INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-500 Course Title: Instrumentation and Experimental Methods**

2. Contact Hours : **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.) **: Theory** 3 **Practical** 0

4. Relative Weight : **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** 0

5. Credits: 4 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre – requisite**: Nil**

9. Objectives of Course: The course is intended for the post graduate students of mechanical engineering disciplines to give them a thorough understanding of a measuring system, different transduction principles, error analysis response etc. and various other issues related to instrumentation system.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Significance of Measurement and Instrumentation**: Introduction; generalized configuration and functional stages of measuring systems. The transducer and its environment; an overview; sensing process and physical laws. Types of measurement problems. Transducer classification and their modeling; information, energy and incremental models; characteristics of instruments, design and selection of components of a measuring system.	5
2	**Dynamic Response of Instruments**: Mathematical model of a measuring system, response of general form of instruments to various test inputs; time-domain and frequency domain analysis. Elementary transfer functions and Bode plots of general transfer functions.	10
3	**Errors in Measurement and Its Analysis**: Causes and types of experimental errors; systematic and random errors. Uncertainty analysis; computation of overall uncertainty; estimation for design and selection for alternative test methods.	4
4	**Transducers**: Developments in sensors, detectors and transducer technology; displacement transducers; force, torque and motion sensors; piezoelectric transducers; capacity type transducers; Strain gage transducers; accelerometers, pressure transducers based on elastic effect of volume and connecting tubing.	10
5	**Data Acquisition and Signal Processing**: Systems for data acquisition and processing; modules and computerized data system; digitization rate; time and	5

	frequency domain representation of signals, and Nyquist criterion. A brief description of elements of mechatronics; modular approach to mechatronics and engineering design.	
6	**Flow Measurement**: Flow visualization, shadowgraph; schlieren and interferometric techniques; Pitot static tubes; hot wire anemometers; Laser Doppler velometer; flow measurements using coriolis effect.	4
7	**Temperature and Heat Flux Measurement**: Thermoelectric sensors; electric resistance sensors; thermistors; radiations pyrometers; Temperature measuring problems in flowing fluids, dynamic compensation.	4
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors / Books / Publisher**	**Year of Publication/ Reprint**
1.	Doeblin E. O., "Measurements System Application and Design", 5th Ed., McGraw Hill	2004
2.	Trietly Harry L., Dekker Marcel, "Transducers in Mechanical and Electronic Design", 1st Ed., CRC Press	1986
3.	Beckwith T. G., Marangoni R. D., and Lienhard J. H., "Mechanical Measurements", 6th Ed., Prentice Hall	2006
4.	Eckert E. R. G. and Goldstein R. J., "Measurements in Heat Transfer", 2nd Ed., Springer	1986
5.	Goldstein R. J., "Fluid Mechanics Measurement", 1st Ed., Hemisphere Publishing Company	1983

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-501** Course Title: **Computer Aided Manufacturing**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre–requisite: **Nil**

9. Objective: To provide knowledge and details of the means of computer aided manufacturing and various functions supporting the automated manufacturing.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Introduction to manufacturing systems and their performance analysis; Introduction to automation; Introduction to computer integrated manufacturing (CIM).	04
2	**Numerical Control (NC):** Introduction, numerical control – its growth and development, components of NC system, input devices, control systems – point to point, straight cut, and continuous path NC, open loop and closed loop NC systems, NC interpolations – linear, circular, helical, parabolic and cubic interpolation, applications of NC systems, merits and demerits.	10
3	**Extensions of NC:** Concepts of computer numerical control (CNC), machining center, and direct numerical control (DNC), and their advantages.	06
4	**Robotics:** Robot anatomy and related attributes, robot control systems – limited sequence, playback with point to point, playback with continuous and intelligent control; End effectors – gripper, tools; Sensors in robotics – tactile sensors, proximity, optical sensors and machine vision; Applications of industrial robots, robot programming.	06
5	**Material Handling and Storage:** Overview of material handling equipments, automated material handling equipments – AGVs, conveyor systems, performance analysis of material handling systems, automated material storage systems – ASRS and carousel storage, analysis of automated storage systems.	06
6	**Manufacturing Support Functions:** Introduction to group technology (GT), computer aided process planning (CAPP), material requirement planning MRP (MRP), capacity planning, scheduling etc.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Groover, M. P., "Automation, Production systems and Computer Integrated Manufacturing", 3rd Ed., Prentice-Hall.	2007
2	Singh, N., "Systems Approach to Computer Integrated Design and Manufacturing", John Wiley & Sons.	1996
3	Chang, T.-C., Wysk, R. A. and Wang, H.-P. "Computer Aided Manufacturing", 3rd Ed., Prentice Hall.	2005
4	Rembold, U., Nnaji, B. O. and Storr A., "Computer Integrated Manufacturing", Addison Wesley.	1994
5	Besant, C. B. and Lui, C. W. K., "Computer Aided Design and Manufacture", Ellis Horwood Ltd.	1991
6	Rao, P. N., Tiwari, N. K. and Kundra, T.K., "Computer Aided Manufacturing", Tata McGraw Hill.	1993
7	Koren, Y. "Computer Control of Manufacturing Systems", McGraw Hill.	1983
8	Lynch, M., "Computer Numerical Control for Machining", McGraw-Hill.	1992
9	Sava, M. and Pusztai, J., "Computer Numerical Control Programming", Prentice Hall.	1990

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-502** Course Title: **Robotics and Control**

2. Contact Hours : **L: 3** **T:1** **P: 2/2**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **PRE** **0**

5. Credits: 4 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre–requisite: **NIL**

9. Objectives of Course: To get exposure about basic robot kinematics, dynamics, control and programming.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Definition, Structure, Classification and Specifications of Robots, Industrial Robots.	02
2	**Robot Elements and Control**: Manipulators, Drives, Sensors, End Effectors, Configuration, Force/Torque Relationship, Trajectory Planning, Position Control, Feedback System, Digital Control	5
3	**Modeling of Robots**: Coordinate Frames, Mapping and Transformation; Direct Kinematic Model; Inverse Kinematics; Manipulator Differential Motion; Static Analysis; Jacobian	10
4	**Manipulator Dynamics**: Acceleration of a rigid body, mass distribution, Newtons equation, iterative Newton Euler dynamic formulation, Lagrangian formulation of manipulator dynamics, Bond graph modeling of manipulators, Trajectory Planning.	10
5	**Linear and Non Linear Control of Manipulators**: control law partitioning, trajectory following control, multi input multi output control systems, Cartesian based control scheme.	10
6	**Force Control of manipulators**: hybrid position/force control	03
7	**Robot Programming**: Robot Programming for Manufacturing and Other Applications, Robot Integration with CAD and CAM.	02
	Total	42

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint

1	Craig John J., “Introduction to robotics: Mechanics & Control”, Addison-Wesley	1986
2	Niku Saeed B., Introduction to Robotics: Analysis, Systems, Applications, PHI, New Delhi	2001
3	Schilling R. J., “Fundamentals of Robotics Analysis and Control”, Prentice Hall Inc	1990
4	Mittal R. K. and Nagrath I. J., “Robotics and Control”, Tata McGraw Hill, New Delhi	2003
5	Ghosal Ashitava, “Robotics: Fundamental Concepts and Analysis”, Oxford University Press	2006
6	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-508** Course Title**: Advanced Automatic Controls**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the advanced concepts of state space approach in control system stability, controllability and observability issues and synthesis of industrial control systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Mathematical Models of Linear Systems**: Linear systems and state equations, linearization of non linear equations, linearizing functions, linearizing differential equations	4
2	**Linear Algebra**: Vector spaces, linear dependence and independence, bases, change of basis, rank and degeneracy, norms, Gram-Schmidt orthonormalization, subspaces and projection theorem	4
3	**State Variable Analysis**: State variable representation, conversion of state variable model to transfer function, characteristic equation, eigenvalues, eigen-vectors, conversion of transfer function to canonical state variable models, solution to state equations,	6
4	**Stability of Control Systems**: Bounded input, bounded output stability, zero input and asymptotic stability of continuous data system, Lyapunov stability, Lyapunov's direct method, external stability, relationship between stability types	6
5	**Controllability and Observability**: Controllability tests for LTI systems, modal controllability and observability, controllability and observability of time varying systems, discrete time systems	5
6	**System Realizations**: Minimal realization, specific realization, Markov parameters, balanced realizations	4
7	**State Feedback and Observers**: State feedback for SISO systems, multivariable canonical forms and feedback, observers, state estimator- multivariable case	5
8	**Optimal Control and Estimation**: The principle of optimality, optimal estimator	5
9	**Pole Placement and Model Matching**: Unity feedback configuration, implementable transfer function, multi variable unity feedback system,	3

	multivariable model matching	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/Reprint
1	Ogata, K., "Modern Control Engineering", Prentice Hall of India.	2002
2	Raven, F.H., "Automatic control Theory", McGraw Hill.	1995
3	Kuo, B.C., "Automatic Control System", 5th, Prentice Hall of India.	1995
4	Chen, C.T., "Linear System Theory & Design", 3rd Edition, Oxford University Press.	1999
5	Harrison, H.L. and Bollinger, J. G., "Automatic Controls", International Text Book Company.	1970
6	Bay, J.S., "Fundamentals of Linear State Space Systems", McGraw Hill.	1999
7	Norman, S.N., "Control Systems Engineering", John Wiley and Sons.	2003

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-515** Course Title: **Manufacturing Systems Analysis**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To teach students various tools and techniques used for the performance analysis of manufacturing systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Definitions of manufacturing with input-output model, definition of system, basic problems concerning systems and system design procedure, modes of manufacturing – job/batch/flow and multi-product, small-batch manufacturing.	4
2	**System Modeling Issues:** Centralized versus distributed control; Real-time vs. discrete event control; Forward vs. backward scheduling approaches with finite/infinite capacity loading; Modeling of absorbing states and deadlocks; Conflicts; Concurrency, and synchronization etc.	8
3	**System Modeling Tools and Techniques:** Introduction to mathematical modeling, optimization, and simulation; Issues related with deterministic and stochastic models; Continuous and discrete mathematical modeling methods - discrete event, monte carlo method; Basic concepts of Markov chains and processes; The M/M/1 and M/M/m queue; Models of manufacturing systems - including transfer lines and flexible manufacturing systems, introduction to Petri nets.	15
4	**Performance Analysis:** Transient analysis of manufacturing systems, analysis of a flexible machining center; Product flow analysis; Rank order clustering; Process flow charting; MRPI & II, kanban, OPT, JIT-pull and JIT-push, line of balance, effects of machine failure, set-ups, and other disruptions on system performance; Calculation of performance measures - throughput, in-process inventory, due dates, MTL, capacity, and machine utilization etc.; Critique of high inventory, long lead time systems; Shop floor control issues.	15
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Askin, R. G., and Standridge, C. R., "Modeling and Analysis of Manufacturing Systems", John Wiley & Sons.	1993
2.	Gershwin, S. "Manufacturing Systems Engineering", Prentice-Hall.	1994
3.	Hitomi, K., "Manufacturing Systems Engineering", Taylor & Francis.	1998
4.	Viswanadham N. and Narahari Y. "Performance Modeling of Automated Manufacturing Systems", Prentice-Hall	1992
5.	Hopp, W. J., and Spearman, M. L., "Factory Physics : Foundation of Manufacturing Management", McGraw Hill.	1996
6.	Chang, T.-C., Wysk, R. A. and Wang, H.-P. "Computer Aided Manufacturing", 3rd Ed., Prentice Hall.	2005

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-516** Course Title: **Artificial Intelligence**

5. Contact Hours: **L: 3** **T: 1** **P: 0**

6. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

7. Relative Weight : **CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: This course is designed to provide basic knowledge of artificial intelligence. The emphasis is on the teaching of various techniques on knowledge representation and search engines with important applications of AI.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Overview of History and Goals of AI**: Artificial Intelligence -- Definition, components, scope, and application areas; Turing's test; Review of AI success and failure.	3
2	**State Spaces, Production Systems, and Search**: State space representation of problems; Problem solving using search; Definition and examples of production systems; Heuristic search techniques i.e. generate-and-test, hill climbing, best-first search, constraint satisfaction and mean-ends analysis.	8
3	**Knowledge Representation**: Definition of knowledge; Issues in knowledge representation; Procedural vs declarative knowledge and their representation; Predicate logic, production rules, semantic nets, and frames; Meta-knowledge.	9
4	**Reasoning and Inference Strategies:** Forward vs backward reasoning; Depth first, breadth first, min-max etc.; Non-monotonic reasoning; Symbolic reasoning under uncertainty; Probability and Baye's theorem; Certainty factors, Dempster-Shafer theory; Fuzzy logic etc.	10
5	**Expert Systems and their Applications**: Justification, structure, knowledge sources; Expert knowledge acquisition; Expert system languages; ES building tools/shells; Applications of AI in CAD, CAPP, process selection, GT, MRP II, adaptive control, robotics, process control, fault diagnosis, failure analysis, etc.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Rich, E., Knight, K. and Nair, S. B., "Artificial Intelligence", 3rd Ed., Tata McGraw Hill.	2010
2	Russell, S. and Norvig, P., "Artificial Intelligence: A Modern Approach", 3rd Ed., Prentice-Hall.	2009
3	Dean, T. L., Allen, J., and Aloimonos, Y. "Artificial Intelligence: Theory and Practice", Benjamin/Cummings Publishing Company.	1995
4	Genesereth, M. R. and Nilsson, N., "Logical Foundations of Artificial Intelligence", Morgan Kaufmann.	1987

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-517** Course Title: **Automated Materials Handling Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To introduce various automated material handling equipment and their utilization.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction of Material Handling:** Overview of MHE, consideration in MHS design, twenty principles of material handling, the unit load concept.	04
2	**Material Transport Systems:** Industrial trucks, automated guided vehicle systems, monorails and other rail guided vehicles, conveyor systems, cranes and hoists.	06
3	**Evaluation and Selection of Material Handling Layout**: Design of bins and hoppers – flow patterns, measurement of flow properties, design methods, feeders, dischargers, silos, chutes and gates; Bulk material sampling and weighing systems, blending of bulk materials, transportation interface – rail and water. monitoring and control.	14
4	**Analysis of Material Transport Systems:** Rate of deliveries, required number of vehicles, economics of material handling systems.	06
5	**Automated Storage & Retrieval Systems (AS/RS):** Functions of AS/RS, operations of AS/RS, AS/RS components, types of AS/RS, design of an AS/RS, system throughput, size parameters determination of AS/RS.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Allegri, T. H., "Material Handling Principles and Practice", Krieger Publishing Company.	1992
2	Meyers, F. E. and Stephens, M. P. "Manufacturing Facilities Design and Material Handling", Prentice Hall.	2000
3	Adam, N. D., Brown, T. W., Rowland, V. D. and Misenheimer, F. P., "Warehouse & Distribution Automation Handbook", McGraw-Hill.	1996
4	Tompkins, J. A., White, J. A., Bozer, Y. A. and Tanchoco, J. M, "Facilities Planning", 4th Ed., John Willey & Sons.	2010
5	Sule, D. R., "Manufacturing Facilities-Location, Planning, and Design", 3rd Ed., CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-550** Course Title: **Advanced Machine Design**
2. Contact Hours : **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**
4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: The course is intended to train the graduates in methods of failure analysis and design of machine parts against likely failures, using advanced concepts and also to design for reliability.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Review of failure theories, their scope of applications under different loading and environmental conditions, Hertzian contact stresses and their effect on load carrying capacities of members, effect of small inelastic strains and residual stresses on load carrying capacity, theory of limit design; Machinery construction principles.	12
2	**Designing against Fracture**: Linear elastic fracture mechanics approach, theories of brittle fracture, fundamental aspects of crack growth and fractures, use of fracture in design.	10
3	**Designing against Fatigue and Creep**: Causes and interpretation of failures, influence of various factors, low cycle and high cycle fatigue, cumulative damage theories, acoustical and thermal fatigue, corrosion and fretting fatigue, pitting of gears, fatigue strength of joints, components and structures; creep behavior; the mechanical equation of state, an elastic and plastic creep, rupture theory, analysis of tensile creep data, creep in high temperature low cycle fatigue, creep analysis of thick walled cylinders and rotating discs.	10
4	**Design for Reliability**: Application of statistics to material properties, fatigue and reliability, early chance and wear out failures, reliability prediction against chance and wear out failures, probabilistic approach to design and its comparison with safety factor approach, reliability prediction of series, parallel and stand by systems.	10
	Total	**42**

11. Suggested Books:

S.	Name of Authors/ Books / Publisher	Year of

No.		Publication /Reprint
1	Faupel, J.H., and Fisher, F.E., "Engineering Design", Wiley-Interscience.	1981
2	Burr, A.H., "Mechanical Analysis and Design", Elsevier.	1982
3	Smith, N., "Advances in Creep Design", Applied Science.	1971
4	Bazovsky, I., Reliability Theory & Practice, Courier Dover Publications.	2004
5	Haugen, E.B., Probabilistic Approach Design, John Wiley.	1968
6	Yotaro Hatamura and Yoshio Yamamoto, "The Practice of Machine Design" Oxford University Press.	1999
7	Kai Cheng, "Machining Dynamics: Fundamentals, Applications and Practices" Springer.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-551** Course Title: **Dynamics of Mechanical Systems**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs.) : **Theory 3 Practical 0**
4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To impart knowledge of principles governing the motion of mechanical systems and to develop their skills in analysis and control of their motion.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic concepts**: Inertial coordinate system, fundamental laws of motion, mechanics of particles and system of particles, principles of linear and angular momentum, work-energy principles.	4
2	**Lagrangian dynamics**: Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Lagrange's equation from d'Alembert's principles, application of Lagrange's equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d'Alembert's principle, Lagrange equation from Hamilton's principle.	10
3	**Multi-body dynamics**: Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.	15
4	**Stability of motion**: Fundamental concept in stability, autonomous systems and phase plane plots, Routh's criteria for stability, Liapunov's method, Liapunov's stability theorems, Liapunov's function to determine stability of the system.	7
5	**Control system dynamics**: Open and close loop systems, block diagrams, transfer functions and characteristics equations, proportional integral and derivative control actions and their characteristics.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1	Ginsberg, J.H., "Advanced Engineering Dynamics", Harper and Row.	1988
2	Meirovitch, L., "Methods of Analytical Dynamics", McGraw Hill Inc.	1970
3	Harold Josephs and Ronald Huston, "Dynamics of Mechanical Systems", CRC Press.	2002
4	Katsuhiko Ogata, "System Dynamics",4th Ed., Prentice Hall;	2003
5	Robert L. Woods and Kent L. Lawrence, "Modeling and Simulation of Dynamic Systems", Prentice Hall.	1997
6	Ramin S. Esfandiari and Bei Lu, "Modeling and Analysis of Dynamic Systems", CRC Press.	2010
7	Dean C. Karnopp, Donald L. Margolis, and Ronald C. Rosenberg, "System Dynamics: Modeling and Simulation of Mechatronic Systems", 4th Ed., Wiley.	2006
8	Richard A. Layton, "Principles of Analytical System Dynamics" (Mechanical Engineering Series), Springer.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Mechanical & Industrial Engineering**

6. Subject Code: **MI-557** Course Title: **Finite Element Methods**

7. Contact Hours: **L: 3** **T: 1** **P: 0**

8. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

9. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Autumn/Autumn** 7. Subject Area: **PEC**

8. Pre–requisite: **NIL**

9. Objective: To provide the basic concepts of finite element method and its applications to wide range of engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts**: Introduction, Weak formulations, Weighted residual methods, Variational formulations, weighted residual, collocation, subdomain, least square and Galerkin's method, direct method, potential energy method	8
2.	**One-Dimensional Analysis**: Basis steps, discretization, element equations, linear and quadratic shape functions, assembly, local and global stiffness matrix and its properties, boundary conditions, applications to solid mechanics, heat and fluid mechanics problems, axisymmetric problems	8
3.	**Plane Truss**: Local and global coordinate systems, stress calculations, example problems	3
4.	**Beams**: Introduction, Euler-Bernoulli beam element, numerical problems	3
5.	**Scalar Field Problems in 2-D**: Triangular and rectangular elements, constant strain triangle, isoparametric formulation, higher order elements, six node triangle, nine node quadrilateral, master elements, numerical integration, computer implementation, Numerical problems	10
7.	**Plane Elasticity**: Review of equations of elasticity, stress-strain and strain-displacement relations, plane stress and plane strain problems	4
8.	**Bending of Elastic Plates**: Review of classical plate theory, plate bending elements, triangular and rectangular elements, Shear deformation plate theory, numerical problems	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Huebner K.H., Dewhirst, D. L., Smith, D. E., and Byrom, T. G., "The Finite Element Method for Engineers", 4th Ed., John Wiley and Sons	2001
2.	Rao, S. S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science	2005
3.	Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill	2005
4.	Fish, J., and Belytschko, T., "A First Course in Finite Elements", 1st Ed., John Wiley and Sons	2007
5.	Chaskalovic J., "Finite Element Methods for Engineering Sciences", 1st Ed., Springer	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-561** Course Title: **Advanced Mechanical Vibrations**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 20** **PRS 20** **MTE 20** **ETE 40** **PRE 0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide detail knowledge about nonlinear and random vibration with fault diagnosis of machinery.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Review of free and forced vibrations with and without damping.	3
2	**Isolation:** Vibration isolation and transmissibility; Un-damped vibration absorbers.	4
3	**Multi degree of freedom system**: Generalized coordinates and coordinate coupling; Orthogonality of modes, Free and forced vibration of multi-degree of freedom systems with and without viscous damping; Lagrange's equation; Holzer's method. Solution of Eigen value problem, transfer matrix and modal analysis.	12
4	**Stability criterion:** Self excited vibrations; Criterion of stability; Effect of friction on stability.	4
5	**Non linear vibration:** Free vibrations with non-linear spring force or nonlinear damping; Phase plane; Energy curves; Lienard's graphical construction; Method of isoclines.	5
6	**Vibration of continuous system:** Vibrations of strings; Free and forced longitudinal vibrations of prismatic bars; Ritz and Galerkin methods.	6
7	**Random vibration:** Mathematical descriptions of stochastic processes; Stationary and ergodicity; Gaussian random process, correlation functions and power spectral density.	4
8	**Diagnostic techniques:** Introduction to diagnostic maintenance and signature analysis.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Rao, S.S., "Mechanical Vibrations", 4th Ed., Pearson Education.	2007
2	Meirovitch, L., "Fundamental of Vibrations", Mc-Graw Hill.	2001
3	Inman, D.J., "Vibration and Control", John Willey & Sons.	2002
4	Tamadonni, S. and Kelly, G.S., "Mechanical Vibrations", Mc-Graw Hill.	1998
5	Rao, J. S., "Vibration Condition Monitoring of Machines", Tata Mc-Graw Hill.	2006

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-563** Course Title: **Mechatronics**

2. Contact Hours: **L: 3 T: 1 P: 2/2**

3. Examination Duration (Hrs.): **Theory 3 Practical 0**

4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits: 4 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **Nil**

9. Objective: The course deals with basic principles of Mechatronics involving sensors, actuators, control systems, and microprocessor systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach.	2
2	**Sensors and Transducers**: Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches.	7
3	**Actuators**: Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems.	5
4	**Signal Conditioning**: Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems.	4
5	**Microprocessors and Microcontrollers**: Microcomputer structure, microcontrollers, applications, programmable logic controllers.	8
6	**Modeling and System Response**: Mathematical models, bond graph models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.	9
7	**Design and Mechatronics**: Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Bolton, W., "Mechatronics", Longman.	1999
2	Alciatore, D. G. and Histrand, M. B., "Introduction to Mechatronics", Tata McGraw Hill.	2003
3	Shetty, D. and Richard, A.K., "Mechatronics System Design", PWS Pub. Boston.	1997
4	Mahalik, N., "Principles, Concept and Applications: Mechatronics", Tata McGraw.	2003
5	Bishop, R.H. "Mechatronics Handbook", CRC Press.	2002
6	Bolton, W., "Mechatronics: A Multidisciplinary Approach", 4th Ed., Prentice Hall.	2009
7.	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**: MI-565** Course Title**: Smart Materials, Structures and Devices**

2. Contact Hours **: L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.)**: Theory 3 Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge on analysis of smart materials for various applications such as sensors, actuators and controllers with reference to various structures and devices.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Intelligent Materials**: Primitive functions of intelligent materials; Intelligence inherent in materials; Materials intelligently harmonizing with humanity; Intelligent biological materials.	2
2	**Smart Materials and Structural Systems**: Actuator materials; Sensing technologies; Microsensors; Intelligent systems; Hybrid smart materials; Passive sensory smart structures; Reactive actuator-based smart structures; Active sensing and reactive smart structures; Smart skins.	4
3	**Electro–Rheological Fluids**: Suspensions and electro, reheological fluids; The electro- rheological phenomenon; Charge migration mechanism for the dispersed phase; Electro rehological fluid actuators.	4
4	**Piezoelectric Materials**: Background; Piezoelectricity; Industrial piezoelectric materials; Smart materials featuring piezoelectric elements.	3
5	**Shape Memory Materials**: Background on shape memory alloys; Applications of shape memory alloys; Continuum applications: structures and machine systems; Discrete applications; Impediments to applications of shape memory alloys; Shape memory plastics.	4
6	**Fiber Optics**: Overview; Light propagation in an optical fiber; Embedding optical fibers in fibrous polymeric thermosets; Fiberoptic strain sensors.	3
7	**The Piezoelectric Vibrations Absorber Systems**: Introduction; The single mode absorber, theory, design solution, extension including viscous modal damping, the electromechanical coupling coefficient, inductance, experimental results; The multimode absorber, derivation of transfer function, design solution, self-tuning absorber, performance function, control scheme.	7
8	**Modeling of Shells:** Derivation of the basic shell equations, equation of motion, equations for specific geometries and cylindrical shell.	10

9	**Modeling of plates and beams:** Plate equations and beam equations.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Gandhi, M. V. and Thompson, B. S., "Smart Materials and structures", Chapman & Hall.	1992
2	Banks, H. T., Smith, R. C. and Qang, Y. W., "Smart Material structures: Modeling, Estimation and Control", John Wiley & Sons.	1996
3	Gabbert, U. and Tzou, H. S., "Smart Structures and Structronic System", Kluwer Academic Publishers.	2001
4	Preumont, A., "Vibration Control of Active Structures", Kluwer Academic Publishers.	2002
5	Cheng, F. Y., Jiang, H. and Lou, K., "Smart Structures: Innovative Systems for Seismic Response Control", CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code:**MI-566** Course Title: **Computer Aided Analysis of Mechanical Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objectives: To introduce computer-based design tools for analyzing the kinematics and dynamics of mechanical systems.

10. Details of Course:

S. No.	Particulars	Contact Hours
1	**Introduction**: Introduction to mechanical systems analysis.	2
2	**Kinematic Modeling**: Modeling the kinematics of mechanical systems; Vector loop methods, vector chain methods.	4
3	**Solution of Kinematic Models**: Solution of kinematic models for displacements, velocities, accelerations; Direct analytical solutions of position, velocity, acceleration problems; Numerical solution of position problem; Matrix method solutions of velocity and acceleration problems.	8
4	**Dynamic Modeling**: Modeling the dynamics of mechanical systems; Newton-Euler methods to define dynamic constraints between forces, moments, and accelerations, energy methods to define dynamic constraints between input and output links.	6
5	**Solution of Dynamics Models:** Solution of inverse dynamics models for joint-link forces and torques, solution of forward dynamics models using numeric integration, model formulation into standard format for solution, Euler's method of integration, Runge-Kutta methods of integration, modeling and analysis of the Trebuchet mechanism.	14
6	**Advanced Dynamic Analysis & Simulation**: Bond graph modeling of dynamic systems, generation of system equations, causality, and simulation.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Norton R., "Design of Machinery", McGraw-Hill	1992
2	Palm W. J., "Introduction to MATLAB 6 for Engineers", McGraw-Hill	2000
3	Nikravesh, P. E., "Computer-Aided Analysis of Mechanical Systems", Prentice Hall.	1988
4	Haug, E. J., "Computer Aided Analysis and Optimization of Mechanical System Dynamics", Springer-Verlag.	1984
5	Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in Modeling, Simulation and Fault Identification", I & K International.	2007

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-567** Course Title: **Computer Graphics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: The course aims is to provide the basics of Computer Graphics needed for CAD/ CAM applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Role of Computer Graphics in CAD/CAM, configuration of graphic workstations, menu design and Graphical User Interfaces (GUI), customization and parametric programming.	04
2	**Geometric Transformations and Projections:** Vector representation of geometric entities, homogeneous coordinate systems, fundamentals of 2D and 3D transformations: Reflection, translation, rotation, scaling, and shearing, various types of projections.	08
3	**Curves:** Modeling planar and space curves, analytical and synthetic approaches, non-parametric and parametric equations.	08
4	**Surfaces:** Modeling of bi-parametric freedom surfaces, Coons, Bezier, B-spline, and NURBS surfaces, surface manipulation techniques.	08
5	**Geometric Modeling:** Geometric modeling techniques, wireframe modeling, solid modeling: B-Rep, CSG, hybrid modelers, feature based, parametric and variational modeling.	10
6	**Data Structure in Computer Graphics:** Introduction to product data standards and data structures, data-base integration for CIM.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Rogers, D. F., and Adams, J. A., "Mathematical Elements for Computer Graphics", McGraw Hill.	1989
2	Faux, I. D. and Pratt, M. J., "Computational Geometry for Design and Manufacture", Ellis Horwood Ltd.	1979
3	Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press.	2006
4	Zeid, I., "CAD/CAM: Theory and Practice", Tata McGraw Hill.	1998
5	Choi, B. K., "Surface Modeling for CAD/CAM", John Wiley & Sons	1991

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-568** Course Title: **Advanced Robotics**

5. Contact Hours: **L: 3** **T: 1** **P: 2/2**

6. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

7. Relative Weight : **CWS** **20** **PRS** 20 **MTE** **20** **ETE** **40** **PRE** 0

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To impart knowledge of robotic vision systems, robot modeling, trajectory planning, manipulator control, and design and control issues of mobile robots, space robots etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Review, forward and inverse kinematics, dynamics	02
2	**Robots with Flexible Elements**: Robots with Flexible Joints, Robots with Flexible Links	04
3	**Parallel Mechanisms and Robots:** Definitions, Type Synthesis of Parallel Mechanisms, Kinematics, Velocity and Accuracy Analysis, Singularity Analysis, Workspace Analysis, Static Analysis and Static Balancing, Dynamic Analysis, Design	06
4	**Mobile Robots:** **Wheeled mobile robots:** mobile robot kinematics, Mobility of Wheeled Robots, State-Space Models of Wheeled Mobile Robots, Wheeled Robot Structures, sensors for mobile robots, planning and navigation **Legged robots:** Analysis of Cyclic Walking, Control of Biped Robots Using Forward Dynamics, Biped Robots in the ZMP Scheme, Multilegged Robots, Performance Indices	08
5	**Cooperative Manipulators**: Kinematics and Statics, Cooperative Task Space, Dynamics and Load Distribution, Task-Space Analysis, Control	03
6	**Advanced Robots:** Modeling and control of space robots, underwater robots	06
7	**Control of Manipulators:** Manipulator control problem; Linear and non linear control schemes; PID control scheme; Force control.	04
8	**Image Processing and Analysis with Vision Systems**: Acquisition of images, digital images, image processing techniques, noise reduction, edge detection, image analysis, object recognition by features, application of	05

	vision systems	
9	**Fuzzy Logic Control:** Crisp values v/s fuzzy values, fuzzy sets: Degrees of membership and truth, fuzzification, fuzzy inference rule base, defuzzification, simulation of fuzzy logic controller, application of fuzzy logic in robotics	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1	Niku, S. B., "Introduction to Robotics: Analysis, Systems, Applications", Prentice Hall.	2001
2	Angeles, J., "Fundamentals of Robotic Mechanical Systems: Theory, Methods and Algorithms", Springer	2003
3	Craig, J. J., "Introduction to Robotics: Mechanics & Control", Addison Wesley.	1989
4	Siegwart, R., Nourbakhsh, I. R., "Introduction to Autonomous Mobile Robots", MIT Press.	2004
5	Xu, Y. and Kanade, T., "Space Robotics: Dynamics and Control", Kluwer Academic Publishers.	1993
6	Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer	2013
7	Siciliano, Bruno, Khatib, Oussama, Handbook of Robotics, Springer	2008
8	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-569** Course Title: **Expert Systems Design**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To cover concepts, techniques and tools for developing expert systems for various engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Overview: Evolution and characteristics of knowledge-based systems.	02
2	**Introduction to Expert System Languages:** CLIPS (C language integrated production system) and JESS (java expert system shell).	06
3	**Pattern Matching**: Basic and advanced pattern matching techniques.	04
4	**Modular Design and Control**: Salience, phases and control facts, modules and execution control	04
5	**Knowledge Representation**: Productions, semantic nets, schemata, frames, logic and set.	04
6	**Methods of Inferences**: Inference rules, resolution system, forward and backward chaining.	04
7	**Reasoning under Uncertainty**: Hubert Dreyfus "From Socrates to Expert Systems: The Limits and Dangers of Computational Rationality" -- CSUS Library video collection, hypothetical reasoning and backward induction, temporal reasoning and Markov chains, uncertainty in inference chains; Probability-based techniques: Objective probability, experimental probability, subjective probability, Bayes' theorem, inexact or heuristic reasoning; Inexact reasoning: uncertainty and rules, certainty factors, Dempster-Shafer theory.	12
8	**Design of Expert Systems**: Approximate reasoning, fuzzy expert systems.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Giarratano, J. C. and Riley, G. D., "Expert Systems: Principles and Programming", 4th Ed., Course Technology.	2004
2	Gonzalez, A., and Dankel, D., "The Engineering of Knowledge-Based Systems", Prentice Hall.	1994
3	Jackson, P., "Introduction to Expert Systems", 3rd Ed., Addison Wesley.	1998
4	Akerkar, R. and Sajja, P., "Knowledge-Based Systems", Jones & Bartlett Publishers.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-575** Course Title: **Product Design and Development**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To expose the students to the concept of design for X, concurrent engineering, reverse engineering, and rapid prototyping techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Product Design**: Traditional and modern design processes; Organization objectives; Innovation, creation, and diffusion techniques; Evaluation of new product ideas – functional, technological, ecological, legal.	06
2	**Product Modeling and Reverse Engineering:** Wireframe modeling; Surface modeling – boundary representation; Solid modeling – CSG; Concept of reverse engineering.	08
3	**Product Data Exchange**: Neutral file formats for product data exchange – DXF, IGES, STEP.	06
4	**Concurrent Engineering**: Concept of concurrent engineering; Design for X; Design for manufacturability (DFM); Design for assemblability (DFA); Design for reliability (DFR); Design for quality (DFQ).	10
5	**Rapid Prototyping (RP) Methods:** Liquid based RP methods – stereolithography apparatus (SLA), solid ground curing (SGC), solid creation system (SCS), etc.; Solid based RP methods: Fused deposition modeling (FDM), laminated object manufacturing (LOM), etc.; Powder based RP methods– selective laser sintering (SLS), 3D printing (3DP), ballistic particle manufacturing (BPM), etc.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1	Andrearsen, M. M., and Hein, L., "Integrated Product Development", Springer.	1987
2	Huang, G. Q., "Design for X: Concurrent Engineering Imperatives", Chapman and Hall.	1996
3	Chitale, A. K. and Gutpa, R. C., "Product Design and Manufacturing", Prentice Hall.	1997
4	Zeid I., "CAD/CAM: Theory and Practice", Tata McGraw Hill.	1998
5	Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press.	2006
6	Boothroyd G., Dewhurst P., and Knight, "Product Design for Manufacture and Assembly", 2nd Ed., Marcel Dekker.	2002
7	Chua, C. K and. Leong, K. F., "Rapid Prototyping: Principles and Applications in Manufacturing", John Wiley & Sons.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**: MI-576** Course Title**: Machine Tool Design and Numerical Control**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** **0** **ITE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**:** Autumn/**Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To introduce various components of numerically controlled machine tools and their application in automated manufacturing systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Machine Tool Design**: General requirements; Electrical and hydraulic drives of machine tools; Layout of gear boxes; Hydraulic, electric and mechanical stepless speed regulations; Design and analysis of guideways; Bed, column, spindle and power screw.	15
2	**Numerical Control (NC):** Introduction to numerical control; Components of NC systems; Open and close loop NC; Types of numerical control: Point-to-point, straight cut, and continuous path NC; Drives and controls; NC-tape coding standards; Coordinate and positioning systems – Cartesian and polar; Reference zero points; NC interpolations – linear, circular, helical, parabolic and cubic interpolation; Applications of NC systems.	6
3	**NC Part Programming Methods**: Structure of NC part program; NC word formats; Introduction to G and M codes; Manual programming methods; Computer-assisted programming methods; APT part programming.	10
4	**Extensions of NC**: Concepts of CNC, machining center, and DNC; Types of CNC systems; Introduction to post processors; Tooling for NC/CNC.	3
5	**CNC Part Programming**: Tool motion commands; Tool length offset; Cutter diameter compensation command; fixed cycle command; Scaling; rotation; Mirror image; Macros programming etc.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1.	Mehta, N. K., "Machine Tool Design and Numerical Control", 2nd Ed., Tata McGraw Hill.	1996
2.	Koren, Y., "Computer Control of Manufacturing Systems", McGraw Hill.	1983
3.	Rapello, R. G., "Essentials of Numerical Control", Prentice Hall.	1986
4.	Chen, S, and Lin, J., "Computer Numerical Control: From Programming to Networking", Thomson Delmer Learning.	1994
5.	Sava, M., and Pusztai, J., "Computer Numerical Control Programming", Prentice Hall.	1990
6.	Rao, P. N., Tewari, N. K, and Kundra, T. K., "Computer Aided Manufacturing", Tata McGraw Hill	1993
7.	Steve, K. and Gill A., " CNC Technology and Programming", McGraw Hill.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-577** Course Title: **Industrial Automation**
2. Contact Hours : **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory 3** **Practical 0**
4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre – requisite**: Nil**
9. Objective: To introduce the concepts of automation theory and its applications in various fields of manufacturing.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts**: Introduction of mechanization and automation, classification and strategies of automation, reasons for and arguments against automation, mechanical, electrical, hydraulic, and pneumatic devices and controls.	6
2.	**High Volume Manufacturing**: Automated flow lines, types of automatic transfer mechanisms, design and fabrication considerations, analysis of automated flow lines.	6
3.	**Assembly Systems**: Assembly systems and their types, manual assembly lines and line balancing.	4
4.	**Assembly Automation**: automated assembly lines and their types, automatic assembly transfer systems, automatic feeding and orienting devices- vibratory and mechanical feeders and their types, orientation of parts, performance and economics of assembly systems, feasibility study for assembly automation.	12
5.	**Design for Assembly**: Design for manual assembly, design for high-speed automatic assembly, design for robot assembly.	4
6.	**Flexible Automation**: Introduction of group technology (GT), steps in implementing Group Technology (GT), part families and machine cell formation, introduction of flexible manufacturing systems (FMS).	6

7.	**Programmable Automation**: Brief introduction of numerical control (NC), computer numerical control (CNC), machining centers, programmable robots, direct numerical control (DNC) and adaptive control.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Groover, M. P., "Automation, Production systems and Computer Integrated Manufacturing", 2nd Ed., Prentice Hall.	2005
2.	Boothroyd, G., "Assembly Automation and Product Design", 2nd Ed., Marcel Dekker.	1992
3.	Boothroyd, G., Dewhurst, P. and Knight, W., "Product Design for Manufacture and Assembly", 2nd Ed., Taylor & Francis.	2002
4.	Boothroyd, G., Poli, C. and Murch, L. E., "Automatic Assembly", Marcel Dekker.	1982
5.	Tergan, V., Andreev, I. and Lieberman, B., "Fundamentals of Industrial Automation", Mir Publishers.	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-578** Course Title: **Computer Aided Process Planning**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre– requisite: **Nil**

9. Objective: To impart knowledge on the integration of design and manufacturing functions leading to the concepts of process planning.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: traditional process planning, product design evaluation, various steps in process planning.	5
2.	**Group Technology**: Introduction, advantages, part families, classification and coding systems, production flow analysis, design of machine cells.	10
3.	**Concepts Related to Process Planning**: Machinability data system, cutting condition optimization.	5
4.	**Automated Process Planning**: Advantages of automated process planning, various approaches to process planning; Variant process planning, its features and different stages, different variant systems; Generative and semi-generative process planning, its features, design strategies, planning, modeling and coding scheme, decision mechanisms; Process capability analysis, intelligent process planning system; Artificial intelligence -- overview and application in process planning; Various recent process planning systems; Case studies.	12
5.	**Interfaces of Process Planning**: Integrating with loading, scheduling, MRP II, and capacity planning and other shop floor functions.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Chang, T. C. and Wysk, R. A, "An Introduction to Automated Process Planning", Prentice-Hall.	1985
2.	Gallagher, C. C and Knight, W. A., "Group Technology: Production Method in Manufacturing", Ellis Horewood.	1986
3.	Nilsson, N. J., "Principles of Artificial Intelligence", Springer Verlag.	1982
4.	Cornelius, L.T, "Computer Aided and Integrated Manufacturing Systems: Manufacturing Processes", World Scientific Publishing Company.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-579** Course Title**: Information Systems and Data Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To expose the students to various information systems and to familiarize with data based systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Role of information system, the function of information system, determination of informational need	4
2	**Information Processing Concepts:** Historical perspective, today's status, systems approach and analysis, concepts of data and information, data collection, data or information, data and information storage, data processing and information generation, transmission of data and information and the information economics of information	10
3	**Information System Analysis:** Overview of system, management and formal information systems, hierarchical and system approach to information systems design and their applications, tailoring the information system to meet specific information requirements using filtering monitoring, interrogative and external methods.	14
4	**Data Base Management System:** Introduction to data base concepts, difference between a file system and a data base systems, goals of DBMS including data independence consistency, data security and integrity; DBMS models hierarchical network and relation, data description and query language, physical database design case studies, system R, Ingress, IDMS etc.; Introduction to distributed database, concurrency control bases recovery etc.	14
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Henry Luces C., "Information Systems Concepts for Management", McGraw Hill.	1978
2	Burch, J. G. and Grudnitski, G., "Information Systems Theory and Practice", John Wiley & Sons.	1989
3	Walker, D. W., "Computer Based Information System An Introduction", Pergamon Press.	1989
4	Mark L. Gillenson, "Fundamentals of Database Management Systems", John Wiley & Sons.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**:** **MI-582** Course Title: **Flexible Manufacturing Systems**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**
4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**
5. Credits: **4** **6.** Semester**: Autumn/Spring** **7**. Subject Area: **PEC**
8. Pre – requisite**: Nil**
9. Objective**:** To introduce the concepts of flexibilities and its importance in batch manufacturing, various types of FMS configurations and their planning and control.
10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	**Introduction**: Definition and classification of manufacturing systems, fundamentals of automated production cycle, need of flexibility, concept of flexibility, various types of flexibility, measures of flexibility.	7
2.	**Flexible Manufacturing System (FMS) Type**: Introduction of FMS, definition of FMS, types of FMS, applications of FMS, FMS configuration, FMS host operator interface.	10
3.	**FMS Planning and Control**: Functional requirements of FMS equipments, functions of FMS host computer, host system design, planning, scheduling of FMS, FMS simulation, Databases in FMS, GT in FMS, cell design and layout design, CAPP in FMS.	14
4.	**Material handling in FMS**: Material handling principles in FMS, applications of robots in FMS.	6
5.	**Case Studies**: Cases on FMS installation and implementation –acceptance testing and maintenance	5
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Books / Authors / Publisher	Year of Publication /Reprint
1.	Groover, M. P., "Automation, Production System and CIM", 2nd Ed., Prentice Hall.	2000
2.	Rankey, P., "Design and Operations of FMS", North-Holland Publishing.	1983
3.	Warnecke, H. J. (Ed.), "Flexible Manufacturing System", Springer.	1985
4.	Bonetto, R., "FMS in Practice", North Oxford Academic Publishers.	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MI-584** Course Title**: Operations Research**
2. Contact Hours **: L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory: 3** **Pra 0**
4. Relative Weight **:CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite**: Nil**
9. Objective**:** To introduce various optimization techniques for· formulating, solving various industrial problems, develop production and service units as a system.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** definition and scope of OR; Techniques and tools; Model formulation; general methods for solution; Classification of optimization problems; Optimization techniques.	2
2.	**Linear Optimization Models:** Complex and revised simplex algorithms; Duality theorems, sensitivity analysis; Assignment, transportation and transshipment models; Traveling salesman problem as an assignment problem; Integer and parametric programming; Goal programming.	12
3.	**Game Problems:** Mini-max criterion and optimal strategy; Two person zero sum game; Games by simplex dominance rules.	6
4.	**Waiting Line Problems:** Classification of queuing situations; Kendall's notation, Poisson arrival with exponential or Erlang service time distribution; Finite and infinite queues; Optimal service rates; Application of queuing theory to industrial problems.	8
5.	**Dynamic Programming:** Characteristic of dynamic programming problems (DPPs); Bellman's principle of optimality; Problems with finite number of stages; Use of simplex algorithm for solving DPPs.	6
6.	**Non-linear Programming:** One dimensional minimization methods; Unconstrained optimization techniques; Optimization techniques-characteristics of a constrained problem; Indirect methods; Search and gradient methods.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication /Reprint
1.	Taha, H. A., "An Introduction to Operations Research", 6th Ed., Prentice Hall.	2006
2.	Hillier, F. J. and Lieberman, G. J., "Introduction to Operations Research", 7th Ed., Holden Day.	2001
3.	Phillips, D. T, Ravindran, A. and Solberg, A. A., "Operations Research: Principles and Practice", 2nd Ed., John Wiley and Sons.	1986
4.	Wagner, H. M., "Principles of OR with Applications to Managerial Decisions", 2nd Ed., Prentice Hall.	1975
5.	Jensen, P. A, and Bard, J. F., "Operations Research Models and Methods", John Wiley and Sons.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT/CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MI-602** Course Title: **Bond Graph Modeling of Engineering Systems**

2. Contact Hours : **L: 3** **T:1** **P: 2/2**

3. Examination Duration (Hrs.) : **Theory 3** **Practical** 0

4. Relative Weight :**CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** 0

5. Credits: 4 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **NIL**

9. Objectives of Course: To introduce the basics of bond graph modeling, causality assignment and generation of system equations. Use of bond graphs in various engineering systems for fault detection and isolation will also be introduced.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: An invariant nature of power exchange, power variables of bond graph, representation of junction elements, reference power directions on the bonds, bond graph standard elements, constitutive laws of single port elements, 2 port elements, 3 port junction elements, mechanical 1 and 0 junctions	02
2	**Causality**: Notion of causality, causality of sources, causality of I, C and R elements, causality of junction elements, causality of two port elements, differential causality, algorithm for assigning causality, examples of assignment of causality	04
3	**Creation of System Equations**: Selection of system states, generation of system equations, a bond graph with a transformer element, electrical systems, systems with differential causality, activation and activated bonds, fields, algebraic loops.	08
4	**Creation of System Bond graph**: basic guidelines. Bond graphs for mechanical systems: method of flow map, method of effort map, method of mixed map. Bond graph of electrical circuits: method of gradual uncover, point potential method, mixed method, gyrator and transformer equivalents	08
5	**Use of non-inertial coordinates**: principle of material objectivity, mapping back to inertial frame, rate of change of generalized momenta, dynamics of rigid bodies,	02
6	**Structural members**: Euler-Bernoulli beam model, Rayleigh beam model, Timoshenko beam model, consistent inertia field, modal bond graph of a continuous system.	03
7	**Modeling of multi body systems**: modeling of mechanisms, modeling of mechanical handling systems, robots.	04

8	**Approaching Control System**: signal flow graph from bond graph, application of bond graph to control systems, proportional control, proportional-integral control, proportional-integral-derivative control, velocity control of moving cars connected by springs, modeling of electronic circuits: modeling of operational amplifiers, semiconductor diode	05
9	**Fault Detection and Isolation (FDI):** classification of FDI procedures, structural controllability and observability, Fault diagnosis using bond graphs, Qualitative FDI, Quantitative FDI, Analytical redundancy relations (ARR) from bond graph model, fault tolerant control	06
	Total	42

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Mukherjee A., Karmarkar R. and Samantray A. K., "Bondgraph in Modeling Simulation and Fault Identification", I. K. International Publishing House Pvt. Ltd.	2006
2	Borutzky, Wolfgang, "Bond Graph Modelling of Engineering Systems", Springer	2011
3	Karnopp Dean C. , Margolis Donald L. , Rosenberg Ronald C., "System Dynamics: Modeling, Simulation, and Control of Mechatronic Systems", Wiley	2012
4	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013
5	Breedveld Peter C., Geneviève Dauphin-Tanguy, "Bond Graphs for Engineers",Elsevier Science Publishers, Amsterdam.	1992

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MI-608** Course Title:**Product and Process Optimization**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: This course will introduce to the students, the basic concepts, techniques and applications of engineering optimization in a comprehensive manner.

10. Details of Course:

S. No.	Contents	Contact Hrs
1.	**Introduction to Design Optimization:** The design process; basic terminology and notations.	2
2.	**Optimum Design Problem Formulation:** The problem formulation process; and illustration with examples.	3
3.	**Graphical Optimization:** Graphical solution process; problems with – bounded (single or multiple) and unbounded solutions.	3
4.	**Optimum Design Concepts:** Local and global optima; necessary and sufficient optimality conditions for unconstrained and constrained multivariate functions.	6
5.	**Linear Programming Methods for Optimum Design:** Basic concepts; simplex method; two-phase simplex method; post-optimality analysis.	4
6.	**Numerical methods for Unconstrained and Constrained Optimum Design:** Gradient-based and direct search methods; Sequential linear and quadratic programming.	6
7.	**Multi-objective Optimization:** Fundamental shift from single-objective optimization; Pareto-set and Pareto-optimal Front.	4
8.	**Evolutionary Techniques for Optimization:** Genetic algorithms; Differential Evolution Algorithms; Ant colony Optimization; and Particle Swarm Optimization.	6
9.	**Advanced topics on Optimum Design:** Meta models for design optimization; design of experiments; discrete design with orthogonal arrays; robust design approach; reliability-based design optimization.	4
10.	**Practical applications of optimization:** Illustration on engineering	4

	problems with single and multiple objectives.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	S. S. Rao; Engineering Optimization; 4th Edition, John Wiley & Sons.	2009
2.	K. Deb; Optimization for Engineering Design; Prentice Hall of India.	2005
3.	K. Deb; Multi-objective Optimization using Evolutionary Algorithms; John Wiley & Sons.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-509** Course Title: **Extended Finite Element Methods**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory 3** **Practical 0**

4. Relative Weight : CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the recent developments in field of finite element analysis for a better engineering design.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic Concepts of Finite Element Methods**: Introduction, weighted residual and weak formulations, variational methods, numerical problems.	4
2	**Finite Element in 1-D**: Basis steps of finite element analysis, Applications to solid mechanics, heat transfer and fluid flow problems.	6
3	**Finite Element in 2-D**: Single variable problems in 2-D, applications to solid mechanics and heat transfer problems, numerical integration, higher order shape functions, plane stress and plane strain problems.	8
4	**Basics of Extended Finite Element Method (XFEM)**: Brief introduction, partition of unity finite element method (PUFEM), generalised finite element method (GFEM), introduction to XFEM, blending elements, concept of level sets and enrichment	8
5	**Engineering Applications**: XFEM on element level: shape functions, displacement, strain, element stiffness matrix, XFEM for weak and strong discontinuities e.g. e.g. static cracks, crack growth, bi-materials, phase change problems.	8
6	**Advanced Concepts of XFEM**: Concept of phantom nodes, tracking the crack path, embedded elements, interface elements, introduction to cohesive zone models, embedded elements, crack initiation/propagation, smeared cracks.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publisher	Year of Publication/Reprint
1	Rao, S.S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science.	2005
2	Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill.	2005
3	Fish, J., and Belytschko, T., "A First Course in Finite Elements", John Wiley and Sons.	2007
4	Chaskalovic J., Finite Element Methods for Engineering Sciences, Springer.	2008
5	Mohammadi, S., "Extended Finite Element Method", Blackwell Publisher.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-511A** Course Title: **Modeling and Simulation**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To cover concepts, techniques and tools for modeling and simulation of thermal systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Modeling**: Concept of system, continuous and discrete systems, types of models, steps in simulation study.	2
2.	**Mathematical Preliminaries:** Review of vector calculus, Cartesian tensors, vector spaces and linear transformations; Interpolation and extrapolation; Numerical differentiation and integration.	6
3.	**Discrete and Continuous systems:** Continuous and discrete systems from fluid mechanics and heat transfer; Characteristics of discrete systems, eigenvalue problems; Characteristics of continuous systems based on differential equations; Inverse problems.	6
3.	**Mathematical Modeling of Thermal Processes**: Conservation laws, mass, momentum and energy balance; Classification of governing equations, boundary conditions; Dimensional analysis, model development for various thermal processes and system; Dynamics of thermo-fluid systems.	10
4.	**Simulation of Thermal Systems:** Numerical methods for solution of partial and ordinary differential equations; Numerical solution of linear and nonlinear algebraic equations; Numerical simulation of steady state and dynamic systems.	12
5.	**Optimization of Thermal Systems:** Introduction to optimization, formulation of objective function, constrained single and multivariable optimization, dynamic integer and geometric programming.	6
	Total	**42**

Laboratory Component: Students will be required to develop mathematical models and computer programs for numerical simulation of various thermal systems.

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Jaluria, Y., "Design and Optimization of Thermal Systems", 2nd Ed., CRC Press.	2007
2.	Bejan, A., Tsatsaronic, G., and Moran, M., "Thermal Design and Optimization", John Wiley & Sons.	1995
3.	Close, C. M., and Frederick, D. K., "Modeling and Analysis of Dynamic Systems", John Wiley & Sons.	2001
4.	Jaluria, Y. "Computer Methods for Engineering with MATLAB Applications", 2nd Edition, CRC Press.	2011
5.	Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P., "Numerical Recipes: The Art of Scientific Computing", Third Edition, Cambridge University Press	2007

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-511B** Course Title: **Modeling and Simulation**

2. Contact Hours: **L: 3 T: 1 P: 2/2**

3. Examination Duration (Hrs.): **Theory 3 Practical 0**

4. Relative Weight : **CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To cover concepts, techniques and tools for modeling and simulation of thermal systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Systems and models, examples of models, models for systems and signals.	4
2	**Physical modeling:** Principles of physical modeling, basic relationship, bond graphs, and computer aided modeling.	4
3	**Mathematical modeling:** Estimating transient response, spectra and frequency functions, parameter estimation in dynamic models, system identification as a tool for model building.	6
4	**Numerical methods:** Ordinary differential equations (ODE); Euler's Method, Trapezoidal Method, Runge–Kutta Method, Predictor–Corrector Method, Boundary Value Problems, Shooting Method, Finite Difference Method, Elliptic partial differential equations (PDE), Parabolic PDE (Explicit Forward Euler Method, Implicit Backward Euler Method, Crank–Nicholson Method, Two-Dimensional Parabolic PDE), Hyperbolic PDE (Explicit Central Difference Method, Two-Dimensional Hyperbolic PDE)	12
5	**Simulation and Simulation application:** Numerical prototyping as modeling for design and synthesis using computational tools, Introduction to techniques for validation of models, Simulation of electromechanical, thermo-mechanical, hydraulic and pneumatic elements.	10
6	**Modeling and Simulation for Optimization:** Introduction to the concept of optimization, the basic terminology and notations; modeling process; and illustration with modeling of engineering problems. Graphical solution process; problems with – bounded (single or multiple) and unbounded solutions. Local and global optima; necessary and sufficient optimality conditions for unconstrained and constrained multivariate functions.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1	Gordon, G., "System Simulation", Prentice Hall.	1978
2	Lennart, L. and Torkel, G., "Modeling of Dynamic Systems" Prentice Hall.	1994
3	Bhonsle, S.R. and Weinmann, K.J., "Mathematical Modeling for Design of Machine Components", Prentice Hall.	1998
4	D'Souza, A.F., and Garg, V.K., "Advanced Dynamics: Modeling and Analysis", Prentice-Hall.	1983
5	Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in Modeling, Simulation and Fault Identification", I & K International.	2007
6	S. S. Rao; Engineering Optimization; 4th Edition, John Wiley & Sons.	2009
7	K. Deb; Optimization for Engineering Design; Prentice Hall of India.	2005
8	K. Deb; Multi-objective Optimization using Evolutionary Algorithms; John Wiley & Sons.	2003

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-515** Course Title: **Manufacturing Systems Analysis**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To teach students various tools and techniques used for the performance analysis of manufacturing systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Definitions of manufacturing with input-output model, definition of system, basic problems concerning systems and system design procedure, modes of manufacturing – job/batch/flow and multi-product, small-batch manufacturing.	4
2	**System Modeling Issues:** Centralized versus distributed control; Real-time vs. discrete event control; Forward vs. backward scheduling approaches with finite/infinite capacity loading; Modeling of absorbing states and deadlocks; Conflicts; Concurrency, and synchronization etc.	8
3	**System Modeling Tools and Techniques:** Introduction to mathematical modeling, optimization, and simulation; Issues related with deterministic and stochastic models; Continuous and discrete mathematical modeling methods - discrete event, monte carlo method; Basic concepts of Markov chains and processes; The M/M/1 and M/M/m queue; Models of manufacturing systems - including transfer lines and flexible manufacturing systems, introduction to Petri nets.	15
4	**Performance Analysis:** Transient analysis of manufacturing systems, analysis of a flexible machining center; Product flow analysis; Rank order clustering; Process flow charting; MRPI & II, kanban, OPT, JIT-pull and JIT-push, line of balance, effects of machine failure, set-ups, and other disruptions on system performance; Calculation of performance measures - throughput, in-process inventory, due dates, MTL, capacity, and machine utilization etc.; Critique of high inventory, long lead time systems; Shop floor control issues.	15
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Askin, R. G., and Standridge, C. R., "Modeling and Analysis of Manufacturing Systems", John Wiley & Sons.	1993
2.	Gershwin, S. "Manufacturing Systems Engineering", Prentice-Hall.	1994
3.	Hitomi, K., "Manufacturing Systems Engineering", Taylor & Francis.	1998
4.	Viswanadham N. and Narahari Y. "Performance Modeling of Automated Manufacturing Systems", Prentice-Hall	1992
5.	Hopp, W. J., and Spearman, M. L., "Factory Physics : Foundation of Manufacturing Management", McGraw Hill.	1996
6.	Chang, T.-C., Wysk, R. A. and Wang, H.-P. "Computer Aided Manufacturing", 3rd Ed., Prentice Hall.	2005

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-516** Course Title: **Artificial Intelligence**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight : **CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: This course is designed to provide basic knowledge of artificial intelligence. The emphasis is on the teaching of various techniques on knowledge representation and search engines with important applications of AI.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Overview of History and Goals of AI**: Artificial Intelligence -- Definition, components, scope, and application areas; Turing's test; Review of AI success and failure.	3
2	**State Spaces, Production Systems, and Search**: State space representation of problems; Problem solving using search; Definition and examples of production systems; Heuristic search techniques i.e. generate-and-test, hill climbing, best-first search, constraint satisfaction and mean-ends analysis.	8
3	**Knowledge Representation**: Definition of knowledge; Issues in knowledge representation; Procedural vs declarative knowledge and their representation; Predicate logic, production rules, semantic nets, and frames; Meta-knowledge.	9
4	**Reasoning and Inference Strategies:** Forward vs backward reasoning; Depth first, breadth first, min-max etc.; Non-monotonic reasoning; Symbolic reasoning under uncertainty; Probability and Baye's theorem; Certainty factors, Dempster-Shafer theory; Fuzzy logic etc.	10
5	**Expert Systems and their Applications**: Justification, structure, knowledge sources; Expert knowledge acquisition; Expert system languages; ES building tools/shells; Applications of AI in CAD, CAPP, process selection, GT, MRP II, adaptive control, robotics, process control, fault diagnosis, failure analysis, etc.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Rich, E., Knight, K. and Nair, S. B., "Artificial Intelligence", 3rd Ed., Tata McGraw Hill.	2010
2	Russell, S. and Norvig, P., "Artificial Intelligence: A Modern Approach", 3rd Ed., Prentice-Hall.	2009
3	Dean, T. L., Allen, J., and Aloimonos, Y. "Artificial Intelligence: Theory and Practice", Benjamin/Cummings Publishing Company.	1995
4	Genesereth, M. R. and Nilsson, N., "Logical Foundations of Artificial Intelligence", Morgan Kaufmann.	1987

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-517** Course Title: **Automated Materials Handling Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To introduce various automated material handling equipment and their utilization.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction of Material Handling:** Overview of MHE, consideration in MHS design, twenty principles of material handling, the unit load concept.	04
2	**Material Transport Systems:** Industrial trucks, automated guided vehicle systems, monorails and other rail guided vehicles, conveyor systems, cranes and hoists.	06
3	**Evaluation and Selection of Material Handling Layout**: Design of bins and hoppers – flow patterns, measurement of flow properties, design methods, feeders, dischargers, silos, chutes and gates; Bulk material sampling and weighing systems, blending of bulk materials, transportation interface – rail and water. monitoring and control.	14
4	**Analysis of Material Transport Systems:** Rate of deliveries, required number of vehicles, economics of material handling systems.	06
5	**Automated Storage & Retrieval Systems (AS/RS):** Functions of AS/RS, operations of AS/RS, AS/RS components, types of AS/RS, design of an AS/RS, system throughput, size parameters determination of AS/RS.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Allegri, T. H., "Material Handling Principles and Practice", Krieger Publishing Company.	1992
2	Meyers, F. E. and Stephens, M. P. "Manufacturing Facilities Design and Material Handling", Prentice Hall.	2000
3	Adam, N. D., Brown, T. W., Rowland, V. D. and Misenheimer, F. P., "Warehouse & Distribution Automation Handbook", McGraw-Hill.	1996
4	Tompkins, J. A., White, J. A., Bozer, Y. A. and Tanchoco, J. M, "Facilities Planning", 4th Ed., John Willey & Sons.	2010
5	Sule, D. R., "Manufacturing Facilities-Location, Planning, and Design", 3rd Ed., CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-520** Course Title: **Advanced Thermodynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25** **PRS 0** **MTE 25** **ETE 50** **RE 0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of the advanced aspects of classical thermodynamics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Review of I and II Laws of Thermodynamics**: Transient flow analysis, entropy balance, entropy generation.	5
2.	**Exergy Analysis**: Concepts, exergy balance, exergy transfer, exergetic efficiency, exergy analysis of power and refrigeration cycles.	9
3.	**Real Gases and Mixtures**: Equations of state, thermodynamic property relations, residual property functions, properties of saturation states.	6
4.	**Thermodynamic Properties of Homogeneous Mixtures**: Partial molal properties, chemical potential, fugacity and fugacity coefficient, fugacity relations for real gas mixtures, ideal solutions, phase equilibrium, Rault's law.	8
5.	**Reacting Systems**: I and II law analysis of reacting systems, absolute entropy and the third law, fuel cells, chemical energy, exergetic efficiency of reacting systems, chemical equilibrium, equilibrium flame temperature.	14
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Wark, K., "Advanced Thermodynamics for Engineers", John Wiley & Sons.	1995
2.	Bejan, A., "Advanced Engineering Thermodynamics", 3rd Ed., John Wiley & Sons.	2006
3.	Annamalai, K. and Puri, I.K., "Advanced Thermodynamics Engineering", CRC Press.	2001
4.	Moran, M. J., and Shapiro, H. N., "Fundamentals of Engineering Thermodynamics", 6th Ed., John Wiley & Sons	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-521** Course Title: **Advanced Fluid Mechanics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge on advanced analytical tools for fluid flow analysis.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Review of Basic Concepts**: Concept of continuum, types of fluid, tensor analysis.	3
2.	**Basic Laws in Integral Form**: Reynold's transport theorem, mass, momentum and energy equations in integral form and their applications.	5
3.	**Differential Fluid Flow Analysis**: Continuity equation, Navier-Stokes equations and exact solutions, energy equation.	7
4.	**Ideal Fluid Flow Analysis**: Two dimensional flow in rectangular and polar coordinates; Continuity equation and the stream function; Irrotationality and the velocity potential function; Vorticity and circulation; Plane potential flow and the complex potential function; Sources, sinks, doublets and vortices; Flow over bodies and d'Alembert's paradox; Aerofoil theory and its application.	8
5.	**Low Reynolds Number Flow**: Approximation of Navier-Stokes equation, approximate solutions of Navier-Stokes equation, Stokes and Oseen flows, hydrodynamic theory of lubrication.	4
6.	**Large Reynolds Number Flow:** Prandtl's boundary layer equations, Blasius solutions, Falkner-Skan solutions, momentum integral equation, Halstein and Bohlen method, thermal boundary layers.	8
7.	**Compressible Fluid Flow**: One dimensional isentropic flow, Fanno and Rayleigh flows, chocking phenomenon, normal and oblique shocks.	7
	Total	**42**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-522** Course Title: **Advanced Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **TE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: It provides the knowledge of advanced techniques for analysis of heat transfer processes in thermal systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Heat Conduction**: Fourier's law, thermal conductivity of matter, heat diffusion equation for isotropic and anisotropic media, boundary and initial conditions; One-dimensional steady-state conduction through plane wall, cylinder and sphere, conduction with thermal energy generation, heat transfer from extended surfaces, radial fins and fin optimization; Multidimensional-dimensional steady-state heat conduction; Transient conduction – lumped capacitance method and its validity, plane wall and radial systems with convection, semi-infinite solid, muti-dimensional transient heat conduction.	12
2.	**Heat Convection**: Boundary layers concepts, laminar and turbulent flows, conservation equation, non-dimensional analysis, boundary layer equations, Reynolds analogy for turbulent flows; Forced convection inside tubes and ducts – correlations for laminar and turbulent forces convection; Forced convection over exterior surfaces – bluff bodies, packed beds, tube bundles in cross flow, free jet; Natural convection; Combined free and forced convection; Combined convection and radiation.	11
3.	**Heat Transfer with Phase Change**: Nucleate, film and pool boiling, boiling in forced convection; Filmwise and dropwise condensation; Heat pipes	5
4.	**Thermal Radiation:** Fundamental concepts, radiation intensity and its relation to emission, irradiation and radiosity, blackbody radiation, Planck distribution, Wien's displacement law, Stefan-Boltzmann law, surface emission, surface absorption, reflection, and transmission, Kirchoff's law, gray surface; Radiation exchange between surfaces, Poljack's and Gehbart's methods and view factor, blackbody radiation exchange, radiation exchange between diffuse gray surfaces in an enclosure with absorbing and emitting media; Flame Radiation, solar Radiation.	10

5.	**Numerical Methods in Heat Transfer:** Finite difference method for numerical simulation of steady state and transient heat transfer problems, iterative methods for solution of multi-dimensional problems, time integration methods.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Kreith, F. and Bohn, M. S., "Principles of Heat Transfer", 6th Ed., Thomson Learning.	2007
2.	Burmeister, L. C., "Convective Heat Transfer", 2nd Ed., John Wiley & Sons.	1993
3.	Kays, W. M., Crawford, M. E., and Weigand, B., "Convective Heat and Mass Transfer", 4th Ed., McGraw Hill.	2004
4	Ozisik, M. N., "Heat Conduction", 2nd Ed., John Wiley & Sons.	1993
5.	Siegel, R., and Howell, J. K., "Thermal Radiation Heat Transfer", Taylor & Francis.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-523** Course Title: **Gas Turbines and Compressors**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: It is intended to give a thorough understanding of gas turbines, compressors, gas turbine cycles, energy and fluid flow dynamics, and power plants based on gas turbines.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Development, classification and field of application of gas turbines.	3
2.	**Gas Turbine Cycles:** Ideal and actual cycles, multi-stage compression, reheating, regeneration, combined and cogeneration.	6
3.	**Energy Transfer and Fluid Flow Characteristics:** Energy transfer between fluid and rotor, axi-symmetric flow in compressors and gas turbines.	6
4.	**Centrifugal Compressors:** Principles of operation, compressor losses, adiabatic efficiency, slip factor, pressure coefficient, power unit, design consideration for impeller and diffuser systems, performance characteristics.	6
5.	**Axial Flow Compressors:** Elementary theory, vortex theory, degree of reaction, simple design, elementary air-foil theory, isolated airfoil and cascade theory, three dimensional flow, stages, stage efficiency and overall efficiency, performance characteristics.	6
6.	**Turbines:** Axial flow and radial flow turbines, impulse and reaction turbines, fundamental relations and velocity triangles, elementary vortex theory, limiting factors in turbine design, application of airfoil theory to the study of flow through turbine blades, aerodynamic and thermodynamic design considerations, blade materials, blade attachment and blade cooling.	10
7.	**Gas Turbine Power Plants:** Fuel and fuel feed systems, combustion systems-design considerations and flame stabilization, regenerator types and design, gas turbine power plant performance and matching, applications.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Saravanamuttoo, H.I.H., Rogers, G.F.C., Cohen, H. and Straznicky, P.V., "Gas Turbine Theory", 6th Ed., Pearson Prentice Hall.	2008
2.	Bathie, W. W., "Fundamentals of Gas Turbines", 2nd Ed., John Wiley & Sons.	1995
3.	Boyce, M. P., "Gas Turbine Engineering Handbook", 3rd Ed., Gulf Professional Publishing.	2006
4.	Lefebvre, H. and Ballal, D. R., "Gas Turbine Combustion", 3rd Ed., CRC Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-524** Course Title: **Two Phase Flow and Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide a thorough understanding of basic mechanism involved in two phase flow and heat transfer with special emphasis on boiling and condensation processes**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Types of flow, volumetric concentration, void fraction, volumetric flux, relative velocity, drift velocity, flow regimes, flow maps, analytical models.	5
2.	**Homogeneous Flow:** One dimensional steady homogeneous equilibrium flow, homogeneous friction factor, turbulent flow friction factor.	8
3.	**Separated Flow:** Slip, Lockhart-Martinelli method for pressure drop calculation, pressure drop for flow with boiling, flow with phase change.	8
4.	**Drift Flow Model:** General theory, gravity flows with no wall shear, correction to simple theory, Armond or Bankoff flow parameters.	7
5.	**Boiling:** Regimes of boiling, nucleation, gas nucleation in bulk liquid, growth of bubbles, motion at a heating surface, heat transfer rates in pool boiling, forced convection boiling, heat transfer correlations, maximum heat flux or burnout, boiling of metals.	7
6.	**Condensation:** Nusselt theory, boundary layer treatment of laminar film condensation, experimental results for vertical and horizontal tubes, condensation inside a horizontal tube.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Ishii, M. and Hibiki, T., "Thermo-fluid Dynamics of Two-Phase Flow", Springer.	2009
2.	Brennen, C. E., "Fundamentals of Multiphase Flow", Cambridge University Press.	2009
3.	Collier, J. G. and Thome, J. R., "Convective Boiling and Condensation", Oxford University Press	1996
4.	Rohsenow, W.M., Hartnett, J.P. and Ganic, E.N. (Ed.), "Handbook of Heat Transfer", McGraw Hill.	1998
5.	Tong, L.S. and Tang, Y. S., "Boiling Heat Transfer and Two-phase Flow", 2nd Ed., CRC Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-525** Course Title: **Solar Energy**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of solar energy with respect to its availability, utilization and economic viability.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Energy demand and supply, energy crisis, conventional and non-conventional energy resources, solar energy applications.	2
2.	**Solar Radiation:** Sun, solar radiation, attenuation by atmosphere, solar radiation on earth, measurement, presentation and utilization of data.	6
3.	**Heat Transfer Concepts:** Radiation characteristics of surface and bodies, absorbance, reflectance and transmittance, selective surface, sky radiation and wind convection.	6
4.	**Flat Plate Collectors:** General description of flat plate collectors, general characteristics, performance, short term and long term performance, design.	8
5.	**Focusing Collectors:** General description of focusing solar collectors, concentrators, receivers and orienting systems, general characteristics, performance, materials, design.	5
6.	**Energy Storage:** Energy storage in solar process system, different types of storages, characteristics and capacity of storage medium, solar pond.	5
7.	**Solar Heating and Cooling:** Passive heating and cooling, nocturnal radiations, green house concept, ponds, active heating and cooling, solar water heaters, absorption cooling, combined solar heating and cooling systems, performance, economics of solar heating and cooling.	4
8.	**Solar Process Modeling:** Solar process systems and components, component models, system models.	2
9.	**Solar Photovoltaics:** Description and principle of working, performance characteristics, efficiency of solar cells, module design, PV systems, applications.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Duffie, J.A. and Beckman, W.A., "Solar Engineering of Thermal Processes", John Wiley & Sons.	2006
2.	Goswami, D.Y., Kreith, F. and Kreider J., "Principles of Solar Energy", Taylor & Francis.	2000
3.	Sukhatme, S.P. and Naik, J.K., "Solar Energy", 3rd Ed., Tata McGraw Hill.	2009
4.	Garg, H.P. and Prakash, J., "Solar Energy", Tata McGraw Hill.	2000
5.	Tiwari, G.N.,"Solar Energy", Narosa Publishing House.	2002
6.	Meinel, A.B., "Applied Solar Energy", Addison Wesley.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-526** Course Title: **Advanced Gas Dynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide knowledge of advanced topics in gas dynamics related to shock waves, perturbations and methods of characteristics.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Equations:** Application of the general differential equation of continuity, momentum and energy to compressible inviscid fluids, compressible Bernoulli equation, irrotational flow, velocity potential and stream function.	6
2.	**Shock Waves in Supersonic Flow:** A review of normal shock relations, Mach waves, equations for finite strength oblique shock waves, Rankine-Hugoniot relations, extended Prandtl relation, hodograph shock polars, reflection and interaction of shock, curved shocks.	7
3.	**Small Perturbation Theory:** Linearization, small perturbation equation, pressure coefficient, subsonic flow past a wave shaped wall, general solution of supersonic flows, supersonic flow past a wave – shaped wall, elements of supersonic thin aerofoil theory.	9
4.	**Similarity Rules:** Similarity rules between two-dimensional subsonic compressible flows and incompressible flows, Gothert rule, Prandtl Glauert rule, application to supersonic flows.	6
5.	**Hodograph Method for Subsonic Flow:** Hodograph equations for two-dimensional subsonic flows, Chaplygin's equation, the tangent gas approximation of Karman and Tsien for subsonic flows, Karman-Tsien formula for pressure correction, comparison with Prandtl-Glauert rule	7
6.	**Method of Characteristics for Supersonic Flow:** Method of characteristics for two dimensional supersonic flows, the characteristic curves, equation of hodograph characteristics, characteristics network, computational methods.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Anderson, J. D. "Modern Compressible Flow", McGraw Hill.	2004
2.	Liepmann, H.W. and Roshko, A., "Elements of Gas Dynamics", Dover Publication.	2002
3.	Rathakrishnan, E., "Applied Gas Dynamics", John Wiley & Sons.	2010
4.	John, J. E. A. and Keith, T. G., "Gas Dynamics", 3rd Ed., Prentice Hall.	2006
5.	Zucker, R. D. and Biblarz, O., "Fundamentals of Gas Dynamics", 2nd Ed., John Wiley & Sons.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-527** Course Title: **Computational Fluid Dynamics and Heat Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of the basic tools for numerical simulation of fluid flow and heat transfer processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Conservation equations; Mass, momentum and energy equations; Conservative forms of the equations and general description.	3
2.	**Classification and Overview of Numerical Methods:** Classification into various types of equations -- parabolic elliptic and hyperbolic; Boundary and initial conditions; Overview of numerical methods.	4
3.	**Finite Difference Method:** Introduction, finite difference approximations, Taylor series expansion, polynomial fitting, approximation of boundary conditions, applications to conduction and advection-diffusion problems.	5
4.	**Finite Volume Method:** Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods - central, upwind and hybrid formulations and comparison for convection-diffusion problem.	5
5.	**Methods of Solution:** Solution of finite difference equations, iterative methods, matrix inversion methods, ADI method, operator splitting, fast Fourier transform, applications.	7
6.	**Numerical Grid Generation:** Basic ideas, transformation and mapping, unstructured grid generation.	5
7.	**Finite Element Method:** Introduction to Rayleigh-Ritz, Galerkin and least square methods, interpolation functions, one and two dimensional elements, applications.	9
8.	**Phase Change Problems:** Different approaches for moving boundary, variable time step method, enthalpy method.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Anderson, D.A., Tannehill, J.C. and Pletcher, R.H., "Computational Fluid Mechanics and Heat Transfer", Taylor & Francis.	1997
2.	Anderson, J.D., Jr., "Computational Fluid Dynamics", McGraw Hill.	1995
3.	Ferziger, J. H. and Peric, M., "Computational Methods for Fluid Dynamics, 3rd Ed., Springer.	2003
4.	Versteeg, H. and Malalasekra, M., "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", 2nd Ed., Prentice Hall.	2007
5.	Reddy, J. N. and Gartling, D. K., "The Finite Element Method in Heat Transfer and Fluid Dynamics", 3rd Ed., CRC Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-528** Course Title: **Boundary Layer Theory**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide in-depth knowledge of the concept of boundary layer, and analytical tools for prediction, investigation and control of the boundary layers.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Ideal and real fluids, the concept of boundary layer, Navier- Stokes equations, the limiting cases of large and small Reynolds number, energy equation.	5
2.	**Laminar Boundary Layer Equation:** Two dimensional equations, displacement and momentum thickness, general properties of the boundary layer equations, skin friction.	6
3.	**Similarity Solutions:** Wedge flow and its particular cases, flow past a cylinder, two dimensional inlet flow in straight channel.	5
4.	**Approximate Methods:** Karman-Polhausen methods, numerical methods.	4
5.	**Axially Symmetrical Boundary Layers:** Circular jet, body of revolution, Manglers transfixion.	3
6.	**Boundary Layer Control:** Different methods of boundary layer control, flow over a flat plate with uniform suction.	4
7.	**Turbulent Boundary Layer:** Two-dimensional equation, Prandtl's mixing layer Karman's hypothesis universal velocity distribution, flow over a flat plate, skin friction drag.	9
8.	**Thermal Boundary Layers:** Two-dimensional equations forced flow over flat plate at zero in advances, natural flow over a vertical plate.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1	Schlichting, H. and Gersten, K., "Boundary Layer Theory", Springer-Verlag.	2004
2.	White, F. M., "Viscous Flow", 3rd Ed., McGraw Hill.	2005
3.	Cebeci, T. and Cousteix, J., "Modeling and Computation of Boundary-Layer Flows", 2nd Ed., Springer-Verlag.	2005
4.	Rozenhead, L., "Laminar Boundary Layers", Dover Publications	1988
5.	Kays, W. M., Crawford, M. E., and Weigand, B., "Convective Heat and Mass Transfer", 4th Ed., McGraw Hill.	2004
6.	Welty, J. R., Wicks C. E., Wilson R. E. and Rorrer, G. L., "Fundamentals of Momentum, Heat, and Mass Transfer", 5th Ed., John Wiley & Sons	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-529** Course Title: **Turbulent Flow**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of analytical, experimental, modeling and computational tools for the analysis of turbulent flow.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Turbulence and equations of fluid motion.	3
2.	**Statistical Descriptions of Turbulent Flows**: Random nature of turbulence, random variables, probability distributions, and averaging techniques.	5
3.	**Experimental Techniques for Measurement of Turbulent Flows**: Hot-wire and hot-film anemometry, laser Doppler velocimetry, and particle image velocimetry.	5
4.	**Dynamics of Turbulence**: Scales of turbulent motion, energy cascade, Kolmogorov hypothesis, structure function, two-point correlations, Fourier modes and velocity spectra.	7
5.	**Homogeneous and Isotropic Turbulence**: Implications of isotropy, energy decay, energy spectrum, homogeneous shear flows.	5
6.	**Anisotropic Turbulence**: Wall bounded flows (channel flow, pipe flow, boundary layers) and free shear flows (jets and mixing layers), coherent structures.	7
7.	**Turbulence Modeling**: RANS modeling, eddy viscosity models, algebraic Reynolds stress models and near-wall models.	5
8.	**Direct Numerical Simulation and Large Eddy Simulation**: Filtering, subgrid scale models (Smagorinsky and dynamic models), LES in wave number space.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Pope, S. B., “Turbulent Flows”, Cambridge University Press.	2000
2.	Bernard, P., and Wallace, J. A., “Turbulent Flow“, John Wiley & Sons	2002
3.	Mathieu, J., and Scott, J., “Introduction to Turbulent Flow”, Cambridge University Press.	2000
4.	Biswas, G., and Eswaran, V., “Turbulent Flows”, Narosa Publishing House.	2002
5.	Piquet, J., Richards, J. A., Jia, X., “Turbulence Flows: Models and Physics”, Springer-Verlag.	2001
6.	Lesieur, M., “Turbulence in Fluids”, Springer-Verlag.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-530** Course Title: **Cold Preservation of Food**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **RS** **0** **ITE** **25** **TE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of various aspects of cold preservation techniques for the perishable commodities.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Necessity of food preservation, general techniques, cold preservation of food.	4
2.	**Biological Aspects:** Live and dead foods, biology of food products such as fruits, vegetables, milk, meat and fish, effect of temperature on food ingredients, respiration rates of food products, controlled atmospheric storage, diseases and deterioration of foods.	10
3.	**Preservation of Food:** Short and long term preservation, methods of chilling, freezing and freeze drying, heat and mass transfer analysis of cooling and freezing.	9
4.	**Cold Storages:** Necessity and present status in the country, site selection, building constructional features, load calculation, equipment, selection, safety consideration, insurance and management of cold storages, storage of some important food products, modern trends in cold storage practices.	10
5.	**Refrigerated Food Handling:** Preparation for cooling/ freezing, packaging of foods, modes of transportation (land, sea and air), thermal load and equipment, marketing of refrigerated food.	9
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Karel, M. and Lund, D. B., "Physical Principles of Food Preservation", 2nd Ed., CRC Press.	2003
2.	"ASHRAE Handbook", American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).	2009
3.	Shafiur Rahman, M., "Handbook of Food Preservation", 2nd Ed., CRC Press.	2007
4.	Evans, J. A., "Frozen Food Science and Technology", Blackwell Publishing.	2008
5.	Wallis-Tayler, A. J., "Refrigeration: Cold Storage and Ice Making", Knowledge Publications.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-531** Course Title: **Hydro-dynamic Machines**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To expose students to theory, design and analysis of hydrodynamic machines such as turbines, pumps etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic fluid mechanics of turbo-machinery, torque-momentum and head-momentum equations, one-dimensional theory and its limitations, two-dimensional theory of flow through axial and radial-flow machines, three-dimensional effects; Classification of turbines and various forms of turbine runners.	8
2.	**Reaction Turbines:** General theory of reaction machines, performance characteristics, types, Francis and Kaplan turbines, runner design, blade design, design of the spiral casing, guide vanes and draft tube design, theory of cavitation flows in hydrodynamic runners.	10
3.	**Impulse Turbines:** General theory of impulse machines, performance characteristics, design of runner, bucket shape and size, design of nozzles, regulation mechanisms, penstock design.	8
4.	**Hydrodynamic Pumps:** Classification of pumps and various forms of pump impellers, general theory of centrifugal pumps, performance characteristics, design of casings and diffusers, cavitation effects in impellers.	10
5.	**Hydrodynamic Transmissions:** General features, primary and secondary units of the systems, fluid couplings and torque converters, general theory, performance characteristics, basic design considerations.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1	Round G.F., "Incompressible Flow Machines", Elsevier Butterworth-Heineman.	2004
2.	Dixon, S. L., "Fluid Mechanics and Thermodynamics of Turbomachinery", 5th Ed., Butterworth Heineman.	2005
3	Douglas J. F., Gasiorek, J. M. and Swaffied, J. A., "Fluid Mechanics", Pearson Education.	2001
4	Karassik, I. J., Messina, J. P., Cooper, P. and Heald, C. C., "Pump Handbook", 3rd Ed., McGraw Hill.	2001
5.	Gopalkrishnan, G. and Prithvi Raj, D., "A Treatise on Turbomachinery", Scitech Publication.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-532** Course Title: **Renewable Energy Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce various renewable energy systems and their applications for sustainable development.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Energy and development, energy demand and availability, energy crisis, conventional and non-conventional, renewable and non-renewable energy resources, environmental impact of conventional energy usage, basic concepts of heat and fluid flow useful for energy systems.	5
2.	**Solar Energy Systems:** Solar radiations data, solar energy collection, storage and utilization, solar water heating, air heating, power generation, refrigeration and air conditioning, solar energy system economics.	7
3.	**Micro and Small Hydro Energy Systems:** Resource assessment of micro and small hydro power, micro, mini and small hydro power systems, economics, pump as turbine, special engines for low heads, velocity head turbines, hydrams, water mills.	6
4.	**Ocean Energy Systems:** Ocean temperature energy conversion system (OTEC), Wave energy systems, Tidal power systems.	4
5.	**Biomass Energy Systems:** Availability of biomass- agro, forest, animal, municipal and other residues, bioconversion technologies, cooking fuels, biogas, producer gas, power alcohol from biomass, power generation, internal combustion engine modifications and performance, system economics.	8
6.	**Wind Energy Systems:** Wind data, horizontal and vertical axis wind mills, wind farms, performance and economics of wind energy.	6
7.	**Integrated Energy Systems:** Concept of integration of conventional and non-conventional energy resources and systems, integrated energy system design and economics.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Boyle, G. "Renewable Energy", 2nd Ed., Oxford University Press.	2004
2.	Da Rosa, A. V. "Fundamentals of Renewable Energy Processes", 2nd Ed., Academic Press.	2009
3.	Hodge, B. K., "Alternative Energy Systems and Applications", John Wiley & Sons.	2009
4.	Sukhatme, S.P. and Naik, J.K., "Solar Energy", 3rd Ed., Tata McGraw Hill.	2009
5.	Duffie, J.A. and Beckman, W.A., "Solar Engineering of Thermal Processes", John Wiley & Sons.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-533** Course Title: **Refrigeration and Air Conditioning System Design**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce basic design principles of refrigeration and air conditioning equipment and components.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Load Calculations:** Solar heat gains through structures, review of refrigeration and air conditioning load calculations.	6
2.	**Refrigeration Systems:** Vapour compression, multiple evaporator and compound compression system with and without inter cooling, dual compressors, cascade systems, vapour absorption system-analysis, solid carbon dioxide, principle of production, three stage system with water and flash inter-cooler, pressure snow chambers, regenerative liquid, binary system.	10
3.	**Refrigeration System Components:** Performance characteristics and capacity control of reciprocating, rotary and centrifugal compressors, screw compressors, hermetically sealed units, analysis of centrifugal compressors, water cooled and air-cooled condensers, overall heat transfer coefficients, fouling factor, performance characteristics and design, performance and heat transfer processes in evaporative condenser, flooded and dry expansion type evaporators, liquid chiller, overall performance of evaporators, capillary tubes, system design factors, pressure and temperature distribution, ASHRAE simplified calculation procedure, expansion valves, operation and performance calculation of thermostatic expansion valve, application of constant pressure expansion valve.	14
4.	**Pressure Drop and Heat Transfer:** Two phase flow, flow regimes, maps, pressure drop in evaporator and condensers, Martinelli relation.	6
5	**Applications and System Design:** Ice manufacture, design of refrigerated cars and ware houses.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1	Stoecker, W. F. and Jones, J. W., "Refrigeration and Air-conditioning", McGraw Hill.	1983
2.	"ASHRAE Handbook", American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).	2009
3.	Whitman, B., Johnson, B., Tomczyk, J. and Silberstein, E., "Refrigeration and Air Conditioning Technology", 6th Ed., Delmar Cengage Learning	2008
4.	Hundy, G. H., Trott, A. R. and Welch, T. C., "Refrigeration and Air-Conditioning", 4th Ed., Butterworth-Heinemann.	2008
5	Arora, C. P., "Refrigeration and Airconditioning", 3rd Ed., Tata-McGrawHill	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-534** Course Title: **Air-conditioning and Ventilation**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the basic physiological principles, comfort charts, air conditioning systems and the design of piping and ducts.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Psychrometry:** Goff and Gratach method of calculation of moist air properties, mass transfer and evaporation of water into moist air, theory of psychrometer, correlation of w.b.t. with temperature of adiabatic saturation, Lewis number, construction of h.w. psychrometric chart.	6
2.	**Physiological Principles:** Comfort, thermal interchanges with environment, physiological body regulatory processes against heat or cold, high and low temperature hazards, extreme environmental conditions, heat stress index, ASHRAE comfort standards.	4
3.	**Simultaneous Heat and Mass Transfer:** Direct contact transfer equipment, simple air washer and indirect evaporative cooling, contact mixture principle, enthalpy potential, basic equation for direct contact transfer equipment, graphical and analytical methods for heat and mass transfer analysis of air-washers with heated and chilled water sprays, cooling towers.	8
4.	**Extended Surface Heat Transfer Apparatus:** Cooling and dehumidifying coils, design of finned surfaces, adsorption cooling systems.	5
5.	**Ventilation:** Necessity, ventilation standards, natural and mechanical ventilation, forces for natural ventilation, general ventilation rules, advantages of mechanical ventilation, various methods, ejector systems, determining ventilation requirement, use of decay equation.	7
6.	**Air Cleaning:** Physical and chemical vitiation of air, permissible concentration of air contaminants, mechanical and electronic air cleaners, dry and wet filters, air sterilization, odour control.	4
7.	**Steam Heating Systems:** Elements of steam, water and warm-air heating systems, radiators and convectors, design of a year-round air conditioning system.	4
8.	**Piping and Ducts:** Pressure drops in piping and fittings, design of water and refrigerant piping, air conditioning duct design methods.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1	Kuehn, T. H., Ramsey, J. W. and Threlkeld J. L., "Thermal Environmental Engineering", 3rd Ed., Prentice Hall.	1998
2.	"ASHRAE Handbook", American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).	2009
3.	Whitman, B., Johnson, B., Tomczyk, J. and Silberstein, E., "Refrigeration and Air Conditioning Technology", 6th Ed., Delmar Cengage Learning	2008
4.	Hundy, G. H., Trott, A. R. and Welch, T. C., "Refrigeration and Air-Conditioning", 4th Ed., Butterworth-Heinemann.	2008
5	Arora, C. P., "Refrigeration and Air-conditioning", 3rd Ed., Tata-McGrawHill	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-535** Course Title: **Cryogenic Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the field of low temperature engineering *(cryogenics)* having applications in rocket propulsion, electronics, biological and medical science.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Historical background, present areas involving cryogenics.	4
2.	**Low Temperature Properties of Engineering Materials:** Mechanical properties, thermal properties, electrical and magnetic properties, properties of cryogenic fluids.	4
3.	**Gas-Liquefaction System:** Joule-Thomson effect, adiabatic expansion, simple Linde-Hampson system, pre-cooled Linde-Hampson system, Linde dual-pressure system, cascade system, Claude system, Kapitza system, Collins helium liquefaction system.	6
4.	**Critical Components of Liquefaction System:** Effect of heat exchanger effectiveness on system performance, effect of compressor and expander efficiency on system performance, effect of heat transfer to the system.	6
5.	**Cryogenic Refrigeration Systems:** Philips refrigerator, importance of regenerator effectiveness for Philips refrigerator, Gifford-McMohan refrigerator	6
6.	**Measurement Systems for Low Temperatures:** Temperature measurement, flow rate measurement, liquid level measurement.	4
7.	**Cryogenic Storage and Transfer Systems:** Cryogenic fluid storage vessels, insulations, cryogenic transfer systems	4
8.	**Vacuum Technology:** Importance of vacuum technology in cryogenics, flow regimes in vacuum systems, conductance in vacuum systems, calculation of pump-down time for a vacuum system, components of a vacuum system, mechanical vacuum pumps, diffusion pumps, ion pumps, cryo-pumping, vacuum gauges and valves.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Barron, R. F., "Cryogenic Systems", Oxford University Press.	1985
2.	Flynn, T., "Cryogenic Engineering", 2nd Ed., CRC Press.	2004
3.	Jha, A. R., "Cryogenic Technology and Applications", Elsevier.	2006
4.	Barron, R. F., "Cryogenic Heat Transfer", Taylor & Francis.	1999
5.	Kays, W. M., and London, A. L., "Compact Heat Exchangers", Krieger Publishing Company.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-536** Course Title: **Convective Heat and Mass Transfer**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of various aspects of the convective heat and mass transfer.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Concepts, conservation principles and laws; Equations of continuity, momentum, and energy; Dimensional analysis and similarity principles.	7
2.	**Laminar Boundary Layer Flow**: Concept of boundary layer, velocity and thermal boundary layer thickness, integral solutions and similarity solutions, laminar forced flow over a flat plate, thermal boundary layer on an isothermal/constant surface heat flux flat plate, flat plate with varying surface temperature	7
3.	**Laminar Duct Flow**: Hydrodynamic entrance length, fully developed flow, hydraulic diameter and pressure drop, heat transfer to developed and developing flow, laminar forced convection in pipe and ducts, dimensional analysis, some exact solutions of Navier-Stokes equations.	6
4.	**Laminar Natural Convection**: Vertical boundary layer equations, integral and similarity solutions, plumes, wakes, buoyant flows, film condensation.	5
5.	**Natural Convection in Enclosures:** Transient heating from the side, boundary layer regime, dimensional analysis	5
6.	**Turbulence Models**: Eddy diffusivity of heat and momentum.	4
8.	**Turbulent Boundary Layers**: Velocity distribution in turbulent flow, Analogies between heat and momentum transfer, turbulent flow through circular tubes and parallel plates, Turbulent heat transfer correlations	4
9.	**Mass Transfer:** Properties of mixtures, mass conservation, laminar forced/natural convection, steady and unsteady state molecular diffusion.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Arpaci, V. S. and Larsen, P. S., "Convection Heat Transfer", Prentice Hall.	1984
2.	Burmeister, L.C., "Convection Heat Transfer", John Wiley & Sons.	1993
3.	Bejan, A. "Convection Heat Transfer", 3rd Ed., John Wiley & Sons.	2004
4.	Kays, W. M. and Crawford, M. E., "Convective Heat and Mass Transfer", Tata McGraw Hill.	2005
5.	Welty, J. R., Wicks, C. E. , Wilson, R. E. and Rorrer, G. L., "Fundamentals of Momentum, Heat and Mass Transfer", 5th Ed., John Wiley & Sons.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-537** Course Title: **I.C. Engines**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course deals with the analysis of internal combustion (IC) engine processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Overview and historical perspectives on development of internal combustion engines.	2
2	**Thermodynamic Analysis of IC Engines Cycle:** Properties of working fluid, fuel air cycle analysis, real cycles, availability analysis of engine processes.	8
3	**Gas Exchange Processes:** Inlet and exhaust processes in the four stroke cycle, volumetric efficiency, quasi-static and dynamic effects, flow through valves, scavenging in two- stroke cycle engines, scavenging parameters and models, actual scavenging processes, flow through ports, supercharging and turbo-charging, basic relationships, compressors, turbines characteristics, matching of compressor, turbines and engine characteristics.	10
4	**Combustion in SI Engines:** Essential features of the process, thermodynamic analysis of SI engine combustion, combustion process characterization, cyclic variations in combustion.	6
5	**Combustion in Compression Ignition Engines**: Essential features of process, types of diesel combustion systems, phenomenological model of compression- ignition engine combustion, fuel spray behaviour, spray structure, atomization, spray penetration droplet size distribution, spray evaporation, ignition delay.	8
6	**Pollutant Formation and Control:** Nature and extent of problem, nitrogen oxides, kinetics of NO formation, NO_x formation in spark- ignition engines, NO_x formation in CI engines, carbon monoxide, unburned hydrocarbon emissions, particulate emissions, exhaust gas treatment, catalytic converters, three way catalysts, particulate traps.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Heywood, J.B., "Internal Combustion Engine Fundamentals", McGraw Hill.	1988
2.	Taylor, C.F., "Internal Combustion Engines", Vol. 1 & 2, 2nd Ed., MIT Press.	1985
3.	Ferguson, C.R. and Kirkpatrick, A. T., "Internal Combustion Engines", 2nd Ed., John Wiley & Sons.	2000
4.	Pulkrabek, W. W., "Engineering Fundamentals of the Internal Combustion Engine", 2nd Ed., Prentice-Hall.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-538** Course Title: **I.C. Engine Combustion Processes Modeling**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course is intended to expose the students to the most widely used mathematical models for in-cylinder spray and combustion processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Essential features of combustion process in S.I. and C.I. engines, flame structure and speed, spray structure, auto-ignition.	4
2.	Engine combustion modeling – an overview.	2
3.	Modeling fluid motions in engines, intake jet flow, swirl generation during induction, squish, pre-chamber flows, crevice flow and blow-by.	6
4.	Modeling Flame Propagation and Heat Release in Engines, laminar burning speed, flame propagation relations, heat release in diesel engines, zero dimension burning rate function, free gas jet theory, packet models.	8
5.	Knock, fundamentals, kinetic modeling of hydrocarbon combustion, autoignition, knock models.	6
6.	Modeling Spray, spray equation, droplet kinematics, spray atomization, droplet breakup droplet/droplet and spray wall interactions, fuel vaporization.	8
7.	Modeling pollutant formation in SI and CI engines, Models for NOx, CO and soot formation.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Heywood, J.B., "Internal Combustion Engine Fundamentals", McGraw Hill.	1988
2.	Stiesch, G., "Modeling Engine Spray and Combustion Processes", Springer-Verlag.	2003
3.	Lakshminarayanan, P. A. and Aghav, Y. V., "Modeling Diesel Combustion", Springer-Verlag.	2010
4.	Sirignano, W. A., "Fluid Dynamics and Transport of Droplets and Sprays", Cambridge University Press.	2000
5.	Warnatz, J., Mass, U., and Dirbble, R. W., "Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation", 4th Ed., Springer-Verlag	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-539** Course Title: **Micro and Nano Scale Thermal Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **RS** **0** **ITE** **25** **TE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide a thorough understanding of heat transfer at micro and nano scales in microchannels, microbiological systems, micro heat pipes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Microscale Energy Transport in Solids:** Microstructure of solids, crystal vibrations and phonons, photon interactions, particle transport theories, non-equilibrium energy transfer.	7
2.	**Molecular Clusters:** Clusters and clustering, thermo-physical properties of clusters, control of clusters and condensation.	4
3.	**Molecular Forces and Phase Change in Thin Liquid Films:** Thermodynamics of thin films, interfacial meniscus properties, interfacial mass flux.	7
4.	**Heat Transfer and Pressure Drops in Microchannels:** Single phase and two phase flow, flow boiling, dryout, bubble behavior, flow pattern	6
5.	**Micro Heat Pipes:** Fundamental operating principles, steady state and transient modeling and construction techniques.	6
6.	**Microscale Heat Transfer in Biological Systems at Low Temperature:** Life above and below the freezing temperature of water, freezing of cells and tissues, mechanism of freeze survival.	3
7.	**Microscale Thermal Sensors and Actuators**: MEMS technology, flow sensors, infrared radiation detectors, thermal conductivity sensor, thermal expansion actuators and micro-steam engine.	4
8.	**Nanofluids:** Preparation of nano-fluids, sputtering, characterization of nano-fluids, thermal properties of nano-fluids, single phase convective and boiling heat transfer processes.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Tien, C. L ., Majumdar, A. and Gerner, F. M., "Microscale Energy Transport", Taylor & Francis.	2003
2.	Zhang, Z., "Nano/Microscale Heat Transfer", McGraw Hill.	2007
3.	Volz, S., "Microscale and Nanoscale Heat Transfer", Springer-Verlag.	2007
4.	Celate, G. P., "Heat Transfer and Transport Phenomena in Microscale", Begell House.	2000
5.	Kakac, S., Vasiliev, L. L., Bayazitoglu, Y., Yener, Y., "Microscale Heat Transfer: Fundamentals and Applications", Springer-Verlag.	2005
6.	Sobhan, C. B. and Peterson, G. P., "Microscale and Nanoscale Heat Transfer: Fundamentals and Engineering Applications", CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-540** Course Title: **Combustion**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of the basic principles involved in the combustion phenomenon and various practical combustion systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Importance of combustion, combustion equipment, hostile fire problems, pollution problems arising from combustion.	2
2	**Thermodynamics of Combustion:** Enthalpy of formation, enthalpy of reaction, heating values, first and second law analysis of reacting systems, chemical equilibrium, equilibrium composition, adiabatic and equilibrium flame temperature.	6
3	**Kinetics of Combustion:** Law of mass action, reaction rate, simple and complex reactions, reaction order and molecularity, Arhenius law, activation energy, chain reactions, steady state and partial equilibrium approximations, chain explosion, explosion limits and oxidation characteristics of hydrogen, carbon monoxide and hydrocarbons.	8
4	**Flames:** Structure and propagation of flames in homogeneous gas mixtures, simplified Rankine-Hugoniot relations, properties of hugoniot curve, analysis of deflagration and detonation branches, properties of Chapman Jouguet wave; Laminar flame structure, theories of flame propagation and calculation of flame speeds, flame speed measurements, stability limits of laminar flames, flammability limits and quenching distance; Burner design; Mechanisms of flame stabilization in laminar and turbulent flows; Flame quenching, diffusion flames, comparison of diffusion with premixed flame, combustion of gaseous fuel jets, Burke and Shumann development.	12
5	**Burning of Condensed Phase:** General mass burning considerations, combustion of fuel droplet in a quiescent and convective environment. Introduction to combustion of fuel sprays.	6
6	**Ignition:** Concepts of ignition, chain ignition, thermal spontaneous ignition, forced ignition.	4
7.	**Combustion Generated Pollution and its Control:** Introduction, nitrogen oxides thermal fixation of atmospheric nitrogen prompt NO, thermal NO_x formation and control in combustors; Fuel NO_x and control, post-combustion destruction of NO_x, nitrogen dioxide, carbon monoxide, oxidation-quenching, hydrocarbons, sulphur oxides.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Glassman, I., "Combustion", 4th Ed., Academic Press.	2008
2.	Warnatz, J., Mass, U., and Dirbble, R. W., "Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation", 4th Ed., Springer-Verlag.	2006
3.	Kuo, K. K., "Principles of Combustion", 2nd Ed., Wiley-Interscience	2005
4.	Annamalai, K. and Puri, I. K., "Combustion Science and Engineering", CRC Press.	2006
5.	Williams, F.A., "Combustion Theory", Addison Wesley	1993

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-541** Course Title: **Bio–fluid Mechanics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide an understanding of fluid dynamics in biological systems in general, and human physiological system in particular.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Overview of basic anatomy and physiology from fluid flow perspective.	4
2.	**Review of Basic Equations and Constitutive Models**: Mass and momentum conservation, models for non-Newtonian fluids.	4
3.	**Blood Rheology and Mechanics of Circulation**: Composition, structure and flow properties of blood; Structure, flow and pressure characteristics of the blood flow in cardio-vascular system; Flow of non-Newtonian fluids in elastic tubes.	7
4.	**Arterial Wave Propagation**: Oscillatory and pulsatile flow, pulse waves, behaviour at bifurcations, wave propagation in flexible tubes.	7
5.	**Flow through Pulmonary System**: Structure and function of pulmonary system, fluid exchange processes, fluid mechanics of breathing.	5
6.	**Flow and Lubrication in Musculo-sketetal System**: Haemodynamics of red blood cells, synovial fluid in joints.	5
7.	**Flow through the Porous Media**: Oxygen diffusion from blood to tissues, flow in ocular and renal system.	5
8.	**Computational Biofluid Mechanics**: Computational methods for flow and wave propagation through elastic tubes, flow through porous media.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Chandran, K. B., Yoganathan, A. P. and Rittgers, S. E., "Biofluid Mechanics: The Human Circulation", CRC Press.	2006
2.	Humphrey, J. D. and Delange, S. L., "An Introduction to Biomechanics", Springer-Verlag.	2004
3.	Fournier, R. L. L., "Basic Transport Phenomena in Biomedical Engineering", Taylor & Francis.	1998
4.	Fung, Y. C., "Biomechanics: Circulation", Springer-Verlag.	1996
5.	Kleinstreuer, C., "Biofluid Dynamics: Principles and Selected Applications", CRC Press.	2006
6.	Waite, L. and Fine, J., "Applied Biofluid Mechanics", McGraw Hill.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-542** Course Title: **Energy Management**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of concepts and techniques required for energy management.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Energy scenario, various forms of energy, energy management and its importance, recent trends in energy conservation.	3
2	**Energy Auditing and Instrumentation:** Definition, methodology, analysis of past trends (plan data), closing the energy balance, laws of thermodynamics, measuring instruments, portable and online instruments.	8
3	**Energy Economics:** Payback period, time value of money, IRR NPV, life cycle cost, cost of saved energy, cost of energy generated.	6
4	**Monitoring and Targeting:** Elements of monitoring and targeting, data and information, analysis techniques; Energy consumption, production, cumulative sum of differences.	7
5	**Energy Efficiency in Thermal Utilities:** Boilers, steam system, furnace insulation and refractories, fluidized bed boilers, cogeneration power plants, waste heat recovery systems.	7
6	**Energy Efficiency in Electrical Utilities:** Electrical systems, electric motors, compressed air system, HVAC and refrigeration systems, fans and blowers, pumps and pumping systems, cooling towers, lighting system, diesel generating system.	11
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Witte, L.C., Schmidt, P.S., Brown, D.R., "Industrial Energy Management and Utilization", Taylor and Francis.	1987
2.	Gyftopoulos, E.P., "Industrial Energy Conservation Manuals", MIT Press.	1988
3.	Capehart, B.L., Turner, W.C., Kennedy, W.J., "Guide to Energy Management", 6th Ed., Fairmont Press.	2008
4.	Turner, W.C. and Doty, S., "Energy Management Handbook", 7th Ed., Fairmont Press.	2009
5.	Kreith, F. and Yogi Goswami, D., "Handbook of Energy Efficiency and Renewable Energy", CRC Press.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-543** Course Title: **Fluid Power Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide knowledge of fluid power systems and control circuits.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Types of fluid power control systems and its components; Physical properties of hydraulic fluids and governing equations.	5
2.	**Pumps and Valves:** Classification, working and performance of gear, vane, piston pumps and their selection; Pressure intensifiers, direction control valves, pressure control valves, flow control valves, servo valves, pressure switches.	8
3.	**Hydraulic Actuators:** Linear and rotary actuators, gear, vane and piston motors, performance of hydraulic motors, hydrostatic transmission.	5
4.	**Hydraulic Circuit Design and Analysis:** Control of single-acting and double-acting cylinders, study of various circuits like regenerative, unloading, counterbalance, speed control etc., maintenance of hydraulic circuits.	5
5.	**Pneumatic Control Systems:** Air preparation and components, compressors and conditioners, air control valves and actuators.	5
6.	**Pneumatic Circuit Design and Analysis:** Design considerations, pressure and energy loss, basic pneumatic systems, vacuum and accumulator systems, circuit analysis.	5
7.	**Fluid Logic Control Systems:** Principles, basic fluidic devices, fluid sensors, Boolean algebra, fluidic control of fluid power systems.	4
8.	**Electrohydraulic Servo Control Systems:** Electric components and controls, dual cylinder sequence circuits, electrohydraulic servo system and their analysis, programmable logic controllers.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication
1.	Esposito, A., "Fluid Power with Applications", 7th Ed., Prentice Hall.	2008
2.	Cundiff, J. S., "Fluid Power Circuits and Controls: Fundamentals and Applications", CRC Press.	2001
3.	Watton, J., "Fundamentals of Fluid Power Control", Cambridge University Press.	2009
4.	Johnson, J. L., "Basic Fluid Power ", Delmar Cengage Learning.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-544** Course Title: **Design of Heat Exchangers**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of various types of heat exchangers, their construction and design, optimization criteria, performance behaviour and testing.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Classification, constructional details, two and multi-fluid heat exchangers, extended surfaces.	4
2	**Design of Heat Exchangers:** Engineering design – steps for designing, designing a workable system, feasible/workable design and optimum systems, economics, equation fitting, probabilistic approach to design, sizing and rating problems; LMTD and ε-NTU approach of design, design of tubular, shell and tube, finned (radial and longitudinal), regenerative and compact heat exchangers.	12
3	**Optimum Design:** Criteria for optimization of heat exchangers, different constraints, feasible and optimum design, optimization based on volume, weight, cost, entropy generation and thermoeconomics; Brief introduction to some traditional and non-traditional optimization techniques.	12
4	**Performance Behaviour:** Design vs simulation, steady state performance – effectiveness, transient performance, non-uniformities in temperature and flow; Three-fluid/ multifluid heat exchanger behaviour.	8
5	**Testing:** Steady state and transient testing technique, j and f characteristics, empirical relations, numerical approach.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1	Kays, W.M., and London, A.L., "Compact Heat Exchangers", Krieger Publishing Company.	1998
2.	Shah, R. K. and Sekulic, D. P., "Fundamentals of Heat Exchanger Design", John Wiley & Sons.	2002
3	Kraus A.D., Aziz A. and Welty J.R., "Extended Surface Heat Transfer", Wiley-Interscience.	2001
4	Rao, S. S., "Engineering Optimization: Theory and Practice", 3rd Ed., Wiley-Interscience.	1996
5.	Hesselgreaves, J.E., "Compact Heat Exchangers: Selection, design and operation", Pergamon Press.	2001
6	Webb, R.L., and Kim, N.H., "Principles of Enhanced Heat Transfer", Taylor and Francis.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-545** Course Title: **Fuel Cells**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **RE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the basics of fuel cell operation and their applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic principle and operation of Hydrogen fuel cells, types of fuel cells.	4
2.	**Fuel Cell Thermodynamics**: Free energy change of a chemical reaction, heat of reaction, reversible and net output voltage, theoretical fuel cell efficiency, effect of pressure	8
3.	**Fuel Cell Electrochemistry**: Electrode kinetics, Butler-Volmer equation, voltage losses, cell potential-polarization curve, fuel cell efficiency.	6
4.	**Transport Mechanisms**: Fuel cell charge transport, electron conductivity of metals, ionic conductivity of polymer electrolytes, fuel cell mass transport- fuel cell mass balance, diffusive and convective mass transports, heat transfer – fuel cell energy balance, heat management	9
5.	**Main Cell Components**: Materials, properties, processes, membrane, electrodes, bipolar plates, stack design, hydrogen and oxygen supply systems, PEM fuel cell	9
6.	**Fuel Cell Applications**: Automobiles, stationary power, fuel cells and hydrogen economy, medium and high temperature fuel cells	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Barbir, F., "PEM Fuel Cells: Theory and Practice", Academic Press.	2005
2.	Larminie, J. and Dicks, A., "Fuel Cell Systems Explained", John Wiley & Sons.	2003
3.	Spiegel, C., "PEM Fuel Cell Modeling and Simulation using MATLAB", Academic Press.	2008
4.	Sammes, N. M., "Fuel Cell Technology – Reaching towards commercialization", Springer.	2006
5.	Gregor, H., "Fuel Cell Technology Handbook", CRC Press.	2003
6.	Srinivasan, S., "Fuel Cells – From Fundamentals to Applications", Springer.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN-546** Course Title**: Welding Metallurgy**
2. Contact Hours**:** **L: 3 T: 1 P: 2/2**
3. Examination Duration (Hrs)**:** **Theory: 3 Practical: 0**

4. Relative Weight **:** **CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**
5. Credits**: 4** 6. Semester **: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objectives**:** The aim of the course is to provide fundamental principles of metallurgy related with welding.

10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	**Fundamentals of physical metallurgy:** Need, phase diagrams: Fe-C, Al-Cu, Cu-Zn system, Phase transformations in Fe-C system, TTT diagram and CCT diagram, Carbon equivalent, Schaffer diagram, relevance of above in welding	8
2.	**Metal strengthen approaches**: introduction, solid solution strengthening, grain refinement, precipitation hardening, transformation hardening, dispersion hardening, work hardening, strain aging	8
3.	**Heat treatment of weld joint: Need,** Annealing; Normalizing; Quenching; Tempering; Austempering; Martempering and stress relieving of steel, Precipitation hardening of Al and copper alloys	8
4.	**Solidification of weld metal:** principle of solidification of weld metal, modes of solidification, effect of welding parameter on weld structure, grain refinement principle of weld metal, method of weld metal refinement: inoculation, arc pulsation, external excitation	10
5.	**Heat affected zone and weld metal:** transformations in HAZ of steel, factors affecting changes in microstructure and mechanical properties of HAZ, reactions in weld pool: gas-metal reaction, slag metal reaction.	8
6	**Metallurgical issues in weld joint:** Mechanisms, causes and remedy of cold cracking, solidification cracking, nonmetallic inclusions; lamellar tearing; hydrogen damage, banding, segregation	
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Author (s)/ Book/ Publisher	Year of Publication/Reprint
1.	Lancaster J F., "Metallurgy of Welding", Allen & Unwin Co.	2000
2.	S D Avner, "Introduction to physical metallurgy", TMH	2011
3.	"Welding, Brazing and soldering", Vol. 6, ASM International, ASM, Ohio.	1993
4.	Kou S., Welding metallurgy, 2nd edition, Wiley Publications	2003
5.	K Esterling, "Introduction to Physical Metallurgy of Welding", BH	1991
6.	Gene Mathers, "Welding of Aluminium and alloys", Wood Head Pub. UK.	2002

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-550** Course Title: **Advanced Machine Design**
2. Contact Hours : **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**
4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: The course is intended to train the graduates in methods of failure analysis and design of machine parts against likely failures, using advanced concepts and also to design for reliability.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Review of failure theories, their scope of applications under different loading and environmental conditions, Hertzian contact stresses and their effect on load carrying capacities of members, effect of small inelastic strains and residual stresses on load carrying capacity, theory of limit design; Machinery construction principles.	12
2	**Designing against Fracture**: Linear elastic fracture mechanics approach, theories of brittle fracture, fundamental aspects of crack growth and fractures, use of fracture in design.	10
3	**Designing against Fatigue and Creep**: Causes and interpretation of failures, influence of various factors, low cycle and high cycle fatigue, cumulative damage theories, acoustical and thermal fatigue, corrosion and fretting fatigue, pitting of gears, fatigue strength of joints, components and structures; creep behavior; the mechanical equation of state, an elastic and plastic creep, rupture theory, analysis of tensile creep data, creep in high temperature low cycle fatigue, creep analysis of thick walled cylinders and rotating discs.	10
4	**Design for Reliability**: Application of statistics to material properties, fatigue and reliability, early chance and wear out failures, reliability prediction against chance and wear out failures, probabilistic approach to design and its comparison with safety factor approach, reliability prediction of series, parallel and stand by systems.	10
	Total	**42**

11. Suggested Books:

S.	Name of Authors/ Books / Publisher	Year of

No.		Publication /Reprint
1	Faupel, J.H., and Fisher, F.E., "Engineering Design", Wiley-Interscience.	1981
2	Burr, A.H., "Mechanical Analysis and Design", Elsevier.	1982
3	Smith, N., "Advances in Creep Design", Applied Science.	1971
4	Bazovsky, I., Reliability Theory & Practice, Courier Dover Publications.	2004
5	Haugen, E.B., Probabilistic Approach Design, John Wiley.	1968
6	Yotaro Hatamura and Yoshio Yamamoto, "The Practice of Machine Design" Oxford University Press.	1999
7	Kai Cheng, "Machining Dynamics: Fundamentals, Applications and Practices" Springer.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-551** Course Title: **Dynamics of Mechanical Systems**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs.) : **Theory 3 Practical 0**
4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To impart knowledge of principles governing the motion of mechanical systems and to develop their skills in analysis and control of their motion.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic concepts**: Inertial coordinate system, fundamental laws of motion, mechanics of particles and system of particles, principles of linear and angular momentum, work-energy principles.	4
2	**Lagrangian dynamics**: Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Lagrange's equation from d'Alembert's principles, application of Lagrange's equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d'Alembert's principle, Lagrange equation from Hamilton's principle.	10
3	**Multi-body dynamics**: Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.	15
4	**Stability of motion**: Fundamental concept in stability, autonomous systems and phase plane plots, Routh's criteria for stability, Liapunov's method, Liapunov's stability theorems, Liapunov's function to determine stability of the system.	7
5	**Control system dynamics**: Open and close loop systems, block diagrams, transfer functions and characteristics equations, proportional integral and derivative control actions and their characteristics.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1	Ginsberg, J.H., "Advanced Engineering Dynamics", Harper and Row.	1988
2	Meirovitch, L., "Methods of Analytical Dynamics", McGraw Hill Inc.	1970
3	Harold Josephs and Ronald Huston, "Dynamics of Mechanical Systems", CRC Press.	2002
4	Katsuhiko Ogata, "System Dynamics",4th Ed., Prentice Hall;	2003
5	Robert L. Woods and Kent L. Lawrence, "Modeling and Simulation of Dynamic Systems", Prentice Hall.	1997
6	Ramin S. Esfandiari and Bei Lu, "Modeling and Analysis of Dynamic Systems", CRC Press.	2010
7	Dean C. Karnopp, Donald L. Margolis, and Ronald C. Rosenberg, "System Dynamics: Modeling and Simulation of Mechatronic Systems", 4th Ed., Wiley.	2006
8	Richard A. Layton, "Principles of Analytical System Dynamics" (Mechanical Engineering Series), Springer.	1998

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPARTMENT: Mechanical & Industrial Engineering

1. Subject Code: **MIN-552** Course Title: **Advanced Mechanics of Solids**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory 3** **Practical 0**

4. **Relative Weight :CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre – requisite: **Nil**

9. Objectives of Course: The course aims at providing advanced concepts in behavior of solids under various loading conditions and to train the graduates in analyzing the resulting stresses and deformations.

10. Details of Course:

S. No.	Particulars	Contact Hours
1	**Mathematical Preliminaries**: Scalars, vectors and matrix variables, index notation and the related rules, Cartesian tensors and their algebra, co-ordinate transformation, transformation rules for the n^{th} order tensors, elements of tensor calculus and the related theorems (divergence, Stokes' and Green's), principal value theorem, eigenvalues and eigenvectors, invariants of a 2^{nd} order tensor.	4
2	**Kinetics of Deformation:** Types of forces (point, surface and body), traction vector, state of stress at a point, Cauchy's relation and its proof, conservation of linear and angular momentum, stress equilibrium equations, symmetry of stress tensor, stress transformation, principal stresses and the associated planes, 3D Mohr's circle representation, planes of maximum shear, octahedral planes, hydrostatic and deviatoric stress, first and second Piola-Kirchoff stress tensors and their properties.	8
3	**Kinematics of Deformation**: Material and spatial co-ordinates, Eulerian and Lagrangian description of motion; deformation and displacement gradients, Green-Lagrange and Almansi strain tensor; Cauchy's small strain tensor and the rotation tensor, geometrical interpretation of strain components and sign convention, principal strains and directions, strain invariants, octahedral strain, maximum shear strain, volumetric strain, strain compatibility equations.	8
4	**Constitutive Modeling**: Thermodynamic principles, first and second law of thermodynamics, Generalized Hooke's law for isotropic materials, elastic constants and their relations, anisotropic, hyperelastic and viscroelastic material models, strain hardening, constitutive relations for elasto-plastic materials, flow and hardening rules.	8

5	**Boundary Value Problems in Linear Elasticity**: Field equations and boundary conditions, Navier equations, Beltrami-Michell stress compatibility conditions, 2D approximations (plane stress and plane strain) and solution strategies.	6
6	**Variational Principles in Solid Mechanics**: Elements of variational calculus, extremum of a functional, Euler-Lagrange equation and its application, types of boundary conditions, principle of virtual work, Principle of total potential energy and complementary potential energy, Ritz method, time-dependent problems and Hamilton's principle for continuum.	8
Total		**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication
1	Sadd, M.H., "Elasticity Theory Applications and Numerics", Elsevier Academic Press.	2005
2.	Boresi, A.P., Sidebottom, O. M., "Advanced Mechanics of Materials", 5th Ed., John Wiley and Sons	2007
3	Singh, A.K., "Mechanics of Solids", PHI Learning Private Limited	2011
4	Timoshenko, S.P., and Goodier, J.M., "Theory of Elasticity", 3rd Ed., McGraw Hill	2004
5.	Srinath, L.S., "Advanced Mechanics of Solids",Tata McGraw Hill Education Private Limited	2009
6.	Fung, Y.C., " Foundations of Solid Mechanics", Prentice Hall Inc.	1965

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-553** Course Title: **Industrial Tribology**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The course has been designed to give an understanding of tribological phenomena, industrial lubricants and additives.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Tribological consideration, nature of surfaces and their contact. Introduction, physico-mechanical properties of surface layer; Geometrical properties of surfaces, method of studying surface; Contact of smooth surfaces, contact of rough surfaces. Role of friction, laws of static friction, causes of friction; Adhesion. Adhesion theory, laws of rolling friction, friction of metals and nonmetals, friction measurement; Wear definitions, types of wear, mechanism of wear, factors affecting wear behavior, measurement of wear a brief introduction of wear test equipments, wear in plastics.	10
2	**Industrial Lubricants and Their Additives**: Functions of lubricants, types of lubricants and their industrial uses; Solid lubricants and their functions, liquid mineral lubricants, synthetic liquid lubricants, greases, properties of liquid and grease lubricants, viscosity, Newtonian and Non-Newtonian lubricants, temperature and pressure dependence measurement, other properties of lubricants; Lubricant additives, general properties and selection for machines and processes; Oil reclamation and preventive maintenance for lubricants.	8
3	**Fluid-Film Lubrication**: Fluid mechanics concepts, equations of continuity and motion; Generalized Reynold's equation with incompressible and compressible lubricants; Hydrodynamic lubrication, Tower's experiment, finite bearings, partial journal bearings, solution of finite bearings using Galerkin, finite difference and FEM.	7
4	**Dynamically loaded journal bearings:** Solution of the generalized Reynold's equation for infinite and short bearing, load carrying capacity, Sommerfield numbers, journal centre locus, whirling; Hydrostatic lubrication-- basic concepts, applications, compensated thrust and journal bearings and their solution using FEM, controlling flow with restrictors, design of restrictors for compensated bearings.	7

5	**Gas Lubrication**: Types of gas bearings and their characteristics; Reynolds equation for iso-thermal, polytropic and adiabatic supporting gas films; Introduction to porus bearing permeability, solution of thrust and journal bearings.	5
6	**Bearing Design and Selection of Bearings**: Comparative performance of various modes of lubrication, and bearing selection; Design of slideway bearing and hydrostatic thrust bearing, fixed type hydrodynamic and hydrostatic journal bearings, materials for sliding bearings; Bearing types, selection of rolling elements bearing, bearing life, bearing load, bearing selection.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books/ Publisher	Year of Publication/ Reprint
1	Conner, J.J. and Boyd, J., "Standard Handbook of Lubrication Engineering", McGraw Hill.	1968
2	Stachowiak, G. and A W Batchelor, A. W., "Engineering Tribology", 3rd Ed, Butterworth-Heinemann.	2005
3	Khonsari, M. M. and Booser, E. R., "Applied Tribology: Bearing Design and Lubrication", 2nd Ed, Wiley.	2008
4	Kudish, I. I. and Covitch, M. J., "Modeling and Analytical Methods in Tribology", Chapman and Hall/CRC.	2010
5	Bhushan, B., "Principles and Applications of Tribology", Wiley.	1999

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-554** Course Title**: Computer Aided Mechanism Design**
2. Contact Hours : **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): **Theory 3** **Practical 0**
4. Relative Weight : **CWS 20** **PRS 20** **MTE 20** **ETE 40** **PRE 0**
5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective: The course aims at providing the basic concepts of analysis and design of mechanisms.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Review of concepts related to kinematic analysis of mechanisms, degrees of freedom, Grashof's and Gruebler's criteria, transmission and deviation angles, mechanical advantage.	6
2	**Kinematic Synthesis of Mechanisms**: Type, number and dimensional synthesis, spacing of accuracy points, Chebyshev polynomials, path motion and function generation, graphical synthesis with two, three, and four prescribed positions and points.	8
3	**Analytical Synthesis Techniques**: complex number modeling, dyad and standard form equation, Freudenstein's equation for three point function generation, coupler curves, Robert's law, cognates of linkages.	8
4	**Path Curvature Theory**: Fixed and moving centrode, inflection points and inflection circle, Euler-Savary equation, Bobillier and Hartmann's construction.	8
5	**Dynamic Force Analysis**: Introduction, inertia forces in linkages, kinetic-static analysis by superposition and matrix approaches and its applications, introduction to spatial mechanisms.	6
6	**Software usages:** Modelling, analysis and synthesis of various mechanisms using software packages	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books/ Publisher	Year of Publication /Reprint
1	Hall, A.S., "Kinematic and Linkage Design", Prentice Hall Inc.	1978
2	Sacks, E. and Joskowicz, L., "The Configuration Space Method for Kinematic Design of Mechanisms", MIT Press.	2010
3	Erdman, A. G. and Sandor, G. N., "Mechanism Design: Analysis and Synthesis", 3rd Ed, Prentice Hall.	1996
4	Shabana, A. A., "Computational Dynamics", 3rd Ed., Wiley.	2010
5	Shabana, A. A., "Dynamics of Multibody Systems", 2nd Ed., Cambridge University Press.	2003
6	Eckhardt, H. D., "Kinematic Design of Machines and Mechanisms", McGraw-Hill.	1998
7	Sandor G.N., and Erdman A.G., "Advanced Mechanism Design: Analysis and Synthesis Vol.2", Prentice Hall Inc	1984

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-555** Course Title: **Experimental Stress Analysis**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): Theory **3** Practical **0**
4. Relative Weight : CWS **20** PRS **20** MTE **20** ETE **40** PRE **0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: The course aims at providing fundamental concepts and applications of the most conventional experimental stress analysis methods used in practice.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Importance of experimental methods and their scope, whole field and point by point methods.	2
2	**Photoelasticity**: Nature of light, photoelastic effect and polarized light, permanent and temporary birefringence, types of polariscopes and their basic elements, optics of plane and circular polariscope, isoclinics and isochromatics, stress optic law and secondary principal stresses; Photoelastic model materials their properties and selection, preparation of models, transition from model to prototypes, measurement of relative retardation and fringe order, compensation techniques, separation of principal stresses by oblique incidence, shear difference and numerical integration of Laplace's equation.	8
3	**Photoelastic methods:** Calibration methods and determination of stress trajectories from isoclinic data; Basic elements of three dimensional photoelasticity, stress freezing and slicing the model and interpretation of the resulting fringe patterns, fringe sharpening and fringe multiplication techniques; Photoelastic methods to determine stress intensity factors.	4
4	**Birefringent Coatings**: Surface stress determinations using birefringent coatings, sensitivity of biregringent coatings; Reinforcing, thickness and other effects of photoelastic coatings; Separation of principal stresses; Birefringent coating materials and applications; Photoelastic stress and strain gauges.	6
5	**Scattered Light Photoelasticity**: Scattering phenomenon and polarization associated with scattering, scattered light technique to solve general three dimensional problem; Scattered light polariscope.	5
6	**Moire Method of Strain Analysis**: Moire phenomenon and formation of Moire fringes; Geometric and displacement approach for in-plane problems, Moire grating production, printing and photography.	5
7	**Brittle Coatings**: Introduction, coating stresses; Brittle coating failure theories; Factors affecting analysis of coating data; Crack patterns due to direct and	6

	relaxation loading; Refrigeration technique, calibration methods and scope of application of brittle coating method.	
8	**Digital Image Processing**: Fringe multiplication, fringe thinning and fringe clustering through data acquisition by DIP methods; Phase shifting, polarization stepping and Fourier transform techniques phase unwrapping and optical enhanced tiling, use of colour image processing techniques for data acquisition in digital photoelasticity.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Phillips, E.A., Durelli, A.J. and Tsao, C.H., "Analysis of Stress and Strain", McGraw Hill.	1958
2	Daily, J.W. and Riley, W.F., "Experimental Stress Analysis", McGraw Hill.	1991
3	Durelli, A.J. and Riley, W.F., "Introduction to Photomechanics", Prentice Hall.	1965
4	Frocht, M.M., "Photoelasticity (Vol. I and II)", John Wiley.	1948
5	Ramesh, K., "Digital Photoelasticity: Advanced Techniques and Applications", Springer-Verlag.	2000
6	James W. Dally and William F. Riley, "Experimental Stress Analysis", College House Enterprises.	2005
7	James F. Doyle, "Modern Experimental Stress Analysis: Completing the Solution of Partially Specified Problems", Wiley.	2004
8	Pramod K. Rastogi, "Photomechanics"(Topics in Applied Physics),Springer.	2000

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-556** Course Title: **Dynamics of Road Vehicles**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.): Theory **3** Practical **0**
4. Relative Weight : CWS **20** PRS **20** MTE **20** ETE **40** PRE **0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To provide fundamental engineering principles underlying the control, stability, handling and cornering behavior of road vehicles.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction to Vehicle Dynamics**: Various kinds of vehicles,motions, mathematical modelling methods; Multibody system approach and Lagrangian formulations, methods of investigations, stability concepts.	4
2	**Mechanics of Pneumatic Tyre**: Tyre construction, physics of tyre traction on dry and wet surfaces, tyre forces and moments, SAE recommended practice, rolling resistance of tyres, ride properties of tyres.	10
3	**Performance Characteristics**: Equation of motion and maximum tractive effort, aerodynamic forces and moments, vehicle power plant and transmission characteristics, prediction of vehicle performance, operating fuel economy, braking performance, antilock braking systems.	8
4	**Handling and Stability Characteristics**: Steering geometry; steady state handling characteristics, steady state response to steering input, transient response characteristics directional stability, effects of tyre factors, suspension, braking and vehicle parameters on stability and handling.	8
5	**Vehicle Ride Characteristics**: Human response to vibration, vehicle ride models, road surface profile as a random function; frequency response function, evaluation of vehicle vertical vibration in relation to ride comfort criterion.	7
6	**Experimental Testing:** Instruments for vehicle measurements, recording and evaluation methods, test methods and measurement procedures for vehicle dynamics, interpretation of test results and correlation between measured values and subjective evaluation of the vehicle handling.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1.	Wong, J.Y., "Theory of Ground Vehicles", John Wiley.	2001
2.	Gillespie, T.D., "Fundamental of Vehicle Dynamics", S.A.E.	1992
3	Rao, V. D., "Road Vehicle Dynamics", SAE International.	2008
4	Rajesh, R., "Vehicle Dynamics and Control", Springer.	2005
5	Hans, T., "The Dynamics of Vehicles on Roads and on Tracks", Taylor and Francis,	2003
6	Barnard, R. H., "Road Vehicle Aerodynamic Design: An Introduction", 2nd Ed., Mechaero Publishing.	2001
7	Wong, J. Y., "Theory of Ground Vehicles", 4th Ed., Wiley.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Mechanical & Industrial Engineering**

1. Subject Code: **MIN-557** Course Title: **Finite Element Methods**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Autumn/Autumn** 7. Subject Area: **PEC**

8. Pre–requisite: **NIL**

9. Objective: To provide the basic concepts of finite element method and its applications to wide range of engineering problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts**: Introduction, Weak formulations, Weighted residual methods, Variational formulations, weighted residual, collocation, subdomain, least square and Galerkin's method, direct method, potential energy method	8
2.	**One-Dimensional Analysis**: Basis steps, discretization, element equations, linear and quadratic shape functions, assembly, local and global stiffness matrix and its properties, boundary conditions, applications to solid mechanics, heat and fluid mechanics problems, axisymmetric problems	8
3.	**Plane Truss**: Local and global coordinate systems, stress calculations, example problems	3
4.	**Beams**: Introduction, Euler-Bernoulli beam element, numerical problems	3
5.	**Scalar Field Problems in 2-D**: Triangular and rectangular elements, constant strain triangle, isoparametric formulation, higher order elements, six node triangle, nine node quadrilateral, master elements, numerical integration, computer implementation, Numerical problems	10
7.	**Plane Elasticity**: Review of equations of elasticity, stress-strain and strain-displacement relations, plane stress and plane strain problems	4
8.	**Bending of Elastic Plates**: Review of classical plate theory, plate bending elements, triangular and rectangular elements, Shear deformation plate theory, numerical problems	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Huebner K.H., Dewhirst, D. L., Smith, D. E., and Byrom, T. G., "The Finite Element Method for Engineers", 4th Ed., John Wiley and Sons	2001
2.	Rao, S. S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science	2005
3.	Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill	2005
4.	Fish, J., and Belytschko, T., "A First Course in Finite Elements", 1st Ed., John Wiley and Sons	2007
5.	Chaskalovic J., "Finite Element Methods for Engineering Sciences", 1st Ed., Springer	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-558** Course Title: **Fracture Mechanics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): Theory **3** Practical **0**
4. Relative Weight : CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the mechanics of anisotropic material, and provide insight into different failure mechanisms typical of anisotropic and heterogeneous systems
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction to Fracture Mechanics**: Introduction to the realm of fracture and back ground history of development of fracture mechanics; Discrepancy between theoretical and real strength of materials, conventional failure criteria based on stress concentration and characteristic brittle failures, Griffith's work.	5
2	**Linear Elastic Fracture Mechanics (LEFM) Based Design Concepts:** Crack deformation modes and basic concepts, crack tip stresses and deformation, stress intensity factor (SIF) and its criticality in different modes, superposition of SIFs, LEFM design concept applications; Concept of energy release rate, equivalence of energy release rate and SIF.	10
3	**Fracture toughness:** Fracture toughness and its laboratory determination procedure, test specimen size requirement etc.; Effect of temperature and loading rate on fracture toughness; Fatigue and fatigue crack propagation laws, fatigue life calculations under constant and variable amplitude loading, mixed-mode fatigue crack propagation.	10
4	**Strain Energy Density Failure Criterion**: Introduction, volume strain energy density, basic hypothesis and application of energy density based failure criteria for two and three dimensional linear elastic crack problems.	7
5	**Elastic Plastic Fracture Mechanics Based Design Criteria**: Design criteria for non-brittle materials; plastic zone corrections, crack opening displacement (COD), J-contour integral and crack growth resistance (R-curve) concepts.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Gdoutos, E.E., "Fracture Mechanics: An Introduction", 2nd Ed., Springer.	2005
2	Broek, D., "Elementary Engineering Fracture Mechanics", 3rd Ed., Springer.	1982
3	Kumar, P., "Elements of Fracture Mechanics", Wheeler Publishing.	1999
4	Anderson, T. L., "Fracture Mechanics: Fundamentals and Applications", 3rd Ed., CRC Press.	2005
5	Shukla, A., "Practical Fracture Mechanics in Design", 2nd Ed., CRC Press.	1989
6	Bazant, Z. P. and Cedoliin, L., "Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories", World Scientific Publishers.	2010

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-559** Course Title: **Computer Aided Design**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weight : **CWS** **20** **PRS** 20 **MTE** **20** **ETE** **40** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre–requisite: **Nil**

9. Objectives of Course: The course aims at providing the basic concepts and elementary tools of CAD.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: The design process, elements of CAD	01
2	**Principles of Software Design**: Characteristics of good software, data structures, algorithm design, flow chart, coding, top-down programming, modular programming, structural coding, testing of the software.	03
3	**Computer Graphics**: Graphics display, transformations, visualizations, computer animation.	03
4	**3D Modeling and Viewing**: Coordinate systems, sketching and sketch planes; Modeling aids and tools; Layers, grids, clipping, arrays, editing.	03
5	**Curves Modeling:** Analytical and synthetic curves, curve manipulations.	07
6	**Surface Modeling:** Surface representation and surface analysis, analytical and synthetic surfaces, surface manipulations, NURBS.	07
7	**Solid Modeling**: Geometry and topology, solid entities, solid representation, fundamental of solid modeling, half spaces, boundary representation, constructive solid geometry, sweeps, solid manipulations.	07
8	**Features**: Feature entities, feature representation, three dimensional sketching, parametrics, relations, constraints, feature manipulation.	03
9	**Mass properties**: Geometric and mass properties evaluation, assembly modeling, product data exchange	04
10	**Optimization technique**: Single variable optimization, multi-variable optimization, Johnson's method of optimum design, genetic algorithm.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Zeid, I., "Mastering CAD/CAM", Tata McGraw Hill.	2007
2	Onwubiko, C., "Foundation of Computer Aided Design", West Publishing Company.	1989
3	Hsu, T. R. and Sinha, D. K., "Computer Aided Design: An Integrated Approach", West Publishing Company.	1991
4	Dimarogonas, A. D., "Computer Aided Machine Design", Prentice Hall.	1988
5	Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press.	2006

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-560** Course Title: **Mechanics of Composite Materials**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): Theory **3** Practical **0**
4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** **7.** Subject Area**: PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the mechanics of anisotropic material and to provide insight into different failure mechanisms typical of anisotropic and heterogeneous systems.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Composite materials, characteristics, classification, advantages and typical problems.	2
2	**Unidirectional Lamina**: Introduction, longitudinal strength and stiffness, transverse strength and stiffness, failure modes, thermal expansion and transport properties.	6
3	**Short Fibre Composites**: Theories of stress transfer, modulus and strength of short fibre composites.	4
4	**Analysis of an Orthotropic Lamina**: Hook's law, stress-strain relation for lamina with an arbitrary orientation, strength of a lamina subjected to biaxial stress field.	6
5	**Analysis of Laminated Composites**: Classical lamination theory, thermal stress in laminates.	12
6	**Special Design Considerations**: Analysis after initial failure, inter-laminar stress, free edge effect, design of joints, elementary fracture mechanics concepts related to composite materials.	8
7	**Experimental Characterization**: Uni-axial tension test, compression test, in-plane shear test, three and four point bending test, determination of interlaminar shear strength.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Agarwal, B.D. and Broutman, L.J., "Analysis and Performance of Fibre Composites", 3rd Ed., John Wiley & Sons.	2006
2	Jones, R.M., "Mechanics of Composite Materials", Taylor & Francis.	1998
3	Ashbee, K.H.G. and Ashbee, H.G., "Fundamental Principles of Fibre Reinforced Composites", 2nd Ed., CRC Press.	1993
4	Daniel, I.M. and Ishai, O., "Engineering Mechanics of Composite Materials", 2nd Ed., Oxford University Press.	2007
5	Christensen, R.M., "Mechanics of Composite Materials", Dover Publications.	2005
6	Kaw, A. K., "Mechanics of Composite Materials", 2nd Ed., CRC Press.	2005

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-561** Course Title: **Advanced Mechanical Vibrations**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 20** **PRS 20** **MTE 20** **ETE 40** **PRE 0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide detail knowledge about nonlinear and random vibration with fault diagnosis of machinery.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Review of free and forced vibrations with and without damping.	3
2	**Isolation:** Vibration isolation and transmissibility; Un-damped vibration absorbers.	4
3	**Multi degree of freedom system**: Generalized coordinates and coordinate coupling; Orthogonality of modes, Free and forced vibration of multi-degree of freedom systems with and without viscous damping; Lagrange's equation; Holzer's method. Solution of Eigen value problem, transfer matrix and modal analysis.	12
4	**Stability criterion:** Self excited vibrations; Criterion of stability; Effect of friction on stability.	4
5	**Non linear vibration:** Free vibrations with non-linear spring force or nonlinear damping; Phase plane; Energy curves; Lienard's graphical construction; Method of isoclines.	5
6	**Vibration of continuous system:** Vibrations of strings; Free and forced longitudinal vibrations of prismatic bars; Ritz and Galerkin methods.	6
7	**Random vibration:** Mathematical descriptions of stochastic processes; Stationary and ergodicity; Gaussian random process, correlation functions and power spectral density.	4
8	**Diagnostic techniques:** Introduction to diagnostic maintenance and signature analysis.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Rao, S.S., "Mechanical Vibrations", 4th Ed., Pearson Education.	2007
2	Meirovitch, L., "Fundamental of Vibrations", Mc-Graw Hill.	2001
3	Inman, D.J., "Vibration and Control", John Willey & Sons.	2002
4	Tamadonni, S. and Kelly, G.S., "Mechanical Vibrations", Mc-Graw Hill.	1998
5	Rao, J. S., "Vibration Condition Monitoring of Machines", Tata Mc-Graw Hill.	2006

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-562** Course Title: **Noise Control in Mechanical Systems**

2. Contact Hours : **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart fundamental knowledge of the subject on noise control problems in mechanical systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Sound vs noise; Time and frequency domain representation, hearing mechanism -- assessment of noise, its units, human response to noise of different types- stead, fluctuating and impulsive, physiological effects of noise, control of noise, need, concepts and options, and its relation to vibrations.	6
2	**Homogeneous Wave Equation**: Linearized wave equation, acoustic velocity potential acoustic impedance, plane wave propagation, intensity, energy density and power, Simple Source models, monopole, dipole, quadrupole and linear, effect of proximity of rigid boundaries, directivity patterns.	6
3	**Inhomogeneous Wave Equation and Aerodynamic Noise Theory**: Effect of solid bodies in flow, vortex flow; Ray Acoustics-- propagation of sound outdoors, divergence, excess attenuation factors, effects of wind, temperature gradient and turbulence anomalous propagation, shadow zones, ground and terrain effects, harriers, cuttings and elevation.	7
4	**Wave-Structure Interaction**: Sound radiation from plates infinite and bounded; radiation ratio, sound transmission through layered media, behavior of infinite and finite panels, coincidence phenomena and design curves, sound transmission loss, fluid loading on structure, impact noise, introduction to statistical energy analysis.	6
5	**Instrumentation**: Sound measuring equipment, microphones, preamplifiers, sound level meters, recorders, frequency analysers statistical measurements, FFT analysers.	5
6	**Noise Control Principles**: Control strategies and limitations, integrated approach to low noise design, typical mechanical noise sources, mechanism of noise generation– vibration, impact, flow excitation, control of solid borne and air-home noise, concept of impedance mismatch, filters, silencers, damping, enclosure, absorbers, active noise control principle.	8

7	**Case Studies**: Noise control in reciprocating and rotating machinery, and fluid flow systems: e.g., gears, bearing, piping systems, automobiles, aircrafts, refrigeration and air conditioning systems elements, machine tools, presses etc., environmental noise control and receiver protection.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Faulkner, L.L, "Handbook of Industrial Noise Control", Industrial Press.	2001
2	Lyon, R.H., "Machinery Noise and Diagnostics", Butterworths.	1995
3	Norton, M.P., "Fundamentals Noise and Vibration Analysis", Cambridge University Press.	1989
4	Rahn, C. D., "Mechatronic Control of Distributed Noise and Vibration", Springer.	2001
5	Fuller, C. C., Elliott, S.J., and Nelson, P. A., "Active Control of Vibration", Academic Press.	1996
6	Moser, M., Zimmermann, S. and Ellis, R., "Engineering Acoustics: An Introduction to Noise Control", 2nd Ed., Springer.	2009

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-563** Course Title: **Mechatronics**

2. Contact Hours: **L: 3 T: 1 P: 2/2**

3. Examination Duration (Hrs.): **Theory 3 Practical 0**

4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits: 4 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **Nil**

9. Objective: The course deals with basic principles of Mechatronics involving sensors, actuators, control systems, and microprocessor systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach.	2
2	**Sensors and Transducers**: Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches.	7
3	**Actuators**: Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems.	5
4	**Signal Conditioning**: Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems.	4
5	**Microprocessors and Microcontrollers**: Microcomputer structure, microcontrollers, applications, programmable logic controllers.	8
6	**Modeling and System Response**: Mathematical models, bond graph models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.	9
7	**Design and Mechatronics**: Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots.	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Bolton, W., "Mechatronics", Longman.	1999
2	Alciatore, D. G. and Histrand, M. B., "Introduction to Mechatronics", Tata McGraw Hill.	2003
3	Shetty, D. and Richard, A.K., "Mechatronics System Design", PWS Pub. Boston.	1997
4	Mahalik, N., "Principles, Concept and Applications: Mechatronics", Tata McGraw.	2003
5	Bishop, R.H. "Mechatronics Handbook", CRC Press.	2002
6	Bolton, W., "Mechatronics: A Multidisciplinary Approach", 4th Ed., Prentice Hall.	2009
7.	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**: MIN-565** Course Title**: Smart Materials, Structures and Devices**

2. Contact Hours **: L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.)**: Theory 3 Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge on analysis of smart materials for various applications such as sensors, actuators and controllers with reference to various structures and devices.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Intelligent Materials**: Primitive functions of intelligent materials; Intelligence inherent in materials; Materials intelligently harmonizing with humanity; Intelligent biological materials.	2
2	**Smart Materials and Structural Systems**: Actuator materials; Sensing technologies; Microsensors; Intelligent systems; Hybrid smart materials; Passive sensory smart structures; Reactive actuator-based smart structures; Active sensing and reactive smart structures; Smart skins.	4
3	**Electro–Rheological Fluids**: Suspensions and electro, reheological fluids; The electro- rheological phenomenon; Charge migration mechanism for the dispersed phase; Electro rehological fluid actuators.	4
4	**Piezoelectric Materials**: Background; Piezoelectricity; Industrial piezoelectric materials; Smart materials featuring piezoelectric elements.	3
5	**Shape Memory Materials**: Background on shape memory alloys; Applications of shape memory alloys; Continuum applications: structures and machine systems; Discrete applications; Impediments to applications of shape memory alloys; Shape memory plastics.	4
6	**Fiber Optics**: Overview; Light propagation in an optical fiber; Embedding optical fibers in fibrous polymeric thermosets; Fiberoptic strain sensors.	3
7	**The Piezoelectric Vibrations Absorber Systems**: Introduction; The single mode absorber, theory, design solution, extension including viscous modal damping, the electromechanical coupling coefficient, inductance, experimental results; The multimode absorber, derivation of transfer function, design solution, self-tuning absorber, performance function, control scheme.	7
8	**Modeling of Shells:** Derivation of the basic shell equations, equation of motion, equations for specific geometries and cylindrical shell.	10

9	**Modeling of plates and beams:** Plate equations and beam equations.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication /Reprint
1	Gandhi, M. V. and Thompson, B. S., "Smart Materials and structures", Chapman & Hall.	1992
2	Banks, H. T., Smith, R. C. and Qang, Y. W., "Smart Material structures: Modeling, Estimation and Control", John Wiley & Sons.	1996
3	Gabbert, U. and Tzou, H. S., "Smart Structures and Structronic System", Kluwer Academic Publishers.	2001
4	Preumont, A., "Vibration Control of Active Structures", Kluwer Academic Publishers.	2002
5	Cheng, F. Y., Jiang, H. and Lou, K., "Smart Structures: Innovative Systems for Seismic Response Control", CRC Press.	2008

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code:**MIN-566** Course Title: **Computer Aided Analysis of Mechanical Systems**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objectives: To introduce computer-based design tools for analyzing the kinematics and dynamics of mechanical systems.

10. Details of Course:

S. No.	Particulars	Contact Hours
1	**Introduction**: Introduction to mechanical systems analysis.	2
2	**Kinematic Modeling**: Modeling the kinematics of mechanical systems; Vector loop methods, vector chain methods.	4
3	**Solution of Kinematic Models**: Solution of kinematic models for displacements, velocities, accelerations; Direct analytical solutions of position, velocity, acceleration problems; Numerical solution of position problem; Matrix method solutions of velocity and acceleration problems.	8
4	**Dynamic Modeling**: Modeling the dynamics of mechanical systems; Newton-Euler methods to define dynamic constraints between forces, moments, and accelerations, energy methods to define dynamic constraints between input and output links.	6
5	**Solution of Dynamics Models:** Solution of inverse dynamics models for joint-link forces and torques, solution of forward dynamics models using numeric integration, model formulation into standard format for solution, Euler's method of integration, Runge-Kutta methods of integration, modeling and analysis of the Trebuchet mechanism.	14
6	**Advanced Dynamic Analysis & Simulation**: Bond graph modeling of dynamic systems, generation of system equations, causality, and simulation.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Norton R., "Design of Machinery", McGraw-Hill	1992
2	Palm W. J., "Introduction to MATLAB 6 for Engineers", McGraw-Hill	2000
3	Nikravesh, P. E., "Computer-Aided Analysis of Mechanical Systems", Prentice Hall.	1988
4	Haug, E. J., "Computer Aided Analysis and Optimization of Mechanical System Dynamics", Springer-Verlag.	1984
5	Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in Modeling, Simulation and Fault Identification", I & K International.	2007

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-567** Course Title: **Computer Graphics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** **20** **MTE** **20** **ETE** **40** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: The course aims is to provide the basics of Computer Graphics needed for CAD/ CAM applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Role of Computer Graphics in CAD/CAM, configuration of graphic workstations, menu design and Graphical User Interfaces (GUI), customization and parametric programming.	04
2	**Geometric Transformations and Projections:** Vector representation of geometric entities, homogeneous coordinate systems, fundamentals of 2D and 3D transformations: Reflection, translation, rotation, scaling, and shearing, various types of projections.	08
3	**Curves:** Modeling planar and space curves, analytical and synthetic approaches, non-parametric and parametric equations.	08
4	**Surfaces:** Modeling of bi-parametric freedom surfaces, Coons, Bezier, B-spline, and NURBS surfaces, surface manipulation techniques.	08
5	**Geometric Modeling:** Geometric modeling techniques, wireframe modeling, solid modeling: B-Rep, CSG, hybrid modelers, feature based, parametric and variational modeling.	10
6	**Data Structure in Computer Graphics:** Introduction to product data standards and data structures, data-base integration for CIM.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Rogers, D. F., and Adams, J. A., "Mathematical Elements for Computer Graphics", McGraw Hill.	1989
2	Faux, I. D. and Pratt, M. J., "Computational Geometry for Design and Manufacture", Ellis Horwood Ltd.	1979
3	Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press.	2006
4	Zeid, I., "CAD/CAM: Theory and Practice", Tata McGraw Hill.	1998
5	Choi, B. K., "Surface Modeling for CAD/CAM", John Wiley & Sons	1991

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-568** Course Title: **Advanced Robotics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **20** **PRS** 20 **MTE** **20** **ETE** **40** **PRE** 0

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To impart knowledge of robotic vision systems, robot modeling, trajectory planning, manipulator control, and design and control issues of mobile robots, space robots etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Review, forward and inverse kinematics, dynamics	02
2	**Robots with Flexible Elements**: Robots with Flexible Joints, Robots with Flexible Links	04
3	**Parallel Mechanisms and Robots:** Definitions, Type Synthesis of Parallel Mechanisms, Kinematics, Velocity and Accuracy Analysis, Singularity Analysis, Workspace Analysis, Static Analysis and Static Balancing, Dynamic Analysis, Design	06
4	**Mobile Robots:** **Wheeled mobile robots:** mobile robot kinematics, Mobility of Wheeled Robots, State-Space Models of Wheeled Mobile Robots, Wheeled Robot Structures, sensors for mobile robots, planning and navigation **Legged robots:** Analysis of Cyclic Walking, Control of Biped Robots Using Forward Dynamics, Biped Robots in the ZMP Scheme, Multilegged Robots, Performance Indices	08
5	**Cooperative Manipulators**: Kinematics and Statics, Cooperative Task Space, Dynamics and Load Distribution, Task-Space Analysis, Control	03
6	**Advanced Robots:** Modeling and control of space robots, underwater robots	06
7	**Control of Manipulators:** Manipulator control problem; Linear and non linear control schemes; PID control scheme; Force control.	04
8	**Image Processing and Analysis with Vision Systems**: Acquisition of images, digital images, image processing techniques, noise reduction, edge detection, image analysis, object recognition by features, application of	05

	vision systems	
9	**Fuzzy Logic Control:** Crisp values v/s fuzzy values, fuzzy sets: Degrees of membership and truth, fuzzification, fuzzy inference rule base, defuzzification, simulation of fuzzy logic controller, application of fuzzy logic in robotics	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1	Niku, S. B., "Introduction to Robotics: Analysis, Systems, Applications", Prentice Hall.	2001
2	Angeles, J., "Fundamentals of Robotic Mechanical Systems: Theory, Methods and Algorithms", Springer	2003
3	Craig, J. J., "Introduction to Robotics: Mechanics & Control", Addison Wesley.	1989
4	Siegwart, R., Nourbakhsh, I. R., "Introduction to Autonomous Mobile Robots", MIT Press.	2004
5	Xu, Y. and Kanade, T., "Space Robotics: Dynamics and Control", Kluwer Academic Publishers.	1993
6	Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer	2013
7	Siciliano, Bruno, Khatib, Oussama, Handbook of Robotics, Springer	2008
8	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-569** Course Title: **Expert Systems Design**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To cover concepts, techniques and tools for developing expert systems for various engineering systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Overview: Evolution and characteristics of knowledge-based systems.	02
2	**Introduction to Expert System Languages:** CLIPS (C language integrated production system) and JESS (java expert system shell).	06
3	**Pattern Matching**: Basic and advanced pattern matching techniques.	04
4	**Modular Design and Control**: Salience, phases and control facts, modules and execution control	04
5	**Knowledge Representation**: Productions, semantic nets, schemata, frames, logic and set.	04
6	**Methods of Inferences**: Inference rules, resolution system, forward and backward chaining.	04
7	**Reasoning under Uncertainty**: Hubert Dreyfus "From Socrates to Expert Systems: The Limits and Dangers of Computational Rationality" -- CSUS Library video collection, hypothetical reasoning and backward induction, temporal reasoning and Markov chains, uncertainty in inference chains; Probability-based techniques: Objective probability, experimental probability, subjective probability, Bayes' theorem, inexact or heuristic reasoning; Inexact reasoning: uncertainty and rules, certainty factors, Dempster-Shafer theory.	12
8	**Design of Expert Systems**: Approximate reasoning, fuzzy expert systems.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Giarratano, J. C. and Riley, G. D., "Expert Systems: Principles and Programming", 4th Ed., Course Technology.	2004
2	Gonzalez, A., and Dankel, D., "The Engineering of Knowledge-Based Systems", Prentice Hall.	1994
3	Jackson, P., "Introduction to Expert Systems", 3rd Ed., Addison Wesley.	1998
4	Akerkar, R. and Sajja, P., "Knowledge-Based Systems", Jones & Bartlett Publishers.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**:** **MIN-570** Course Title**: Operations Management**

2. Contact Hours **:** **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.)**:** **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** **6**. Semester**:** **Autumn** **7.** Subject Area**: PCC**

8**.** Pre – requisite**:** **Nil**

9**.** Objective**:** To impart knowledge on various strategic issues of operations management and developing their skills to design and model various facilities of an organization.

10**.** Details of Course**:**

S. No.	Contents	Contact Hours
1.	**Introduction:** Basic concepts of operations and production management, types of manufacturing systems and their characteristics.	4
2.	**Product and Process Design:** System planning and design, long-range planning, product and process design and technological considerations.	4
3.	**Demand Forecasting:** Role of demand forecasting in operations decisions; various demand patterns, qualitative and quantitative techniques of demand forecasting.	6
4.	**Production Planning and Scheduling:** Aggregate production planning, operation scheduling, various scheduling criteria, lot sizing, job shop control; Mutli-stage manufacturing systems, their scheduling and management, capacity planning.	16
5.	**Materials Planning:** Details of material requirement planning (MRP) and manufacturing resource planning (MRP-II) and their various techniques.	6
6.	**Facilities Planning:** Plant design, types and considerations in the plant location, plant layout types, design, evaluation, principles and types of material flow, optimum plant layout.	6
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Authors / Books /Publisher	Year of Publication/ Reprint
1.	Buffa, E. S. and Sarin, R. K., "Modern Production/Operations Management", 8th Ed., John Wiley & Sons.	2003
2.	Adam, E., Jr. and Ebert, R. E., "Production Operations Management", 5th Ed., Pearson Education.	1992
3.	Brown, S., Blackmon, K., Cousins, P. and Maylor H., "Operations Management: Policy, Practice, and Performance Improvement", Butterworth-Heinemann.	2001
4.	Dervitsiotis, K. N., "Operations Management", 2nd Ed., McGraw Hill.	1987
5.	Starr M. K., "Production and Operations Management", Thomson Business Information.	2009
6.	Karjewski, L. J, Ritzman, L. P. and Malhotra, M. K., "Operations Management: Processes & Supply Chains, 9th Ed., Pearson Education.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**:** **MIN-571** Course Title: **Quality Management**
2. Contact Hours **:** **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory 3** **Practical 0**
4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits**:** **4** **6**. Semester**: Autumn** **7.** Subject Area**: PCC**
8. Pre – requisite**: Nil**
9. Objective: To impart knowledge on various concepts and philosophies of quality management.
10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	**Fundamentals of Quality Management** : Quality of products, services and total quality control and its impact on the organization; Buyer, producer and market place demand for quality, quality cost and quality system economics; Quality management factors and jobs, system approach for quality management, commitment, leadership and team work.	9
2.	**Techniques of Quality Engineering**: Quality policy, product reliability and life cycle, safety, product quality and process capability, evaluation of methods, processes and materials, quality cost optimization; Quality planning, implementation and inspection, quality information feedback, corrective actions, Taguchi's philosophy and robust product and process design.	4
3.	**Process Control Engineering**: Machine and process capability analysis, multi-vary chart, vendor performance and their ratings, mechanization of process for quality.	4
4.	**Statistical Quality Control** : Review on variables, attributes quantities and their measurements etc; Theory of control charts, brief review on X, R, P, C, charts; Different adaptation of control charts, viz, group control chart, control charts with variable subgroup sizes, moving average and moving range charts, acceptance control charts, charts for trended universe average, CUSUM charts, different control charts.	4
5.	**Acceptance Sampling**: Acceptance sampling tables, acceptance sampling plans for attributes and variables.	5
6.	**Quality Improvement Techniques**: Variance concept in manufacturing cycle; Fish bone diagrams; Pareto charts; Just in Time (JIT) - philosophy, evaluation and concept.	6
7.	**System Approach and Quality System Establishment**: ISO-9000 pre-requisites, different quality systems and their structure, quality policies and	5

	objectives, management responsibility, documentation and methodology of implementation, quality audits and assessment.	
8.	**Achieving Total Commitment to Quality**: Participative approach and team work, training and motivation; quality circles, their characteristics, objectives and organization structure; Quality circle implementation structures and techniques; Communicating quality commitment to vendors and customers.	5
	Total	**42**

11. Suggested Books**:**

S. No.	**Name of Authors / Books /Publisher**	**Year of Publication /Reprint**
1.	Jackson, P. and Ashton, D., "Implementing Quality Through ISO-9000", Viva Book Pvt Ltd.	1993
2.	Grant, E. and Lavenworth, R., "Statistical Quality Control", 11th Ed., McGraw Hill.	1997
3.	Ross, P. J., "Taguchi Techniques For Quality Engineering", 2nd Ed., McGraw Hill.	1995
4.	Gryna, F., Chua, R. and Defeo, J., "Juran's Quality Planning and Analysis for Enterprise Quality", 5th Ed., McGraw Hill.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code**:** **MIN-572** Course Title**:** **Advanced Manufacturing Processes**

2. Contact Hours**:** **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.)**:** **Theory 3** **Practical 0**

4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PCC**

8. Pre – requisite: Nil

9. Objective**:** The course covers the details of the advanced machining theory and practices, advanced machining processes, advanced metal forming processes, advanced welding processes and advanced foundry processes.

10. Details of Cou**rse:**

S. No.	Contents	Contact Hours
1	**Machining:**Introduction: Review of mechanisms of machining, Advances in machining processes: Diamond turning, Hybrid machining, Micro machining	8
2	**Newer Machining Processes:** Introduction, process principle, process parameters and applications of processes such as ultrasonic machining (USM), abrasive water jet machining (AWJM), electrochemical machining (ECM), electro discharge machining (EDM), electron beam machining (EBM), and laser beam machining (LBM) processes, abrasive flow machining, biomachining	12
3.	**Metal Casting:** Introduction to solidification, Nucleation and grain growth, Solidification of pure metals and alloys, Advanced casting processes: Centrifugal and continuous casting processes, squeeze casting, vacuum mould casting, evaporative pattern casting, Semi solid metal working processes, ceramic shell casting	8
4.	**Rapid prototyping (RP):** process chain in RP, layering techniques, steriolithography, fused deposition modeling, laminated object manufacturing, repetitive masking and depositing.	4
5.	**Metal Forming:** Introduction: stress/strain, strain-rate characteristics of materials, y criteria of metals, c1assification of metal working processes, various methods analyzing the metal working processes (slip-line field theory; stab methods), Effec strain rate and temperature in metal forming **Advanced metal forming processes:** Details of high energy rate forming (HERF) process: electro-magnetic forming, explosive forming, electro-hydraulic forming; stretch forming, contour roll forming, Microforming.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books /Publisher	Year of Publication/ Reprint
1.	Bhattacharya A., "Metal Cutting: Theory and Practices", 2nd Edition, New Central Book Agency.	1984
2.	Armarego E. J. A. and Brown R. H., "Machining of Metals", 1st edition, Prentice Hall Inc. Englewood Cliffs, New Jersey.	1969
3.	DeGarmo E. P., Black J. T. and Kohser R. A., "Materials and Processes in Manufacturing", 8th Edition, Prentice Hall of India, New Delhi.	1997
4.	Ghosh A. and Mallik A. K., "Manufacturing Science", Affiliated East-West Press Pvt. Ltd. New Delhi.	1985
5.	Benedict G.F., "Nontraditional Manufacturing Processes", Marcel Dekker, Inc. New York.	1987
6.	Pandey P. C. and Shan H.S., "Modern Machining Processes", Tata McGraw-Hill Publishing Company Ltd, New Delhi.	1980
7.	Jain V. K., "Advanced Machining Processes", Allied Publishers, New Delhi.	2002
8.	Heine and Roshenthal, "Principles of Metal Casting", Tata McGraw-Hill Publishing Company Ltd, New Delhi.	1983
9.	Chakrabarti, A. K., "Casting Technology and Cast Alloys" Prentice-Hall of India, New Delhi	2005
10	Dieter George E., "Mechanical Metallurgy", McGraw-Hill Book Company, London	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-573** Course Title: **Design for Manufacturability**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce students about inter-relationship between various design, manufacture and assembly related activities.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to Design for Manufacturability (DFM), fundamentals of manufacturing technology and the interrelationship between design and manufacturing processes. Organizational changes in DFM.	10
2.	**Concurrent Engineering:** Need for concurrent engineering, industrial practices of concurrent engineering.	8
3.	**Automation**: Automation of design and manufacturing functions in CIM, computer aided process planning, Design for X, approaches to DFM.	7
4.	**Design Knowledge Representation**: Design, manufacturing, and re-design considerations, Design and manufacturing knowledge representation.	10
5.	**Evaluation of Manufacturability**: Evaluation of the manufacturability of a part design, various methods for defining manufacturability index, interpretation of MI value.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication/ Reprint
1.	Boothroyd G., Dewhurst P., and Knight W., "Product Design for Manufacture and Assembly", 2nd Edition, Marcel Dekker.	2002
2.	Bralla J. G., "Design for Manufacturability Handbook", 4th edition, McGraw Hill.	1998
3.	Huang G. Q., "Design for X: Concurrent Engineering Imperatives", Chapman & Hall.	1996
4.	Kusiak A., "Concurrent Engineering: Automation, Tools, and Techniques", Wiley.	1993

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code**: MIN-574** Course Title**: Maintenance Management**

2. Contact Hours **: L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester : **Spring** 7.Subject area: **PEC**

8. Pre – requisite: **Nil**

9. Objective**:** To expose students about the various policies, strategies, and schedules of maintenance applicable in Indian Industries.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction: Importance of maintenance, Objectives, duties, functions and responsibilities of maintenance engineering department, Organization and structure of maintenance systems.	04
2	Maintenance Policies and Planning: Maintenance strategies, advantages and disadvantages of each strategy, Planned maintenance procedure, advantage of planned maintenance, Scientific maintenance, Safety in maintenance.	06
3	System Reliability**:** Quantitative estimation of reliability economies of introducing a standby unit into the production system, Optimum design configuration of a series/parallel system, Breakdown time distribution.	06
4	Maintenance Activities**:** Optimal overhaul/repair or replacement policies for equipment subject to breakdown, Budgeting and control, Production maintenance integration.	04
5	Replacement Decisions: Economic models, block replacement policy, age replacement policy, replacement policies to minimize downtime, Economics of preventive maintenance.	08
6	Maintainability and Availability: Economics of maintainability and reliability, Maintainability increment, Equipment and mission availability.	08
7	Maintenance Organization: Computer applications in maintenance management, automatic chalk out equipment kits capabilities and limitations, Management information system for maintenance.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1	Dhillon B.S., "Engineering Maintenance: a Modern Approach". 1 edition, CRC.	2002
2	Kelly A., "Maintenance Planning and Control", Butterworth-Heinemann.Ltd, London.	1983
3	Niebel B.W., "Engineering Maintenance Management", Marcel Dekker, New York.	1994
4	Cliffton R. H.,"Principle of Planned Maintenance", McGraw Hill Inc. New York.	1983
5	Heintzelman J. E., "Handbook of Maintenance Management", Prentice-Hall Inc., Englewood Cliffs, New Jersey.	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-575** Course Title: **Product Design and Development**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**: Autumn/Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To expose the students to the concept of design for X, concurrent engineering, reverse engineering, and rapid prototyping techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Product Design**: Traditional and modern design processes; Organization objectives; Innovation, creation, and diffusion techniques; Evaluation of new product ideas – functional, technological, ecological, legal.	06
2	**Product Modeling and Reverse Engineering:** Wireframe modeling; Surface modeling – boundary representation; Solid modeling – CSG; Concept of reverse engineering.	08
3	**Product Data Exchange**: Neutral file formats for product data exchange – DXF, IGES, STEP.	06
4	**Concurrent Engineering**: Concept of concurrent engineering; Design for X; Design for manufacturability (DFM); Design for assemblability (DFA); Design for reliability (DFR); Design for quality (DFQ).	10
5	**Rapid Prototyping (RP) Methods:** Liquid based RP methods – stereolithography apparatus (SLA), solid ground curing (SGC), solid creation system (SCS), etc.; Solid based RP methods: Fused deposition modeling (FDM), laminated object manufacturing (LOM), etc.; Powder based RP methods– selective laser sintering (SLS), 3D printing (3DP), ballistic particle manufacturing (BPM), etc.	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1	Andrearsen, M. M., and Hein, L., "Integrated Product Development", Springer.	1987
2	Huang, G. Q., "Design for X: Concurrent Engineering Imperatives", Chapman and Hall.	1996
3	Chitale, A. K. and Gutpa, R. C., "Product Design and Manufacturing", Prentice Hall.	1997
4	Zeid I., "CAD/CAM: Theory and Practice", Tata McGraw Hill.	1998
5	Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press.	2006
6	Boothroyd G., Dewhurst P., and Knight, "Product Design for Manufacture and Assembly", 2nd Ed., Marcel Dekker.	2002
7	Chua, C. K and. Leong, K. F., "Rapid Prototyping: Principles and Applications in Manufacturing", John Wiley & Sons.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**: MIN-576** Course Title**: Machine Tool Design and Numerical Control**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** **0** **ITE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **4** 6. Semester**:** Autumn/**Spring** 7. Subject Area**:** **PEC**

8. Pre–requisite: **Nil**

9. Objective: To introduce various components of numerically controlled machine tools and their application in automated manufacturing systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Machine Tool Design**: General requirements; Electrical and hydraulic drives of machine tools; Layout of gear boxes; Hydraulic, electric and mechanical stepless speed regulations; Design and analysis of guideways; Bed, column, spindle and power screw.	15
2	**Numerical Control (NC):** Introduction to numerical control; Components of NC systems; Open and close loop NC; Types of numerical control: Point-to-point, straight cut, and continuous path NC; Drives and controls; NC-tape coding standards; Coordinate and positioning systems – Cartesian and polar; Reference zero points; NC interpolations – linear, circular, helical, parabolic and cubic interpolation; Applications of NC systems.	6
3	**NC Part Programming Methods**: Structure of NC part program; NC word formats; Introduction to G and M codes; Manual programming methods; Computer-assisted programming methods; APT part programming.	10
4	**Extensions of NC**: Concepts of CNC, machining center, and DNC; Types of CNC systems; Introduction to post processors; Tooling for NC/CNC.	3
5	**CNC Part Programming**: Tool motion commands; Tool length offset; Cutter diameter compensation command; fixed cycle command; Scaling; rotation; Mirror image; Macros programming etc.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1.	Mehta, N. K., "Machine Tool Design and Numerical Control", 2nd Ed., Tata McGraw Hill.	1996
2.	Koren, Y., "Computer Control of Manufacturing Systems", McGraw Hill.	1983
3.	Rapello, R. G., "Essentials of Numerical Control", Prentice Hall.	1986
4.	Chen, S, and Lin, J., "Computer Numerical Control: From Programming to Networking", Thomson Delmer Learning.	1994
5.	Sava, M., and Pusztai, J., "Computer Numerical Control Programming", Prentice Hall.	1990
6.	Rao, P. N., Tewari, N. K, and Kundra, T. K., "Computer Aided Manufacturing", Tata McGraw Hill	1993
7.	Steve, K. and Gill A., " CNC Technology and Programming", McGraw Hill.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-577** Course Title: **Industrial Automation**
2. Contact Hours : **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory 3** **Practical 0**
4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre – requisite**: Nil**
9. Objective: To introduce the concepts of automation theory and its applications in various fields of manufacturing.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Basic Concepts**: Introduction of mechanization and automation, classification and strategies of automation, reasons for and arguments against automation, mechanical, electrical, hydraulic, and pneumatic devices and controls.	6
2.	**High Volume Manufacturing**: Automated flow lines, types of automatic transfer mechanisms, design and fabrication considerations, analysis of automated flow lines.	6
3.	**Assembly Systems**: Assembly systems and their types, manual assembly lines and line balancing.	4
4.	**Assembly Automation**: automated assembly lines and their types, automatic assembly transfer systems, automatic feeding and orienting devices- vibratory and mechanical feeders and their types, orientation of parts, performance and economics of assembly systems, feasibility study for assembly automation.	12
5.	**Design for Assembly**: Design for manual assembly, design for high-speed automatic assembly, design for robot assembly.	4
6.	**Flexible Automation**: Introduction of group technology (GT), steps in implementing Group Technology (GT), part families and machine cell formation, introduction of flexible manufacturing systems (FMS).	6

7.	**Programmable Automation**: Brief introduction of numerical control (NC), computer numerical control (CNC), machining centers, programmable robots, direct numerical control (DNC) and adaptive control.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Groover, M. P., "Automation, Production systems and Computer Integrated Manufacturing", 2nd Ed., Prentice Hall.	2005
2.	Boothroyd, G., "Assembly Automation and Product Design", 2nd Ed., Marcel Dekker.	1992
3.	Boothroyd, G., Dewhurst, P. and Knight, W., "Product Design for Manufacture and Assembly", 2nd Ed., Taylor & Francis.	2002
4.	Boothroyd, G., Poli, C. and Murch, L. E., "Automatic Assembly", Marcel Dekker.	1982
5.	Tergan, V., Andreev, I. and Lieberman, B., "Fundamentals of Industrial Automation", Mir Publishers.	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-578** Course Title: **Computer Aided Process Planning**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre– requisite: **Nil**

9. Objective: To impart knowledge on the integration of design and manufacturing functions leading to the concepts of process planning.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: traditional process planning, product design evaluation, various steps in process planning.	5
2.	**Group Technology**: Introduction, advantages, part families, classification and coding systems, production flow analysis, design of machine cells.	10
3.	**Concepts Related to Process Planning**: Machinability data system, cutting condition optimization.	5
4.	**Automated Process Planning**: Advantages of automated process planning, various approaches to process planning; Variant process planning, its features and different stages, different variant systems; Generative and semi-generative process planning, its features, design strategies, planning, modeling and coding scheme, decision mechanisms; Process capability analysis, intelligent process planning system; Artificial intelligence -- overview and application in process planning; Various recent process planning systems; Case studies.	12
5.	**Interfaces of Process Planning**: Integrating with loading, scheduling, MRP II, and capacity planning and other shop floor functions.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Chang, T. C. and Wysk, R. A, "An Introduction to Automated Process Planning", Prentice-Hall.	1985
2.	Gallagher, C. C and Knight, W. A., "Group Technology: Production Method in Manufacturing", Ellis Horewood.	1986
3.	Nilsson, N. J., "Principles of Artificial Intelligence", Springer Verlag.	1982
4.	Cornelius, L.T, "Computer Aided and Integrated Manufacturing Systems: Manufacturing Processes", World Scientific Publishing Company.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-579** Course Title**: Information Systems and Data Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight :**CWS** **25** **PRS** 0 **MTE** **25** **ETE** **50** **PRE** 0

5. Credits**:** 4 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre–requisite: **Nil**

9. Objective: To expose the students to various information systems and to familiarize with data based systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Role of information system, the function of information system, determination of informational need	4
2	**Information Processing Concepts:** Historical perspective, today's status, systems approach and analysis, concepts of data and information, data collection, data or information, data and information storage, data processing and information generation, transmission of data and information and the information economics of information	10
3	**Information System Analysis:** Overview of system, management and formal information systems, hierarchical and system approach to information systems design and their applications, tailoring the information system to meet specific information requirements using filtering monitoring, interrogative and external methods.	14
4	**Data Base Management System:** Introduction to data base concepts, difference between a file system and a data base systems, goals of DBMS including data independence consistency, data security and integrity; DBMS models hierarchical network and relation, data description and query language, physical database design case studies, system R, Ingress, IDMS etc.; Introduction to distributed database, concurrency control bases recovery etc.	14
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Henry Luces C., "Information Systems Concepts for Management", McGraw Hill.	1978
2	Burch, J. G. and Grudnitski, G., "Information Systems Theory and Practice", John Wiley & Sons.	1989
3	Walker, D. W., "Computer Based Information System An Introduction", Pergamon Press.	1989
4	Mark L. Gillenson, "Fundamentals of Database Management Systems", John Wiley & Sons.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**:** **MIN-580** Course Title: **Welding Science**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Th** **3** **Pract** **0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **Nil**

9. Objective: To familiarize students the concepts of welding engineering, processes, affecting parameters related to welding. Also to introduce with fundamentals of arc welding processes, metal transfer and weldability of metals as well.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction: Welding as compared with other fabrication processes, Classification of Welding Processes	02
2	Physics of Welding Arc: Welding arc, arc initiation and maintenance, voltage distribution along the arc, cathode and anode drops, Arc column, Thermionic and non thermionic cathode, Theories of cathode and anode mechanisms, arc characteristics, arc efficiency, heat generation at cathode and anode Effect of shielding gas on arc, isotherms of arcs, arc blow.	10
3	Metal Transfer: Mechanism and types of metal transfer in various arc welding processes, factors controlling melting rate in various welding processes.	04
4	Welding Power Sources: Basic characteristics of power sources for various arc welding processes, arc length regulation in mechanized welding processes, Transformer, rectifier and generators, Duty cycle and power factor, Static and dynamic characteristics of power sources.	05
5	Welding Processes: Critical review of MMA; TIG. MIG and CO_2 welding processes, plasma arc, submerged arc welding, electro- gas and electro-slag welding; resistance welding. Theory and mechanism of solid state welding; technique and scope of friction welding, diffusion welding; cold pressure welding and ultrasonic welding, scope and application of electron beam and laser welding processes.	12
6	Heat Flow in Welding: Calculation of peak temperature; width of Heat Affected Zone; cooling rate and solidification rates; weld thermal cycles; residual stresses and their measurement; weld distortion and its prevention.	04
7	Weldability of Metals: Effects of alloying elements on weld ability, welding of plain carbon steel, stainless steel, Cast Iron and aluminium.	05

	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	"Welding Handbook", 7th Edition-Volume l to 5, American Welding Society.	1982
2	Houdlecroft P.T., "Welding Process Technology", Cambridge University Press.	1977
3	Udin H, Fruk F and Wulff J, "Welding for Engineers", John Wiley.	1978
4	Rossi E., "Welding Technology", Mc-Graw Hill.	1969
5	Baldev, R., "Welding Technology for Engineers", ASM International	2006
6	Bowditch, W.A., Bowditch M. A., Bowditch, K. E., "Welding Technology Fundamentals", 4th Edition, Goodheart-Willcox Pub.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-581** Course Title: **Manufacturing Resources Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To introduce various types of resources in manufacturing systems, their importance and management.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction: Production as input output system; Resources of production; Forecasting and resources planning.	5
2.	Material Management: Definition and scope; Functions; Types of materials; Analytical structure of inventory models; Material requirement planning (MRP); Inventory control systems; Purchase management; Storekeeping and issue of materials; Material handling; Just in Time (JIT) and Kanban systems.	7
3.	Human Resources Management: Objective; function; organizational planning and development; staffing policies and process; training and executive development; wage and salary policies and administration; motivation; employee services; employee record; labor relations; collective bargaining; personnel research.	10
4.	Production Management: Direct and indirect; Machines and equipment planning; jigs and tools planning, material handling equipment planning; Planning of land, roads, building, warehouses etc.; General vs special purpose equipment; Economic analysis; Equipment replacement; Capital resources planning; Method of allocation of resources.	10
5.	Production Information Management: Management of production technology; information systems; Management Information Systems (MIS); Strategic Information System (SIS); Information networking; Parts oriented production information systems.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication/ Reprint
1.	Hitomi K., "Manufacturing System Engineering", 2nd Edition, Viva Books.	1996
2.	Hitomi K, "Manufacturing Systems Engineering: A Unified Approach to Manufacturing Technology, Production Management and Industrial Economics", 2nd Edition, CRC Press.	1996
3.	Groover, M. P., "Fundamentals of Modern Manufacturing: Materials, Processes, and Systems",4th Edition, Wiley	2010
4.	Gary Dessler, "Personnel Management", 4th Edition, Reston Publishing.	1988
5.	Nauhria R. N. and Rajneesh Prakash, "Management of Systems", Wheeler Publishing.	1995
6.	Thomas Vollman E., William Berry L. and Clay Whybark D., "Manufacturing Planning and Control Systems", 5th Edition, Galgotia Publishing.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code**:** **MIN-582** Course Title: **Flexible Manufacturing Systems**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**
4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**
5. Credits: **4** **6.** Semester**: Autumn/Spring** **7**. Subject Area: **PEC**
8. Pre – requisite**: Nil**
9. Objective**:** To introduce the concepts of flexibilities and its importance in batch manufacturing, various types of FMS configurations and their planning and control.
10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	**Introduction**: Definition and classification of manufacturing systems, fundamentals of automated production cycle, need of flexibility, concept of flexibility, various types of flexibility, measures of flexibility.	7
2.	**Flexible Manufacturing System (FMS) Type**: Introduction of FMS, definition of FMS, types of FMS, applications of FMS, FMS configuration, FMS host operator interface.	10
3.	**FMS Planning and Control**: Functional requirements of FMS equipments, functions of FMS host computer, host system design, planning, scheduling of FMS, FMS simulation, Databases in FMS, GT in FMS, cell design and layout design, CAPP in FMS.	14
4.	**Material handling in FMS**: Material handling principles in FMS, applications of robots in FMS.	6
5.	**Case Studies**: Cases on FMS installation and implementation –acceptance testing and maintenance	5
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Books / Authors / Publisher	Year of Publication /Reprint
1.	Groover, M. P., "Automation, Production System and CIM", 2nd Ed., Prentice Hall.	2000
2.	Rankey, P., "Design and Operations of FMS", North-Holland Publishing.	1983
3.	Warnecke, H. J. (Ed.), "Flexible Manufacturing System", Springer.	1985
4.	Bonetto, R., "FMS in Practice", North Oxford Academic Publishers.	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTER: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-583** Course Title**: Materials Management**

2. Contact Hours**: L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.)**: Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **RS** **0** **TE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** **6.** Semester**: Spring** **7.** Subject Area: **PEC**

8. Pre – requisite: Nil

9. Objective**:** The aim of this course is to introduce to the students the basic concepts of purchase and supply of materials for the production process in an industry.

10. Details of Course**:**

S. No.	Contents	Contact Hours
1	**Introduction**: Operating environment:, scope, and issues	04
2	Material Requirement Planning**:** Introduction, Bills of material, Material requirement plans and planning process.	06
3	**Capacity Management:** Definition of capacity, capacity planning, Capacity requirement planning, capacity available and required, Scheduling order, make plan	06
4	**Production Activity and Control:** Data requirements, order preparation, scheduling, load leveling, Scheduling bottlenecks, production reporting.	06
5	**Purchasing, forecasting, and Inventory fundamentals**: Establishing specifications, selecting suppliers, price determination, demand management, demand forecasting, principle of forecasting, forecasting techniques, seasonality, tracking the forecast, inventory and flow of materials, supply and demand pattern, functions of inventories, ABC, VED and FSN system of selective inventory, EOQ, variation of EOQ models, period order quantity, quantity discount.	16
6	**Just in time Manufacturing**: JIT philosophy, JIT environment, Manufacturing planning and control in JIT environment, MRP, Kanban, theory and constraints.	04
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint
1	Handfield R.B. and Nichols E.L., Jr "Introduction to Supply Chain Management", Prentice-Hall Inc.	1999
2	Bowersox D. J. and Closs D. J., "Logistical Management: The Integrated Supply Chain Process", McGraw-Hill, New York.	1996
3	Leenders M.R. and Fearon H.E., "Purchasing and Materials Management", 11th Edition, Irwin Burr Ridge, Illinois.	1997
4	Arnold J. R. T. and Chapman S. N., "Introduction to Materials Management", 4th Edition, Pearson Education Asia.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-584** Course Title**: Operations Research**
2. Contact Hours **: L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory: 3** **Pra 0**
4. Relative Weight **:CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**
5. Credits: **4** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**
8. Pre-requisite**: Nil**
9. Objective**:** To introduce various optimization techniques for· formulating, solving various industrial problems, develop production and service units as a system.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** definition and scope of OR; Techniques and tools; Model formulation; general methods for solution; Classification of optimization problems; Optimization techniques.	2
2.	**Linear Optimization Models:** Complex and revised simplex algorithms; Duality theorems, sensitivity analysis; Assignment, transportation and transshipment models; Traveling salesman problem as an assignment problem; Integer and parametric programming; Goal programming.	12
3.	**Game Problems:** Mini-max criterion and optimal strategy; Two person zero sum game; Games by simplex dominance rules.	6
4.	**Waiting Line Problems:** Classification of queuing situations; Kendall's notation, Poisson arrival with exponential or Erlang service time distribution; Finite and infinite queues; Optimal service rates; Application of queuing theory to industrial problems.	8
5.	**Dynamic Programming:** Characteristic of dynamic programming problems (DPPs); Bellman's principle of optimality; Problems with finite number of stages; Use of simplex algorithm for solving DPPs.	6
6.	**Non-linear Programming:** One dimensional minimization methods; Unconstrained optimization techniques; Optimization techniques-characteristics of a constrained problem; Indirect methods; Search and gradient methods.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication /Reprint
1.	Taha, H. A., "An Introduction to Operations Research", 6th Ed., Prentice Hall.	2006
2.	Hillier, F. J. and Lieberman, G. J., "Introduction to Operations Research", 7th Ed., Holden Day.	2001
3.	Phillips, D. T, Ravindran, A. and Solberg, A. A., "Operations Research: Principles and Practice", 2nd Ed., John Wiley and Sons.	1986
4.	Wagner, H. M., "Principles of OR with Applications to Managerial Decisions", 2nd Ed., Prentice Hall.	1975
5.	Jensen, P. A, and Bard, J. F., "Operations Research Models and Methods", John Wiley and Sons.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-585** Course Title: **Supply Chain Management**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory: 3** **Practical: 0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre – requisite: Nil

9. Objective: To provide an insight into functioning and networking of supply chain decisions for the success of a business. The course will provide foundation for design, analysis and performance metrics and to frame a sound supply chain network in the country.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: Understanding supply chain, supply chain performance; supply chain drivers and obstacles.	4
2	**Planning Demand and Supply in a Supply Chain**: Demand forecasting in supply chain, aggregate planning in supply chain, planning supply and demand; managing predictable variability, Economic Order Quantity Models, Reorder Point Models, Multi-echelon Inventory Systems.	12
3	**Planning and Managing inventories in a Supply Chain**: Managing economies of supply chain, managing uncertainty in a supply chain, determining optimal levels of product availability.	6
4	**Transportation, Network Design and Information Technology**: Transportation aspects in a supply chain, facility Decision, Network design in a supply chain, Information technology and its use in supply chain.	10
5	**Coordination in Supply Chain and effect of E- Business:** Role of Coordination and E-business in a supply chain; financial evaluation in a supply chain.	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1	Hopp W. J., Spearman M. L. and Irwin, "Factory Physics: Foundations of Manufacturing", McGraw-Hill Inc. New York.	1996
2	Viswanadham N., "Analysis of Manufacturing Enterprises", Kluwer Academic Publishers, UK.	2000

3	Sridhar Tayur, Ram Ganeshan and Michael Magazine (editors), "Quantitative Models for Supply Chain Management", Kluwer Academic Publishers, UK.	1999
4	Handfield R.B. and Nochols E.L.Jr., "Introduction to Supply Chain Management", Prentice Hall Inc. Englewood- Cliff, New Jersey.	1999
5	Viswanadham N. and Narahari Y., "Performance Modeling of Automated Manufacturing Systems", Prentice Hall of India, New Delhi.	1998
6	Chopra S. and Meindel P., "Supply Chain Management: Strategy, Planning, and Operation", Prentice Hall of India, New Delhi.	2002
7	Shapiro J. F., Duxbury Thomson Learning, "Modeling the Supply Chain", Duxbury Thomson Learning Inc., Duxbury, Pacific Grove.	2001
8	Levi D. S., Kaminsky P. and Levi E. S., "Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies", McGraw Hill Inc. New York.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-586** Course Title: **Metal Forming**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory: 3** **Practical: 0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre – requisite: Nil

9. Objective: The course aims to explain the advanced scientific theoretical aspects of metal forming processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction: stress/strain, strain-rate characteristics of materials, yield criteria of metals, c1assification of metal working processes, formability and theory of sheet metal working, friction and lubrication in metal working operation, theories of friction and lubrication; assessment of friction at interface.	9
2.	Process analysis: various methods of analyzing the metal working processes (slip-line field theory; upper bound solution; stab methods).	3
3.	Mechanics of forming processes: rolling- determination of rolling pressure, roll separating force, driving torque and power, and power loss in bearings; forging- determination of forces in strip forging and disc forging; drawing- determination of force and power, determination of maximum allowable reduction; deep drawing force analysis, analysis of tube drawing process with fixed and moving mandrel, tandem tube drawing; bending- determination of work load and spring back; extrusion- determination of work load from stress analysis and energy consideration, power loss, hydrostatic extrusion; punching and blanking- mode of metal deformation and failure, two-dimensional deformation model and fracture analysis, determination of working force.	20
4.	Hydrostatic extrusion: comparison with conventional extrusion; pressure required to extrude, variables affecting the process.	4
5.	High speed forming: classification, comparison of low and high speed forming operation problems in high speed forming operation, introduction to high forming process such as explosive forming, electrical and mechanical high speed forming techniques.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication / Reprint
1.	Rowe, and Geoffrey W, "An Introduction to Principles of Metal Working", St. Martin Press.	1965
2.	Avitzur B., "Metal Forming Analysis", Mc Graw Hill.	1980
3.	Polukhin V.P., "Mathematical Simulation and Computer Analysis of Thin Strip Rolling Mill", MIR Publishers.	1975
4.	Jhonson W.and Meller P.B., "Plasticity of Mechanical Engineers", Van Nostrand.	1983
5.	"High Velocity Working of Metals", ASTME.	1964
6.	Ghosh A. and Mallik A. K., "Manufacturing Science", Affiliated East-West.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-587** Course Title: **Metal Casting**
2. Contact Hours : **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.) : **Theory: 3** **Practical: 0**
4. Relative Weight : **CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre – requisite: **Nil**

9. Objective: To explain the advanced scientific theoretical aspects of metal casting processes.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Features of casting problem, a survey and scope of foundry industry.	3
2.	**Solidification**: Solidification of pure metals and al1oys, nucleation and growth in alloys, solidification of actual castings, progressive and directional solidification, centerline feeding resistance, rate of solidification, Chvorinov's Rule, electrical analog of solidification problem; Fluidity- measurement of fluidity, effects of various parameters on fluidity	8
3.	**Risering and Gating System**: Riser design, risering curves, NRL method of riser design, feeding distance, risering of complex casting, risering of alloy other than steel, recent developments in riser design by the application of geometrical programming; Gating systems and their characteristics, the effects of gates on aspiration, turbulence and dross trap, recent trends.	5
4.	**Pattern and Casting Design**: Pattern design, recent developments in pattern design, materials and construction; Casting design considerations- review of casting design, recent trends.	9
5.	**Melting, Molding and Core Making Processes**: Selection and control of melting furnaces, boiling, refining and pouring, recent trends in cupola design; Review and critical comparison of various established processes, recent developments e.g. low pressure and ferrous die casting, high pressure molding, full mold process, flaskless molding, hot and cold box molding, ceramic shell molding, V-process, continuous casting, squeeze and pressed casting, Nishiyama process, Shaw process, Anitoch process etc.	6
6.	**Internal Stresses, Defects and Surface Finish**: Residual stresses, hot tears and cracks in castings, stress relief, defects and their causes and remedies, various parameters affecting surface finish and related defects e.g. rough casting, sand bum-on sand bum-in and metal penetration, facing and washes, mold wall movement, vapor transpol1 zones, expansion scabbing etc; Gases in metal- methods of	7

	elimination and control of dissolved gases in castings.	
7.	**Testing, Inspection and Quality Control**: Testing of sand**,** recent developments e.g. mulling index, moldability index, compactability; deformability; Review of X-ray and gamma ray radiography, magnetic particle, die penetrant and ultrasonic inspection, use of statistical quality control in foundry.	4
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors / Books / Publisher**	**Year of Publication /Reprint**
1.	Flinn R.A., "Fundamentals of Metal Casting", Addison Wesley Inc., Reading.	1963
2.	Heine R.W, Loper C.R. and Rosenthal P.C., "Principles of Metal Casting", Tata McGraw-Hill.	1997
3.	Niebel B.W., and Draper A.B., "Modern Manufacturing Process Engineering", McGraw Hill.	1990
4.	"Metals Handbook-Metal Casting", ASM.	1985
5	Beeley, Peter R. , "Foundry Technology", Butterworth-Heinemann.	2001
6	Jain, P. L., "Principles of Foundry Technology", Tata Mc. Graw-Hill.	1999

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-588** Course Title: **Non-Traditional Machining Processes**

2. Contact Hours: **L: 3 T: 1 P: 2/2**

3. Examination Duration (Hrs.): **Theory: 3 Practical : 0**

4. Relative Weight : **CWS** 20 **PRS 20** **MTE** 20 **ETE** 40 **PRE ---**

5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre – requisite: NIL

9. Objectives of Course: This course covers the details of various non-traditional/unconventional or advanced machining processes (AMPs).

10. Details of Course:

S. No.	Particulars	Contact Hours
1	**Introduction:** Types of advanced manufacturing processes; Evolution, need, and classification of advanced machining processes (AMPs).	**02**
2	**Mechanical Type AMPs:** USM, Rotary Ultra Sonic Machining (RUM), AJM, WJM, AWJM processes - Process principle and mechanism of material removal; Process Parameters; Process Capabilities; Applications; Operational characteristics; Limitations.	**08**
3	**Advanced Fine Finishing Process:** Abrasive Flow Machining (AFM), Magnetic Abrasive Finishing (MAF), Magneto Rheological Abrasive Finishing (MRAF) - Process principle; Process equipment; Process Parameters; Process Capabilities; Applications; Limitations.	**06**
4	**Chemical Type AMPs:** Process principle and details of Chemical Machining (CHM), Photo-Chemical Machining (PCM), and Bio-Chemical Machining (BCM) processes.	**04**
5	**Electro Chemical Type AMPs:** ECM - Process principle; Mechanism of material removal; Process Parameters; Process Capabilities; Applications	**06**
6	**Thermal Type AMPs:** EDM, Wire Electro Discharge Machining (WEDM), LBM, EBM, IBM, PAM processes – Process principle and mechanism of material removal; Process parameters and characteristics; Surface finish and accuracy, Process Capabilities; Applications; Limitations.	**08**
7	**Derived and Hybrid AMPs:** Electro Stream Drilling (ESD), Shaped Tube Electro Machining (STEM), Electro Chemical Honing (ECH), Electro Chemical Deburring (ECDE), Electro Chemical Discharge Machining (ECDM) - Process Parameters; Process Capabilities; Applications; Limitations, Introduction to form machining.	**08**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication/ Reprint

1.	Pandey P. C., Shan H. S. "Modern Machining Processes", Tata McGraw-Hill Publishing Co. Ltd, New Delhi	1977
2.	Ghosh A., Mallik A. K., "Manufacturing Science", Affiliated East-West Press Ltd, New Delhi	1985
3.	Benedict G. F., "Nontraditional Manufacturing Processes", Marcel Dekker, Inc. New York	1987
4.	McGeough J. A.,"Advanced Method of Machining", Chapman and Hall, New York	1988
5.	Mishra P. K., "Nonconventional Machining", Narosa Publishing House, New Delhi	1997
6.	Jain V. K.,"Advanced Machining Processes", Allied Publishers, New Delhi	2002
7.	"Machining Data Handbook: Vol. 2", Machinability Data Center, (3rd edition), Metcut Research Associates Inc., Ohio	1980

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**:** **MIN-590** Course Title**:** **Theory of Arc Welding Processes**
2. Contact Hours**:** **L: 3 T: 1 P: 2/2**
3. Examination Duration (Hrs)**:** **Theory: 3** **Practical: 0**
4. Relative Weight **:** **CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**
5. Credits**:** **4** 6. Semester**:** **Autumn** 7. Subject Area**:** **PCC**

8. Pre-requisite**:** **Nil**
9. Objective**:** To introduce theoretical and practical knowledge about the mechanism of the arc, metal transfer during consumable arc welding, the process and their applications.

10. Details of Course**:**

S. No.	Contents	Contact Hours
1	**Introduction**: Brief history of welding, classification of welding processes, heat sources and shielding methods; Physics of welding arc, voltage distribution along the arc, thermionic and non-thermionic cathodes, arc characteristics and its relationship with power source, arc efficiency, heat generation, effect of shielding gases on arc, isotherms of arcs, arc blow.	6
2	**Metal Transfer:** Classification, forces acting on the drop, metal transfer mechanisms, transition current, melting rate, effect of polarity, deposition efficiency, current and voltage oscillograms, high speed films.	3
3	**Welding Power Sources**: Conventional welding power sources, constructional features, static and dynamic characteristics, duty cycle, influence of inductance on arc and power source characteristics, internal and external regulation, specific power source requirements, special welding power sources.	5
4	**Gas Metal Arc Welding Processes**: Consumable electrode welding processes. Manual metal arc (MMA) welding: type composition and functions of flux covering, ISI and other international codes for electrodes, concepts of special electrodes, consumables, arc length control in pulsed MIG welding, selection of parameters, self shielded and gas shielded flux cored wire welding.	10
5	**Submerged Arc and Electroslag Welding**: Specific features, process variables, types and composition of fluxes and their manufacturing, arc length control, significance of flux-metal combination; Electroslag welding- heat generation, principle, wire and consumable guide technique, selection of parameters, nature of fluxes.	8

6	**Non Consumable Electrode Welding Processes:** Gas tungsten arc welding, electrodes, compositions, shielding gases, arc ignition and maintenance, selection of polarity, arc voltage rectification and remedy, cathode spot and normal mode operations; Plasma arc welding: transferred and non-transferred plasma arc welding, selection of gases, welding parameters, keyhole technique.	10
	Total	**42**

11. List of Experiments

1. Effect of welding parameters in SMAW, GMAW and GTAW processes.
2. Comparison of rutile, basic and cellulosic electrodes in MMAW process.
3. Effect of shielding gases on performance of GMAW process.
4. Effect of welding fluxes in submerged arc welding process.
5. Study of optical profile gas cutting.

12. Suggested Books**:**

S. No.	Name of Author (s)/ Book/ Publisher	Year of Publication/ Reprint
1.	Lancaster J. F., "The Metallurgy of Welding", 6th Ed., William Andrew Publishing.	1999
2.	"Welding Handbook" Volumes 1, 2 & 3, 9th Ed., American Welding Society.	2001
3.	"Metals Handbook", Vol. 6, ASM International Publication.	1993
4.	"Procedure Handbook of Arc Welding", 14th Ed., Lincoln Electric Co.	2004
5.	Larry J. and Jeffus L., "Welding Principles and Application", 5th Ed., Delmer Publication.	2002
6.	Messler R. W., "Principles of Welding (Processes, Physics, Chemistry and Metallurgy)", John Wiley & Sons.	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN–591** Course Title**: Inspection and Quality Control of Weldments**
2. Contact Hours**:** **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs)**:** **Theory: 3** **Practical: 0**
4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**
5. Credits**: 4** **6.** Semester**: Autumn** **7.** Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective**:** To provide knowledge of dimensional inspection, destructive testing, NDT methods, WPS and PQR requirements and welder qualification standards.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Types and purposes of weldment testing, important welding terms, symbols for welding and testing.	4
2.	**Weld Related Discontinuities**: Classification of discontinuities in weldment, occurrence, causes and prevention of discontinuities, location, orientation and extent of discontinuities, method for testing weld and base metal imperfections.	4
3.	**Destructive Testing of Welds**: Chemical tests, metallographic tests, hardness tests, mechanical test for groove and fillet welds-full section, reduced section and all-weld-metal tensile tests, root, face and side bend tests, fillet weld break tests, fillet weld shear strength test.	8
4.	**Non-Destructive Testing (NDT) of Weldments**: Visual inspection, dye-penetrant inspection, magnetic particle inspection; Ultrasonic inspection-principle of ultrasonic testing, types of ultrasonic probes, standard blocks for calibration; Radiographic inspection – principle of radiography, X-ray tubes, gamma-ray sources, interpretation of radiographs, defect discernibility, neutron radiography; Eddy current inspection; Proof test, leak tests: NDT AWS (American Welding Society) standards, safety in NDT.	12
5.	**Inspection of Weldments**: Duties and requirement of an inspector before, during and after welding, codes governing welding inspection, ASME (American Society of Mechanical Engineers) Code.	5
6.	**Welding Procedure and Performance Qualifications**: Standard procedure for specification and qualification of welding procedure, operator	9

	qualification, standard method of recording of qualification tests, welding procedure specification (WPS), procedure qualification record (PQR) and Welding performance qualification (WPQ).	
	Total	**42**

List of Experiments:

1. Visual inspection for weld quality
2. Dye-penetrant inspection of surface defects in welded joints
3. Magnetic particle inspection surface defects in welded joints
4. Ultrasonic inspection for assessing sub-surface defects
5. Radiographic inspection of weld joints

11. Suggested Books:

S. No.	Name of Author (s)/ Book/ Publisher	Year of Publication/ Reprint
1.	"Welding Inspection", 3rd Ed., American Welding Society.	2000
2.	"Welding Hand Book", Vol. 5, 7th Ed., American Welding Society.	1984
3.	"ASME Code Section IX ", ASME.	1998
4.	"Structural Welding Code – Steel", AWS D1.1:2000 AWS	2000
5.	"Specifications for Welding Procedure & Performance Qualification", ANSI /AWS B2.1:1998	1998
6.	Jeffus, L., "Welding: Principles and Applications", 6th Ed., Delmar Cengage Learning.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN–592** Course Title**: Design and Analysis of Welded Structures**

2. Contact Hours**:** **L: 3 T: 1 P: 2/2**

3. Examination Duration (Hrs.)**:** **Theory: 3 Practical: 0**

4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits**:** **4** 6. Semester**: Autumn** 7. Subject Area**: PCC**

8**.** Pre-requisite **: Nil**

9. Objective**:** To introduce procedure of designing welded joints for static and dynamic load conditions and their analysis.

10. Details of Course**:**

S. No.	**Contents**	**Contact Hours**
1.	**Introduction**: Introduction to design, engineering properties of steels, weldability of structural steels, carbon equivalent, fatigue and creep properties of welded joints, theories of failures.	7
2.	**Weld Joints and Connections**: Type of welds and weld joints, description of welds terminology, welding symbols, edge preparation, sizing of welds in structure, type of connections in welded structures, combined groove and fillet weld connections.	6
3.	**Design for Static Loading**: Weld calculations for lap, butt and fillet welds, analysis of connections for direct tension or compression and shear loading conditions, resistance to moment by combined tension and compression	6
4.	**Design for Fatigue loading**: Introduction to Fatigue, mechanism of fatigue fracture, residual fatigue strength, factors affecting fatigue life, design of welded joints for fatigue loading, fatigue behaviour of hollow section joints, methods for improving the fatigue strength of welded joints, reliability analysis and safety factors applied to fatigue design with reference to fracture toughness.	8
5.	**Industrial Applications of Weld Design**: Design of tubular structure, circular and rectangular hollow sections under static loading; Introduction to design of weld joint for pressure vessel -- cylindrical and head section; Weld design for automobile applications: chassis and body design; Design of brazed and soldered joints.	8

6.	**Heat flow and Residual Stresses in Welds**: Heat flow in welding, effect of welding parameters on heat distribution, calculation of peak temperature, weld thermal cycle, cooling rate and solidification time, residual stress distribution, influence of residual stress in static and dynamic loading, introduction to stress corrosion.	7
	Total	**42**

List of Experiments:

- Study the effect of type of welds on tensile properties of weld joint
- Development of weld thermal cycle during arc welding
- Measurement of residual stress in welded joints
- Measurement of hardness, toughness and fracture toughness of welded joints
- Study stress corrosion cracking behaviour of stainless steel joints

11. Suggested Books**:**

S. No.	**Name of Author (s)/ Book/ Publisher**	**Year of Publication /Reprint**
1.	Fuchs, H. O. and Stephen, R I., "Metal Fatigue in Engineering", John Wiley & Sons.	2000
2.	Gray, T. G. F. and Spence, J., "Rational Welding Design", Butterworths.	1992
3.	"Welding Hand Book", Vol. 2 & 3, 9th Ed., American Welding Society.	2001
4.	Dieter, G., "Mechanical Metallurgy", McGraw Hill.	1988
5.	Messler, R.W. Jr., "Principles of Welding", John Wiley & Sons.	1999

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN-593** Course Title**: Non Conventional Welding Processes**
2. Contact Hours**:** **L: 3 T: 1 P: 2/2**
3. Examination Duration (Hrs)**:** **Theory: 3 Practical: 0**
4. Relative Weight **:** **CWS 20 PRS 20 MTE 20 ETES 40 PRE 0**
5. Credits**: 4** 6. Semester **: Spring** 7. Subject Area**: PEC**
8. Pre-requisite**: nil**
9. Objectives**:** The aim of the course is to provide theoretical and practical details of various non-conventional welding/joining processes and techniques including high energy density welding processes.
10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	Resistance Welding: Principle of contact resistance; calculation of current, time and voltage for spot welding, choice of electrode material; electrode shapes; shunt current; shop tests for soundness of spot welds, seam, projection, butt and flash welding; selection of welding and other process details; stud welding; power sources for resistance welding**.**	10
2.	High Power Density Welding Processes: Electron Beam (EB) welding in different degrees of vacuum, applications; Laser welding; principle of operation; laser materials, applications.	4
3.	Solid State Welding Processes : Fundamental principles of various non- conventional pressure welding processes and their applications; friction, explosive, diffusion and ultrasonic welding; induction welding.	8
4.	Special Topics: Soldering; brazing and braze welding; welding of plastics.	5
5.	Cutting and Surfacing : Plasma and thermal cutting and surfacing operations; parameters; consumables; and equipment; arc and gas gouging.	8
6.	Safety Measures in Welding: Various safety measures for conventional and non-conventional welding processes. Gas cylinder colour codes; storage and transportation of gases; protection from fire and explosions. Protection against electric shocks and short circuiting; chemistry and mechanism of formation of fumes; effect of fumes; radiations and noise on welder's health; eye flash, skin burn, heat exhaustion and other diseases; protective devices such as exhaust hoods, booths, shields, goggles, screens, clothing and ear covers; safety during welding in confined spaces.	7
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Authors/ Books/ Publisher	Year of Publication/Reprint
1.	"Welding Handbook", Vol. 2 & 3, 9 th Edition, American Welding Society.	2003
2.	"Metals Handbook", Vol. 6, American Society of Metals.	1993
3.	"Procedure Handbook of Arc Welding", Lincoln Electric Co., USA.	2004
4.	Tylecote R.F., "The Solid phase welding of Metals", Edward Arnold Pub. Ltd.	1968
5.	Richard Little L., "Welding and Welding Technology", McGraw Hill.	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Mechanical and Industrial Engineering**

1. Subject Code: **MIN-594** Course Title: **Safety Aspect of Welded Structures**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre – requisite: Nil

9. Objectives of Course: Objective of this course is to provide knowledge of safety of welded structure.

10. Details of Course:

S. NO.	Contents	Contact Hours
1.	**Basis of Safety Concept**: Definition of safety and definition of safety concept; Basic mechanism of failure of components; Brittle and ductile fracture; Collapse fatigue fracture mechanism and representations at sub-microscopic and macroscopic levels through Mohr's Circle; Specific problems of safety related to weldments; Definition and safety relevance of weld imperfections.	8
2.	**Conventional Methods for Safety Analysis**: Concepts of strength and toughness of engineering materials; Determination and consequences of stress and strain state; Material - stress and strain state embitterment, their reasons and consequences; Effects of notches, stress state in notched component, safety analysis and assessment of notched components using notch theory; Semi quantitative Fracture Analysis Diagrams (Pellim's FAD); limitations of conventional methods.	8
3.	**Fracture Mechanics:** Concepts of stress-strain state of cracked components; Introduction and basic principles of fracture mechanics; Linear Elastic Fracture Mechanics (LEFM); Stress intensity factor; Determination of fracture toughness.	9
4.	**Methods for Safety Analysis:** ASTME:399 method; Limitations of LEFM; Modified LEFM (ASTME 1820); General yielding criterion; Plastic Limit Load Calculations (PLLC); Principles of Two Criteria Approach (TCA); Failure assessment diagram (CEGB Report R-6); Mechanism of cyclic crack growth; Paris law; Modifications of Paris law; Effects of temperature and environment; Elastic plastic fracture mechanics (EPFM); Stable crack growth; COD concept (CTOD BS: 5762); R-curve technique; Instability diagram.	9
5.	**Application of Safety Concepts to Welded Structures:** Material imperfections and stress states in weldments; Quality - degradation in welded structures; CODE requirements; Case studies as examples of failures; Design and service requirements for engineering structures fabricated by welding i.e. welded structures.	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Books/ Authors/ Publisher	Year of Publication/Reprint
1.	Anderson T. L., "Fracture Mechanics: Fundamentals and Applications", 3rd Edition, Taylor & Francis Group.	2000
2.	Farahmand Bahram.,"Fracture Mechanics of Metals, Composites, Welds and Bolted Joints", Hardcover, Kluwer Academic Publishers .	2000
3.	Broek D., "Elementary Engineering Fracture Mechanics", Martinus Nijhoff.	1982
4.	Latzko D.G.H, "Post Yield Fracture Mechanics", 2nd Edition, Elsevier Applied Science Publication.	1984
5.	Maddox S.J., "Fatigue of Welded Structures", 2nd Edition, Woodhead Publishing.	1991
6.	Gurney T.R.,"Fatigue of Welded Structures", Cambridge University Press.	1979
7.	Chell G.G.,"Development of fracture Mechanics", Elsevier Applied Science Publication.	1979

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Mechanical & Industrial Engineering Department**

1. Subject Code: **MIN-595** Course Title: **Failure Analysis of Welding Joints**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 20 PRS 20 MET 20 ETE 40 PRE 0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To provide basic knowledge about the nature of failure of weld joint, engineering tools for failure analysis, methodology, use of fracture mechanics in analysis of failure and safety of welded structure.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Fundamental Sources of Failure**: Deficiencies in design, material and processing errors, improper service condition, residual stresses	8
2.	**Tools for failure analysis:** Fault tree diagram, Failure mode and effective analysis, Weibull distribution, Pareto diagram	6
3.	**General Practice in Failure Analysis**: Objective, collection of background data, selection of samples; Selection, cleaning and preservation of fractured surface, identification of mode of failure, approach for failure analysis, ascertaining causes of failure, reporting practice.	6
4.	**Examination of Fractured Components**: Preliminary examination of fractured surface, equipment used for preliminary examination, preservation of failure records, Identification of Mode of Failure: Classification, specific characteristics, distinction between different type of fractures, factors affecting mode of fracture and defects.	6
5.	**Analysis of the Causes of Failure**: Chemical analysis, optical microscopic examination, use of scanning electron microscope, micro probe analyser and X-ray diffraction etc. Correlation of weldment failure of different materials developed using various welding processes including repair welding	10
6.	**Application of Fracture Mechanics in Failure Analysis**: Physical meaning of K_{Ic}, J_{IC} and CTOD with reference to fracture control, fracture	6

	analysis in the light of fatigue crack growth rate behaviour of material, residual life assessment . Case studies of failure in different components such as pressure vessel and nuclear reactor.	

11. Suggested Books:

S. No.	Name of Books / Authors/Publisher	Year of Publication/Reprint
1.	Becker, W. T. and Shipley, R. J. "Metals Handbook, Failure Analysis and Prevention", Volume 11, ASM International.	2002
2.	Hutchings, F. R. and Unterweiser, Paul M., "Failure Analysis, The British Engineering Technical Report", ASM International.	1981
3.	Robert H. and Bhadeshia H. H.K.D.H. "Steels: Microstructure and Properties", 3rd Edition, Butterworth-Heinemann.	1995
4.	"Metals Handbook, Fractography", Volume 12, ASM International.	1992
5.	Das A. K., "Metallurgy of Failure Analysis", Special Indian Edition, Tata McGraw- Hill.	1997
6	Besterfield, D C and Besterfield C (1999), Total Quality Management, Pearson Education Asia,	2002
7	Andrew K. S. and Albert H. C. Tsang, "Maintenance, replacement, and Reliability", Taylor & Francis.	2006
8	Dhillon B.S., "Engineering Maintenance: a Modern Approach". 1st Edition, CRC.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN–596** Course Title**: Automation and Application of Robots in Welding**
2. Contact Hours**:** **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs.)**:** **Theory: 3 Practical: 0**
4. Relative Weight **:** **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**:** **4** 6. Semester**: Spring** 7. Subject Area**: PEC**
8. Pre-requisite **: Nil**

9. Objective**:** To expose students to various automation devices and robot construction and their application during welding.

10. Details of Course:

. No.	Contents	Contact Hours
1.	**Automated Devices for Welding**: Concept of manual, mechanized and automated welding; Concept of automation in welding; Positioners, arc moving devices, welding fixtures and brazing fixtures.	7
2.	**Mechanization in Welding:** Mechanization of flat / circular joints; Mechanization of I beams (arc welding); Longitudinal, circumferential Submerged Arc (SA) –welding (Roller- blocks, column booms, flux supports) circular welding joints (Rotating tables, positioners); Manufacture of longitudinal welded pipes by TIG, plasma and SA welding, spiral welded pipes.	7
3.	**Mechanization of Pipe Welding**: Butt- welding; Tungsten Inert Gas (TIG)- orbital welding; Metal Inert Gas (MIG) / Metal Active Gas (MAG) -orbital welding; Flash butt welding, tube-tube / plate welding.	7
4.	**Automation in Welding**: Automatic lines for welding; Automation of track wheels;Automation of weld components in automobile industry.	5
5.	**Introduction to Robotics**: The concept of robotics: The robot classification; Concept of robots, robot arms, devices, sensors, end effectors, robot work volume and robot cell; Robot elements and control-manipulators, drives, sensors, end effectors, configuration, force/torque relationship, trajectory planning, position control, feedback system, digital control.	9
6.	**Applications of Robots in Welding and Allied Processes**: Application of robot in production: Exploration of practical application of robots in welding: robots for car body's welding, robots for box fabrication, robots for micro electronic welding and soldering; Efficiency of robotics in welding.	7
	Total	**42**

11. Suggested Books:

S.No.	Name of Books/ Authors/ Publisher	Year of Publication
1.	Shimon Y.N. "Industrial Robots Handbook", John Wiley & Sons	1985
2.	"Procedure Handbook of Arc Welding", Lincoln Electric	1994
3.	"Welding Handbook Vol. 3, 9th Edition", AmericanWelding Society	2001
4.	Mittal and Nagrath, "Robotics and Control" Tata McGraw-Hill.	2002
5.	Pires, J.N., Loureiro, A and Bolmsjo, G. "Welding Robots: technology, System Issues and Applicatio", Ist Edition, Springer.	2005

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT/CENTER: **Mechanical & Industrial Engineering**

1. Subject Code: **MIN-597** Course Title: **Welding Procedure for Specific Applications**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.) : **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits: **4** **6.** Semester: **Spring** **7.** Subject Area: **PEC**

8. Pre-requisite: Nil

9. Objective: To introduce the students to the field problems of welding and provide details for solving them.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction and Economic Consideration:** Groove geometry and weld metal deposition rates for different welding processes; Welding cost estimation; Standard data for cost estimation; Comparative cost study for various welding procedures.	6
2.	**Welding of Offshore Constructions:** Requirement of offshore construction welding; Problems in underwater welding; Various underwater welding techniques.	6
3.	**Welding of Low Temperature Containment Plants:** Materials used for cryogenic applications; Problems of welding; Welding processes and procedures used for cryogenic materials.	6
4.	**Welding of Pressure Vessels:** Materials used for construction of pressure vessels; Processes and procedures for pressure vessels welding; Requirement of various codes.	6
5.	**Repairing of Castings:** Specific problems in repairing of castings of various materials; Welding methods used for repairing and reclamation.	6
6.	**Micro joining Techniques:** Various techniques used for joining of electronic circuitry and other micro joining applications.	6
7.	**Corrosion in Weldments**: Various types of corrosion; Factors affecting corrosion; Minimization of susceptibility to corrosion; Corrosion testingand stress corrosion cracking.	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Books/ Authors/ Publisher	Year of Publication/Reprint
1.	Peter Thomas, "Welding Process Technology", Houldcroft Technology.	1977
2.	"Developments in Micro joining", TWI, Abbington, Cambridge U.K	1983
3.	"Welding Hand Book" Vol. 3 and 4, 9th Edition., AWS	2001
4.	"Rules for Construction of Pressure Vessels", ASME	1977
5.	Yahalom J. and Aladjan A., "Stress corrosion Cracking", SN Publishers	1980
6.	Nixon, J.H.,"Underwater Repair Technology", Gulf Professional Publishing	2000

NAME OF DEPTT./CENTRE: **Mechanical and Industrial Engineering**

1. Subject Code: **MIN-598** Course Title: **Weldability of Metals**

2. Contact Hours : **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**

4. Relative Weight : **CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

5. Credits: **4** 6.Semester: **Spring** 7. Subject Area: **DEC**

8. Pre-requisite: Nil

9. Objective: To provide fundamental understanding on weldability of metals like steels, cast iron and Aluminum besides various problems encountered, their remedies and precautions to be undertaken during the welding of these metals.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Fundamentals:** Weldability, definitions, factor affecting the weldability of steel Carbon equivalent, solidification of weld metal; heat affected zone (HAZ), factors affecting properties of HAZ, gas-metal, slag-metal and solid state reactions in welding and their influence on soundness of weld joint, common metal system and their weldability: work hardenable, precipitation hardenable and heat treatable alloys	4
2.	**Weldability of Plain Carbon Steels:** Various grade of plain-C steels, factors affecting Weldability, viz., Carbon content, section thickness, Mn/S ratio, phosphorus concentration, microstructure of weld and HAZ, cold cracking and lamellar, tearing gas porosity, mechanism, causes and prevention of defects in plain –C steel welds,	6
3.	**Weldability of Stainless and Heat Resisting Steels:** properties of stainless steels affecting weldability, common types of stainless steel austenitic, martensitic, ferritic and PH steel and their weldability, problems in welding of stainless steel and their remedy, weld decay, sigma phase formation, knife line cracking, stress corrosion cracking.	8
4.	**Weldability of HSLA Steels:** Common grades of high strength low alloy (HSLA) steels, effect of various alloying elements on weldability, factors affecting weld-metal and HAZ Properties, problems and defects encountered in welding, post weld heat treatment of HSLA steels	6
5.	Weldability of Cast Irons: Common grades of cast irons, carbon equivalent in cast irons, factors affecting weldability of cast irons, approaches for welding of cast irons common problems encountered during the welding of cast and their remedy.	6

6.	Weldability of Aluminium Alloys: Physical metallurgy of heat treatable and work hardenable aluminium alloys, properties of aluminium alloys and weldability, solidification cracking, hydrogen induced porosity, partial melting zone and liquation cracking, HAZ softening, precautions in the welding of age hardenable alloy.	6
7.	Weldability of Copper Alloys: Common copper alloys, properties of copper alloys and weldability, effect of various alloying element of weldability, problem in welding of heat treatable and none-heat treatable copper alloys and their remedy.	6
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	Lancaster J F., "Metallurgy of Welding", Allen & Unwin Co.	**2000**
2.	Castro R. and Cadenet J. J. de., "Welding Metallurgy of Stainless and heat-resisting steels", Cambridge Uni. Press.	**1975**
3.	"Welding, Brazing and soldering", Vol. 6, ASM International, ASM, Ohio.	**1993**
4.	Kou S., Welding metallurgy, 2nd edition, Wiley Publications	**2003**
5.	Hrivnák, I., "Theory of Weldability of Metals and Alloys", Elsevier Science	**1991**
6.	Gene Mathers, "Welding of Aluminium and alloys", Wood Head Pub. UK.	**2002**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN–599** Course Title: **Surface Engineering**
2. Contact Hours : **L: 3** **T: 1** **P: 2/2**
3. Examination Duration (Hrs.) : **Theory:** 3 **Practical:** 0
4. Relative Weight : **CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** 0
5. Credits 4 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre – requisite: **Nil**
9. Objective: The course will highlight the different surface degradation phenomena, importance of the surface engineering techniques, their benefits and limitations. Selective characterisation techniques for quality assurance of engineered surfaces will be introduced.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Concept and Importance, classification of surface modification techniques, advantages and their limitations.	3
2	**Surface Degradation**: Causes, types and consequences of surface degradation, Forms of wear – adhesive, abrasive, surface fatigue, corrosive, fretting and erosive wear, Classical governing laws related to wear, techniques to evaluate the wear damage.	10
3	**Materials for Surface Engineering**: Materials characteristics, their importance in surface engineering, wear resistant materials, selection of materials for engineering the surfaces for specific applications, New coating concepts including multi-layer structures, functionally gradient materials (FGMs), intermetallic barrier coatings and thermal barrier coating.	9
4	**Coating based Surface Modification Techniques**: Principles and application of weld surfacing: SMAW, SAW, GMAW, Thermal spraying – flame spraying, electric arc spraying, plasma spraying, detonation gun spraying and high velocity oxy fuel spraying Electro deposition and electro less coatings.	8
5	**Diffusion based Surface Modification Techniques**: Ion implantation, chemical vapour deposition (CVD) and physical vapour deposition (PVD), carburizing, nitriding, plasma nitriding, cyaniding.	4
6	**Irradiation based and Laser Assisted Surface Engineering (LASE) Techniques**: Laser cladding, alloying, glazing, laser and induction hardening, heat treatment of steel and remelting by laser / TIG. Microwave glazing.	4
7	**Characterisation and Quality Assurance of Engineered Surfaces**: Importance,	4

	Different characterisation techniques – physical, mechanical and functional characterisations, surface finish, microhardness, strength and tribological characterisations.	
	Total	**42**

11. Suggested Books:

S.No	Name of Author (s)/ Book/ Publisher	Year of Publication/ Reprint
1	Burakowski T. and Wierzchoń T., "Surface Engineering of Metals: Principles, Equipment, Technologies", CRC Press, Boca Raton, Florida.	1999
2	Burnell-Gray J.S. and Datta P.K. (eds.), "Surface Engineering Casebook", Woodhead Publishing Limited, Cambridge, England.	1996
3	Grainger, S. and Blunt J. (eds.), "Engineering coatings - design and application", Abington Publishing, Cambridge, England.	1998
4	Rickerby D. S. and Matthews A. (eds), "Advanced Surface Coatings: a Handbook of Surface Engineering", Blackie, London.	1991
5	Holmberg K. and Matthews A., "Coatings Tribology: Properties, Techniques and Applications in Surface Engineering", Elsevier Science B.V., Amsterdam.	1994

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPARTMENT: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-601** Course Title: **Additive Manufacturing**

2. Contact Hours: **L: 3** **T:1** **P: 0**

3. Examination Duration (Hrs.) : Theory 3 Practical 0
Hours

4. Relative Weight :**CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits: 4 6. Semester: **Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **CAD**

9. Objectives: To impart knowledge about the effective and creative applications of additive manufacturing technologies in different stages of time based new product development.

10. Details of Course:

S.No.	Contents	Contact Hours
1	Classification of additive manufacturing (AM) processes. AM based rapid prototyping (RP) Systems like Stereo-lithography, Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), 3-D Printing, LENS etc.	10
2	Role of additive manufacturing and rapid prototyping in product design and development. Solid modeling techniques for additive manufacturing with comparison, advantages and disadvantages.	12
3	Process planning for rapid prototyping, STL file generation Defects in STL files and repairing algorithms, Slicing and various slicing procedures.	08
4	Accuracy issues in additive manufacturing, Properties of metallic and non-metallic additive manufactured surfaces, Stress induced in additive manufacturing (AM) processes. Surface roughness problem in rapid prototyping, Part deposition orientation and issues like accuracy, surface finish, build time, support structure, cost etc.,	10
5	Rapid tooling techniques such as laminated metallic tooling, direct metal laser sintering, vacuum casting etc.	02
		42

11. Suggested Books**:**

S.No	Name of Book / Authors / Publisher	Year of Publication/ Reprint
1	Chua, C.K., Leong, K.F., Rapid Prototyping: Principles and Applications in Manufacturing, John Wiley and Sons Inc.	2000
2	Pham, D.T., Demov, S.S., Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer-Verlag London Limited.	2001
3	Hopkinson, N., Hague, R.J.M. and Dickens, P.M., Rapid Manufacturing and Industrial Revolution for the Digital Age, John Wiley and Sons Ltd, Chichester.	2005
4	Gebhardt, A., Rapid Prototyping, Hanser Gardner Publications, Inc., Cincinnati	2003
5	Noorani, R., Rapid Prototyping: Principles and Applications, John Wiley & Sons, Inc., New Jersey.	2006
6	Gibson, I., Software Solutions for Rapid Prototyping, Professional Engineering Publication Ltd	2002
7	Patri, K. V., and Weiyin, Ma, Rapid Prototyping - Laser-based and Other Technologies, Kluwer Academic Publishers, U.S.A.	2003
8	Mortenson, M.E., Geometric Modelling, John Wiley and Sons, Inc.	1997
9	Saxena, A., Sahay, B., Computer Aided Engineering Design, Anamaya Publishers, New Delhi.	2005
10	Zeid, I., Mastering CAD/CAM, Tata McCraw Hill.	2006

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPTT/CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-602** Course Title: **Bond Graph Modeling of Engineering Systems**

2. Contact Hours : **L: 3** **T:1** **P: 2/2**

3. Examination Duration (Hrs.) : **Theory 3** **Practical** 0

4. Relative Weight :**CWS** 20 **PRS** 20 **MTE** 20 **ETE** 40 **PRE** 0

5. Credits: 4 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre–requisite: **NIL**

9. Objectives of Course: To introduce the basics of bond graph modeling, causality assignment and generation of system equations. Use of bond graphs in various engineering systems for fault detection and isolation will also be introduced.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction**: An invariant nature of power exchange, power variables of bond graph, representation of junction elements, reference power directions on the bonds, bond graph standard elements, constitutive laws of single port elements, 2 port elements, 3 port junction elements, mechanical 1 and 0 junctions	02
2	**Causality**: Notion of causality, causality of sources, causality of I, C and R elements, causality of junction elements, causality of two port elements, differential causality, algorithm for assigning causality, examples of assignment of causality	04
3	**Creation of System Equations**: Selection of system states, generation of system equations, a bond graph with a transformer element, electrical systems, systems with differential causality, activation and activated bonds, fields, algebraic loops.	08
4	**Creation of System Bond graph**: basic guidelines. Bond graphs for mechanical systems: method of flow map, method of effort map, method of mixed map. Bond graph of electrical circuits: method of gradual uncover, point potential method, mixed method, gyrator and transformer equivalents	08
5	**Use of non-inertial coordinates**: principle of material objectivity, mapping back to inertial frame, rate of change of generalized momenta, dynamics of rigid bodies,	02
6	**Structural members**: Euler-Bernoulli beam model, Rayleigh beam model, Timoshenko beam model, consistent inertia field, modal bond graph of a continuous system.	03
7	**Modeling of multi body systems**: modeling of mechanisms, modeling of mechanical handling systems, robots.	04
8	**Approaching Control System**: signal flow graph from bond graph, application	05

	of bond graph to control systems, proportional control, proportional-integral control, proportional-integral-derivative control, velocity control of moving cars connected by springs, modeling of electronic circuits: modeling of operational amplifiers, semiconductor diode	
9	**Fault Detection and Isolation (FDI):** classification of FDI procedures, structural controllability and observability, Fault diagnosis using bond graphs, Qualitative FDI, Quantitative FDI, Analytical redundancy relations (ARR) from bond graph model, fault tolerant control	06
	Total	42

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1	Mukherjee A., Karmarkar R. and Samantray A. K., "Bondgraph in Modeling Simulation and Fault Identification", I. K. International Publishing House Pvt. Ltd.	2006
2	Borutzky, Wolfgang, "Bond Graph Modelling of Engineering Systems", Springer	2011
3	Karnopp Dean C. , Margolis Donald L. , Rosenberg Ronald C., "System Dynamics: Modeling, Simulation, and Control of Mechatronic Systems", Wiley	2012
4	Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer	2013
5	Breedveld Peter C., Geneviève Dauphin-Tanguy, "Bond Graphs for Engineers",Elsevier Science Publishers, Amsterdam.	1992

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE: **Department of Mechanical and Industrial Engineering**

1. Subject Code: **MIN-603** Course Title: **Finite Element Method for Thermal Engineering**
2. Contact Hours : **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.) : **Theory 3** **Practical 0**
4. Relative Weight : CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the recent developments in field of finite element analysis for a better engineering design.
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic Concepts of Finite Element Methods**: Introduction, variational methods, collocation method, subdomain method, Galerkin's method, least squares method.	4
2	**Finite Element in 1-D**: Basis steps of finite element analysis, linear element, notation, weighted functions, weighted residual integral, boundary condtions, global matrix, Galerkin's formulation, Applications to fin problem, fluid flow problems.	8
3	**Finite Element in 2-D**: Single variable problems in 2-D, types of elements, triangular and rectangular elements, iso-parametric concept, higher order elements, numerical integration and computer implementation, higher order shape functions, boundary conditions, Galerkin's formulation, applications to conduction and convection heat transfer problems, plane stress and plane strain problems.	10
4	**Time dependent field problems**: Galerkin's method, consistent and lumped formulations, finite difference solution in time, numerical oscillations, example problem from heat transfer and flow problems, computer implementation	6
5	**Flow problems**: Governing equations for continuity, momentum and energy conservations, velocity-pressure formulation, velocity-vorticity formulation, finite element implementation for the solution of Navier-Stokes equations, Eulerian velocity correction method, application to two-dimensional problem, pressure boundary condition, computer implementation	8
6	**Non-linear problems:** Non-linear elasticity, non-linear thermo-physical properties, implementation of Galerkin's method for non-linear heat conduction equation, application of Newton-Raphson method and other methods for non-linear heat transfer and flow problems.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publisher	Year of Publication/Reprint
1	Segerlind, L. J., "Applied Finite Element Analysis", 2nd Ed., John Wiley and Sons.	1984
2	Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill.	2005
3	Rao, S.S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science.	2005
4	Zienkiewicz, O. C., Taylor, C., and Nithiarasu, P., "Finite Element Method for Fluid Dynamics", 6th Ed., Butterworth-Heinemann.	2005
5	Bathe, K. J., "Finite Element Procedures in Engineering Analysis", Prentice Hall.	1982

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-604** Course Title: **Fire Dynamics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**

5. Credits**:** **4** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce students to the fundamental concepts of fire dynamics a base-level understanding of the principals of fire dynamics, compartment fire and smoke movement.

10. Details of Course:

S. No.	Contents	Contact Hours
1	**Introduction:** Fuels and combustion processes; physical chemistry of combustion in fires; summary of the heat transfer equations of conduction, conection and radiation	3
2	**Premixed Flames:** Limits of flammability; structure of premixed flame; heat loss and measurement of burning velocity; variation of burning velocity with composition, temperature, pressure, suppressant and turbulence.	6
3	**Diffusion Flames and Fire Plumes:** Laminar and turbulent jet flames; flames from natural fire: buoyant plume, fire plume, upward flow; interaction of fire plume with compartment boundaries; effect of wind on fire plume	7
4	**Steady Burning of Liquids and Solids:** Burning of liquids: pool fire, burning of liquid droplets; burning of solids: synthetic polymers, wood, dusts and powders	4
5	**Frictionless Compressible Flow:** Governing equations, full potential equation, flow through constant area ducts with heat transfer, Rayleigh lines.	6
6	**Ignition and Spread of Flames:** Ignition of liquids and solids; Flame spread over liquids and solids;.	5
7	**Pre-flashover and Post-flashover Compartment Fire:** Growth of flash-over: necessary conditions; ventilation requirements; factors affecting time to flashover and fire growth; fully developed fire behavior; temperature in fully developed fire; fire resistance and fire severity.	6

8	**Production and Movement of Smoke:** Production and measurement of smoke particles**;** test for smoke production potential; smoke movement; smoke control systems	5
	Total	**42**

11. Suggested Books:

S. No.	Author(s) / Title / Publisher	Year of Publication/ Reprint
1.	Drysdale, D. "Introduction to Fire Dynamics", John Wiley	2011
2.	Karlsson, B., Quintiere, J., "Enclosure Fire Dynamics", James; CRC Press	2000
3	Quintiere, J.G.,., "Fundamentals of Fire Phenomena", John Wiley	2006
4	Gorbet, G.E., and Pharr, J.L, Fire Dynamics; Pearson Education	2010

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPARTMENT: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-605** Course Title: **Friction and Wear**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory : 03** **Practical :0**.

4. Relative Weight **: CWS : 25** **PRS : 0** **MTE : 25** **ETE : 50** **PRE : 0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7.Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To impart knowledge on concepts of friction and wear of engineering materials.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Concept of a surface and surface topography of engineering surfaces; Interaction between contacting surfaces, concept of elastic and plastic deformation, Hertz's contact theory; Concept of surface forces – electrostatic forces, capillary forces and van der Waal forces.	4
2.	**Friction:** Concept and laws of friction; Theories of friction, rolling friction, sliding friction, Coulomb model, junction growth, asperity deformation, stresses in friction; Temperature in friction.	5
3.	**Friction and Engineering Materials:** Friction of metallic materials, ceramics, polymers and lamellar solids.	7
4.	**Assessment and Control of Friction:** Assessment of co-efficient of friction, measurement of friction force and contact temperature, assessment of surface forces, tribometer and atomic force microscope (AFM); Lubricants in reducing friction..	4
5.	**Wear:** Concept of wear of engineering surfaces; Types of wear; Sliding wear, dry and lubricated wear of surfaces, chemical wear.	5
6.	**Wear Mechanisms:** Abrasion; Adhesion; Erosion; Fatigue; Corrosion; Other forms of wear.	7
7.	**Wear Characteristics of Engineering Materials:** Wear of metallic materials, ceramics, composites and polymers.	6
8.	**Wear estimation and Control:** ASTM standards for estimation of wear of engineering surfaces; Modification of functional surfaces for minimization of wear, selection of materials and techniques.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Rabinowicz, E., "Friction and Wear of Materials", John Wiley and Sons, Inc., New York.	1965
2.	Hutchings, I.M., "Tribology: Friction and Wear of Engineering Materials", Edward Arnold, London.	1992
3.	Rigney, D.A.(ed.), "Fundamentals of Friction and Wear of Materials", American Society for Metals, Ohio, USA.	1981
4.	ZumGahr, K. H., "Microstructure and Wear of Materials", Elsevier, Amsterdam.	1987
5.	Burnell-Gray, J. S. and Datta, P.K. (eds.), "Surface Engineering Casebook", Woodhead Publishing Limited, Cambridge, England.	1996
6.	Dowson, D., "History of Tribology", Longman, London.	1978
7.	Bowden, F. P. and Tabor, D., "The Friction and Lubrication of Solids", Part I & II, Clarendon Press, Oxford.	1964
8.	Takadoum, J., "Materials and Surface Engineering in Tribology", John Wiley and Sons, Inc., London.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-606** Course Title: **Numerical Methods in Manufacturing**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To expose the students to in various numerical methods and modeling tools to model and simulate manufacturing and materials processing operations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction to Numerical Methods:** Introduction, Linear equations, Non-linear equations, Functional approximation, Numerical differentiation, Numerical integration, Ordinary differential equations, Partial differential equations, Finite difference method, Finite element method, Finite volume method, Orthogonal collocation, Boundary integral method, Optimization	8
2.	**Science Base of Mathematical Model Development:** Introduction, Fluid flow phenomenon, Heat transfer, Diffusion and mass transfer, Multiphase flow	8
3.	**Modeling of Casting & Solidification Process:** Fundamentals of casting and solidification process, Heat flow in solidification, Solidification of mushy zones, Finite element simulation of solidification problems, Modeling and formulation of casting problems, case studies, Macro-modeling of solidification; Numerical approximation methods, Discretization of governing equations, Solution of discretized equations, Application of macro-modeling of solidification	10
4.	**Modeling of Metal Forming Processes:** Introduction, Plasciticity fundamentals: von Mises yield criterion, Tresca yield criterion, Flow rule, Generalised stress & generalised strain increment, Plastic anisotropy, Anisotropic yield criterion, Plastic instability, Process modeling: Uniform energy method, slab method, slip-line field method, upper bound method, Visioplasticity method, Finite element method, Application of finite element method, Eulerian rigid-plastic FEM formulation for plane strain rolling, Governing equations	10
5.	**Modeling of Welding Processes:** Weld pool heat & fluid flow, Modeling of fluid dynamics & coupled phenomenon in arch weld pools, finite element analysis of welding residual stress & distribution	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication/ Reprint
1.	Ilegbusi, Olusegun J., Iguchi, M., Wanhsiedler, W., "Mathematical and Physical Modelling of Materials Processing Operations", Chapman & Hall/ CRC Press	2000
2.	Stefanescu, D. M., "Science and Engineering of Casting Solidification", Kluwer Academic/ Plenum Publishers,	2002
3.	Lal, G. K., Dixit, P. M., Reddy, N. Venkata., "Modelling Techniques for Metal Forming Processes", Narosa Publishimg House, 2011	2011
4.	Gupta Santosh K, Numerical Methods for Engineers, New Age International (P) Limited Publishers,	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-608** Course Title:**Product and Process Optimization**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 4** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: This course will introduce to the students, the basic concepts, techniques and applications of engineering optimization in a comprehensive manner.

10. Details of Course:

S. No.	Contents	Contact Hrs
1.	**Introduction to Design Optimization:** The design process; basic terminology and notations.	2
2.	**Optimum Design Problem Formulation:** The problem formulation process; and illustration with examples.	3
3.	**Graphical Optimization:** Graphical solution process; problems with – bounded (single or multiple) and unbounded solutions.	3
4.	**Optimum Design Concepts:** Local and global optima; necessary and sufficient optimality conditions for unconstrained and constrained multivariate functions.	6
5.	**Linear Programming Methods for Optimum Design:** Basic concepts; simplex method; two-phase simplex method; post-optimality analysis.	4
6.	**Numerical methods for Unconstrained and Constrained Optimum Design:** Gradient-based and direct search methods; Sequential linear and quadratic programming.	6
7.	**Multi-objective Optimization:** Fundamental shift from single-objective optimization; Pareto-set and Pareto-optimal Front.	4
8.	**Evolutionary Techniques for Optimization:** Genetic algorithms; Differential Evolution Algorithms; Ant colony Optimization; and Particle Swarm Optimization.	6
9.	**Advanced topics on Optimum Design:** Meta models for design optimization; design of experiments; discrete design with orthogonal arrays; robust design approach; reliability-based design optimization.	4
10.	**Practical applications of optimization:** Illustration on engineering	4

	problems with single and multiple objectives.	
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	S. S. Rao; Engineering Optimization; 4th Edition, John Wiley & Sons.	2009
2.	K. Deb; Optimization for Engineering Design; Prentice Hall of India.	2005
3.	K. Deb; Multi-objective Optimization using Evolutionary Algorithms; John Wiley & Sons.	2003

NAME OF DEPTT./CENTRE **:** **Mechanical and Industrial Engineering**

1. Subject Code**: MIN-609** Course Title**: Solid State Joining Processes**
2. Contact Hours**:** **L: 3 T: 1 P: 2/2**
3. Examination Duration (Hrs)**:** **Theory: 3 Practical: 0**

4. Relative Weight **:** **CWS 20 PRS 20 MTE 20 ETE 40 PRE 0**
5. Credits**: 4** 6. Semester **: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objectives**:** The aim of the course is to provide theoretical and practical details of solid state welding/joining processes and their significance in manufacturing.

10. Details of Course**:**

S. No.	Contents	Contact Hours
1.	Joining defined; Fundamental forces involved in joining; Mechanical fastening and integral attachment: using mechanical forces; Adhesive bonding: using chemical forces; Welding: using physical forces; Overview of fusion and solid state welds; Fundamental principles of solid state welding processes; Classification of solid state/non-fusion welding processes.	8
2.	Adhesive bonding as a joining process; General description of adhesive bonding; Cementing and mortaring as an adhesive joining process; The functions of adhesives; Mechanisms of adhesion; Failure in adhesive-bonded joints; Adhesive joint designs; Design criteria and analysis of adhesive joints.	8
3.	Friction welding process; application of friction welding process; friction welding process parameters; radial and orbital friction welding; direct drive and inertia drive friction welding; study of friction welds; joint quality of friction welds.	8
4.	Overview of friction stir welding (FSW) process principles; welding tools used for FSW; Parameters' effects; Materials used with FSW;thermomechanical aspect of FSW; Plastic deformation in relation to material properties; Material flow and property relationships of the resultant FSW joint, friction stir processing (FSP), process parameters of FSP; Application of FSW and FSP processes.	10
5.	Diffusion joining processes: conventional diffusion, deformation diffusion, resistance diffusion & continuous seam diffusion welding; diffusion brazing; braze welding, combined forming and diffusion welding; solid-state deposition welding processes. Pressure non-fusion welding processes: cold welding processes, pressure gas welding process, forge welding process; Roll welding; Explosion welding process.	8
	Total	**42**

11. Suggested Books**:**

S. No.	Name of Author (s)/ Book/ Publisher	Year of Publication/ Reprint
1.	Messler Robert W. Jr., "Joining of Materials and Structures"Elsevier Butterworth–Heinemann.	2004
2.	Messler Robert W. Jr., "Principles of welding"WILEY-VCHVerlag GmbH & Co. KGaA**,** Weinheim.	2004
3.	"Friction stir welding From basics to applications" Edited by Daniela Lohwasser and Zhan Chen,Woodhead Publishing India Pvt. Ltd.	2010
4.	"Welding Handbook", Vol. 2 & 3, 9thEdition, American Welding Society.	2003
5.	Richard Little L., "Welding and Welding Technology", McGraw Hill.	1976
6.	TylecoteR.F., "The Solid phase welding of Metals", Edward Arnold Pub. Ltd.	1968

INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

NAME OF DEPARTMENT: **Department of Mechanical & Industrial Engineering**

1. Subject Code: **MIN-610** Course Title: **Laser Material Processing**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory : 03** **Practical :0**.

4. Relative Weight **: CWS : 25** **PRS : 0** **MTE : 25** **ETE :** 50 **PRE : 0**

5. Credits**: 4** 6. Semester**: Spring** 7.Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To impart knowledge on processing of engineering materials using laser as the source of energy.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Concept of laser, basic mechanisms in lasers; Properties of laser; Types of laser, gas, liquid and solid state lasers; Pulsed and CW lasers.	5
2.	**Laser-Material Interaction:** Interaction of laser with metals, ceramics, polymers, composites and other materials; Laser heating fundamentals.	6
3.	**Laser Machining:** One, two and three dimensional laser machining; Application of laser in material removal processes like cutting, drilling, grooving; Laser assisted machining (LAM); Laser micromachining.	13
4.	**Laser Welding:** Principles, Significance of laser welding variables; Laser welding of various materials including steel, aluminium and its alloys and titanium and its alloys.	8
5.	**Laser Heat Treatment:** One dimensional thermal heating and cooling of metals; Mechanisms of hardening in steel and cast irons.	5
6.	**Lasers in Surface Engineering Applications:** Laser glazing; Laser alloying; Microstructural considerations in laser rapid heating process.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Bass, M., "Laser Materials Processing", North Holland Publishing Co., Amsterdam.	1983
2.	Chryssolouris, G., "Laser Machining- Theory and Practice", Springer-Verlog, New York Inc.	1991
3.	Luxon, J. T. and Parker, D. E., Industrial Lasers and Their Applications", Prentice-Hall, Englewood Cliffs, NJ.	1985