills and attitudes of a professional engineer.

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	2
CO2	3		3	3	2
CO3	3		3	3	2
CO4	1	3	3	3	2
CO5	3	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

OPEN ELECTIVES

COURSE INFORMATION SHEET

Course code: ME582
Course title: Design Methodology
Pre-requisite(s): Nil
Co- requisite(s): Nil
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: I/II /05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Gain concepts of design research and methodology
2.	Carry out research into design.
3.	Understand design as a phenomenon.
4.	Identify research topics.
5.	Understand structures of research documentation.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Determine type of research to be persuaded.
CO2.	Improve design aspects in a systematic way.
CO3.	Develop a research plan.
CO4.	Validate the improvements in a methodical manner.
CO5.	Document and report research process and outcomes.

SYLLABUS

Module 1:

Introduction to design research: What and Why; Current issues with design research and the need for a design research methodology; Major facets of design and design research. Introduction to design research methodology - its main components, and examples to explain the components. (8L)

Module 2:

Starting design research: Clarification of requirements: Identifying research topics, carrying out literature search, consolidating the topic into research questions and hypotheses, and developing a research plan. (8L)

Module 3:

Descriptive study: Type, Processes for carrying out descriptive studies for developing an understanding a facet of design and its influences; Introduction to associated descriptive study real-time and retrospective research methods for data collection such as protocol analysis, questionnaire surveys, interviews etc; Introduction to quantitative and qualitative data analysis methods. (8L)

Module 4:

Prescriptive study: Types, Processes for developing design support and associated prescriptive study research methods. Types of support evaluation; Processes for evaluating a design support, and associated Evaluation study research methods. (8L)

Module 5:

Documentation: Types and structures of research documentation, Approaches and guidelines for documenting and reporting research process and outcomes. (8L)

Text Books

1. The Future of Design Methodology, Editors: Birkhofer, Herbert (Ed.) Springer-Verlag, 2011.
2. Design Thinking Methodology, Emrah Yayici.
3. Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions, Bruce Hanington and Bella Martin 2012

Reference Books

1. Blessing, L.T.M., Chakrabarti A. and Wallace, K.M. An Overview of Design Studies in Relation to a Design Research Methodology, Designers: the Key to Successful Product Development, Frankenberger & Badke-Schaub (Eds.), Springer-Verlag, 1998.

Course Evaluation:
Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :
Cost effective design methods.
POs met through Gaps in the Syllabus: **PO3**

Topics beyond syllabus/Advanced topics/Design:
Advanced design methods.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2		2
CO2	1	3	2		2
CO3	1	3	2		1
CO4	2	3	2		1
CO5	2	3	2		3

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME583
Course title: Renewable Energy
Pre-requisite(s): Basic of Physics, Chemistry and Mathematics
Co- requisite(s): Nil
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: I/II /05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Create awareness about sources of energy and able to estimate how long the available conventional fuel reserves will last.
2.	Learn the fundamental concepts about solar energy systems and devices.
3.	Design wind turbine blades and know about applications of wind energy for water pumping and electricity generation.
4.	Understand the working of advanced renewable energy sources.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Understand of renewable and non-renewable sources of energy.
CO2.	Gain knowledge about working principle of various solar energy systems
CO3.	Understand the application of wind energy and wind energy conversion system.
CO4.	Develop capability to do basic design of bio gas plant.
CO5.	Understand the applications of different advanced renewable energy sources.

SYLLABUS

Module 1: INTRODUCTION TO ENERGY STUDIES

Introduction, Energy science and Technology, Forms of Energy, Importance of Energy Consumption as Measure of Prosperity, Per Capita Energy Consumption, Roles and responsibility of Ministry of New and Renewable Energy Sources, Needs of renewable energy, Classification of Energy Resources, Conventional Energy Resources , Non-Conventional Energy Resources, World Energy Scenario, Indian Energy Scenario. (8L)

Module 2: SOLAR ENERGY

Introduction, Solar Radiation, Sun path diagram, Basic Sun-Earth Angles, Solar Radiation Geometry and its relation, Measurement of Solar Radiation on horizontal and tilted surfaces, Principle of Conversion of Solar Radiation into Heat, Collectors, Collector efficiency, Selective surfaces, Solar Water Heating system , Solar Cookers , Solar driers, Solar Still, Solar Furnaces, Solar Greenhouse. Solar Photovoltaic, Solar Cell fundamentals, Characteristics, Classification, Construction of module, panel and array. Solar PV Systems (stand-alone and grid connected), Solar PV Applications. Government schemes and policies.

(8L)

Module 3: WIND ENERGY

Introduction, History of Wind Energy, Wind Energy Scenario of World and India. Basic principles of Wind Energy Conversion Systems (WECS), Types and Classification of WECS, Parts of WECS, Power, torque and speed characteristics, Electrical Power Output and Capacity Factor of WECS, Stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, Site selection criteria, Wind farm, Wind rose diagram.

(8L)

Module 4: BIOMASS ENERGY

Introduction, Biomass energy, Photosynthesis process, Biomass fuels, Biomass energy conversion technologies and applications, Urban waste to Energy Conversion, Biomass Gasification, Types and application of gasifier, Biomass to Ethanol Production, Biogas production from waste biomass, Types of biogas plants, Factors affecting biogas generation, Energy plantation, Environmental impacts and benefits, Future role of biomass , Biomass programs in India. (8L)

Module 5: ADVANCED RENEWABLE ENERGY SOURCES

Introduction to advanced renewable energy, Hydropower, Wave Energy, Tidal Energy, Ocean Thermal Energy, Geothermal Energy, Bio-fuels, Animal Energy. (8L)

Text Books

1. Sukhatme. S.P., Solar Energy, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1997.
2. B. H. Khan, Non-Conventional Energy Resources, , The McGraw Hill
3. G N Tiwari, R K Mishra, Advanced renewable energy sources, RSC Publishing, 2012
4. Twidell, J.W. & Weir, A. Renewable Energy Sources, EFN Spon Ltd., UK, 2006.
5. S. P. Sukhatme and J.K. Nayak, Solar Energy – Principles of Thermal Collection and Storage, Tata McGraw-Hill, New Delhi.
6. Garg, Prakash, Solar Energy, Fundamentals and Applications, Tata McGraw Hill.

Reference Books

1. G.D. Rai, Non-Conventional Energy Sources, Khanna Publications, New Delhi, 2011.
2. Godfrey Boyle, "Renewable Energy, Power for a Sustainable Future", Oxford University Press, U.K., 1996.
3. Khandelwal, K.C., Mahdi, S.S., Biogas Technology – A Practical Handbook, Tata McGraw-Hill, 1986.
4. Tiwari. G.N., Solar Energy – "Fundamentals Design, Modeling & Applications", Narosa Publishing House, New Delhi, 2002.
5. Freris. L.L., "Wind Energy Conversion Systems", Prentice Hall, UK, 1990.
6. Frank Krieth& John F Kreider ,Principles of Solar Energy, John Wiley, New York

Course Evaluation:

Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

High temperature solar thermal application

POs met through Gaps in the Syllabus: **PO3**

Topics beyond syllabus/Advanced topics/Design:

Advance bio fuels

POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	1	2	3	-	2
CO2	1	2	3	-	2
CO3	1	2	3	-	2
CO4	2	2	3	-	2
CO5	1	2	3	-	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2, CD6
CO3	CD1, CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME584
Course title: Energy Management Principles and Auditing
Pre-requisite(s): Basic of Physics, Chemistry and Mathematics
Co- requisite(s): Nil
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: I/II /05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Gain introductory knowledge of Energy management and energy audit.
2.	Understand basic concepts of Energy conservation.
3.	Understand Energy efficiency and cost benefit.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Outline energy management system and related policies and Acts.
CO2.	Apply the concept of Energy Management in energy related issues.
CO3.	Work with energy management system and energy audit of whole system.
CO4.	Analyze energy conservation related to environmental issues.
CO5.	Carry out Auditing of relevant interdisciplinary systems.

SYLLABUS

Module 1: INTRODUCTION

Energy and Sources of energy, Energy consumption and GDP, Costs of exploration and utilization of resources, Energy pricing, Energy demand and supply, National energy plan, Need for Energy Policy, National and State level Energy Policies. Basic concepts of Energy Conservation and its importance, Energy Strategy for the Future, The Energy Conservation Act and its Features, Energy conservation in household, Transportation, Agricultural, Service and Industrial sectors, Lighting, HVAC Systems. (8L)

Module 2: ENERGY MANAGEMENT

History of Energy Management, Definition and Objective of Energy Management and its importance. Need of energy management, General Principles of Energy Management, Energy Management Skills, and Energy Management Strategy. Energy Management Approach. Understanding Energy Costs, Benchmarking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution. Organizing, Initiating and Managing an energy management program. Roles, responsibilities and accountability of Energy Managers. (8L)

Module 3: ENERGY AUDIT

Energy audit concepts, Definition, Need and Types of energy audit. Energy Audit Approach and Methodology. Systematic procedure for technical audit. Understanding energy audit costs, Benchmarking and Energy Performance. Energy audit based on First law and Second law of thermodynamics, Mass and Energy balances, Availability analysis, Evaluation of energy conserving opportunities, Economic analysis and life cycle costing. Duties and responsibilities of energy auditors. Energy audit instruments and their usage for auditing**.** Report-writing, preparations and presentations of energy audit reports. (8L)

Module 4: ENERGY CONSERVATION AND ENVIRONMENT

Energy conservation areas**,** Energy transmission and storage, Plant Lecture wise energy optimization Models, Data base for energy management, Energy conservation through controls, Computer aided energy management, Program organization and methodology. Energy environment interaction, Environmental issues, Global Warming, Climate Change Problem and Response, Carbon dioxide emissions, Depletion of ozone layer, Governments Regulations, Energy Economy interaction. Energy Conservation in Buildings, Energy Efficiency Ratings & ECBC (Energy Conservation Building Code). (8L)

Module 5: INTERDISCIPLINARY CASE STUDIES

Study of 4 to 6 cases of Energy Audit & Management in Industries (Mechanical, Chemical and other systems). (8L)

Text Books

1. Amlan Chakrabarti, Energy Engineering and Management, PHI, Eastern Economy Edition.
2. Smith CB, Energy Management Principles, Pergamon Press, New York.
3. Hamies, Energy Auditing and Conservation; Methods, Measurements, Management & Case study, Hemisphere, Washington
4. L. C. Witte, P. S. Schmidt and D. R. Brown, Industrial Energy Management and Utilization, Hemisphere Publications, Washington.

Reference Books

1. W.R.Murphy, G.Mckay, Energy Management, Butterworths.
2. C.B.Smith Energy Management Principles, Pergamon Press.
3. L.C. Witte, P.S. Schmidt, D.R. Brown , Industrial Energy Management and Utilization, Hemisphere Publication, Washington
4. Archie, W Culp , Principles of Energy Conservation, McGraw Hill
5. Munasinghe, Mohan Desai, Ashok V, Energy Demand: Analysis, Management and Conservation, Wiley Eastern Ltd., New Delhi.

Course Evaluation:

Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

Cost effective energy management

POs met through Gaps in the Syllabus: **PO3**

Topics beyond syllabus/Advanced topics/Design:

Advance energy auditing system

POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	1	2	3	-	2
CO2	1	2	3	-	2
CO3	1	2	3	-	2
CO4	1	2	3	-	2
CO5	1	2	3	-	2

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2, CD6
CO3	CD1, CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME585
Course title: Industrial Robotics
Pre-requisite(s): Engineering Mathematics, Engineering Mechanics.
Co- requisite(s): Nil
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: I/II /05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Understand the kinematic design and dynamic formulation of a typical industrial robot.
2.	Foresee the possibilities in design uncertainties in kinematic model of a robot and make necessary changes in the modelling to make the controller perform precisely.
3.	Estimate the possible errors in dynamic forces/torques that may come on the actuators due to un-modelled parameters.
4.	Understand the parallel robot kinematic design and solve its inverse and forward kinematics.
5.	Evaluate a robot performance based on standard parameters.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Outline the structure of a typical robotic system, understand its link and joint parameters, and perform robot kinematics.
CO2.	Identify the geometric parameters of a serial robot by applying the knowledge of serial robot kinematics and generalized differential model of the robot.
CO3.	Identify the dynamic parameters of a serial robot by applying the knowledge of general form of dynamic equation of motion.
CO4.	Analyse planar and spatial parallel robots in context to its forward and inverse kinematics, and evaluate its singularity, condition number and manoeuvrability.
CO5.	Design a robotic manipulator and evaluate its primary and secondary workspace. Evaluate the performance of an industrial robot based on ISO standards.

SYLLABUS

Module 1:

Robotic systems - Its role in automated manufacturing; robot anatomy; classifications and specifications, Serial robot kinematics: forward and inverse, homogeneous transformations.
(8L)

Module 2:

Robot sensors, different types of contact and non-contact sensors; Robot vision and their interfaces. (8L)

Module 3:

Robot actuators and control; Pneumatic, hydraulic and electrical drives, controls used in robots. Robot end-effectors: mechanical, magnetic and vacuum grippers, gripping forces RCC and design features of grippers. (8L)

Module 4:

Robot languages and programming techniques. Performance analysis of Robots: Accessibility, Workspace of a robot manipulator: primary and secondary spaces, Orientation workspace, Local performances: Manipulability, Repeatability, Isotropy and Dexterity.
(8L)

Module 5:

Applications of robots in materials handling, machine loading/unloading, inspection, welding, spray painting and finish coating, and assembly, etc. Robot installation and planning. (8L)

Text Books

1. Industrial Robotic Technology - Programming and Application by M. P. Groover et. al., McGraw Hill
2. KS Fu, C. S. G Lee, R. Gonzalez, Robotics: Control, Sensing, Vision and Intelligence, McGraw-Hill Education, 1987.
3. S. K. Saha, Introduction to Robotics, McGraw Hill Education, 2008.

Reference Books

1. Bruno Siciliano and Oussama Khatib, Handbook of Robotics, Springer, 2016.
2. ISO 9283:1998 Manipulating industrial robots -- Performance criteria and related test methods, ISO, 1998.

Course Evaluation:

Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements):
Cost effective performance analysis of robots.
POs met through Gaps in the Syllabus: **PO3**

Topics beyond syllabus/Advanced topics/Design:
Performance analysis of robots.
POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	3	2
CO2	3	3	3	3	2
CO3	3	3	3	3	2
CO4	3	3	3	3	2
CO5	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: ME586
Course title: Reliability in Design
Pre-requisite(s): Nil
Co- requisite(s): Nil
Credits: 3   L: 3   T: 0   P: 0
Class schedule per week: 03
Class: M. Tech
Semester / Level: I/II /05
Branch: Mechanical Engineering
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Understand role of reliability evaluation.
2.	Identify reliability assessment techniques that may provide guidance for robust designs.
3.	Apply common concepts from statistics in design.
4.	Explore types of maintenance.
5.	Assess reliability of components and systems.

Course Outcomes

At the end of the course, a student should be able to:

CO1.	Perform reliability improvement and life tests.
CO2.	Recommend how further analysis, testing, or quality control may increase safety and efficiency of a structural design.
CO3.	Evaluate and apply statistical methods to structural design.
CO4.	Design for maintainability and its considerations.
CO5.	Formulate and solve reliability-based structural optimization problems.

SYLLABUS

Module 1: RELIABILITY BASICS

Basic Concepts of Reliability, Definition of Reliability, Role of Reliability evaluation, Design for reliability, Design under uncertainty, Why use probabilistic methods, Success stories, bath-tub-curve, system reliability, reliability improvement, maintainability and availability, Life tests, Acceptance sampling based on life tests. (8L)

Module 2: RELIABILITY IN DESIGN AND DEVELOPMENT

Introduction to Design of Experiments (DOE) and Taguchi Method, Failure mode and effects analysis, Basic symbols, Fault Tree construction and analysis, Monte Carlo Simulation, Human factors in design and design principles. (8L)

Module 3: RELIABILITY MANAGEMENT

Objectives of maintenance, types of maintenance, Maintainability, factors affecting maintainability, system down time, availability - inherent, achieved and operational availability (Numerical treatment). Introduction to Reliability Centered Maintenance. Design for maintainability and its considerations, Reliability and costs, Costs of Unreliability. (8L)

Module 4: SYSTEM RELIABILITY ANALYSIS

Reliability Improvement, Redundancy, element redundancy, unit redundancy, standby redundancy types of stand by redundancy, parallel components single redundancy, multiple redundancies (problems). (8L)

Module 5: LIFE TESTING & RELIABILITY ASSESSMENT

Censored and uncensored field data, burn-in testing, acceptance testing, accelerated testing, identifying failure distributions & estimation of parameters, reliability assessment of components and systems. (8L)

Text Books

1. Nikolaidis E., Ghiocel D. M., Singhal S., Engineering Design Reliability Handbook, CRC Press, Boca Raton, FL, 2004.
2. McPherson J.W., Reliability Physics and Engineering: Time to Failure Modeling, 2nd Edition, Springer, 2013.
3. Ebeling, C. E., An Introduction to Reliability and Maintainability Engineering, Waveland Press, Inc., 2009 (ISBN 1-57766-625-9).
4. Bryan Dodson, Dennis Nolan, Reliability Engineering Handbook, Marcel Dekker Inc, 2002.
5. Kapur, K. C., and Lamberson, L. R., Reliability in Engineering Design, John Wiley and Sons, 1977.

Reference Books

1. Reliability toolkit: Commercial practices edition. Reliability Analysis Center, 1995.
2. Blischke, Wallace R., and DN Prabhakar Murthy. Reliability: modeling, prediction, and optimization. Vol. 767. John Wiley & Sons, 2011.
3. Leemis, Lawrence M. Reliability: probabilistic models and statistical methods. Prentice-Hall, Inc., 1995.
4. Modarres, Mohammad, Mark P. Kaminskiy, and Vasiliy Krivtsov. Reliability engineering and risk analysis: a practical guide. CRC press, 2009.
5. O'Connor, Patrick, and Andre Kleyner. Practical reliability engineering. John Wiley & Sons, 2011.
6. Singiresu S Rao, Reliability Engineering, Pearson Education, 2014, ISBN: 978-0136015727.
7. Webpage : https://goremote.itap.purdue.edu/Citrix/XenApp/auth/login.aspx

Course Evaluation:

Individual assignment, Seminar, Theory (Quiz and End semester) examinations

Gaps in the syllabus (to meet Industry/Profession requirements) :

Cost effective reliable design methods.

POs met through Gaps in the Syllabus: **PO3**

Topics beyond syllabus/Advanced topics/Design:

Advanced methods for reliable design.

POs met through Topics beyond syllabus/Advanced topics/Design: **PO3**

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

MAPPING BETWEEN COURSE OUTCOMES AND PROGRAM OUTCOMES

CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	-	1
CO2	2	2	3	-	1
CO3	2	2	2	3	1
CO4	2	2	2	-	1
CO5	2	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6