CURRICULUM AND SYLLABI

B. Tech.

in

MECHANICAL ENGINEERING

COURSES

(I to VIII Semesters)

(Applicable to 2017 admission onwards)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601
KERALA, INDIA

The Program Educational Objectives (PEOs) of B.Tech. in Mechanical Engineering

PEO1	Excel in industry, technical profession and/or higher education by acquiring a strong foundation in mathematics, science and engineering fundamentals.
PEO2	Acquire scientific and engineering competencies to comprehend, analyze, design and create novel products and solutions to mechanical and industrial problems that are technically sound, economically feasible and socially acceptable.
PEO3	Exhibit professionalism, ethical attitude, communication and team working skills, multidisciplinary approach and an ability to relate engineering issues to the broader social context.

The Programme Outcomes (POs) of B. Tech. in Mechanical Engineering

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

The Programme Specific Outcomes (PSOs) of B. Tech. in Mechanical Engineering

PSO1	Design and develop mechanical systems for structural, thermal and manufacturing applications.
PSO2	Ability to effectively utilize resources for improving the performance of mechanical systems.
PSO3	Demonstrate the ability to develop methods, procedures and solutions for cost-effective decisions in mechanical engineering.

CURRICULUM

The total minimum credits for completing the B.Tech. programme in Mechanical Engineering is 160.

MINIMUM CREDIT REQUIREMENT FOR THE VARIOUS COURSE CATEGORIES

Sl. No.	COURSE CATEGORY	Number of Courses	Credits
1.	Mathematics (MA)	4	12
2.	Science (BS)	5	10
3.	Humanities (HL)	3	9
4.	Basic Engineering (BE)	6	15
5.	Professional Core (PC)	31	84
6.	Open Electives (OE)	2	6
7.	Departmental Electives (DE)	6	18
8.	Other Courses (OT)	4	6
	TOTAL	**61**	**160**

COURSE REQUIREMENTS:

1. MATHEMATICS

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MA1001D	Mathematics I	3	1	0	3
2.	MA1002D	Mathematics II	3	1	0	3
3.	MA2001D	Mathematics III	3	1	0	3
4.	MA2002D	Mathematics IV	3	1	0	3
Total			**12**	**4**	**0**	**12**

2. SCIENCE

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	PH1001D	Physics	3	0	0	3
2.	PH1091D	Physics Lab	0	0	2	1
3.	CY1001D	Chemistry	3	0	0	3
4.	CY1094D	Chemistry Lab	0	0	2	1
5.	BT1001D	Introduction to Life Science	2	0	0	2
Total			**8**	**0**	**4**	**10**

3. HUMANITIES

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	MS1001D	Professional Communication	3	0	0	3
2.	ME2111D	Essentials of Management	3	0	0	3
3.	MS4002D	Industrial Economics	3	0	0	3
Total			**9**	**0**	**0**	**9**

4. BASIC ENGINEERING

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	ZZ1001D	Engineering Mechanics	3	0	0	3
2.	ZZ1003D	Basic Electrical Sciences	3	0	0	3
3.	ZZ1002D	Engineering Graphics	2	0	2	3
4.	ZZ1004D	Computer Programming	2	0	0	2
5.	ZZ1091D	Workshop I	0	0	3	2
6.	ZZ1092D	Workshop II	0	0	3	2
Total			**10**	**0**	**8**	**15**

5. OTHER COURSES (OT)

Sl. No.	Course Code	Course Title	L	T	P	Credits
1.	ZZ1093D	Physical Education	1	0	1	1
2.	ZZ1094D	Value Education	1	0	1	1
3.	ZZ1095D	NSS	0	0	3	1
4.	ME2015D	Environmental Studies for Mechanical Engineers	3	0	0	3
Total			**5**	**0**	**5**	**6**

6. PROFESSIONAL CORE

Sl. No.	Course Code	Course Title	Pre-requisites	L	T	P	Credits
1.	EE2013D	Electrical Measurements and Machines	-	3	0	0	3
2.	ME2001D	Fluid Mechanics	-	3	0	0	3
3.	ME2003D	Solid Mechanics	ZZ1001D	4	0	0	4
4.	ME2101D	Materials Science and Metallurgy	-	3	0	0	3
5.	ME2091D	Machine Drawing	ZZ1002D	0	0	3	2

6.	EE2093D	Electrical Measurements and Machines Laboratory	-	0	0	3	2
7.	ME2011D	Fluid Machinery	ME2001D	3	0	0	3
8.	ME2012D	Kinematics of Mechanisms	ZZ1001D	3	0	0	3
9.	ME2013D	Thermodynamics	-	3	0	0	3
10.	ME2092D	Fluid Mechanics and Fluid Machinery Laboratory	ME2001D / ME2004D	0	0	3	2
11.	CE2095D	Strength of Materials Laboratory	ME2002D / ME2003D / Eqv.	0	0	3	2
12.	ME3001D	Dynamics of Machines	ME2012D	3	0	0	3
13.	ME3002D	Principles of Heat Transfer	-	3	0	0	3
14.	ME3003D	Thermal Engineering I	ME2013D / ME2016D	3	0	0	3
15.	ME3101D	Manufacturing Science	-	3	0	0	3
16.	ME3102D	Management of Production Systems	ME2111D	3	0	0	3
17.	ME3091D	Heat Transfer Laboratory	-	0	0	3	2
18.	ME3191D	Production Engineering Laboratory I	-	0	0	3	2
19.	ME3011D	Machine Design I	ME2003D	3	0	0	3
20.	ME3111D	Operations Research	-	3	1	0	3
21.	ME3112D	Metrology and Instrumentation	-	3	0	0	3
22.	ME3113D	Machining Science and Machine Tools	-	3	0	0	3
23.	ME3192D	Metrology and Instrumentation Laboratory	-	0	0	3	2
24.	ME3193D	Production Engineering Laboratory II	-	0	0	3	2
25.	ME3099D	Seminar	-	0	0	3	1
26.	ME4001D	Machine Design II	ME2003D	3	0	0	3
27.	ME4002D	Thermal Engineering II	ME2013D	3	0	0	3
28.	ME4091D	Heat Engines Laboratory	ME3003D	0	0	3	2
29.	ME4191D	CAD/CAM Laboratory	-	0	0	3	2

30.	ME4098D	Project: Part 1	-	0	0	6	3
31.	ME4099D	Project: Part 2	ME4098D	0	0	10	5
Total				**55**	**1**	**49**	**84**

7. DEPARTMENT ELECTIVES

Sl. No.	Course Code	Course Title	Pre-requisites	L	T	P	Credits
1.	ME3021D	Introduction to Finite Element Methods	ME2003D / Eqv.	3	0	0	3
2.	ME3022D	Experimental Stress Analysis	ME2002D / ME2003D / Eqv.	3	0	0	3
3.	ME3023D	Theory of Elasticity	ME2002D / ME2003D / CE2001D	3	0	0	3
4.	ME3024D	Control Systems Engineering	-	3	0	0	3
5.	ME3025D	Nonlinear Dynamics and Chaos	ZZ1001D	3	0	0	3
6.	ME3026D	Engineering Fracture Mechanics	ME2003D / Eqv.	3	0	0	3
7.	ME3027D	Fluid Power Controls	ME2001D / Eqv.	3	0	0	3
8.	ME3028D	Advanced Thermodynamics	ME2013D / Eqv.	3	0	0	3
9.	ME3029D	Computational Methods in Engineering	-	3	0	0	3
10.	ME3030D	Newtonian and Analytical Mechanics	ZZ1001D	3	0	0	3
11.	ME3031D	Theory of Plasticity	ME2003D / ME3023D	3	0	0	3
12.	ME3032D	Automobile Engineering	-	3	0	0	3
13.	ME3121D	Powder Metallurgy	-	3	0	0	3
14.	ME3122D	Introduction to Marketing	ME2111D / Eqv.	3	0	0	3
15.	ME3123D	Design and Analysis of Management Information Systems	ME2111D / Eqv.	3	0	0	3

16.	ME3124D	Work Design and Measurement	-	3	0	0	3
17.	ME3125D	Cost Analysis and Control	-	3	0	0	3
18.	ME3126D	Supply Chain Management	-	3	0	0	3
19.	ME3127D	Management of Organisational Behaviour	ME2111D / Eqv.	3	0	0	3
20.	ME3129D	Management of Human Resources	ME2111D / Eqv.	3	0	0	3
21.	ME3130D	Quality Planning and Analysis	-	3	0	0	3
22.	ME4021D	Industrial Tribology	1. ME2001D / ME2004D & 2. ME2003D / ME3023D	3	0	0	3
23.	ME4022D	Vehicle Dynamics	ZZ1001D	3	0	0	3
24.	ME4023D	Introduction to Robotics	ZZ1001D	3	0	0	3
25.	ME4024D	Design for Manufacturability	-	3	0	0	3
26.	ME4025D	Mechatronics	-	3	0	0	3
27.	ME4026D	Renewable Energy Systems	-	3	0	0	3
28.	ME4028D	Aerodynamics	ME2001D / Eqv.	3	0	0	3
29.	ME4029D	Heating, Ventilation and Air Conditioning	-	3	0	0	3
30.	ME4030D	Fundamentals of Combustion	ME2013D / Eqv.	3	0	0	3
31.	ME4031D	Refrigeration and Air Conditioning Systems	-	3	0	0	3
32.	ME4033D	Introduction to Computer Graphics	ZZ1004D	3	0	0	3
33.	ME4034D	Experimental Methods in Fluid Flow and Heat Transfer	-	3	0	0	3
34.	ME4036D	Surface Engineering and Coating Technology	-	3	0	0	3

35.	ME4037D	Gas Dynamics	1. ME2001D / Eqv. & 2. ME2013D / Eqv.	3	0	0	3
36.	ME4122D	Mechanical Behaviour and Testing of Materials	ME2101D	3	0	0	3
37.	ME4123D	Technology Management	-	3	0	0	3
38.	ME4125D	Management of Lean Production Systems	-	3	0	0	3
39.	ME4126D	Optimization Methods in Engineering	-	3	0	0	3
40.	ME4127D	Accounting and Finance for Engineers	-	3	0	0	3
41.	ME4128D	Simulation Modelling and Analysis	-	3	0	0	3
42.	ME4129D	Modeling of Manufacturing Systems	-	3	0	0	3
43.	ME4130D	Human Factors in Engineering and Design	-	3	0	0	3
44.	ME4131D	Machine Learning for Data Science and Analytics	-	3	0	0	3

Notes: 1. Consent of the course faculty is a prerequisite for all the elective courses.
2. The course faculty shall decide on the equivalence of prerequisites.

8. OPEN ELECTIVES

Two elective courses, which are offered as “Open Electives” by any department in the Institute, can be credited.

Course Structure

Semester I

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	MA1001D	Mathematics I	3	1	0	3	MA
2.	PH1001D / CY1001D	Physics / Chemistry	3	0	0	3	BS
3.	MS1001D / ZZ1003D	Professional Communication / Basic Electrical Sciences	3	0	0	3	HL/BE
4.	ZZ1001D / ZZ1002D	Engineering Mechanics / Engineering Graphics	3/2	0	0/2	3	BE
5.	ZZ1004D / BT1001D	Computer Programming / Introduction to Life Science	2	0	0	2	BE/BS
6.	PH1091D / CY1094D	Physics Lab / Chemistry Lab	0	0	2	1	BS
7.	ZZ1091D / ZZ1092D	Workshop I / Workshop II	0	0	3	2	BE
8.	ZZ1093D / ZZ1094D / ZZ1095D	Physical Education / Value Education / NSS	-	-	-	3*	OT
Total			**14/13**	**1**	**5/7**	**17+3***	

*Note: Three courses of 1 credit each are to be credited within the first four semesters.

Semester II

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	MA1002D	Mathematics II	3	1	0	3	MA
2.	CY1001D / PH1001D	Chemistry / Physics	3	0	0	3	BS
3.	ZZ1003D / MS1001D	Basic Electrical Sciences / Professional Communication	3	0	0	3	BE/HL
4.	ZZ1002D / ZZ1001D	Engineering Graphics / Engineering Mechanics	2/3	0	2/0	3	BE
5.	BT1001D / ZZ1004D	Introduction to Life Science / Computer Programming	2	0	0	2	BS/BE
6.	CY1094D / PH1091D	Chemistry Lab / Physics Lab	0	0	2	1	BS
7.	ZZ1092D / ZZ1091D	Workshop II / Workshop I	0	0	3	2	BE
Total			**13/14**	**1**	**7/5**	**17**	

Semester III

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	MA2001D	Mathematics III	3	1	0	3	MA
2.	EE2013D	Electrical Measurements and Machines	3	0	0	3	PC
3.	ME2001D	Fluid Mechanics	3	0	0	3	PC
4.	ME2003D	Solid Mechanics	4	0	0	4	PC
5.	ME2101D	Materials Science and Metallurgy	3	0	0	3	PC
6.	ME2091D	Machine Drawing	0	0	3	2	PC
7.	EE2093D	Electrical Measurements and Machines Laboratory	0	0	3	2	PC
Total			**16**	**1**	**6**	**20**	

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	MA2002D	Mathematics IV	3	1	0	3	MA
2.	ME2011D	Fluid Machinery	3	0	0	3	PC
3.	ME2012D	Kinematics of Mechanisms	3	0	0	3	PC
4.	ME2013D	Thermodynamics	3	0	0	3	PC
5.	ME2111D	Essentials of Management	3	0	0	3	HL
6.	ME2015D	Environmental Studies for Mechanical Engineers	3	0	0	3*	OT
7.	ME2092D	Fluid Mechanics and Fluid Machinery Laboratory	0	0	3	2	PC
8.	CE2095D	Strength of Materials Laboratory	0	0	3	2	PC
Total			**18**	**1**	**6**	**19+3***	

Semester V

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	ME3001D	Dynamics of Machines	3	0	0	3	PC
2.	ME3002D	Principles of Heat Transfer	3	0	0	3	PC
3.	ME3003D	Thermal Engineering I	3	0	0	3	PC
4.	ME3101D	Manufacturing Science	3	0	0	3	PC
5.	ME3102D	Management of Production Systems	3	0	0	3	PC
6.		Elective I	3	0	0	3	DE
7.	ME3091D	Heat Transfer Laboratory	0	0	3	2	PC
8.	ME3191D	Production Engineering Laboratory I	0	0	3	2	PC
Total			**18**	**0**	**6**	**22**	

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.	ME3011D	Machine Design I	3	0	0	3	PC
2.	ME3111D	Operations Research	3	1	0	3	PC
3.	ME3112D	Metrology and Instrumentation	3	0	0	3	PC
4.	ME3113D	Machining Science and Machine Tools	3	0	0	3	PC
5.		Elective II	3	0	0	3	DE
6.		Elective III	3	0	0	3	DE
7.	ME3192D	Metrology and Instrumentation Laboratory	0	0	3	2	PC
8.	ME3193D	Production Engineering Laboratory II	0	0	3	2	PC
9.	ME3099D	Seminar	0	0	3	1	PC
Total			**18**	**1**	**9**	**23**	

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	Cred its	Categ-ory
1.	ME4001D	Machine Design II	3	0	0	3	PC
2.	ME4002D	Thermal Engineering II	3	0	0	3	PC
3.	MS4002D	Industrial Economics	3	0	0	3	HL
4.		Elective IV	3	0	0	3	DE
5.		Open Elective I	3	0	0	3	OE
6.	ME4091D	Heat Engines Laboratory	0	0	3	2	PC
7.	ME4191D	CAD/CAM Laboratory	0	0	3	2	PC
8.	ME4098D	Project: Part 1	0	0	6	3	PC
Total			**15**	**0**	**12**	**22**	

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	Credits	Categ-ory
1.		Elective V	3	0	0	3	DE
2.		Elective VI	3	0	0	3	DE
3.		Open Elective II	3	0	0	3	OE
4.	ME4099D	Project: Part 2	0	0	10	5	PC
Total			**9**	**0**	**10**	**14**	

Notes:

1. For the successful completion of B.Tech. programme, a student must complete the minimum number of courses of each category specified in the curriculum of the specific programme. In addition to the above, the student must have acquired a total of 160 credits.
2. A student who completes all the course requirements (except the project) before the final semester may be permitted to undertake project at an institute/industry outside, with the consent of the department.

MA1001D MATHEMATICS I

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

Students will be able to:

CO1: Find the limits, check for the continuity and differentiability of functions of a single variable as well as several variables.

CO2: Test for the convergence of sequences and series of numbers as well as functions.

CO3: Formulate different mensuration problems as multiple integrals and evaluate them.

CO4: Use techniques in vector differential calculus to solve problems related to curvature, surface normal and directional derivative.

CO5: Find the parametric representation of curves and surfaces in space and will be able to evaluate the integral of functions over curves and surfaces.

Module 1: (13 Lecture hours)

Real valued function of real variable: Limit, Continuity, Differentiability, Local maxima and local minima, Curve sketching, Mean value theorems, Higher order derivatives, Taylor's theorem, Integration, Area under the curve, Improper integrals.

Function of several variables: Limit, Continuity, Partial derivatives, Partial differentiation of composite functions, Differentiation under the integral sign, Local maxima and local minima, Saddle point, Taylor's theorem, Hessian, Method of Lagrange multipliers.

Module 2: (13 Lecture hours)

Numerical sequences, Cauchy sequence, Convergence, Numerical series, Convergence, Tests for convergence, Absolute convergence, Sequence and series of functions, point-wise and uniform convergence, Power series, Radius of convergence, Taylor series.

Double integral, Triple integral, Change of variables, Jacobian, Polar coordinates, Applications of multiple integrals.

Module 3: (13 Lecture hours)

Parameterised curves in space, Arc length, Tangent and normal vectors, Curvature and torsion, Line integral, Gradient, Directional derivatives, Tangent plane and normal vector, Vector field, Divergence, Curl, Related identities, Scalar potential, Parameterised surface, Surface integral, Applications of surface integral, Integral theorems: Green's Theorem, Stokes' theorem, Gauss' divergence theorem, Applications of vector integrals.

References:

1. H. Anton, I. Bivens, and S. Davis, *Calculus*, 10th ed. John Wiley & Sons, 2015.
2. G. B. Thomas, M.D. Weir, and J. Hass, *Thomas' Calculus*, 12th ed. Pearson Education, 2015.
3. E. Kreyszig, *Advanced Engineering Mathematics*, 10th ed. John Wiley & Sons, 2015.
4. Apostol, *Calculus*, Vol 1, 1st ed. Wiley, 2014.

MA1002D MATHEMATICS II

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

Students will be able to:

CO1: Test the consistency of system of linear equations and then solve it.

CO2: Test for linear independence of vectors and perform orthogonalisation of basis vectors.

CO3: Diagonalise symmetric matrices and use it to find the nature of quadratic forms.

CO4: Formulate some engineering problems as ODEs and hence solve them.

CO5: Use Laplace transform and its properties to solve differential equations and integral equations.

Module 1: (16 Lecture hours)

System of Linear equations, Gauss elimination, Solution by LU decomposition, Determinant, Rank of a matrix, Linear independence, Consistency of linear system, General form of solution.

Vector spaces, Subspaces, Basis and dimension, Linear transformation, Rank-nullity theorem, Inner-product, Orthogonal set, Gram-Schmidt orthogonalisation, Matrix representation of linear transformation, Basis changing rule.

Types of matrices and their properties, Eigenvalue, Eigenvector, Eigenvalue problems, Cayley-Hamiltonian theorem and its applications, Similarity of matrices, Diagonalisation, Quadratic form, Reduction to canonical form.

Module 2: (13 Lecture hours)

Ordinary Differential Equations (ODE): Formation of ODE, Existence and uniqueness solution of first order ODE using examples, Methods of solutions of first order ODE, Applications of first order ODE.

Linear ODE: Homogenous equations, Fundamental system of solutions, Wronskian, Solution of second order non-homogeneous ODE with constant coefficients: Method of variation of parameters, Method of undetermined coefficients, Euler-Cauchy equations, Applications to engineering problems, System of linear ODEs with constant coefficients.

Module 3: (10 Lecture hours)

Gamma function, Beta function: Properties and evaluation of integrals.

Laplace transform, Necessary condition for existence, General properties, Inverse Laplace transform, Transforms of derivatives and integrals, Differentiation and Integration of transform, Unit-step function, Shifting theorems, Transforms of periodic functions, Convolution, Solution of differential equations and integral equations using Laplace transform.

References:

1. E. Kreyszig, *Advanced Engineering Mathematics*, 10th ed. Wiley, 2015.
2. G. Strang, *Introduction to Linear Algebra*, Cambridge Press, 2016.
3. R. P. Agarwal and D. O'Regan, *An Introduction to Ordinary Differential Equations*. Springer, 2008.
4. V. I. Arnold, *Ordinary Differential Equations*. Springer, 2006.
5. P. Dyke, *An Introduction to Laplace Transforms and Fourier Series*. Springer, 2014.

PH1001D PHYSICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
Students will be able to:

CO1: To enable students to apply relevant fundamental principles of modern physics to problems in engineering.

CO2: To develop knowledge of basic principles of Quantum Physics

CO3: Acquire knowledge of the basic physics of a collection of particles and the emergent macroscopic properties.

CO4: Apply principles of quantum and statistical physics to understand properties of materials.

Module 1: (12 hours)
Particle nature of radiation – Photoelectric effect, Compton effect, Wave nature of matter – matter waves, wave packets description, phase and group velocity, uncertainty principle. Formulation of Schrödinger equation, physical meaning of wave function, expectation values, time-independent Schrödinger equation, quantization of energy for bound particles. Application of time-independent Schrödinger equation to free particle, infinite well, finite well, barrier potential, tunneling.

Module 2: (14 hours)
Simple Harmonic Oscillator, two-dimensional square box, the scanning tunneling microscope. Wave function for two or more particles, indistinguishable particles, symmetry and anti-symmetry under exchange of particles, Pauli's exclusion principle, electronic configurations of atoms. Quantum model of a solid – periodicity of potential and bands, E – k diagram, effective mass, band gap.

Module 3: (13 hours)
Microstates and macrostates of a system, equal probability hypothesis, Boltzman factor and distribution, ideal gas, equipartition of energy, Maxwell speed distribution, average speed, RMS speed, Quantum distributions - Bosons and Fermions, Bose-Einstein and Fermi-Dirac distribution, applications.

References:

1. K. Krane, *Modern Physics*, 2nd ed. Wiley, 2009.
2. A. Beiser, *Concepts of Modern Physics*, 6th ed. Tata McGraw–Hill, 2009.
3. R. Eisberg and R. Resnick, *Quantum Physics of atoms, Molecules, Solids, Nuclei and Particlse*, 2nd ed. John Wiley, 2006.
4. D. Halliday, R. Resnick, and J. Walker, *Fundamentals of Physics*, 6th ed. Wiley, 2004.

CY1001D CHEMISTRY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

Students will be able to:

CO1: Acquire knowledge about separation strategies, identification and characterization of molecules

CO2: Understand the causes and mechanism of corrosion and understand its prevention methods

CO3: Attain knowledge about electrochemical reactions and their current applications

CO4: Comprehend the principles of industrial catalytic processes and enzyme catalysis

Module 1: (14 hours)

Spectroscopy – General Principles, Infrared, group frequencies, Electronic spectroscopy of conjugated molecules, Woodward-Fieser Rule.

Chromatography – Retention and Separation factors, Theoretical plates, Instrumentation and uses of Gas Chromatography and High Performance Liquid Chromatography

Thermal analysis – Thermogravimetry, Differential Scanning Calorimetry and Differential Thermal Analysis

Module 2: (12 hours)

Electrochemical corrosion – Mechanisms, control and prevention.

Cyclic voltammetry, Switching potentials, Cathodic and anodic peak currents Potentiometry, Fuel cells – Types and applications

Liquid crystals – Phase types, uses in displays and thermography.

Module 3: (13 hours)

Catalysis – Homogeneous and heterogeneous catalysis, Organometallic compounds, 18-electron rule, Oxidative addition, Reductive elimination, insertion and Elimination reactions, Wilkinson's catalyst in alkene hydrogenation, Zeigler-Natta catalysis in polymerization of olefins.

Enzyme catalysis – Mechanisms, significance of Michaelis – Menten constant, Turnover number, Co-enzymes and cofactors

References:

1. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th ed. Tata McGraw Hill, 2010.
2. D. A. Skoog, D. M. West, F. J. Holler, and S. R. Crouch, *Fundamentals of Analytical Chemistry*. Brooks Cole, 2004.
3. H. H. Williard, L. L. Merrit, J. A. Dean, and F. A. Settle, *Instrumental Methods of Analysis*. Wadsworth Publishing Company, 1986.
4. B. R. Puri, L. R. Sharma, and M. S. Pathania, *Principles of Physical Chemistry.* Vishal Publishing, 2000.
5. J. E. Huheey, E.A. Keiter, and R.L. Keiter, *Inorganic Chemistry, Principles of Structure and Reactivity*, 4th ed. Harper Collins College Publishers, 1993.
6. C. Elschenbroich, *Organometallics*, 3rd ed. Wiley-VCH Verlag GmbH, 2006.

MS1001D PROFESSIONAL COMMUNICATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes

Students will be able to:

CO1: Ability to distinguish the different types of meaning for constructive criticism, by developing a comprehensive understanding of the extensive vocabulary and usage in formal English language.

CO2: Learn and practice principles related to good formal writing.

CO3: Develop competence in group activities such as group discussions, debates, mock interviews, etc. by practicing the integration of unique qualities of nonverbal and verbal styles.

CO4: Deliver clear and effective presentation of ideas in the oral / written medium and to acquire the ability to modify it according to the target audience.

Module 1: (12 hours)

Role and importance of verbal communication, Everyday active vocabulary, Common words used in transitions, enhancing vocabulary, affixes and changes in pronunciation and grammatical functions, words often confused in pronunciation and usage. Passage comprehension- skimming, scanning techniques, note making, note taking and summarizing. Deciphering meaning from contexts. Two types of meaning- literal and contextual. Constructive criticism of speeches and explanations.

Module 2: (15 hours)

Fundamental grammar, Simple structures, passivizing the active sentences, reported speech, the judicious use of tenses and moods of verbs, forming questions and conversion from questions to statements and vice versa, forming open –ended and close- ended questions. Words and style used for formal and informal communication. Practice converting informal language to formal, the diction and the style of writing. Dealing with the nuances of ambiguous constructions in language. Learning authoritative writing skills, polite writing and good netiquette. Writing for internships and scholarships.

Module 3: (12 hours)

Kinesics, Proxemics, Haptics, and other areas of non-verbal communication, fighting communication barriers, positive grooming and activities on the same. Different types of interviews, and presentation- oral, poster, ppt. Organizing ideas for group discussions, the difference between GD and debates.

References:

1. S. Duck and D. T. Macmahan, *Communication in Everyday Life*, 3rd ed. Sage, 2017.
2. K. M. Quintanilla and S. T. Wahl, *Business and Professional Communication*. Sage, 2016.
3. K. T. Gamble and M. W. Gamble, *The Public Speaking Playbook*. Sage, 2015.
4. E. Tebeaux and S. Dragga, *The Essentials of Technical Communication*, 3rd ed. OUP, 2015.
5. M. Raman and S. Sharma, *Technical Communication: Principles and Practice*. OUP, 2015.
6. J. MacLennan, *Readings for Technical Communication*. OUP, 2007.

ZZ1001D ENGINEERING MECHANICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Course Outcomes:

Students will be able to:

CO1: Determine the resultants of a force system.

CO2: Solve rigid body statics problems using equations of equilibrium and principle of virtual work.

CO3: Perform kinematic analysis of a particle.

CO4: Solve particle dynamics problems using Newton's laws, energy methods and momentum methods

Module 1: Basic Concepts (13 hours)

Introduction: idealizations of mechanics, vector and scalar quantities, equality and equivalence of vectors, laws of mechanics, elements of vector algebra.

Important vector quantities: position vector, moment of a force about a point, moment of a force about an axis, the couple and couple moment, couple moment as a free vector, moment of a couple about a line.

Equivalent force systems: translation of a force to a parallel position, resultant of a force system, simplest resultant of special force systems, distributed force systems, reduction of general force system to a wrench.

Module 2: Statics (13 hours)

Equations of equilibrium: free-body diagram, free bodies involving interior sections, general equations of equilibrium, problems of equilibrium, static indeterminacy.

Applications of equations of equilibrium: Trusses: solution of simple trusses using method of joints and method of sections; Friction forces: laws of Coulomb friction, simple contact friction problems; Cables and chains.

Properties of surfaces: first moment and centroid of plane area, second moments and product of area for a plane area, transfer theorems, rotation of axes, polar moment of area, principal axes.

Method of virtual work: principles of virtual work for rigid bodies and its applications.

Module 3: Dynamics (13 hours)

Kinematics of a particle: introduction, general notions, differentiation of a vector with respect to time, velocity and acceleration calculations in rectangular coordinates, velocity and acceleration in terms of path variables and cylindrical coordinates, simple kinematical relations and applications.

Dynamics of a particle: introduction, Newton’s law for rectangular coordinates, rectilinear translation, Newton’s law for cylindrical coordinates, Newton’s law for path variables, energy and momentum methods: introduction, conservative force field, conservation of mechanical energy, alternative form of work-energy equation, impulse and momentum relations, moment-of-momentum equation.

References:

1. I. H. Shames, *Engineering Mechanics—Statics and Dynamics*, 4th ed. Prentice Hall of India, 1996.
2. F. P. Beer and E.R. Johnston, *Vector Mechanics for Engineers – Statics.* McGraw Hill Book Company, 2000.
3. J. L. Meriam and L. G. Kraige, *Engineering Mechanics – Statics*, John Wiley & Sons, 2002.
4. R. C. Hibbler, *Engineering Mechanics—Statics and Dynamics*, 11th ed. Pearson, 2009.

ZZ1002D ENGINEERING GRAPHICS

Pre-requisites: Nil

L	T	P	C
2	0	2	3

Total hours: 52

Course Outcomes:
Students will be able to:
CO1: Make use of the Indian Standard Code of Practice in Engineering Drawing.
CO2: Represent any engineering object by its orthographic views.
CO3: Convert orthographic viewsof an engineering object into its isometric view.
CO4: Enhance the capacity of visualization of engineering objects.

Module 1: (15 hours)
Introduction; drawing instruments and their uses; lines, lettering and dimensioning; geometrical construction; constructions of plain, diagonal and vernier scales; orthographic projection—first and third angle projections; orthographic projection of points on principal, profile, and auxiliary planes.

Module 2: (17 hours)
Orthographic projection of straight line in simple and oblique positions; application of orthographic projection of line; orthographic projection of planes in simple and oblique position on principal and profile planes; orthographic projection of lines and planes on auxiliary planes.

Module 3: (20 hours)
Orthographic projection of solids in simple and oblique positions on principal and profile planes; orthographic projections of solids in oblique position using auxiliary plane method; orthographic projection of spheres; orthographic projection of solids in section; development of surfaces of solids; method of isometric projection.

References:

1. N. D. Bhatt, *Engineering Drawing*, 53rd ed. Charotar Publishing House, 2016.
2. B. Agrawal and C. M. Agrawal, *Engineering Drawing*, 2nd ed. McGraw Hill Education, 2014.

ZZ1003D BASIC ELECTRICAL SCIENCES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
Students will be able to:
CO1: Design simple resistive circuits for various applications in Electrical and Electronics engineering.
CO2: Design simple magnetic circuits and inductive components for signal and power processing.
CO3: Carry out design verification calculations, power and power loss calculations, voltage drop calculations etc. in single phase ac circuits.
CO4: Analyze Amplifiers and Digital Circuits in terms of critical parameters and complexity.
CO5: Design sub modules for systems/ Solutions for real life problems using suitable sensors /transducers, amplifiers, data converters and digital circuits.

Module 1: (11 hours)
Analysis of Resistive Circuits: v-i relationship for Independent Voltage and Current Sources
Solution of resistive circuits with independent sources- Node Voltage and Mesh Current Analysis, Nodal Conductance Matrix and Mesh Resistance Matrix and symmetry properties of these matrices
Source Transformation and Star-Delta / Delta-Star Conversions to reduce resistive networks
Circuit Theorems: Superposition Theorem, Thevenin's Theorem, Norton's Theorem and Maximum Power Transfer Theorem.
Magnetic Circuits: MMF, Magnetic Flux, Reluctance, Energy stored in a Magnetic Field, Solution of Magnetic Circuits.
Two Terminal Element Relationships: Inductance - Faraday's Law of Electromagnetic Induction, Lenz's Law, Self and Mutual Inductance, Inductances in Series and Parallel, Mutual Flux and Leakage Flux, Coefficient of Coupling, Dot Convention, Cumulative and Differential Connection of Coupled Coils.
Capacitance: Electrostatics, Capacitance, Parallel Plate Capacitor, Capacitors in series and parallel, Energy stored in Electrostatic Field, v-i relationship for Inductance and Capacitance

Module 2: (9 hours)
Single Phase AC Circuits:
Alternating Quantities - Average Value, Effective Value, Form and Peak factors for square, triangle, trapezoidal and sinusoidal waveforms.
Phasor representation of sinusoidal quantities - phase difference, Addition and subtraction of sinusoids, Symbolic Representation: Cartesian, Polar and Exponential forms.
Analysis of a.c circuits - R, RL, RC, RLC circuits using phasor concept, Concept of impedance, admittance, conductance and susceptance.
Power in single phase circuits - instantaneous power, average power, active power, reactive power, apparent power, power factor, complex power, solution of series, parallel and series parallel a.c circuits.

Module 3: (11 hours)
Sensors and Transducers:
principles of piezoelectric, photoelectric, thermoelectric transducers, thermistors, strain gauge, LVDT, etc, Measurement of temperature, pressure, velocity, flow, pH, liquid level, etc.
Basics of Signal Amplification:
(Explanation based on two port models is only envisaged) – voltage gain, current gain and power gain, amplifier saturation, types of amplifiers (voltage, current, transconductance and transresistance amplifiers) and relationship between these amplifier models, frequency response of amplifiers, single time constant networks.
Operational amplifier basics:
Ideal op-amp, inverting, noninverting, summing and difference amplifiers, integrator, differentiator.

Module 4: (8 hours)
Digital Electronics:

Review of number systems and Boolean algebra, Logic Gates and Truth Tables, Simplification of Boolean functions using Karnaugh map (upto 4 variable K-maps), Implementation of Simple combinational circuits (Adder, Code Converters, 7-Segment Drivers, Comparators, Priority Encoders, etc.) - MUX-based implementation of combinatorial circuits, Sequential circuits: SR, JK, T and D filpflops, counters and registers using D flip flops, Basics of data converters (at least one ADC and DAC).

References:

1. J. W. Nilsson and S.A. Riedel, *Electric Circuits*, 8th ed. Pearson, 2002.
2. K. S. Suresh Kumar, *Electric Circuits & Networks*. Pearson Education, 2009.
3. C. A. Desoer and E. S. Kuh, *Basic Circuit Theory*. McGraw Hill, 2009.
4. J. A. Edminister, *Electric Circuit Theory*, Schaum's Outline series: 6th ed. McGraw Hill, 2014.
5. A. D. Helfrick and W. D. Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, Prentice Hall of India, 2003.
6. A. S. Sedra and K. C. Smith, *Microelectronics*, 6th ed. Oxford University Press, 2013
7. C. H. Roth and L. L. Kinney, *Fundamentals of Logic Design*,7th ed. Cengage Learning, 2014.

ZZ1004D COMPUTER PROGRAMMING

Pre-requisites: Nil.

L	T	P	C
2	0	0	2

Total hours: 26

Course Outcomes:
Students will be able to:
CO1: Design of algorithms for simple computational problems.
CO2: Express algorithmic solutions in the C programming language.

Module 1: (10 hours)
Data Types, Operators and Expressions: Variables and constants - declarations - arithmetic and logical operators – Assignment operator – Input/Output.
Control Flow: Statements and blocks – if-else, switch, while, for and do-whilestatements – break and continue – goto and labels.

Module 2: (08 hours)
Functions and Program structure: Basics of functions, Parameter passing – scope rules – recursion.

Module 3: (08 hours)
Aggregate data types: Single and multidimensional arrays, structures and unions – Pointers to arrays and structures – passing arrays and pointers as arguments to functions.

References:
1. B. S. Gottfried, *Programming with C (Schaum's Outline Series)*, 2nd ed. McGraw-Hill, 1996.
2. B. W. Kernighan and D. M. Ritchie, *The C Programming Language*, 2nd ed. Prentice Hall, 1988.
3. W. Kernighan, *The Practice of Programming*, Addison-Wesley, 1999.

BT1001D INTRODUCTION TO LIFE SCIENCE

Pre-requisites: Nil

L	T	P	C
2	0	0	2

Total hours: 26

Course Outcomes:
CO1: Comprehend the chemical and molecular basis of life.
CO2: Summarize about the basic molecules of life-proteins, lipids, DNA, and RNA.
CO3: Develop idea about cell, its structure, functions and significance of compartmentalization.
CO4: Students will describe the concepts in ecology and biodiversity and its impact on global change.

Module 1: (09 hours)
Origin and evolution of life, Biogenesis and Louis Pasteur, Oparin-Haldane hypothesis, Darwin's view on natural selection. unity and diversity of life, Chemistry of life, introduction to structure and function of the biological macromolecules like carbohydrates, proteins, lipids, DNA and RNA

Module 2: (09 hours)
Prokaryotic and eukaryotic cells, structure and organization of cells, intracellular compartmentalization, functions of various organelles. Extracellular components and cell-cell communication, overview of Mitosis and Meiosis, basic concepts in energy transformation and photosynthesis.

Module 3: (08 hours)
Principles of Mendelian inheritance and chromosomal basis of heredity, linked genes, genetic disorder. Ecosystems and restoration ecology, energy flow, chemical and nutrient cycling, primary production in ecosystems, conservation of biodiversity.

References:

1. L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, and J. B. Reece, *Campbell Biology*, 11th ed. Pearson, 2017.
2. D. L. Nelson and M. M. Cox, *Lehninger Principles of Biochemistry*, 4th ed. W H Freeman and Company, 2005.
3. C. Starr, C. Evers, L. Starr, *Biochemistry, Biology: Concepts and Applications*, 10th ed. 2017.
4. J. M. Berg, J. L. Tymoczko, and L. Stryer, *Biochemistry*, 6th ed. W H Freeman and Company, 2007.
5. H. Lodish, A. Berk, C. A. Kaiser, and M. Krieger, *Molecular Cell Biology*, 6th ed. W. H. Freeman, 2007.

PH1091D PHYSICS LAB

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:
Students will be able to:

CO1: To develop experimentation skills and understand importance of measurement practices in Science & Technology.

CO2: Develop analytical skills for interpreting data and drawing inferences.

CO3: Estimate the nature of experimental errors and practical means to obtain errors in acquired data.

CO4: Develop skills for team work and technical communication and discussions.

CO5: Apply theoretical principles of modern physics to analysis and measurements performed in the laboratory.

List of Experiments:

1. Magnetic Hysteresis loss - Using CRO
2. Band gap using four probe method
3. Hall effect- determination of carrier density, Hall coefficient and mobility
4. Solar cell characteristics
5. Double refraction – measurement of principle refractive indices.
6. Measurement of N.A & Attenuation
7. Measurement of e/m of electron – Thomson's experiment
8. Determination of Planck's constant
9. Measurement of electron charge – Millikan oil drop experiment
10. Determination of magnetic field along the axis of the coil
11. Newton's rings
12. Laurent's Half shade polarimeter –determination of specific rotatory power
13. Study of P-N junction
14. Study of voltage-current characteristics of a Zener diode.
15. Laser – measurement of angle of divergence & determination of λ using grating
16. Measurement of magnetic susceptibility- Quincke's Method / Gouy's balance.
17. Mapping of magnetic field
18. Temperature measurement by using thermocouple

NOTE: Any 8 experiments have to be done.

References:

1. A. C. Melissinos and J. Napolitano, *Experiments in Modern Physics*. Academic Press, 2003.
2. Avadhanulu, Dani and Pokley, *Experiments in Engineering Physics*, S. Chand & Company, 2002.
3. S. L. Gupta and V. Kumar, *Practical physics*, Pragathi Prakash, 2005.

CY1094D CHEMISTRY LAB

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:
Students will be able to:
CO1: Acquire practical knowledge on the separation of mixtures and their identification
CO2: Understand chirality and the specific rotation of a compound
CO3: Attain practical experience in the synthesis of new molecules
CO4: Apply different techniques to quantitatively determine the amount of components

List of Experiments:
1. Determination of specific rotation by polarimetry
2. Potentiometric titrations
3. Estimation of ions using complexometry
4. Determination of strength of an acid using pH meter
5. Analysis of organic and inorganic compounds
6. Conductometric titrations using acid or mixture of acids
7. Separation of compounds using chromatography
8. Colorimetric estimations
9. Determine the eutectic temperature and composition of a solid two component system
10. Synthesis of organic/inorganic compounds and their characterizations
11. Determination of molecular weight of polymers

Note: Selected experiments from the above list will be conducted

References:
1. G. H. Jeffery, J. Bassett, J. Mendham and R.C. Denny, *Vogel's Text Book of Quantitative Chemical Analysis*. Longmann Scientific and Technical, John Wiley,1989.
2. A. I. Vogel, *Elementary Practical Organic Chemistry – Small Scale Preparations*. Pearson India, 2011.
3. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, and P. W. G. Smith, *Vogel's Text Book of Practical Organic Chemistr*y. Longman and Scientific Technical, 1989.

ZZ1091D WORKSHOP I

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:

Students will be able to:

CO1: Perform experiments to ascertain the quality requirements and quality testing procedures of selected building material, viz., cement, fine aggregate, coarse aggregate, concrete, timber and steel.

CO2: Identify and evaluate various driver characteristics as driver of a vehicle.

CO3: Acquire knowledge about basic civil engineering practices of brick masonry, plumbing and surveying.

CO4: Perform wiring estimation and costing for simple building/commercial electrical wiring systems.

CO5: Use commonly employed wiring tools and lighting and wiring accessories.

CO6: Adopt electrical safety measures in using and servicing household appliances.

Civil Engineering Workshop (24 hours)

1. Introduction to Surveying – Linear measurements – Hands on session on Setting out of a small residential building.
2. Introduction to Levelling – Hands on sessions using Dumpy level – Levelling exercise.
3. Introduction to Total Station – Hands on sessions - small exercises.
4. Tests on cement and aggregates: Demonstration of standard consistency, initial and final setting time of cement - Hands on sessions - Compressive strength test on cement mortar cubes and sieve analysis for coarse and fine aggregates.
5. Tests on hardened concrete, brick, timber and steel: Demonstrations on hardness tests (Rockwell hardness), impact tests (Charpy and Izod) on steel specimens-demonstration on properties of timber – Hands on sessions - Compression test on concrete cubes, bricks and tension test on mild steel specimen.
6. Masonry: Hands on sessions - English bond, Flemish bond – wall junction – one brick – one and a half brick - Arch construction.
7. Water supply and sanitation: Study of water supply pipe fittings – tap connections – sanitary fittings
8. Various tests on Driver characteristics – Visual acuity and colour blindness, peripheral vision, depth perception, driver reaction time.

Electrical Engineering Workshop (15 hours)

1. (a) Familiarization of wiring tools, lighting and wiring accessories, various types of wiring systems.
   (b) Wiring of one lamp controlled by one switch.
2. (a) Study of Electric shock phenomenon, precautions, preventions,Earthing.
   (b) Wiring of one lamp controlled by two SPDT Switches and one 3 pin plug socket independently.
3. (a) Familiarization of various types of Fuses, MCBs, ELCBs, etc.
   (b) Wiring of fluorescent lamp controlled by one switch with ELCB & MCB.
4. (a) Study of estimation and costing of wiring.
   (b) Wiring, control and maintenance of domestic appliances like Mixer machine, Electric Iron, fan, motor, etc.

References:

1. T. P. Kanetkar, S. V. Kulkarni, *Surveying and Levelling*, Part 1. Pune Vidyarthi Griha Prakashan, 1994.
2. B. C. Punmia, *Building Construction*. Laxmi Publications, 1999.
3. R. Satheesh Gopi, N. M. Sathikumar, *Advnaced Surveying*, Pearson Education, 2007.
4. M. S. Shetty, *Concrete Technology*, S. Chand & Company, 2005.
5. K. B. Raina and S. K. Bhattacharya, *Electrical Design Estimating and costing*, New Age International Publishers, 2005.
6. S. K. Khanna and C. E. G. Justo, *Highway Engineering*, Nemchand and Bros, 2001.
7. S. L. Uppal, *Electrical Wiring & Estimating*, 5th ed. Khanna Publishers, 2003.
8. J. H. Watt and Terrell Croft, *American Electricians' Handbook: A Reference Book for the Practical Electrical Man*, 9th ed. McGraw-Hill, 2002.

ZZ1092D WORKSHOP II

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:

Students will be able to:

CO1: Select suitable material for a given purpose applying knowledge of material properties and processing.
CO2: Use measuring devices like Vernier Calipers, Micrometers, etc.
CO3: Fabricate simple components using basic manufacturing processes like Casting, Forming, Joining and Machining.
CO4: Sequence various operations so as to execute the task within minimum time.
CO5: Perform diagnostic measurements using analog and digital meters for troubleshooting electronic systems.
CO6: Select appropriate electronic components for a given design task and assemble the prototype on breadboard.
CO7: Troubleshoot electronic boards used in various household appliances.
CO8: Perform cost estimation and costing of PCB soldering and carry out the soldering.

Mechanical Engineering Workshop (24 hours)

The course is intended to expose the student to various manufacturing processes through hands on training in different sections of Central Workshop. During the course, the student learns the properties and selection of different materials and acquires the skill in using various tools and measuring devices.

1. Carpentry: Study of tools and joints: plaining, chiseling, marking and sawing practice, one typical joint-Tee halving/Mortise and Tenon/Dovetail.
2. Fitting: Study of tools- chipping, filing, cutting, drilling, tapping, about male and female joints, stepped joints. Edge preparation for single V joint.
3. Welding: Study of arc and gas welding, accessories, joint preparation. Welding of a single V-joint
4. Smithy: Study of tools. Forging of square or hexagonal prism/chisel/bolt
5. Foundry: Study of tools, sand preparation. Moulding practice using the given pattern.
6. Sheet Metal: Study of tools, selection of different gauge sheets, types of joints. Fabrication of a tray or a funnel
7. Machine Shop: Study of the basic lathe operations. Simple step-turning exercise.

Electronics Engineering Workshop (15 hours)

1. (a) Familiarization of electronic components, colour code, multimeters.
   (b) Bread board assembling-Common emitter amplifier.
2. (a) Study of soldering components, solders, tools, heat sink.
   (b) Bread board assembling-phase shift oscillator.
3. (a) Soldering practice-Common emitter amplifier.
   (b) Soldering practice-Inverting amplifier circuit.
4. (a) Study of estimation and costing of soldering PCB, 3 phase connections.
   (b) PCB wiring and fault Identification of appliances like Electronic Ballast, fan regulator, inverter, UPS, etc.

References:

1. W. A. J. Chapman, *Workshop Technology*, Parts 1 & 2, 4th ed. CBS Publishers & Distributors, 2007.
2. *Welding Handbook*, 9th ed. American Welding Society, 2001.
3. J. Anderson, *Shop Theory*. Tata McGraw Hill, 2002.
4. J. H. Douglass, *Wood Working with Machines*, McKnight & McKnight Pub. Co., 1995.
5. W. A. Tuplin, *Modern Engineering Workshop Practice*. Odhams Press, 1996.

6. P. L. Jain, *Principles of Foundry Technology*, 5th ed. Tata McGraw Hill, 2009.
7. J. H. Watt, T. Croft, *American Electricians' Handbook: A Reference Book for the Practical Electrical Man*, 9th ed. McGraw-Hill, 2002.
8. G. R. Slone, *Tab Electronics Guide to Understanding Electricity and Electronics*, 2nd ed. McGraw-Hill, 2000.
9. J. C. Whitaker, *The Resource Handbook of Electronics*. CRC Press, 2001.

ZZ1093D PHYSICAL EDUCATION

L	T	P	C
1	0	1	1

Course Outcomes:

CO1: Select a game/ activity of his/ her choice to pursue on the campus to enjoy/ entertain and thereby develop good health and fitness which he/she would carry over to post-campus life for maintaining health, fitness and wellness.
CO2: Be more proficient in a game, which may lead him/her to a berth in the institute teams.
CO3: Gain exposure to professional training, so as to enable him / her to excel in sports activities.
CO4: Participate in intramural and open mass participation activities.
CO5: Participate and organise in-campus or off-campus sports activities.

UNIT – I: Introduction, definition, aims & objectives of Physical Education. Health, Physical fitness and wellness. Importance, scope and relevance of Physical Education in NITC curriculum.

UNIT – II: Physical fitness and components. Health related Physical fitness and components. Benefits of exercise – physical and physiological.

UNIT – III: Physical exercise and its principles. Activities for developing physical fitness – walking, jogging, running, weight training, stretching, yogasanas. Athletic injuries and their management. Nutritional balance.

UNIT – IV: Motivation and its importance in sports. Stress, anxiety, tension, aggression in sports. Personality, self-confidence and performance. Team cohesion and leadership in sports.

UNIT – V: Lifestyle diseases and its management, Diabetes and Obesity, Hypertension, Osteoporosis, Coronary heart diseases and cholesterol. Backpain, Postural deformities and their remedies.

UNIT – VI: Olympic Values Education. Event & Crisis management.

References:

1. A. M. Najeeb, M. Atul, D. Sumesh, and E. Akhilesh, *Fitness Capsule for university curriculum*. 2015.

ZZ1094D VALUE EDUCATION

L	T	P	C
1	0	1	1

Course Outcomes:

CO1. Identify the purpose of education and the problems faced by mankind, in terms of socio economic and environmental issues.

CO2. Describe the social and intellectual needs to transform the society to a better one where everyone meets the basic economic and social security, freedom and atmosphere to live a meaningful life.

CO3. Practise a meaningful life avoiding all kinds of corrupt practices and develop unconditional love, universal brotherhood and simulate international peace and prosperity.

CO4. Persuade others to practise a righteous life, which would stimulate a synergy of universal harmony and peace.

CO5. Create an ideal society where everyone enjoys the fruits of love, peace and harmony.

Unit I (3 hours): **Social Justice** Definition –need-parameters of social justice –factors responsible for social injustice –caste and gender –contributions of social reformers.

Unit II (5 hours)**: Human Rights and Marginalized People** Concept of Human Rights-Principles of human rights-human rights and Indian Constitution-Rights of Women and children-violence against women –Rights of marginalized People-like women, children, dalits, minorities, physically challenged etc.

Unit III (5 hours): **Social Issues and Communal Harmony** Social issues–causes and magnitude-alcoholism, drug addiction, poverty, unemployment etc.-communal harmony-concept-religion and its place in public in public domain-separation of religion from politics-secularism role of civil society.

Unit IV (5 hours): **Media Education and Globalized World Scenario** Mass media-functions-characteristics-need and purpose of media literacy-effects and influence –youth and children-media power-socio cultural and political consequences mass mediated culture-consumerist culture-Globalization-new media –prospects and challenges-Environmental ethics

Unit V (2 hours): **Values and Ethics** Personal values –family values-social values-cultural values-professional values-and overall ethics-duties and responsibilities

Project: 10 hours

References:

1. Sharma, B. K. (2010), ‘Human Rights Covenants and Indian Law’, PHI Learning Pvt. Ltd.
2. Law Commission of India, (1971), ‘Indian Penal code’, (http://lawcommissionofindia.nic.in/1-50/report42.pdf), accessed on February 14, 2018.
3. Srivastava, S. S. (2017), ‘Central Law Agency's Indian Penal Code along with General Principles (IPC)’, Central Law Agency.
4. ‘Gandhiji on Communal Harmony’, (2003), Mani Bhavan Gandhi Sangrahalaya’, Mumbai.
5. ‘Social Impact of Drug Abuse’, UNDCP, ((https://www.unodc.org/pdf/technical_series_1995-03-01_1.pdf, accessed on February 14, 2018).
6. Bryfonski, D. (2012), ‘The Global Impact of Social Media’, Green Heaven Publications**.**
7. Schmidtz, D. & Willott, E. (2012), ‘Environmental Ethics: What Really Matters, What Really Works’, Oxford University Press.
8. Ranganathanda, S. (1987), ‘Eternal Values for a Changing Society: Education for human excellence’, BharatiyaVidyaBhavan.
9. Rokeach, M. (1979), ‘Understanding human values: Individual and Societal’, The New Free Press.

ZZ1095D NSS

L	T	P	C
0	0	3	1

Course Outcomes:

CO1: Acquire awareness in social and environmental issues thereby improving social consciousness and commitment towards the community.
CO2: Participate in socially relevant activities that are aimed at betterment of the campus and the society, thereby instilling a helpful attitude
CO3: Develop a positive attitude towards dignity of labour, self-help and the need for combining physical work with intellectual pursuits.
CO4: Improve inter-personal skills and contribute to nation building by serving the local community, thereby promoting a healthy and positive attitude towards life.

NSS activities have been divided in two major groups. These are Regular NSS Activities and Special Camping programme.

(a) Regular NSS Activity: NSS volunteers undertake various activities in adopted villages and slums for community service. The NSS units organise the regular activities as detailed below:

i) Orientation of NSS volunteers: To get the NSS volunteers acquainted with the basics of NSS programmes, for their orientation through lectures, discussions, field visits, audio-visuals etc.
ii) Campus Work: The NSS volunteers may be involved in the projects undertaken for the benefit of the institution and students concerned. Such projects cover maintenance of public properties, tree plantation, waste management and Swach Bharat activities, conservation of water and energy sources, social audits, awareness programmes on drug-abuse, AIDS, population education, and other projects
iii) Community service will be in adopted villages/urban slums independently or in collaboration with others in this field.
iv) Institutional work: The students may be placed with selected voluntary organisations working for the welfare of women, children, aged and disabled outside the campus.
v) Rural Project: The rural projects generally include the working of NSS volunteers in adopted villages for e-governance and digital literacy, watershed management and wasteland development, rainwater harvesting, agricultural operations, health, nutrition, hygiene, sanitation, mother and child care, gender equality sensitization programmes, family life education, gender justice, development of rural cooperatives, savings drives, construction of rural roads, campaign against social evils etc.
vi) Urban Projects: In addition to rural projects other include adult education, welfare of slum dwellers, work in hospitals, orphanages, destitute home, environment enrichment, population education, drug, AIDS awareness, and income generation,
vii) National Days and Celebrations: The National Service Scheme programmes also include the celebration of National days. The purpose of such a provision is to celebrate such occasions in a befitting manner,
viii) Blood Donation Activities,
ix) Campus farming activities,
x) Activities for social inclusion such as organizing programmes for differently – abled children.

Students shall volunteer and contribute to the activities of the National Service Scheme for a minimum duration of 45 hours for the award of credit.

b) Special Camping Programme: Under this, camps of 7 days' duration are organised during vacations with some specific projects by involving local communities. 50% NSS volunteers are expected to participate in these camps.

MA2001D MATHEMATICS III

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Handle application problems involving random variables and functions of random variables.
CO2: Identify statistical problems and make use of statistical inference while handling stochastic systems.
CO3: Apply regression and correlation analysis for studying relationship between variables.
CO4: Identify situations where analysis of variance is appropriate and apply it.
CO5: Use probabilistic and statistical analysis in various applications of engineering.

Module 1: (15 Hours)

Probability distributions, Random variables, Expectation of a function of a random variable, Mean, Variance and Moment generating function of a probability distribution, Chebyshev's theorem, Binomial distribution, Poisson distribution, Geometric distribution, Hyper- geometric distribution, Normal Distribution, Uniform distribution, Gamma distribution, Beta distribution and Weibull distribution. Transformation of a random variable, Probability distribution of a function of a random variable, Jointly distributed random variables, Marginal and conditional distributions, Bi-variate Normal distribution, Joint probability distribution of functions of random variables.

Module 2: (14 hours)

Population and samples, The sampling distribution of the mean (σ known and σ unknown), Sampling distribution of the variance, Point estimation, Maximum likelihood estimation, Method of moments, Interval estimation, Point estimation and interval estimation of mean and variance. Tests of hypothesis, Hypothesis tests concerning one mean and two means. Hypothesis tests concerning one variance and two variances, Estimation of proportions, Hypothesis tests concerning one proportion and several proportions, Analysis of $r \times c$ contingency tables, Chi – square test for goodness of fit.

Module 3: (10 hours)

Analysis of variance, General principles, Completely randomized designs, Randomized block design. Curve fitting, Method of least squares, Estimation of simple regression models and hypotheses concerning regression coefficients, Correlation coefficient- Estimation of correlation coefficient, Hypothesis concerning correlation coefficient. Estimation of curvilinear regression models.

References:

1. R. A. Johnson, *Miller and Freund's Probability and Statistics for Engineers*, 8th ed. PHI, 2011.
2. W. W. Hines, D. C. Montgomery, D. M. Goldsman, and C. M. Borror, *Probability and Statistics in Engineering*, 4th ed. John Wiley & Sons, 2003
3. S. M. Ross, *Introduction to Probability and statistics for Engineers and Scientists*, 5th ed. Academic Press (Elsevier), 2014.

EE2013D ELECTRICAL MEASUREMENTS AND MACHINES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Acquire knowledge about the fundamental principles and classification of electromagnetic machines.

CO2: Acquire knowledge about the constructional details, principle of operation and applications of dc machines, transformers, alternators and induction motors.

CO3: Acquire knowledge about the measurement of resistance, electrical power and electrical energy.

Module 1: Electromechanical Energy Conversion (7 hours)

Fundamental principles: types of machines, classification, static and rotating machines, generators, motors and transformers; elements of electromagnetic machines: rotating magnetic field, emf and torque, losses and efficiency, introduction to power generation, transmission and distribution.

Module 2: DC Machines and Transformers (14 hours)

DC machines: construction, principle of operation, armature reaction, commutation, methods of excitation, power flow diagram; generators: emf equation, magnetisation characteristics, terminal characteristics; motors: back emf, torque and speed equations, performance characteristics, starting methods, methods of speed control; testing: load test, Swinburne's test; applications.

Transformers: types and construction, principle of operation, equivalent circuit, phasor diagram, losses, efficiency, voltage regulation, OC and SC tests, applications.

Module 3: Alternators and Induction Motors (10 hours)

Alternators: construction, types, principle of operation, synchronous motors, starting, applications.

Induction motors: 3-phase induction motors, construction, types, principle of operation, slip, torque, performance characteristics, starting, speed control schemes, applications; single-phase induction motors; universal motors; stepper motors; servo motors; tachogenerators.

Module 4: Electrical Measurements (8 hours)

Measurement of high and low resistances: voltmeter-ammeter method; measurement of single phase power: three voltmeter method, three ammeter method, wattmeter method; measurement of three phase power: two wattmeter method; measurement of single phase energy with energy meter.

References:

1. I. J. Nagarath and D. P. Kothari, *Electric Machines*. Tata McGraw Hill, 1999.
2. M. G. Say, *The Performance and Design of AC Machines*. CBS, 1983.
3. S. J. Chapman, *Electric Machine Fundamentals*. McGraw Hill, 1999.
4. V. D. Toro, *Electrical Machines and Power Systems*. Prentice Hall, 1988.
5. A. K. Sawhney, *A Course in Electrical and Electronic Measurements and Instrumentation*. Dhanpat Rai & Co., 2015.

ME2001D FLUID MECHANICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Describe and estimate the forces exerted by a fluid at rest.
CO2: Perform kinematic analysis of fluid flow.
CO3: Analyze typical flow situations applying conservation of mass, momentum and Bernoulli equations.
CO4: Analyze ideal flows and flow in boundary layers.

Module 1: (15 hours)
Fluid as a continuum: properties of fluids, density, pressure, viscosity, surface tension, capillarity, vapour pressure; fluid statics, basic equations of fluid statics, variation of pressure in a fluid, manometry; forces on surfaces and bodies in fluids, floatation, stability conditions, determination of metacentric height; fluid kinematics, Eulerian and Lagrangian description, local and material rates, deformation of a fluid element, strain rate-velocity relations, graphical description of flow, streamlines, path lines, streak lines, stream tube; fluid dynamics, control volume, Reynolds transport equation and its application to formulate fluid mechanics problems, integral and differential forms of the continuity, momentum and energy equations, Illustrative examples.

Module 2: (11 hours)
One dimensional flow through pipes; non viscous equation for the flow through a stream tube and along a stream line; Euler's equation; Bernoulli's equation; applications of the one dimensional equations; velocity and discharge measuring devices; laminar and turbulent flows through pipes; Hagen-Poiseuille equation; Darcy-Weisbach equation; pipe friction; Moody's chart, energy losses in pipes.

Module 3: (13 hours)
Two dimensional incompressible inviscid flows; irrotational flow, velocity potential, stream function , relation between stream function and potential function in ideal flows, fundamental flow patterns, Combination of basic patterns, Rankine half body, Rankine oval, doublet and flow over a cylinder, Magnus effect and the calculation of lift on bodies; Plane viscous flow past bodies, boundary layer, Prandtl's boundary layer equations, Blasius solution for the boundary layer over a flat plate, Karman's Momentum Integral equations, solutions using simple profiles for the boundary layer on flat plate, calculation of skin friction drag; introduction to compressible fluid flows, speed of sound, Mach number, qualitative difference between incompressible, subsonic and supersonic flows.

References:
1. F. M. White, *Fluid Mechanics*, 7th ed. McGraw Hill, 2011.
2. Y. A. Cengel and J. M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, 3rd ed. McGraw Hill, 2014.
3. S. K. Som, G. Biswas, and S. Chakraborty, *Introduction to Fluid Mechanics and Fluid Machines,* 3rd ed. Tata McGraw Hill Education, 2012.
4. P. J. Pritchard and J. C. Leylegian, *Fox and McDonald's Introduction to Fluid Mechanics*, 8th ed. Wiley, 2011.
5. M. J. Zuckrow and J. D. Hoffman, *Gas Dynamics*, Vol.1. John Wiley and Sons, 1976.

ME2003D SOLID MECHANICS

Pre-requisites: ZZ1001D Engineering Mechanics

L	T	P	C
4	0	0	4

Total Hours: 52

Course Outcomes:
CO1: Analyze mechanical components with uniform stress distribution.
CO2: Perform stress and deformation analysis of beams and circular shafts.
CO3: Perform structural analysis of columns.
CO4: Solve 2D problems in elasticity using fundamental concepts.

Module 1: (19 hours)
Introduction: general concepts, definition of stress; stress analysis of axially loaded members; shear stresses; direct shear problems; strength-based design of members (deterministic method); axial strains and deformations in bars; Hooke's Law; Poisson's ratio; thermal strain; Saint Venant's principle; elastic strain energy; statically indeterminate systems; Hooke's law for isotropic materials; relationships between elastic constants; analysis of thin-walled pressure vessels.
Torsion: torsion of circular elastic bars, statically indeterminate problems, torsion of inelastic circular bars, strain energy in torsion, torsion of thin-walled tubes.

Module 2: (18 hours)
Axial force, shear force and bending moment diagrams: sign conventions, axial force, shear force and bending moments by direct approach and integration; bending stresses in beams: elastic flexure formula, bending stresses, elastic strain energy in bending, inelastic bending, elastic bending with axial loads, shear stresses in beams, shear flow and shear stress formula; deflection of beams: direct integration method, superposition techniques, moment-area method, elementary treatment of statically indeterminate beams.
Theory of columns: buckling theory, Euler's formula, effect of end conditions, eccentric loads and secant formula.

Module 3: (15 hours)
Two-dimensional elasticity: plane stress and plane strain problems; stress at a point: stress tensor, stress transformation, principal stresses and planes, Mohr's circle; strain at a point: strain tensor, analogy with stress tensor; equations of elasticity: equations of equilibrium, strain-displacement relations, compatibility conditions, constitutive equations; boundary conditions: traction, displacement and mixed boundary conditions; generalized problem formulation and solution strategies.

References:

1. E. P. Popov, *Engineering Mechanics of Solids*, 2nd ed. Pearson, 2000.
2. F. P. Beer, E. R. Johnston, J. T. DeWolf, and S. Sanghi, *Mechanics of Materials*, 7th ed. McGraw Hill Education India, 2017.
3. I. H. Shames and J. M. Pitarresi, *Introduction to Solid Mechanics*, 3rd ed. Pearson, 2015.
4. S. H. Crandall, N. C. Dahl, T. J. Lardner, and M. S. Sivakumar, *Introduction to Mechanics of Solids*, 3rd ed. Tata McGraw-Hill, 2012.
5. L. S. Srinath, *Advanced Mechanics of Solids*, 3rd ed. Tata McGraw Hill, 2003.
6. S. P. Timoshenko and J. N. Goodier, *Theory of elasticity*. McGraw Hill International, 1970.
7. M. H. Sadd, *Elasticity: Theory, Applications and Numerics*, 3rd ed. Academic Press, 2014.

ME2101D MATERIALS SCIENCE AND METALLURGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Explain the basics of crystal structures.
CO2: Describe phase transformation of alloys.
CO3: Describe the various thermo-mechanical treatments of alloys.
CO4: Describe the properties and applications of major ferrous and non-ferrous alloys.

Module 1: (15 hours)
Engineering materials: classification, requirements, properties and selection of engineering materials; review of fundamentals: crystal structure, crystal imperfections, edge and screw dislocations, interaction between dislocations, frank-reed source; experimental techniques for metallographic studies: optical microscopy, electron microscopy (SEM and TEM), X-ray diffraction, grain size, grain size measurement, ASTM grain size number.
Solidification of metals: cooling curves, nucleation-homogeneous and heterogeneous nucleation, supercooling; critical radius: grain growth, dendritic pattern, equiaxed and columnar grains; grain boundary, grain boundary effects; solidification and structure of castings-coring, homogenization; alloys, solid solutions: interstitial, substitutional ordered and disordered solid solutions; Hume-Rothery rules; intermetallic compounds; phase diagrams; construction from cooling curves; lever rule: equilibrium diagrams of binary alloys, isomorphous (Cu-Ni), eutectic (Bi-Cd, Pb-Sn) detailed study of Fe-C systems; diffusion: mechanisms of diffusion, Fick's laws of diffusion, applications;

Module 2: (12 hours)
Deformation of metals: cold working, hot working, annealing of a cold worked article recovery; recrystallisation and grain growth; elastic and plastic deformations: mechanisms of plastic deformation, deformation by slip, slip systems, slip planes and slip directions, critical resolved shear stress: deformation by twinning; strengthening mechanisms: work hardening, solid solution hardening, dispersion hardening, precipitation hardening, grain boundary strengthening; heat treatment of steels: stress relieving, annealing, normalising, hardening, TTT diagram, tempering, hardenability, Jominy test; surface hardening: flame hardening, induction hardening, case hardening: carburising, nitriding, cyaniding, etc; metallic coatings; hard facing; metal cladding; anodizing; diffusion coatings.

Module 3: (12 hours)
Ferrous alloys: steels, alloy steels, tool steels, stainless steels; effect of alloying elements on properties of steels; cast irons: classification, structure, properties, applications; non-ferrous alloys: Al and Al alloys, Cu and Cu alloys, Mg and Mg alloys, Zn and Zn alloys: major types, composition, properties and applications; non-metallic materials: thermoplastics, thermosetting plastics, elastomers, composites, ceramics, glasses; recent developments in materials science: smart materials, shape memory alloys, functionally graded materials, piezo-electric materials.

References:

1. W. F. Smith, *Science of Engineering Materials*, 4th ed. Prentice-Hall, 1996.
2. W. D. Callister, *Materials Science and Engineering*, 5th ed. John Wiley, 2000.
3. S. H. Avner, *Introduction to Physical Metallurgy*, 2nd ed., Tata McGraw Hill, 1982.
4. L. H. Van, Vlack, *Elements of Materials Science*, 6th ed. Addison Wesley, 1989.
5. J. F. Shackelford, *Materials Science for Engineers*, 2nd ed. Prentice-Hall, 1996.
6. R. A. Higgins, *Engineering Metallurgy: Part I*, 6th ed. Applied Physical Metallurgy, ELBS, 1991.
7. V. Raghavan, *Material Science and Engineering.* Prentice-Hall of India, 2005.
8. R. Abbaschian and R. E. Reed-Hill, *Physical Metallurgy Principles,* 4th ed. Affiliated East-West Press, 2009.
9. Z. D. Jastrzebiski*, Nature and Properties of Engineering Materials*, 2nd ed. John Wiley & Sons, 1977.
10. J. A. Charles, F. A. A. Crane, and J. A. G. Furness, *Selection and Use of Engineering Materials*, 3rd ed. 1997.

ME2091D MACHINE DRAWING

Pre-requisites: ZZ1002D Engineering Graphics

L	T	P	C
0	0	3	2

Total Hours: 39

Course Outcomes:
CO1: Draw mechanical engineering components adopting standard conventions
CO2: Create assembly and production drawings of mechanical engineering systems
CO3: Read drawings and understand mechanical engineering systems
CO4: Perform computer aided drafting of mechanical engineering components and systems

Drawing Sheets:
1. Conversion of pictorial views into orthographic projections
2. Drawing of parts with sectional views
3. Screw threads and screwed fasteners
4. Simple assemblies I: couplings and keys / shaft joints / pipe joints
5. Simple assemblies II: engine components / bearings
6. Assembly drawing: machine vice / lever safety valve / lathe tailstock / water pump / crane hook
7. Production drawing I: conventions of geometric dimensioning and tolerancing (GD&T)
8. Production drawing II: Exercise on reading and interpreting production drawings

CAD Exercises:
1. Modeling of 3D parts from orthographic views
2. Assembly of parts and motion simulation of mechanical systems
3. Preparation of drawings from CAD models
4. Development of production drawings using CAD software

References:

1. N. D. Bhatt and V. M. Panchal, *Machine Drawing,* 53rd ed. Charotar Publishing House, 2014.
2. K. L. Narayana, P. Kannaiah, and K. V. Reddy, *Machine Drawing,* 3rd ed. New Age, 2009.
3. K. C. John and P. I. Varghese, *Machine Drawing.* PHI Learning Private Limited, 2009.
4. P. S. Gill, *A Textbook of Machine Drawing,* 18th ed. S. K. Kataria & Sons, 2013.
5. N. Sidheswar, P. Kannaiah, and V. V. S. Sastry, *Machine Drawing.* Tata McGraw-Hill, 2007.
6. A. Singh, *Machine Drawing: Includes AutoCAD,* 2nd ed. Tata McGraw-Hill, 2010.

EE2093D ELECTRICAL MEASUREMENTS AND MACHINES LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:

CO1: Acquire hands on experience of conducting measurements of various electrical quantities.

CO2: Acquire hands on experience of conducting various tests on electrical machines such as dc machines, transformers, induction motors and alternators.

CO3: Acquire hands on experience of obtaining the performance indices of various electrical machines using standard analytical as well as graphical methods.

List of Experiments:

1. (a) Determination of V-I characteristics of a linear resistor and an incandescent lamp.
   (b) Measurement of high and low resistances using voltmeter-ammeter method.
2. Measurement of power in single phase ac circuit using three ammeter, three voltmeter and Wattmeter methods and determination of circuit parameters.
3. Measurement of energy using single phase energy meter and verification by power measurement.
4. Measurement of power in 3-phase circuits using two-wattmeter method.
5. Determination of efficiency and regulation of single-phase transformer by direct loading.
6. Open circuit and short circuit tests on a single-phase transformer and predetermination of efficiency and voltage regulation at various loads conditions.
7. (a) Study of Starters for 3-phase Induction motors.
   (b) Load test on squirrel cage induction motor and determination of its performance characteristics.
8. Load test on slip ring induction motor and determination of its performance characteristics.
9. Determination of Open circuit characteristic and load characteristics of a dc shunt generator.
10. Determination of performance characteristics of a dc shunt motor by conducting load test.
11. Determination of performance characteristics of a dc series motor by conducting load test.
12. Determination of Open circuit characteristic of a 3-phase alternator.

References:

1. I. J. Nagarath and D. P. Kothari, *Electric Machines*. Tata McGraw Hill, 1999.
2. M. G. Say, *The Performance and Design of AC Machines*. CBS, 1983.
3. S. J. Chapman, *Electric Machine Fundamentals*. McGraw Hill, 1999.
4. V. D. Toro, *Electrical Machines and Power Systems*. Prentice Hall, 1988.
5. A. K. Sawhney, *A Course in Electrical and Electronic Measurements and Instrumentation*. Dhanpat Rai & Co., 2015.

MA2002D MATHEMATICS IV

Pre-requisites: 1. MA1001D Mathematics I
2. MA1002D Mathematics II

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Find solutions of linear differential equations using power series method and Frobenius series method.
CO2: Formulate various engineering problems as partial differential equations and solve them.
CO3: Identify analytic functions and find harmonic conjugates.
CO4: Find images of regions under complex transformations.
CO5: Evaluate line integrals in the complex plane
CO6: Use techniques of complex analysis to evaluate integrals of real valued functions.

Module 1: Series Solutions and Special Functions (11 Hours)

Power series solutions of differential equations, Theory of power series method, Legendre Equation, Legendre Polynomials, Frobenius Method, Bessel's Equation, Bessel functions, Bessel functions of the second kind, Sturm-Liouville's Problems, Orthogonal eigen function expansions.

Module 2: Partial differential Equations (10 Hours)

Basic Concepts, Cauchy's problem for first order equations, Linear Equations of the first order, Nonlinear Partial Differential Equations of the first order, Charpit's Method, Special Types of first order equations, Classification of second order partial differential equations, Modeling: Vibrating String, Wave equation, Separation of variables, Use of Fourier Series, D'Alembert's Solution of the wave equation, Heat equation: Solution by Fourier series, Heat equation: solution by Fourier Integrals and transforms, Laplace equation, Solution of a Partial Differential Equations by Laplace transforms.

Module 3: Complex Numbers and Functions (9 Hours)

Complex functions, Derivative , Analytic function, Cauchy- Reimann equations, Laplace's equation, Geometry of Analytic functions: Conformal mapping, Linear fractional Transformations, Schwarz-Christoffel transformation, Transformation by other functions.

Module 4: Complex Integration (9 Hours)

Line integral in the Complex plane, Cauchy's Integral Theorem, Cauchy's Integral formula, Derivatives of analytic functions. Power series, Functions given by power series, Taylor series and Maclaurin's series. Laurent's series, Singularities and Zeros, Residue integration method, Evaluation of real Integrals.

References:

1. E. Kreyszig, *Advanced Engineering Mathematics*, 8th ed. John Wiley & Sons, 1999.
2. I. N. Sneddon, *Elements of Partial Differential Equations*. Dover Publications, 2006.
3. C. R. Wylie and L. C. Barret, *Advanced Engineering Mathematics*, 6th ed. McGraw Hill, 1995.
4. D. W. Trim, *Applied Partial Differential Equations*. PWS – KENT publishing company, 1994.

ME2011D FLUID MACHINERY

Pre-requisites: ME2001D Fluid Mechanics

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Develop and apply non-dimensional parameters to fluid machines.
CO2: Acquire knowledge of constructional details regarding pumps and turbines and conduct their model studies.
CO3: Evaluate the performance of turbo-machines.
CO4: Select fluid machines and other hydraulic devices for various applications.

Module 1: (10 hours)
Integral form of continuity, momentum and energy equations; dynamic action of fluids over flat plates and curved surfaces; force, work done and efficiency; dimensional analysis: Rayleigh's method, Buckingham's pi method; principles of models and similitude as applied to hydraulics and turbo-machines; Non-dimensional parameters applicable to hydraulic machines like capacity coefficient, head coefficient, power coefficient and specific speed and as applicable to hydraulics like Reynolds number, Mach number, Froude number, Weber number and Euler number.

Module 2: (14 hours)
Euler's equation for turbo-machines; classification of hydraulic turbines; constructional features of Pelton, Francis and Kaplan turbines; speed regulation and performance analysis of hydraulic turbines; model studies; theory of draft tubes and cavitations in turbines.

Module 3: (15 hours)
Classification of pumps; Features of rotodynamic and positive displacement pumps; rotodynamic pumps: principle of working, vortex motion, spiral motion; constructional features of centrifugal pumps; performance analysis; efficiencies; classification of centrifugal pumps; pump characteristics; theoretical and actual head; capacity relationship; pump selection; model studies; cavitations in pumps; positive displacement pumps: reciprocating pump, principle of working, effect of acceleration and friction, use of air vessels, cavitation, pump characteristics; rotary pumps: working principle of rotary piston pump, vane pump and gear pump; miscellaneous fluid devices: intensifier and accumulator; application to hydraulic devices; hydraulic ram.

References:

1. D. G. Shepherd, *Principles of Turbo machinery,* Macmillan Company, 1956.
2. J. Lal, *Hydraulic Machines*, 6th ed. Metropolitan book Co., 1975.
3. A. J. Stepanoff*, Centrifugal and Axial Flow Pumps*, 2nd ed. John Wiley & Sons, 1957.
4. S. L. Dixon and C. A. Hall, *Fluid Mechanics and Thermodynamics of Turbo machinery*, 4th ed. Pergamon Press, 1998.
5. J. M. Vance, *Rotordynamics of Turbomachinery*, Wiley-Interscience Publication, John Wiley & Sons, 1988.
6. Y. A. Cengel and J. M. Cimbala, *Fluid Mechanics: Fundamentals & Applications*, 2nd ed. McGraw-Hill, 2006.
7. J. Lal, *Fluid Mechanics and Hydraulics*. Metropolitan, 1975.

ME2012D KINEMATICS OF MECHANISMS

Pre-requisites: ZZ1001D Engineering Mechanics

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Analyze planar mechanisms using graphical and analytical methods.
CO2: Design cam mechanism and perform kinematic analysis of gear mechanisms and gear trains.
CO3: Synthesize simple mechanisms for specified kinematic tasks.
CO4: Understand the basic configuration of robots.

Module 1: (13 hours)
Introduction to mechanisms; applications of mechanisms; kinematics of mechanisms: kinematic diagrams, degrees of freedom, kinematic inversions, Grashof criterion; position and displacement analysis: graphical methods, velocity analysis: relative motion, graphical method; instantaneous center; mechanical advantage; acceleration analysis: graphical method; analytical methods in mechanism analysis: complex number method, computer oriented methods.

Module 2: (15 hours)
Cam design: cam and follower types, displacement diagrams, polynomial motion; cam profile synthesis: graphical and analytical methods; design of plate cam with reciprocating flat-face follower; design of plate cam with reciprocating roller follower.
Gears: law of gearing, involute spur gears, involutometry; spur gear details: interference, backlash; brief introduction to gear standardization, non-standard gears, internal gear, cycloidal gear, bevel gear, helical gear, worm gear.
Gear trains: simple and compound gear trains, planetary gear trains; applications: automotive gearbox, differential.

Module 3: (11 hours)
Kinematic synthesis: tasks of kinematic synthesis, type and dimensional synthesis; graphical synthesis for motion generation, path generation without prescribed timing, function generation; analytical synthesis techniques; complex number modelling: Freudenstein's equation; case studies in synthesis of mechanisms.
Introduction to robotics: fundamentals, types of industrial robots, classification based on mechanical configuration, kinematic modeling using geometrical method.

References:
1. J. J. Uicker Jr., G. R. Pennock, and J. E. Shigley, *Theory of Machines and Mechanisms*, 4th ed. Oxford University Press, 2014.
2. G. N. Sandor and A. G. Erdman, *Advanced Mechanism Design: Analysis and Synthesis,* Vol. I & II. Prentice-Hall of India, 1988.
3. H. H. Mabie and C. F. Reinholtz, *Mechanisms and Dynamics of Machinery*, 4th ed. John Wiley & Sons, 1987.
4. A. Ghosh and A. K. Mallik, *Theory of Mechanisms and Machines*, 3rd ed. East-West Press, 2006.
5. K. J. Waldron, G. L. Kinzel, and S. K. Agrawal, *Kinematics, Dynamics and Design of Machinery*, 3rd ed. Wiley, 2016.
6. R. L. Norton, *Design of Machinery*, 5th ed. Tata McGraw-Hill, 2011.
7. G. T. Martin, *Kinematics and Dynamics of Machines*, 2nd ed. Waveland Press, 2002.
8. S. S. Rattan, *Theory of Machines*, 4th ed. Tata McGraw-Hill, 2014.
9. S. B. Niku, *Introduction to Robotics: Analysis, Systems, Applications*. John Wiley and Sons, 2010.

ME2013D THERMODYNAMICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: State and define different forms of energy and energy transfer.

CO2: Evaluate the performance of different thermo-mechanical systems based on thermodynamic process and cycle.

CO3: Assess the performance of engineering systems based on entropy and exergy.

CO4: Model the thermodynamic properties of simple compressible systems.

Module 1: (17 hours)

Basic concepts: thermodynamic systems, properties, state and equilibrium, processes and cycles, continuum, classical thermodynamics; forms of energy; energy transfer by heat and work; temperature and zeroth law of thermodynamics; first law of thermodynamics applied to closed system executing a process and cycle; energy transfer by mass; first law of thermodynamics applied to steady and unsteady flow processes: steady flow engineering devices; pure substance: phases, phase change processes of pure substances, property diagrams for phase change processes, property tables; ideal-gas: internal energy, enthalpy, specific heats of ideal gases, thermodynamic processes executed by ideal gases, compressibility factor, different equations of state.

Module 2: (12 hours)

The second law of thermodynamics: limitations of first law, thermal energy reservoirs, heat engines, Kelvin-Planck statement, energy conversion efficiencies, refrigerators and heat pumps, Clausius statement, equivalence of the two statements, reversible and irreversible processes, irreversibilities, Carnot cycle, Carnot principles, thermodynamic temperature scale, Carnot heat engine, Carnot refrigerator and heat pump; entropy: increase of entropy principle, entropy change of pure substances, isentropic processes, property diagram involving entropy, the T-ds relations, entropy change of liquids and solids, entropy change of ideal gases.

Module 3: (10 hours)

Exergy: reversible work and irreversibility, exergy of fixed mass and flow stream, exergy transfer by heat, work and mass, second law efficiency; thermodynamic property relations: Maxwell relations, Clapeyron equation, general relations for change in properties, Joule-Thomson coefficient, change in properties for real gases.

References:

1. Y. A. Cengel and M. A. Boles, *Thermodynamics: An Engineering Approach*, 8th ed. Mc Graw-Hill, 2015.
2. R. E. Sonntag and C. Borgnakke, *Fundamentals of Thermodynamics*, 9th ed., John Wiley & Sons, 2016.
3. M. J. Moran and H. N. Shapiro, *Fundamentals of Engineering Thermodynamics*, 8th ed. John Wiley & Sons, 2017.
4. P. K. Nag, *Engineering Thermodynamics*, 5th ed. Tata Mc Graw Hill, 2013.

ME2111D ESSENTIALS OF MANAGEMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain management, organization and the managerial skills.
CO2: Illustrate the functions of management.
CO3: Explain the functional areas of management.
CO4: Develop and solve analytical models for managerial decisions.

Module 1: (14 Hours)
The management process: managerial skills and roles, evolution of management theory; principles of planning: types of plans, steps in planning; principles of organizing: organizational structures; directing; motivation; controlling; sustainability in management.

Module 2: (12 Hours)
Human resource management: human resource planning, performance metrics.
Marketing management: fundamentals of marketing, market segmentation, consumer and industrial markets.
Financial management: principles of double entry book keeping, financial statements, sources of finance, classification of costs, break-even analysis.

Module 3: (13 Hours)
Managerial decision making process: decision making under certainty, risk and uncertainty; analytical models for decision making; network techniques for project management: critical path method; Programme Evaluation and Review Technique (PERT): time/cost trade-off in critical path networks.
Entrepreneurial processes: analysis of new ventures/start-ups, creating new products/services and business plans, intellectual property issues.

References:
1. H. Koontz, and H. Weihrich, *Essentials of Management: An International Perspective*, 8th ed. McGraw-Hill, 2009.
2. R. W. Griffin, *Management: Principles and Applications*. Cengage Learning, 2008.
3. P. Kotler, K. L. Keller, A. Koshy, and M. Jha, *Marketing Management: A South Asian Perspective,* 14th ed. Pearson, 2012.
4. M. Y. Khan, and P. K. Jain, *Financial Management*. Tata-McGraw Hill, 2008.
5. R. D. Hisrich, and M. P. Peters, *Entrepreneurship: Strategy, Developing, and Managing a New Enterprise*, 4th ed. McGraw-Hill Education, 1997.
6. E. B. Roberts, *Entrepreneurs in High Tech - Lessons from MIT and beyond*. Oxford University Press, 1991.

ME2015D ENVIRONMENTAL STUDIES FOR MECHANICAL ENGINEERS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Interpret current global environmental issues.
CO2: Develop feasible solutions to comply with environmental regulations.
CO3: Evaluate industry, products or services for their suitability with environmental friendliness based on certifications and ratings.

Module 1: (12 hours)
Scope and importance of environmental studies; environmental ethics; environmental acts and regulations; climate change; global warming; acid rain; ozone layer depletion; environmental pollution: causes, effects and control measures.

Module 2: (13 hours)
Natural resources and associated problems: water conservation; disaster management; solid waste management: sources, effects and control measures of urban and industrial wastes; wasteland reclamation; consumerism and waste products; role of Information Technology in environment and human health.

Module 3: (14 hours)
From unsustainable to sustainable development: sustainable energy technologies; renewable and non-renewable resources: use of alternate energy resources; energy audit; BEE rating; carbon capture and storage: analysis using carbon foot print and water foot print; sustainable manufacturing technologies: sustainable production and consumption; life cycle analysis; green manufacturing standards; green logistics.

Project work:
A project work based on a field trip / visit to an industry to study the environmental impact.

References:

1. H. Jadhav and V. M. Bhosale, *Environmental Protection and Law*. Himalaya Publication House, 1995.
2. M. L. Mckinney and R. M. Schocr, *Environmental Science Systems and Solutions*, Web enhanced edition, Jones and Bartlett Publishers, 1998.
3. D. S. Sengar, *Environmental law.* Prentice hall of India, 2007.
4. K. D. Wagner, *Environmental Management*. W.B. Saunders Co., 1998.
5. United Nations Industrial Development Organization, *Industrial Development Report 2016*. Vienna, 2016.
6. G. Seliger, *Sustainable Manufacturing - Shaping Global Value Creation*. Springer, 2012.
7. D. A. Dornfeld, *Green Manufacturing: Fundamentals and Applications*. Springer, 2012.
8. N. K. Jha, *Green Design and Manufacturing for Sustainability*. CRC Press, 2015.

ME2092D FLUID MECHANICS AND FLUID MACHINERY LABORATORY

Pre-requisites: ME2001D Fluid Mechanics / ME2004D Fluid Mechanics and Fluid Machinery

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:
CO1: Calibrate various flow measuring devices.
CO2: Evaluate various losses in flow through a piping system.
CO3: Evaluate the performance of fluid machines.

Measurement of metacentric height and radius of gyration of a floating body; calibration of flow measuring devices: venturimeter, orifice meter, notches and weirs, nozzle meters; determination of major and minor losses in piping system; verification of Bernoulli's theorem; determination of lift and drag coefficients of cylinder and airfoil; demonstration of laminar and turbulent flow in pipes; Osborne Reynolds experiment; study of jet forces; experiments on turbines: performance and operating characteristics; experiments on pumps: centrifugal pumps, reciprocating pumps, gear pumps; experiment on torque converter; flow visualization techniques; study and visualization of vortices.

List of Suggested Experiments:
1. Calibration of flow meters such as nozzle meter, orifice meter and orifice meter.
2. Calibration of notches such as rectangular notch and triangular notch.
3. Determination of major and minor losses in piping system.
4. Determination of meta-centric height of a floating body.
5. Flow past a small orifice to determine the various coefficients of it.
6. Measurement of a drag on a given specimen in an air flow.
7. Demonstration of flow visualization technique
8. Determination of impact of jet.
9. Determination of performance characteristics of Francis turbine.
10. Determination of performance characteristics of gear pump.
11. Determination of performance characteristics of single and multi-stage centrifugal pump.
12. Determination of performance characteristics of Pelton turbine
13. Determination of performance characteristics of reciprocating pump.
14. Determination of performance characteristics of torque converter.

References:
1. F. M. White, *Fluid Mechanics*, 7th ed. McGraw Hill, 2011.
2. Y. A. Cengel and J. M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, 3rd ed. McGraw Hill, 2014.
3. J. Lal, *Hydraulic Machines*, 6th ed. Metropolitan book Co., 1975.
4. J. Lal, *Fluid Mechanics and Hydraulics*. Metropolitan, 1975.

CE2095D STRENGTH OF MATERIALS LABORATORY

Pre-requisites: ME2002D Elements of Solid Mechanics / ME2003D Solid Mechanics / Equivalent

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:

CO1: Integrate the hands on experience on material testing with their theoretical understanding of mechanical behavior of materials

CO2: Prepare reports and present the results based on the test data complying with the codes/regulations

CO3: Refer codes and other reference materials for standard property data

CO4: Interpret the results and recommend the suitability of a material for a given load case.

List of Exercises:

1. Tension test on MS rod
2. Shear Test on MS rod
3. Torsion test on MS Specimen
4. Hardness tests on metals
5. Impact tests on metals
6. Bending test on steel beam
7. Spring test: open and close coiled springs
8. Compression test on cubes and cylinders – determination of modulus of elasticity
9. Study of extensometers and strain gauges

References:

1. S. P. Timoshenko, *Strength of materials*. CBS publishers, 1988.
2. J. M. Gere, *Mechanics of Materials*. Thomson, 2001.
3. Relevant BIS Standards.

ME3001D DYNAMICS OF MACHINES

Pre-requisites: ME2012D Kinematics of Mechanisms

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Perform dynamic force analysis of machines
CO2: Perform balancing of rotating and reciprocating masses.
CO3: Analyze the dynamics of gyroscope, governor and flywheel.
CO4: Analyze the vibration of single-DoF, multi-DoF and continuous systems

Module 1: (13 Hours)
Static force analysis of machines, static force analysis with friction, force analysis of gears, method of virtual work, dynamic force analysis of machines, principle of superposition, complex algebra method. gyroscopes and its applications; basics of governors.

Module 2: (13 Hours)
Balancing: static and dynamic unbalance; balancing of rotating masses, balancing machines, balancing of single-cylinder engines, balancing of multi-cylinder engines, balancing of V-engines; design of flywheels.
Single DoF vibration systems: free and forced vibration; response to harmonic and periodic excitation; rotating unbalance; support-excited vibration; critical speed of shafts; vibration measuring instruments; response to arbitrary excitation.

Module 3: (13 Hours)
Vibration of two DoF systems: formulation, normal mode analysis, solution of matrix eigenvalue problem; forced harmonic vibration of two DoF system; vibration absorber, multi-DoF systems: matrix formulation.
Application of Lagrange’s equation; introduction to vibration of continuous systems: vibration of string. Approximate methods: Dunkerley's equation; geared system.

References:

1. J. J. Uicker Jr., G. R. Pennock, and J. E. Shigley, *Theory of Machines and Mechanisms*, 4th ed. Oxford University Press, 2014.
2. H. H. Mabie and C. F. Reinholtz, *Mechanisms and Dynamics of Machinery*, 4th ed. John Wiley & Sons, 1987.
3. A. Ghosh and A. K. Mallik, *Theory of Mechanisms and Machines*, 3rd ed. East-West Press, 2006.
4. A. R. Holowenko, *Dynamics of Machinery*, John Wiley & Sons, 1965.
5. K. J. Waldron, G. L. Kinzel, and S. K. Agrawal, *Kinematics, Dynamics and Design of Machinery*, 3rd ed. Wiley, 2016.
6. R. L. Norton, *Design of Machinery*, 5th ed. Tata McGraw-Hill, 2011.
7. S. S. Rattan, *Theory of Machines*, 4th ed. Tata McGraw-Hill, 2014.
8. W. T. Thomson, M. D. Dahleh, and C. Padmanabhan, *Theory of Vibrations with Applications*, 5th ed. Pearson Education, 2008.
9. L. Meirovitch, *Elements of Vibration Analysis*, 2nd ed. McGraw-Hill, 2007.
10. J. P. Den Hartog, *Mechanical Vibrations*, 4th ed. McGraw-Hill, 1985.

ME3002D PRINCIPLES OF HEAT TRANSFER

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop state-of-the-art concepts of various modes of heat transfer.

CO2: Attain the capability of transforming the physical model of a heat transfer problem into an equivalent mathematical model.

CO3: Acquire the knowledge of evaluating rate of heating/cooling from thermal systems.

Module 1: (13 hours)

Review of basic concepts: heat, control volume, energy theorem; basic modes of heat transfer; generalized differential energy equations of heat conduction; types of boundary conditions; steady, one-dimensional heat conduction with and without energy generation; Steady, one-dimensional heat conduction in fins; transient heat conduction: lumped heat capacity systems, transient heat conduction in a semi-infinite solid.

Module 2: (15 hours)

Convective heat transfer: forced, mixed and natural convection heat transfer; differential and integral energy equations for laminar boundary layer over a flat plate; forced convection over a flat plate with two different boundary conditions; forced convection in laminar tube flow with uniform wall heat flux condition; concept of bulk mean temperature; empirical relations for forced convection; integral analysis of natural convection on a vertical flat plate; empirical relations for natural convection; heat exchangers: overall heat transfer coefficients, types of heat exchangers; design of heat exchangers: log mean temperature difference method, effectiveness-NTU method.

Module 3: (11 hours)

Radiation heat transfer: physical mechanism, black and gray bodies, opaque and transparent/ translucent bodies; radiation intensity and emissive power; irradiation and radiosity; laws of thermal radiation; characteristics of real surfaces; radiation heat transfer between two surfaces: view factor, view factor between two differential elements, view factor between differential element and finite area, view factors for two finite areas; methods for evaluating view factors: view factor algebra for pair of surfaces.

References:

1. J. P. Holman and S. Bhattacharya, *Heat Transfer*, 10th ed. McGraw Hill Education, 2002.
2. Y. A. Cengel and A. J. Ghajar, *Heat and Mass Transfer*, 5th ed. McGraw Hill Education, 2015.
3. W. S. Janna, *Engineering Heat Transfer*, 3rd ed. CRC Press, 2009.

ME3003D THERMAL ENGINEERING I

Pre-requisites: ME2013D Thermodynamics / ME2016D Thermodynamics and Heat Transfer

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyze ideal and actual cycles for IC engines.
CO2: Acquire knowledge on combustion in IC engines.
CO3: Evaluate performance of IC engines.
CO4: Analyze ideal and actual cycles for gas turbine power plants and jet engines.

Module 1: (12 Hours)
Analysis of gas power cycles: Carnot cycle; air-standard cycles; assumptions, Otto, diesel and dual-combustion cycles; comparison of cycles; analysis of fuel air cycle; analysis of actual cycles; engines: nomenclature; four-stroke SI and CI engines; valve timing diagrams; two-stroke SI and CI Engines; port-timing diagrams; scavenging terminologies; scavenging methods; comparison of four-stroke and two-stroke engines; comparison of SI and CI Engines; engine systems: fuel systems; cooling system; lubrication system; ignition system.

Module 2: (18 Hours)
Thermochemistry: equivalence ratio; self-ignition temperature; ignition delay; ignition limits; combustion in SI engines: stages of combustion; ignition lag; flame propagation; knocking in SI engines; pre ignition, factors affecting knocking, octane number; combustion in CI engines: stages of combustion; ignition delay; knocking in CI engines, factors affecting knocking; comparison of knocking in SI and CI engines; knocking control; cetane number; electronic fuel injection systems; multi point fuel injection systems; gasoline direct injection system; common rail direct injection system; IC engine performance: constant speed and variable speed characteristics; determination of friction power; performance parameters; measurements; performance curves of IC engines; heat balance sheet; governing of IC engines; fuels: properties; lubricants; air pollution; emission norms; exhaust treatment technologies.

Module 3: (9 Hours)
Analysis and application of gas turbine cycles: open and closed cycles; Brayton cycle; actual Brayton Cycle; regeneration, reheat and intercooled cycles; Ericsson cycle; ideal jet propulsion cycles; turbojet engines, turboprop engines and ramjet engines; combustion chambers; compressors.

References:
1. Y. A. Cengel and M.A. Boles, *Thermodynamics – An engineering approach*, 4th ed. Tata McGraw Hill, 2005.
2. J. B. Heywood, *Internal Combustion Engines Fundamentals*, McGraw Hill, 2017.
3. V. L. Maleev, *Internal Combustion Engines: Theory and Design*. McGraw Hill, 1983.
4. M. L. Mathur and R. P. Sharma, *A Course in Internal Combustion Engines*, Dhanpat Rai Publications, 2005.
5. V. Ganesan, *Internal Combustion Engines*, 4th ed. McGraw Hill, 2017.
6. H. Cohen, *Gas Turbines Theory*, 4th ed. Longman, 1996.
7. V. Ganesan, *Gas Turbines*. Tata McGraw Hill, 1999.

ME3101D MANUFACTURING SCIENCE

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Select suitable manufacturing process for a given product.
CO2: Apply fundamental knowledge in the analysis of casting, forming and joining processes.
CO3: Select equipment and design moulds, tools & dies for casting and forming operations.
CO4: Estimate energy requirement and select process parameters for casting, forming and joining processes.

Module 1: (13 hours)
Foundry: foundry materials; moulding and core sand; binders; additives; sand preparation; sand control tests; pattern and pattern making; mould and core making; expendable and non-expendable moulds; mould assembly; melting furnaces and melting practice; pouring and fettling; solidification of pure metals and alloys; grain growth; casting processes: sand casting; shell moulding; investment casting; slush casting; gravity and pressure die casting; centrifugal casting; casting design; gating system design; riser design; casting defects; inspection; testing: destructive and non – destructive; casting alloys; economics of casting.

Module 2: (13 hours)
Yield criteria of metals (von Mises, Tresca); representation in stress space; isotropic hardening; kinematic hardening; plastic stress strain relationship; cold working and hot working; metal forming operations: principle, process and equipment for rolling, forging, drawing, extrusion, sheet metal forming; HERF; powder metallurgy; analysis of forming operations: load calculation and power requirement for rolling, forging, drawing, extrusion.

Module 3: (13 hours)
Metal joining: classification; welding heat sources; fusion and non-fusion welding processes; gas welding and gas cutting; electric arc welding; arc welding machines; physics of welding arc; arc production; arc characteristics; metal transfer; arc blow; welding electrode; consumable and non-consumable arc welding: carbon arc welding; SMAW; GTAW; GMAW; SAW; AHW; PAW; resistance welding; electro slag welding; thermit welding; ultrasonic welding; electron beam welding; laser beam welding; solid state welding; arc cutting; welding metallurgy: Heat Affected Zone; weldability of ferrous and non-ferrous metals; design of weldments; joint design; residual stresses and distortion; defects in welding; testing of welded joints; brazing and soldering.

References:

1. A. Ghosh and A. K. Mallik, *Manufacturing Science*. Affiliated East west Press, 2001.
2. R. Heine, C. Loper, and P. Rosenthal, *Principles of Metal Casting*. Tata McGraw Hill, 2004.
3. R. Little, *Welding and welding Technology*. Tata McGraw Hill, 2004.
4. S. Kalpakjian, *Manufacturing Engineering & Technology*. Addison Wesley Longman, 1995.
5. O. Hoffman and G. Sachs, *Introduction to Theory of Plasticity for Engineers*. McGraw-Hill Book Company, 1953.
6. M. C. Flemings, *Solidification Processes,* McGraw Hill, American Welding Society, Welding Hand Book, 1974.
7. L. E. Doyle, *Manufacturing Processes and Materials for Engineers*, 3rd ed. Prentice Hall of India, 1984.
8. H. F Taylor, M. C. Flemings, and J. Wulff, *Foundry Engineering,* 1st ed. John Wiley & Sons, 1959.
9. *Metals Hand Book* – Vol. 5. Welding Institute of Metals, USA, 1977.

ME3102D MANAGEMENT OF PRODUCTION SYSTEMS

Pre-requisites: ME2111D Essentials of Management

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the characteristics of problems in production systems.

CO2: Identify the characteristics of time series data and apply simple moving averages for demand forecasting.

CO3: Identify production planning hierarchy; develop and evaluate material plans and operational schedules.

CO4: Develop simple inventory policies, identify layout planning issues and develop quality control plans.

Module 1: (15 hours)

Historical development of operations and supply chain management; operations strategy and competitiveness; characteristics of modern production systems: push and pull production systems; forecasting; time series analysis: components of time series, moving average, simple exponential smoothing, simple regression, error measurement, tracking signal.

Production planning and control: framework, aggregate planning, master production scheduling.

Module 2: (14 hours)

Material Requirements Planning (MRP): technical issues, using the MRP system, production activity control, types of Gantt chart, flow shop scheduling (make span optimisation), job prioritisation methods, performance measures.

Inventory control: functions of inventory, inventory problem classification, relevant cost, selective inventory control, independent demand systems (continuous review and periodic review inventory control systems), deterministic models, sensitivity analysis, all unit quantity discount, economic production quantity, Introduction to probabilistic models, basic concepts of supply chain management.

Module 3: (10 hours)

Facilities planning: objectives of facility planning, assembly chart, operation process chart, equipment requirement estimation; facility design: flow, space and activity relationship, flow patterns, layout planning, systematic layout planning; types of layout: process layout, product layout, group technology layout; method study and time study.

Quality Control: statistical process control, control charts for variables, X-bar and R chart, control charts for attributes, P and C chart, introduction to acceptance sampling.

References:

1. R. B. Chase, Ravi Shankar, and F. R. Jacobs, *Operations and Supply Chain Management*, 14th ed. McGraw Hill Education (India) Private Limited, 2015.
2. R. J. Tersine, *Principles of Inventory and Materials management*, 4th ed. Prentice-Hall International, 1994.
3. F. R. Jacobs, W. L. Berry, D. Clay Whybark, and T. E. Vollmann, *Manufacturing Planning and Control for Supply Chain Management*, 6th ed., McGraw Hill Education (India), 2015
4. J. A. Tomkins, J. A.White, Y. A. Bozer, and J. M. A. Tanchoco, *Facility Planning*, 4th ed. Wiley India, 2013.
5. E. L. Grant, and R. S. Leavenworth, Statistical Quality Control, 7th ed. McGraw-Hill Education (Indian Edition), 2017.

ME3091D HEAT TRANSFER LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:
CO1: Analyze the working principle of heat transfer components.
CO2: Compare the experimental results with the theoretical results.
CO3: Apply experimental techniques for typical heat transfer situations.
CO4: Infer the results and apply to practical cases.

Thermal conductivity of metals; steady and unsteady state conduction heat transfer; forced convection and radiation heat transfer; emissivity measurement; natural convection heat transfer; drop wise and film wise condensation; effectiveness of fins; vapour compression refrigeration and air-conditioning systems; heat exchangers.

List of suggested experiments:
1. Determination of thermal conductivity of a metal
2. Determination of emissivity of a test surface
3. Determination of heat transfer coefficient in forced convection heat transfer
4. Determination of effectiveness of shell and tube heat exchanger
5. Determination of heat transfer coefficient in natural convection heat transfer
6. Determination of heat transfer coefficient in unsteady state heat transfer
7. Determination of critical heat flux in boiling heat transfer
8. Determination of heat transfer coefficient in drop wise and film wise condensation
9. Determination of Effectiveness of Plate Type Heat Exchanger
10. Determination of heat transfer coefficient in combined convection and radiation
11. Determination of COP of a vapour compression refrigeration system

References:

1. J. P. Holman and S. Bhattacharya, *Heat Transfer*, 10th ed. McGraw Hill Education, 2002.
2. Y. A. Cengel and A. J. Ghajar, *Heat and Mass Transfer*, 5th ed. McGraw Hill Education, 2015.
3. W. S. Janna, *Engineering Heat Transfer*, 3rd ed. CRC Press, 2009.

ME3191D PRODUCTION ENGINEERING LABORATORY I

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total Hours: 39

Course Outcomes:

CO1: Select suitable machining operations for fabricating any given component applying knowledge of material properties and machine tools.
CO2: Make use of measuring devices like vernier calipers, micrometers, etc.
CO3: Create simple components using turning operations on lathe.
CO4: Plan the sequence of various operations so as to execute the task within minimum time.

Machine tools and machining processes; classification; specifications of machine tools; general features, parts and functions; cutting tool materials and types; cutting variables: selection of speeds, feeds and depth of cut; use of cutting fluids; work holding methods and devices; tolerance and surface finish; machining operations on lathe like straight turning, taper turning, eccentric turning, profile turning, thread cutting, knurling, boring, etc.

List of suggested exercises:

Machining operations on Lathe like (1) straight turning, (2) taper turning, (3) eccentric turning, (4) profile turning, (5) thread cutting, (6) knurling, (7) boring, etc.

References:

1. W. A. J. Chapman, *Workshop Technology Vol II,* 4th ed. CBS Publishers & Distributors, 2007.
2. G. Boothroyd, *Fundamentals of Metal Machining and Machine Tools*. McGraw Hill, 1975.
3. B.D Henry, A. Aaron, and A. James, *Machine Tool Operations,* Vol **II***,* 4th ed. Tata McGraw Hill, 1960.
4. H. Chowdhary, *Workshop Technology, Vol II – Machine Tools*. Media Promoters and Publishing, 1997
5. HMT, *Production Technology*. Tata McGraw Hill, 2004.

ME3011D MACHINE DESIGN I

Pre-requisites: ME2003D Solid Mechanics

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Understand the design process and basic theories of failure
CO2: Design basic machine components and joints for strength and stiffness considerations
CO3: Design shafts and couplings using analysis and design standards.

Module 1: (14 hours)
Introduction to design: design process, design factors, principles of standardization, selection of materials, statistical considerations in design, stress concentration, theories of failure, design for impact and fatigue loads, consideration of creep and thermal stresses in design.
Threaded fasteners: thread standards, stresses in screw threads, analysis of power screws, bolted joints, preloading of bolts, gasketed joints, eccentric loading; Riveted joints: stresses in riveted joints, strength analysis, boiler and tank joints, structural joints.

Module 2: (11 hours)
Welded joints: types of welded joints, stresses in butt and fillet welds, torsion and bending in welded joints, welds subjected to fluctuating loads, design of welded machine parts and structural joints.
Springs: stresses in helical springs, deflection of helical springs, extension, compression and torsion springs, design of helical springs for static and fatigue loading, critical frequency of helical springs, stress analysis and design of leaf springs.

Module 3: (14 hours)
Keys and pins: types of keys and pins, stresses in keys and pins, design of cotter and pin joints.
Power shafting: stresses in shafts, design for static loads, reversed bending and steady torsion, design for strength and deflection, design for fatigue loading, critical speed of shafts; stresses in couplings, design of couplings, design of keyed and splined connections.

References:

1. J. E. Shigley, *Mechanical Engineering Design*, 1st Metric ed. McGraw-Hill, 1986.
2. J. E. Shigley and C. R. Mischke, *Mechanical Engineering Design*, 6th ed. Tata McGraw-Hill, 2003.
3. M. J. Siegel, V. L. Maleev, and J. B. Hartman, *Mechanical Design of Machines*, 4th ed. International Textbook Company, 1965.
4. R. M. Phelan, *Fundamentals of Mechanical Design*, 3rd ed. Tata McGraw-Hill, 2015.
5. V. L. Doughtie and A. V. Vallance, *Design of Machine elements*, 4th ed. McGraw-Hill, 1964.
6. R. C. Juvinall and K. M. Marshek, *Fundamentals of Machine Component design*, 5th ed. John Wiley & Sons, 2011.
7. R. L. Norton, *Machine Design*, 5th ed. Pearson Education, 2013.

Data Handbooks (allowed for reference during examinations):

1. B. R. Narayana Iyengar and K. Lingaiah, *Machine Design Data Handbook*, Vol. I & II.
2. P. S. G. Tech., *Machine Design Data Hand Book*.
3. K. Mahadevan and B. Reddy, *Design Data Handbook for Mechanical Engineers*, 4th ed. CBS Publishers and Distributors, 2013.

ME3111D OPERATIONS RESEARCH

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Formulate and solve decision problems using linear programming.
CO2: Explain and apply the concept of shadow prices.
CO3: Formulate and solve distribution-allocation problems.
CO4: Model and analyze waiting line systems.

Module 1: (15 hours)
An overview of operations research modeling approach; mathematical formulation of linear programming problems; graphical solution; Simplex algorithm: artificial starting solution, Big M-method, two-phase method, alternative optimal solutions, unboundedness, degeneracy; duality in linear programming: primal-dual relationships, economic interpretation of duality; solving linear programming problems using solvers.

Module 2: (13 hours)
Transportation problems: formulation and solution; assignment problems: formulation and solution; network flow models: shortest route problem, minimum spanning tree and maximum flow algorithms; Lagrange multiplier method for constrained optimization problems.

Module 3: (11 hours)
Queuing theory: generalized Poisson queuing model, steady state solution of single server models for infinite queue size and finite queue size.

References:

1. H. A. Taha, *Operations Research: An Introduction*, 9th ed. Pearson Education, 2013.
2. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, 9th ed. Tata McGraw-Hill, 2011.
3. G. Srinivasan, *Operations Research: Principles and Applications*, 2nd ed. PHI Learning, 2011.
4. A. Ravindran, D. Philips, and J. J. Solberg, *Operations Research: Principles and Practice*, 2nd ed. John Wiley & Sons, 1989.
5. G. Hadley, *Linear Programming*. Narosa Book Distributors, 2002.
6. G. Srinivasan, *Fundamentals of Operations Research*. [online] available: http://nptel.ac.in/courses/112106134/1
7. W. L. Winston, *Operations Research: Applications and Algorithms*, 4th ed. Brooks/Cole Cengage Learning, 2004.

ME3112D METROLOGY AND INSTRUMENTATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the basic terms and definitions in the metrology vocabulary
CO2: Calculate the measurement uncertainty according to the International standards
CO3: Design and plan experiments involving a single factor.
CO4: Describe and explain the working of common instruments used for dimensional measurement.
CO5: Describe and explain the working of common instruments used for measurement of temperature, strain, pressure, force and torque

Module 1: (14 hours)

Introduction: vocabulary of measurement: quantities and units, measurement, results, errors, accuracy etc; measurement uncertainty: Introduction, Type A: large sample, small sample, regression, Type B: normal, uniform and triangular distributions, determination of combined standard uncertainties and expanded uncertainties for uncorrelated inputs, correlated inputs, numerical approach, Monte Carlo simulation, applications in conformity assessment and decision making, case studies.

Module 2: (13 hours)

Experiment planning: theory vs experiment, problems with analysis of past data / improperly conducted experiments, case-studies, demonstration)

Dynamic characteristics: general model, zero order, first order: step response and frequency response, second order: step response and frequency response, experimental determination of parameters.

Module 3: (12 hours)

Dimensional and angular measurement: slip gauges, comparators, Abbe's principle; pneumatic transducer, electronic transducers, sine bar, angle gauges, interferometry.

Surface finish: parameters, stylus instruments.

Instrumentation: strain measurement: resistance and semiconductor strain gauges, circuits and arrangements.

Pressure measurements: manometers, elastic transducers; force &torque measurements.

Temperature measurement: expansion thermometers, resistance temperature detectors, thermistors, thermocouples, radiative measurements.

References:

1. L. Kirkup and R. B. Frenkel, *An Introduction to Uncertainty in Measurement Using the GUM*. Cambridge University Press, 2006.
2. E. O. Doebelin, *Measurement Systems*, 5th ed. McGraw-Hill International, 2004.
3. C. V. Collett and A. D. Hope, *Engineering Measurements*, 2nd ed. ELBS/Longman, 1983.
4. T. G. Beckwith, R. D. Marangoni, and J. H. Lienhard, *Mechanical Measurements*, 5th ed. Pearson Education, 1993.
5. J. F. W. Galyer, C. R. Shotbolt, *Metrology for Engineers*, 5th ed. Thomson Learning, 1990.
6. J. P. Holman, *Experimental Methods for Engineers*, 7th ed. McGraw-Hill Company, 2000.

ME3113D MACHINING SCIENCE AND MACHINE TOOLS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the influence of tool geometry on cutting performance, define the nomenclature of single point and multipoint cutting tools as per the industrial standards.

CO2: Analyse and predict the cutting forces, power requirements in machining based on different analytical models and on mechanics of metal/material cutting.

CO3: Propose an ideal machining/manufacturing process for fabricating advanced materials for specific applications with due considerations for the process capabilities and product quality requirements.

CO4: Identify suitable cutting tools, machine tools and optimal cutting parameters for various machining requirements by considering tool life/wear, machinability and surface integrity aspects.

CO5: Explain various machine tool mechanisms and design the machine elements, jigs and fixtures for different operations and applications.

CO6: Develop CNC part programs from production drawings (manual and CAD/CAM software based), and implement it in CNC Machines to fabricate the component.

Module 1: (13 hours)

Kinematic elements in metal cutting; tool nomenclatures; mechanics of chip formation: orthogonal and oblique cutting, shear angle, velocity relationship; merchant's analysis of cutting forces; cutting power estimation; Inserts: coatings, nomenclature; various types of drills; milling cutters and tool materials; material removal analysis in milling, drilling, grinding; effect of cutting variables on forces; tool failure analysis; theories of tool wear: measurement of tool wear; cutting tool dynamometers; thermal aspects of machining; tool life and economics of machining.

Module 2: (12 hours)

Basic concepts of machine tools; tool - work motions; machine tools for various machining processes; kinematics of machine tools and gear boxes; feed and speed mechanism; machine tool drives; machine tool dynamics; gear manufacture: milling, hobbing and shaping; special purpose machine tools; hydraulic control of machine tools: components of hydraulic circuits, control circuits and their characteristics; testing of machine tools; jigs and fixtures: basic principles of location, type and mechanics of locating and clamping elements, design of jigs and fixtures.

Module 3: (14 hours)

CNC machine tools: constructional features, drives and controls, feedback devices; interpolators: linear, circular interpolation and other emerging techniques; adaptive control systems; CNC part programming: post processors, use of various CAD/CAM software packages, CNC programming with CAD/CAM software, development of CNC programmes for special problems; micro/nano machining; additive manufacturing: recent developments; modern machining processes: mechanics, process parameters and applications of AJM, ECM, EDM, USM, EBM, LBM; hybrid machining Introduction to robotics and automation.

References:

1. A. Ghosh and A.K. Mallik, *Manufacturing Science*, 2nd ed. Affiliated East West Press, 2010.
2. G. Boothroyd and W. A. Knight, *Fundamentals of Metal Machining and Machine Tools*, 3rd ed. CRC press, 2005.
3. A. B. Chattopadhyay, *Machining and Machine Tools*, 2nd ed. Wiley India, 2017.
4. M. C. Shaw, *Metal Cutting Principles*, 2nd ed. Oxford University Press, 2004.
5. A. Bhattacharyya, *Metal Cutting, Theory and Practice*, New Central Book Agency, 1984.
6. S. Kalpakjian and S. R. Schmid, *Manufacturing Engineering and Technology*, 7th ed. Pearson, 2014.
7. P. C. Pandey and H. S. Shan, *Modern Machining Processes*, 1st ed. Tata Mc Graw Hill, 1980.

8. G. C. Sen and A. Bhattacharyya, *Principles of Machine Tools*, 2nd ed. New Central Book Agency, 2009.
9. N. K. Mehta, *Machine Tool Design and Numerical Control*, 3rd ed. Tata McGraw Hill, 2012.
10. A. B. Chattopadhyay, *Manufacturing Processes II.* [online] Available: http://nptel.ac.in/courses/112105126/
11. A. Esposito, *Fluid Power with Applications*, 7th ed. Pearson Education, 2008.
12. M. H. A. Kempster, *An Introduction to Jig and Tool Design*, 3rd ed. Butterworth-Heinemann, 1974.
13. M. P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 4th ed. Pearson Education, 2015.
14. P. N. Rao, *CAD/CAM: Principles and Applications*, 3rd ed. Tata McGraw Hill, 2010.
15. K. S. Fu, R. C. Gonzalez, and C. S. G. Lee, *Robotics: Control, Sensing, Vision and Intelligence*, 1st ed. McGraw-Hill Book Company, 1987.

ME3192D METROLOGY AND INSTRUMENTATION LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:
CO1: Plan and conduct experiments involving a single factor.
CO2: Use common measuring instruments.
CO3: Determine the measurement uncertainty after carrying out the measurement.
CO4: Explain the principle and working of specialized measuring instruments.

Calibration of strain gauge load cells, Bourdon tube pressure gauge, LVDT, thermocouple, tachometers using stroboscopes, etc.; Measurement of thread parameters using universal measuring microscope, three wire method, thread pitch micrometer; evaluation of straightness using autocollimator, spirit level; measurement of tool angles of single point tool using TMM; measurement of gear parameters using profile projector; study and measurement of surface finish using surface roughness tester; experiments on limits and fits; study and use of ultrasonic flaw detector; exercises on measurement system analysis; study and making measurements with thread pitch micrometer, disc micrometer, thread pitch gauge, height gauge, slip gauges, optical flat, three pin micrometer, pyrometer, RTD, sling psychrometer, zoom microscope, etc.; demonstrations of coordinate measuring machine, 3D profilometer, cylindricity testing machine, etc.

List of Suggested Experiments:

1. Measure various screw thread parameters using instruments like thread plug and ring gauges, universal measuring microscope, three wire sets, thread pitch micrometer and thread pitch gauge
2. Study the straightness error using autocollimator and spirit level
3. Psychrometric studies using sling psychrometer
4. Calibration of pressure gauge using dead weight pressure gauge tester.
5. Measurements using LVDT, slip gauges, three-pin micrometer and bore dial gauge.
6. Determine stress-strain relationship using strain gauges and load cell.
7. Studies using the ultrasonic flaw detecting equipment
8. Measurements using the profile projector
9. Measurements using disc micrometer
10. Measurement of the tool angles using tool maker’s microscope and digital dial gauge.
11. Use of optical flat for determining parallelism error and combination set for determining angle.
12. Measure the speed of a rotating object using stroboscope.
13. Thermocouple-based experiments
14. R&R study between observers
15. Studies using gear tooth vernier
16. Studies using the Feeler gauge and sine bar
17. Studies on the surface profilometer
18. Measurement of area using planimeter
19. Determining the class of fits between given shafts and hole
20. Studies on coordinate measuring machine
21. Studies on cylindricity testing machine, laser scan micrometer and coating thickness gauge

Note: The students registering for ME3192D should have either completed or registered for the theory courses ME3112D Metrology and Instrumentation / ME3104D Metrology and Computer Aided Inspection in the current semester.

References:

1. K. J. Hume and G. H. Sharpe, *Practical Metrology.* Macdonald & Co, 1953.
2. C. Dotson, *Fundamentals of Dimensional Metrology*, 5th ed. Delmar Cengage Learning, 2006.
3. J. P. Holman, *Experimental Methods for Engineers*, 7th ed. McGraw-Hill, 2000

ME3193D PRODUCTION ENGINEERING LABORATORY II

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total Hours: 39

Course Outcomes:

CO1: Select suitable machining operations for fabricating any given component applying knowledge of material properties and machine tools.

CO2: Create simple components employing machining operations on milling machines, shaper, grinding machine, CNC machines, etc.

CO3: Plan the sequence of various operations so as to execute the task within minimum time.

CO4: Function independently as well as a team member in planning and execution of fabrication and assembly of a given product.

Introduction to limits and fits; horizontal and vertical milling machines; kinematic structure; milling cutters; use of indexing head; simple, compound and differential indexing; shaping machine; quick return mechanism; slotting machine; surface, cylindrical and centreless grinding operations; tool and cutter grinder; modern machining; part programming and operation of CNC machines; machining operations on shaping machine: flat and bevel surfaces; grooves; slots; guide ways; key ways; etc.; machining operations on horizontal and vertical milling machines: surface; slot; key way and gear milling; grinding operations on surface, cylindrical and centreless grinding machines; modern machining processes: EDM, WEDM; CNC part programming and operation; group project on fabrication and assembly of a product or a simple mechanism.

List of suggested exercises:

1. Machining operations on shaping machine: (a) Flat and bevel surfaces, (b) grooves, (c) slots, (d) guide ways, (e) key ways, etc.
2. Machining operations on horizontal and vertical milling machines: (a) surface, (b) slot, (c) key way and (d) gear milling.
3. Grinding operations using (a) surface, (b) cylindrical and (c) centreless grinding machines.
4. Non-traditional machining: (a) EDM, (b) WEDM.
5. CNC part programming and operation.
6. A group project on fabrication and assembly of a product or a simple mechanism.

References:

1. HMT, *Production Technology.* Tata McGraw Hill, 2004.
2. ASTME, *Tool Engineer's Handbook*. 1976.
3. W. A. J. Chapman, *Workshop Technology,* Vol. 2 & 3. CBS Publishers & Distributors, 1980
4. P. N. Rao, *Manufacturing Technology: Metal Cutting & Machine Tools,* 2nd ed. Tata McGraw Hill, 2008.
5. M. P. Groover and E.W. Zimmers, *CAD/CAM: Computer-Aided Design and Manufacturing*. 1984.
6. N. K. Mehta, *Machine Tool Design and Numerical Control,* 2nd ed. Tata McGraw Hill, 1996.

ME3099D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	3	1

Total hours: 39

Course Outcomes:
CO1: Review technical literature and identify technically and socially relevant topics.
CO2: Understand and appreciate the significance of professional ethics.
CO3: Develop capability for self-learning of advanced topics in a selected field.
CO4: Acquire oral and written communication skills required for a successful professional career.

Students should search the technical literature in the form of peer reviewed journals and conference proceedings, and identify a current research topic relevant to Mechanical Engineering/Production or any interdisciplinary field, which has application in Mechanical Engineering. Preference should be given for a topic, which is expected to be selected for the final year project, so that the literature survey for the selected project could be done in the VI semester itself. The students should comprehend the topic and prepare a technical report on the topic in the specified format, prepare presentation aids and deliver a technical presentation to the class and the teacher. Appropriate weightage will be given for communications skills (both verbal and written) as well as the capacity to impress the audience and ability to handle question-and-answer session.

ME4001D MACHINE DESIGN II

Pre-requisites: ME2003D Solid Mechanics

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Design brake systems and transmission elements based on design standards and practices.
CO2: Design gear systems for strength and durability, based on standards and practices.
CO3: Understand the mechanism of lubrication in hydrodynamic bearings.
CO4: Design journal bearings for various applications.
CO5: Select rolling contact bearings for various applications, based on standards and practices.
CO6: Design machine components and products giving due importance to manufacturability.

Module 1: (13 Hours)
Design of clutches, brakes, belts and chain drives: friction clutches and brakes; uniform pressure and uniform wear assumptions; design of disc and cone types of clutches and brakes; design of external contracting and internal expanding elements; band type clutches and brakes; belt and chain drives of common types; design of flat and V-belt drives; selection of roller chains.

Module 2: (14 Hours)
Design of gears: spur, helical, bevel and worm gears; tooth loads; gear materials; design stresses; basic tooth stresses; stress concentration; service factor; velocity factor; bending strength of gear teeth; Buckingham's equation for dynamic load; surface strength and durability; heat dissipation; design for strength and wear.
Lubrication and journal bearing design: types of lubrication and lubricants; viscosity; journal bearing with perfect lubrication; hydrodynamic theory of lubrication; design considerations; heat balance; journal bearing design.

Module 3: (12 Hours)
Rolling contact bearings: bearing types, bearing life, static and dynamic capacity, selection of bearings with axial and radial loads, selection of tapered roller bearings, lubrication, seals, shaft, housing and mounting details.
Design for manufacturing: general design recommendations for rolled sections, forgings, screw machine products, turned parts, machined round holes, parts produced on milling machine, welded parts and castings; modification of design for manufacturing easiness for typical products.

References:

1. J. E. Shigley, *Mechanical Engineering Design*, 1st Metric ed. McGraw-Hill, 1986.
2. J. E. Shigley and C. R. Mischke, *Mechanical Engineering Design*, 6th ed. Tata McGraw-Hill, 2003.
3. M. J. Siegel, V. L. Maleev, and J. B. Hartman, *Mechanical Design of Machines*, 4th ed. International Textbook Company, 1965.
4. R. M. Phelan, *Fundamentals of Mechanical Design*, 3rd ed. Tata McGraw-Hill, 2015.
5. V. L. Doughtie and A. V. Vallance, *Design of Machine elements*, 4th ed. McGraw-Hill, 1964.
6. R. C. Juvinall and K. M. Marshek, *Fundamentals of Machine Component design*, 5th ed. John Wiley & Sons, 2011.
7. R. L. Norton, *Machine Design*, 5th ed. Pearson Education, 2013.
8. J. G. Bralla, Design for Manufacturability Handbook, 2nd ed. McGraw Hill, 1998.

Data Hand Books (allowed for reference during examinations):

1. B. R. Narayana Iyengar and K. Lingaiah, *Machine Design Data Handbook*, Vol. I & II.
2. P. S. G. Tech., *Machine Design Data Handbook*.
3. K. Mahadevan and B. Reddy, *Design data handbook for Mechanical Engineers*, 4th ed. CBS Publishers and Distributors, 2013.

ME4002D THERMAL ENGINEERING II

Pre-requisites: ME2013D Thermodynamics

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply thermodynamic cycles to steam power plant and refrigeration systems.
CO2: Develop thermal refinement methods for performance improvement of steam power plant.
CO3: Analyse the components of steam power plant and refrigeration systems.
CO4: Acquire knowledge on pollution control methods.

Module 1: (15 hours)
Properties of steam: use of steam tables and Mollier chart; separating and throttling calorimeter; properties of atmospheric air; psychrometric chart; energy scenario: national and global; vapour and combined power cycle; Carnot vapour cycle; ideal Rankine cycle; deviations in an actual Rankine cycle; methods to increase the efficiency of Rankine cycle, reheat and regenerative cycles; open and closed feed water heaters; deaerator; co-generation; combined gas power cycles; vapour compression refrigeration cycle: ideal and actual; air refrigeration cycle; components and systems.

Module 2: (11 hours)
Steam generators: fire tube, Lancashire, locomotive and Nestler boilers; water-tube; Babcock and Wilcox and bent-tube boilers; mountings and accessories; schematic diagram of a modern steam generator; combustion equipment; overfeed and underfeed stokers; travelling-grate and spreader stokers, pulverized coal burners, cyclone furnace, fluidized-bed combustion; coal based synthetic fuels; steam nozzles: condition for maximum discharge, design for throat and exit areas, effect of friction, supersaturated flow.

Module 3: (13 hours)
Steam turbines: classification, impulse and reaction turbines; velocity diagrams, efficiencies, end thrust, blade height; turbine performance and governing; condensers: surface and mixing condensers; solution of problems on evaporative cooling towers and wet cooling towers; different types of modern wet and dry cooling towers; power plant economics; load curve and load duration curve, load factor, diversity factor, capacity factor and use factor, depreciation and replacement; environmental aspects of thermal power systems; dust collectors; waste heat recovery techniques.

References:
1. Y. A. Cengel and M. A. Boles, *Thermodynamics - An engineering approach*, 4th ed., Tata McGraw Hill, 2005.
2. M. M. El-Wakil, *Power Plant Engineering*, 1st ed. McGraw Hill, 1985.
3. W. A. Vopat and B. G. A. Skrotzki, *Power Station Engineering and Economy*. Tata McGraw Hill, 1999.
4. P. K. Nag, *Power Plant Engineering*, 4th ed. McGraw Hill, 2017.
5. W. F. Stoecker and J.W. Jones, *Refrigeration & Air Conditioning*, 2nd ed. McGraw Hill, 1983.
6. C. P. Arora, *Refrigeration & Air Conditioning*, 3rd ed. McGraw Hill, 2008.

MS4002D INDUSTRIAL ECONOMICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: Analyze operations of markets under varying competitive conditions.

CO2: Evaluate benefit/cost, and conduct life cycle and breakeven analyses on one or more economic alternatives.

CO3: Estimate cost/revenue data to justify or reject alternatives/projects on an economic basis.

CO4: Examine a social problem by demonstrating knowledge of global factors influencing business and ethical issues.

CO5: Use models to make predictions about the impact of government intervention as well as changing market conditions on consumer and producer behaviour.

Module 1: (9 hours)

General foundations of economics: forms of organizations, objectives of firms, opportunity principle, discounting, marginalism versus incrementalism, production possibility frontier, central problems of an economy- Two sector, Three sector and Four sector circular flow of income. Demand analysis- Individual, Market and Firm demand, Determinants of demand and supply, Shifts and changes in demand and supply, Market equilibrium, Shortages versus surpluses, Price ceiling, Price floor-Elasticity of demand and business decision making.

Module 2: (15 hours)

Production functions in the short and long run-cost concepts- Short run and long run costs-economies and diseconomies of scale-economies and diseconomies of scope-Break even analysis-Vertical & horizontal integration-Product markets-Market structure-Competitive market-Imperfect competition (Monopoly, Monopolistic competition and Oligopoly) and barriers to entry-Pricing in different markets- Price discrimination-Dead weight loss-consumer's surplus – Pricing strategies-Game Theory-Prisoner's Dilemma-Maximin, Minimax, Saddle point, Nash Equilibrium.

Module 3: (15 hours)

Macro-Economic Aggregates-Gross Domestic Product; Gross national product, net domestic product, Transfer payments, Depreciation, Economic Indicators; Models of measuring national income; Fiscal deficit, primary deficit, Inflation and deflation ; Fiscal and Monetary Policies; Monetary system; Indian stock market; Development Banks; NBFIs, role of Reserve Bank of India, Money Market, Capital market; NIFTY, SENSEX, Break even analysis, Margin of safety, Leverage, Depreciation, scrap value, salvage value, straight line method, declining balance method. double declining method, Taxes, Externalities, Financial ratios-Current ratio, Debt ratio, ROE, Quick ratio, net profit margin, debt to equity ratio.

References:

1. R. S. Pindyck, D. L. Rubinfield, and P. L. Mehta, *Microeconomics*, 9th ed. Pearson Education, 2018.
2. P. A. Samuelson and W. D. Nordhaus, *Economics*, 19 ed. Tata McGraw Hill, 2015.
3. G. N. Mankiw, *Principles of Micro Economics*, 7th ed. Cengage Publications, 2014.
4. S. B. Gupta, *Monetary Economics: Institutions, Theory & Policy*. S. Chand & Co., 2013.
5. K. E. Case, R. C. Fair, and S. Oster, *Principles of Economics*, 10th ed. Prentice Hall, 2011.

P.N.: Supplementary materials would be suggested / supplied for selected topics on financial markets Indian economy.

ME4091D HEAT ENGINES LABORATORY

Pre-requisites: ME3003D Thermal Engineering I

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:
CO1: Acquire knowledge of constructional details and working of IC engines.
CO2: Evaluate the performance of IC engines, compressors and blowers.
CO3: Gain practical knowledge on operational details IC engines, compressors and blowers.

Study of IC engine systems: fuel system, lubrication system, cooling system, starting system, ignition system, governing system, power transmission system, types of carburetors, multi point fuel injection (MPFI) system, common rail direct injection (CRDI) system, gasoline direct injection (GDI) system; study of fuel properties measuring systems: bomb calorimeter, gas calorimeter, red-wood viscometer, flash and fire apparatus; study of dynamometers; constant speed performance characteristics of SI engine; Morse test at constant throttle and at constant load; constant speed performance characteristics of CI engine; determination of frictional horse power (FHP) by retardation test; variable speed performance characteristics of SI engine (with carburetor and MPFI system); performance characteristics of CI variable speed engine; effect of cooling water on engine performance; heat balance sheet; valve timing diagrams of IC engines; determination of viscosity, flash and fire point, calorific value of the given fuel/oil; performance characteristics of centrifugal blower and rotary type positive displacement compressor; constant speed performance characteristics of reciprocating compressor.

List of suggested experiments:
1. To conduct constant speed performance characteristics test on SI engine.
2. To conduct Morse test at constant throttle and at constant load.
3. To conduct constant speed performance characteristics test on CI engine.
4. Determination of frictional horse power (FHP) by retardation test.
5. To conduct variable speed performance characteristics test on SI engine (with carburetor and MPFI system).
6. To conduct performance characteristics test on variable speed CI engine.
7. To determine the effect of cooling water on engine performance.
8. To perform the heat balance test on engine and to draw the heat balance sheet.
9. To draw the valve timing diagram of IC engines.
10. Determination of viscosity, calorific value, and flash and fire point of the given fuel/oil.
11. To conduct performance characteristics test on centrifugal blower and rotary type positive displacement compressor.
12. To conduct constant speed performance characteristics test on reciprocating compressor.

References:

1. J. B. Heywood, *Internal Combustion Engines Fundamentals*. McGraw Hill, 2017.
2. M. L. Mathur and R. P. Sharma, *A Course in Internal Combustion Engines*. Dhanpat Rai Publications, 2005.
3. V. Ganesan, *Internal Combustion Engines*, 4th ed. McGraw Hill, 2017.

ME4191D CAD/CAM LABORATORY

Pre-requisites: Nil

L	T	P	C
0	0	3	2

Total Hours: 39

Course Outcomes:
CO1: Model complex mechanical systems using CAD software.
CO2: Analyze mechanical components and systems using various analysis software.
CO3: Develop CNC codes and STL files using CAD software for manufacturing various components.
CO4: Learn to use various automation tools.

Usage of commercial solid modeling packages like Creo, CATIA, Nx etc.: part modeling, assembly and motion visualization; finite element analysis using commercial software: modeling and mesh generation, structural, thermal and fluid flow analysis, linear and nonlinear analysis, dynamic analysis, interpretation of results; synthesis and analysis of mechanisms: exercises on various mechanisms like four bar linkages and its variations, cam and follower, etc.; dynamic analysis of machines like ADAMS; usage CAD tools for manufacturing/prototyping: manual and computer-aided part programming; demonstrations on CNC lathe and machining center / milling machines, rapid prototyping; automation and industrial robots: design and experimentation of pneumatics based automation circuits; automation using PLCs: PLC programming and testing; robot programming for various operations; repeatability and accuracy measurements of robot; demonstration of coordinate measuring machines.

List of suggested exercises:

1. Part modeling using CAD software like Creo, Catia, Nx, etc.
2. Modeling assemblies using CAD software
3. Visualization of mechanisms using CAD software
4. Static structural finite element analysis using ANSYS/Abacus
5. Thermal analysis and coupled thermal-stress analysis
6. Analysis of fluid flows
7. Nonlinear analysis with material, geometric and/or contact nonlinearity
8. Transient thermal and structural analysis
9. Dynamic analysis of mechanisms and machines using ADAMS
10. CNC part program development using CAD/Mastercam software
11. Demonstrations on CNC machines / RP machine / CMM machine
12. Demonstrations on robots and automation
13. PLC programming and testing
14. Robot programming for various operations
15. Repeatability and accuracy measurements on robots

References:

1. D. F. Rogers and J. A. Adams, *Mathematical Elements for Computer Graphics,* 2nd ed. Tata McGraw Hill, 2009.
2. D. F. Rogers, *Procedural Elements for computer Graphics,* 2nd ed. Tata McGraw Hill, 2010.
3. R. D. Cook, D. S. Malkus, M. E. Plesha, and R.J. Witt, *Concepts and Applications of Finite Element Analysis,* 4th ed. Wiley India, 2007.
4. Y. Koren, *Computer Control of Manufacturing Systems,*1st ed. McGraw Hill Education,2005.
5. P. N. Rao, N. K. Tewari, and T. K. Kundra, *Numerical Control & Computer Aided Manufacturing,* Tata McGraw Hill.
6. V. Ramamurthy, *Computer Aided Mechanical Design and Analysis,* 4th ed. Tata McGraw Hill, 2000.
7. K. S. Fu, R. C. Gonzalez, and C. S. G. Lee, *Robotics, Control, Sensing, Vision and Intelligence*, 1st ed. McGraw Hill Education, 2008.
8. Y. Koren, *Robotics for Engineers,* Tata McGraw Hill, 1985.
9. J. A. Bosch, *Coordinate measuring Machines & Systems,* Marcel Decker, Year?
10. S. S. Rattan, *Theory of Machines*, 4th ed. Tata McGraw-Hill, 2014.

ME4098D PROJECT: PART 1

Pre-requisites: Nil

L	T	P	C
0	0	6	3

Total hours: 78

Course Outcomes:
CO1: Identify a project with social relevance, and conduct its feasibility study.
CO2: Update knowledge by conducting a thorough review of literature.
CO3: Work in the team to achieve a goal in stipulated time.
CO4: Acquire oral and written communication skills required in the professional career.
CO5: Understand and attain ethical values, and show responsibility towards the society.

Students are required to take up a project on any topic related to Mechanical/Production Engineering or an interdisciplinary area with applications in Mechanical/Production Engineering, under the guidance of a faculty member of the department. The project work shall commence in VII Semester (approximately 6 hours/week), and be continued in VIII Semester. The project work is evaluated based on a mid semester presentation and an end semester presentation in front of an evaluation committee. At the end of the VII semester, an interim report describing the details of the project work carried out is to be submitted to the Department, in the prescribed format.

ME4099D PROJECT: PART 2

Pre-requisites: ME4098D Project: Part 1

L	T	P	C
0	0	10	5

Total hours: 130

Course Outcomes:

CO1: Develop socially relevant products or conduct theoretical/experimental studies with social relevance using fundamental concepts.
CO2: Develop self-learning capability, and an ability to identify and correct own mistakes.
CO3: Work in the team to achieve a goal in stipulated time.
CO4: Communicate with a wide audience in the form of technical or general-purpose articles, presentations or product demonstrations.
CO5: Understand and attain ethical values, and show responsibility towards the society.

The project work commenced in VII Semester shall be continued in VIII Semester. The students should spend approximately 10 hours/week on project work. The project work will be evaluated based on mid semester and end semester presentations in front of an evaluation committee. At the end of the VIII semester, the final report/thesis describing the details of the entire project work is to be submitted to the Department, in the prescribed format. Presentation of the entire work is to be done before an evaluation committee and a successful oral defense of the thesis before the committee is required.

Elective Courses

ME3021D INTRODUCTION TO FINITE ELEMENT METHODS

Pre-requisites: ME2003D Solid Mechanics / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Understand the basics and significance of finite element method.
CO2: Develop formulations for various problems using finite element method.
CO3: Solve field problems using finite element method by writing programs or using commercial software.

Module 1: (12 hours)
Analysis of discrete systems: introduction, formulation of spring and rod element matrices, assembly process, application of boundary conditions and solution, formulation of beam elements, assembly and boundary conditions for systems of beam elements.
Continuous systems and function approximation: introduction to continuous systems; function approximation: point collocation method, least square approximation, weighted residual method, finite difference method and finite element method.

Module 2: (14 hours)
One-dimensional finite element analysis: shape functions, Galerkin weighted residual method, assembly and boundary conditions, continuity requirements and order of shape functions.
Two-dimensional finite element analysis: introduction; scalar-field problems: heat transfer, torsion and potential flow problems, shape functions for triangular elements, formulation, assembly and solution; vector-field problems: stress analysis problem, rectangular elements, Lagrangian interpolation polynomials, isoparametric formulation and higher order elements, formulation, assembly and solution.

Module 3: (13 hours)
Computational aspects: mesh generation; element shape parameters; node numbering; storage and solution schemes; finite element analysis using commercial software.
Advanced Topics: nonlinear analysis: convergence and tolerance; fixed-point iteration, Newton-Raphson and modified Newton-Raphson schemes; time-dependent problems: time-stepping schemes, stability and accuracy.

References:
1. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, *The Finite Element Method: Its Basis & Fundamentals*, 7th ed. Butterworth-Heinemann, 2013.
2. O. C. Zienkiewicz and K. Morgan, *Finite Elements and Approximation*, Dover Publications, 2006.
3. R. D. Cook, D. S. Malkus, M. E. Plesha, and R. J. Witt, *Concepts and Applications of Finite Element Analysis*, 4th ed. Wiley, 2001.
4. K. J. Bathe, *Finite Element Procedures*, Prentice-Hall of India, 1996.

ME3022D EXPERIMENTAL STRESS ANALYSIS

Pre-requisites: ME2002D Elements of Solid Mechanics / ME 2003D Solid Mechanics / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:
CO1: Understand analytical methods to solve elasticity problems
CO2: measure the strains in a body using experimental methods
CO3: understand brittle coating techniques and methods for brittle coating analysis
CO4: measure the stresses and strains in body using photoelastic methods

Module 1: (13 hours)
Overview of theory of elasticity: analysis of stress at a point and strain at a point, governing equations for three dimensional elasticity problem, solution to plane stress and plane strain problems, Airy's stress function approach for solving plane elasticity problems, forms of stress function in polar coordinates, stress concentration at a circular hole in tension field; principal stresses and principal strains, prediction of failures; overview of experimental stress analysis.

Module 2: (13 hours)
Strain measurements, strain and its relation to experimental determinations, types of strain gauges: mechanical strain gauges, optical strain gauges, inductance strain gauges, electrical resistance strain gauges; strain sensitivity in metallic alloys; gauge construction-strain gauge adhesives and mounting methods; gauge sensitivities and gauge factor; performance characteristics of foil strain gauges; temperature compensation; strain gauge circuits: potentiometer, Wheatstone bridge circuits; strain rosettes: rectangular and delta rosette.
Theory of brittle coating method: coating stresses, failure theories, brittle coating patterns, crack detection, ceramic based and resin based brittle coatings, test procedures for brittle coating analysis, analysis of brittle coating data.

Module 3: (13 hours)
Photoelasticity: basics of optics, double refraction, stress optic law, stress and birefringence; two dimensional photoelasticity: plane polariscope, circular polariscope, isoclinics, isochromatics, effects of stressed model in a plane polariscope and circular polariscope, dark field and light field arrangements, compensation techniques, photoelastic materials, calibration methods, separation methods, scaling model to prototype stresses; three-dimensional photoelasticity: stress freezing.

References:

1. J. W. Dally and W. E. Riley, *Experimental Stress Analysis*, 3rd ed. McGraw-Hill, 1991.
2. R. G. Budynas, *Advanced Strength and Applied Stress Analysis*, 2nd ed. McGraw-Hill, 1999.
3. L. S. Sreenath, M. R. Raghavan, K. Lingaiah, G. Garghesha, B. Pant, and K. Ramachandra, *Experimental Stress Analysis*, Tata McGraw-Hill, 1984.
4. S. Timoshenko and J. N. Goodier, *Theory of elasticity,* 3rd ed. McGraw-Hill, 2017.

ME3023D THEORY OF ELASTICITY

Pre-requisites: ME2002D Elements of Solid Mechanics / ME2003D Solid Mechanics / CE2001D Mechanics of Solids

Total hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Understand the mechanics of deformable bodies with adequate mathematical vigor.
CO2: Analyze stresses and strains in a three dimensional body.
CO3: Formulate mathematical models using governing equations of elasticity.
CO4: Solve elasticity problems using energy methods and Airy's stress function approach.
CO5: Solve unsymmetric bending and non-circular torsion problems

Module 1: (14 hours)

Introduction to three-dimensional elasticity: stress at a point, stress tensor; stress transformation; principal stresses; principal planes; Mohr's circle; octahedral stresses; hydrostatic and pure shear states; strain at a point: strain tensor; analogy with stress tensor.
Equations of elasticity: equation of equilibrium, strain-displacement equations, compatibility conditions, boundary conditions: traction, displacement and mixed boundary conditions, constitutive equations, Navier equations; St. Venant's principle; general equations in polar coordinates.

Module 2: (13 hours)

Simplification to two-dimensional problems: plane stress and plane strain problems; axisymmetric problems: Lame's problem, rotating disks and shrink fits.
Energy methods: introduction to energy methods; uniqueness theorem; strain energy and complementary strain energy; Betti's reciprocal theorem, principle of virtual work; minimum potential energy principle.
Airy's stress function approach: analysis of cantilever with a point load at the end, simply supported beam with a uniformly distributed load, comparison of solutions with strength of materials solutions.

Module 3: (12 hours)

Special problems in bending: unsymmetric bending, shear centre, curved beams.
Torsion of non-circular sections: St. Venant's theory, Prandtl's stress function approach, elliptical and equilateral triangular cross sections; analogies in torsion; torsion of narrow rectangular cross sections and thin walled hollow sections; torsion of rectangular cross sections.

References:

1. S. P. Timoshenko and J.N. Goodier, *Theory of elasticity*, 3rd ed. Tata McGraw-Hill, 2010.
2. L. S. Srinath, *Advanced Mechanics of Solids*, 3rd ed. Tata McGraw-Hill, New Delhi, 2008.
3. D. Hartog, *Advanced Strength of Materials*, 1st ed. McGraw-Hill, New York, 2016.
4. A. J. Durelli, E. A. Philips, and C. H. Psao, *Introduction to the Theoretical and Experimental Analysis of Stress and Strain*, McGraw-Hill, New York.
5. F. B. Seely and J. O. Smith, *Advanced Mechanics of Materials*, 2nd ed. John Wiley and Sons, New York, 1957.
6. K. B. M. Nambudiripad, *Advanced Mechanics of Solids – A Gentle Introduction*, Narosa Publishing house, 2018.

ME3024D CONTROL SYSTEMS ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Model control systems using block diagram reduction, transfer function and state space methods.
CO2: Analyse the transient response of systems and perform stability analysis using Routh-Hurwitz criterion and root locus method.
CO3: Analyse the frequency response of systems using rectangular, polar, Bode, Nichols and Nyquist plots.
CO4: Design controllers using root locus, Bode plot and state space methods.

Module 1: (15 hours)

Introduction to control system engineering: history, representation of feedback control system by block diagrams, physical systems and their mathematical models; representation of linear time invariant systems; order of the system; classical method; transfer function approach; block diagram reduction; state space representation; mathematical models of mechanical, electrical, hydraulic and pneumatic elements and systems; conversion of state space to transfer function and transfer function to state space.

Module 2: (12 hours)

Transient response analysis: solution of first order, second order and higher order systems, solution by Laplace transform, solution of states space equation, performance parameters of first order and second order systems; stability of systems, Routh-Hurwitz criterion, steady state error, error constants, improving time response and steady state error, root locus techniques.

Module 3: (15 hours)

Frequency response of systems: plotting the frequency response, rectangular plots, polar plots, Bode plots and Nichols chart; stability analysis: Nyquist plots and Nyquist criterion, gain margin, phase margin.

Design of control systems: design philosophy, design of lead, lag, lead-lag, proportional, integral, derivative and PID controllers using root locus and Bode plot methods; tuning of controllers and PID controller gain tuning techniques; design of controllers via state space, controllability and observability.

Text book:

1. B. C. Kuo, *Automatic Control Systems*, 9th ed. Wiley, 2014.

References:

1. K. Ogata, *Modern Control Engineering*, 5th ed. Pearson, 2009.
2. I. J. Nagrath, and M. Gopal, *Control Systems Engineering*, 6th ed. New Age International, 2017.
3. K. Ogata, *System Dynamics*, 4th ed. Pearson Education Inc., 2004.
4. C. T. Chen, *Linear System Theory and Design*, 3rd ed. Oxford University Press, 1999.
5. G. F. Franklin, J. D. Powell, and A. E. Naeini, *Feedback Control of Dynamic Systems*, 4th ed. Prentice Hall, 2002.
6. R. C. Dorf and R. H. Bishop, *Modern Control Systems*, 11th ed. Pearson Education, 2008.
7. J. J. D. Azzo and C. H. Houpis, *Linear Control System Analysis and Design*, 4th ed. McGraw-Hill Publishers, 1995.

ME3025D NONLINEAR DYNAMICS AND CHAOS

Pre-requisites: ZZ1001D Engineering Mechanics

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:
CO1: Understand nonlinear systems, through discrete time systems or maps.
CO2: Comprehend dynamics of nonlinear continuous-time periodic dynamical systems.
CO3: Analyze continuous time systems using fractal characteristics.

Module 1: (13 hours)
Introduction to dynamical systems: discrete and continuous time systems, autonomous and non-autonomous systems, discrete time systems; one-dimensional map, fixed points of maps and their stability, bifurcation of maps, chaotic solutions of maps, Henon map; continuous time systems, phase space and flows, attracting sets, concepts of stability.

Module 2: (13 hours)
Equilibrium solutions, fixed points and stability of continuous time systems: classification and stability of equilibrium solutions; periodic solutions: periodic solutions of continuous time dynamical systems, autonomous and non-autonomous systems, limit cycle, Poincaré section; bifurcation: local and global bifurcation of continuous systems, static and dynamic bifurcations, Hopf bifurcations; quasiperiodic solutions, circle map.

Module 3: (13 hours)
Continuous systems: Duffing's equation, Rossler equations, period doubling and Intermittency mechanisms; tools to identify and analyze motions: time history, state-space and pseudo state space, Fourier spectra, Poincare' sections and maps, Lyapunov exponents.
Fractals and dynamical systems: examples of fractals, Koch curve, Cantor set etc., fractal dimension: measures of fractal dimension; computational methods: shooting method, harmonic balance method, determination of Lyapunov exponents and fractal dimensions; applications of nonlinear dynamics.

References:

1. S. H. Strogatz, *Nonlinear Dynamics and Chaos*, 2nd ed. Westview Press, 2014.
2. A. H. Nayfeh and B. Balachandran, *Applied Nonlinear Dynamics*. John Wiley & Sons, 1995.
3. J. M. T. Thomson and H. B. Stewart, *Nonlinear Dynamics and Chaos*, 2nd ed. John Wiley & Sons, 2002.
4. F. C. Moon, *Chaotic and Fractal Dynamics*, 2nd ed. Wiley-VCH, 1992.
5. G. L. Baker and J. P. Gollub, *Chaotic Dynamics*, 2nd ed. Cambridge University Press, 2012.
6. H.-O. Peitgen, H. Jurgens, and D. Saupe, *Chaos and Fractals*, 2nd ed. Springer, 2004.
7. E. R. Scheinerman, *Invitation to Dynamical Systems*. Dover, 2012.
8. P. G. Drazin, *Nonlinear Systems*. Cambridge University Press, 1992.
9. R. L. Devaney, *An Introduction to Chaotic Dynamical Systems*, 2nd ed. Westview Press, 2003.
10. D. W. Jordan and P. Smith, *Nonlinear ordinary differential equations*, 4th ed. Oxford University Press, 2007.

ME3026D ENGINEERING FRACTURE MECHANICS

Pre-requisites: ME2003D Solid Mechanics / Equivalent

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse brittle failures using LEFM theories.
CO2: Analyse ductile failures using EPFM theories.
CO3: Analyse fatigue failure of components.

Module 1: Linear Elastic Fracture Mechanics (13 hours)
Introduction: historic overview of fracture mechanics, atomistic calculation of material strength; effect of flows on strength of a material; Griffith energy balance approach: Irwin's modification to the Griffith theory; R-curve approach; stress intensity factor approach; I, II & III modes of fracture; crack tip plasticity; Irvin approach; strip yield model; mixed mode problems, propagation of angled crack; testing of K_{IC}; ASTM E 399 standard; K-R curve testing

Module 2: Elasto Plastic Fracture Mechanics (13 hours)
Elasto-plastic fracture mechanics: J integral, nonlinear energy release rate, path independence of J integral; J as stress intensity parameter; crack tip opening displacement approach, relationship between J and CTOD, J integral testing of materials; CTOD testing of materials; two parameter fracture models: elastic T- stress, J-Q failure theories, imitations of two parameter fracture mechanics models.

Module 3: Fatigue (13 hours)
Fatigue crack propagation: empirical fatigue crack growth equations, Paris law, crack closure mechanisms, fatigue threshold, effect of environmental conditions of fatigue threshold; variable amplitude loading and fatigue-crack retardation; micro mechanisms of fatigue; testing of fatigue crack growth; life prediction in fatigue.
Environment-assisted cracking: stress corrosion cracking, hydrogen embrittlement.

Text book:
1. T. L. Anderson, *Fracture mechanics*, 4th ed. CRC Press, 2017.

References:
1. H. L. Ewalds and R. H. Wanhill, *Fracture Mechanics*, Edward Arnold Edition, 1984.
2. D. Broek, *Elementary Engineering Fracture mechanics*, 2nd ed. Springer, 1982.
3. K. Hellan, *Introduction to Fracture Mechanics*, 1st ed. McGraw-Hill, 1984.
4. P. Kumar, *Elements of Fracture Mechanics*, 1st ed. McGraw-Hill, 2017.

ME3027D FLUID POWER CONTROLS

Pre-requisites: ME2001D Fluid Mechanics / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: Describe the hydraulic and pneumatic systems with various pump and motors.
CO2: Explain various actuators like DCV, flow control valve, check valve, solenoid valve, push button for hydraulic and pneumatic system.
CO3: Identify the various ISO symbols for simple circuit design for both hydraulic and pneumatic systems.
CO4: Design hydraulic and pneumatic circuits for various industry applications.

Module 1: (13 Hours)

Introduction to oil hydraulics and pneumatics: their advantages and limitations, ISO symbols and standards in oil hydraulics and pneumatics, recent developments, applications; basic types and constructions of hydraulic pumps and motors: performance curves and parameters; hydraulic actuators; hydraulic control elements; direction, pressure and flow control valves: valve configurations, general valve analysis, valve lap; flow forces and lateral forces on spool valves; series and parallel pressure compensation; flow control valves; electro-hydraulic servo valves-specifications; selection and use of servo valves.

Module 2: (13 Hours)

Electro hydraulic servomechanisms: electro hydraulic position control servos and velocity control servos; basic configurations of hydraulic power supplies; bypass regulated and stroke regulated hydraulic power supplies; heat generation and dissipation in hydraulic systems; design and analysis of typical hydraulic circuits: use of displacement-time and travels-step diagrams; synchronization circuits and accumulator sizing; meter-in, meter - out and bleed-off circuits; fail safe and counter balancing circuits.

Module 3: (13 Hours)

Components of pneumatic systems: direction, flow and pressure control valves in pneumatic systems; development of single and multiple actuator circuits; safety circuits; valves for logic functions: time delay valve, exhaust and supply air throttling; examples of typical circuits using displacement-time and travel-step diagrams; cascade method; Karnaugh-Veitech mapping method; will-dependent control; travel-dependent control and time dependent control; combined control; program logic control (PLC); electro-pneumatic control and air hydraulic control; applications in assembly, feeding, metalworking, materials handling and plastics working of case studies.

References:

1. A. Esposito, *Fluid Power with applications*, 7th ed. Pearson, 2008.
2. J. L. Johnson, *Introduction to Fluid Power*, 1st ed. Delmar Cengage Learning, 2001.
3. P. Joji, *Pneumatic Controls*, 1st ed. Wiley India, 2008.
4. A. C. Morse, *Electro hydraulic Servomechanism*, 1st ed. McGraw-Hill (New York), 1963.
5. J. J. Pippenger and R. M. Koff, *Fluid Power Control systems*, McGraw-Hill (New York), 1959.
6. E.C. Fitch, *Fluid Power Control Systems*, McGraw-Hill (New York), 1966.
7. E. M. Khaimovich, *Hydraulic Control of Machine Tools, 1st ed. Pergamon, 1965*.
8. J. Watton, *Fluid Power Systems: Modeling, Simulation and Microcomputer Control*, Prentice Hall, 1989.
9. H. E. Merritt, *Hydraulic control systems*, 1st ed. Wiley, 1991.
10. J. P. Hasebrink and R. Kobler, *Fundamentals of Pnuematics/Electropeumatics*, FESTO, 1975.
11. W. Deppert and K. Stoll, *Pneumatic Control-An introduction to the principles*, Vogel-Verlag, 1975.
12. B. W. Andersen, *The analysis and Design of Pneumatic Systems*, Krieger Pub. Co., 2001.
13. J. F. Blackburn, G. Reethof, and J.L. Shearer, *Fluid Power Control*, MIT Press, 1966.

ME3028D ADVANCED THERMODYNAMICS

Pre-requisites: ME2013D Thermodynamics / Equivalent

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Understand the thermodynamic principles in detail.
CO2: Solve practical thermodynamics related problems.
CO3: Analyze real life issues on the basis of entropy.
CO4: Perform calculations related to chemical and irreversible thermodynamics.

Module 1: (13 hours)
General principles of classical thermodynamics; overview of microscopic thermodynamics; first law analysis; integral and differential forms; second law and entropy evaluation; local and global equilibrium; maximum entropy and minimum energy principles; availability analysis including chemical availability.

Module 2: (13 hours)
Postulatory thermodynamics: postulates for simple systems; entropy and energy based equations; state relationship for real gases and liquid; two and three parameter equations of state; thermodynamic properties of pure fluids and its evaluation; thermodynamic properties of mixtures; phase equilibrium and stability.

Module 3: (13 hours)
Chemically reacting systems; combustion and thermochemistry; mass conservation and mole balance equations; reaction direction and chemical equilibrium; first and second law analysis of reacting systems; adiabatic flame temperature and isothermal combustion; introduction to irreversible thermodynamics; entropy production and Onsager relations.

References:
1. K. Annamalai and I. K. Puri, *Advanced Thermodynamics Engineering,* 2nd ed. CRC Press, 2011.
2. M. W. Zemansky, M. M. Abbot, and H. C. Van Ness, *Basic Engineering Thermodynamics*, 2nd ed. McGraw-Hill, 1975.
3. M. A. Saad, *Thermodynamics for Engineers*. Prentice Hall of India, 1987.
4. K. Wark Jr., *Advanced Thermodynamics for Engineers*. McGraw-Hill, 1995.
5. J. P. O' Connell and J. M. Haile, *Thermodynamics – Fundamentals for Applications*. Cambridge University Press, 2004.

ME3029D COMPUTATIONAL METHODS IN ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Solve and analyze engineering problems using computational methods.
CO2: Develop programs to compute derivatives and integrals numerically for engineering problems.
CO3: Analyze engineering data and fit most appropriate curve to the data.
CO4: Solve algebraic and differential equations numerically for engineering applications.

Module 1: (11 hours)
Introduction; basic considerations in numerical methods: round-off error, truncation error, accuracy of numerical results, numerical stability, conditions for convergence of numerical results, rate of convergence, termination of iterations, step-size, and convergence criterion; finite difference method for numerical differentiation: Taylor series expansion and polynomial fitting approaches, higher order accuracy approximations.

Module 2: (15 hours)
Root of equations: search method for real roots, bisection method, Newton-Raphson method; numerical solution of system of linear algebraic equations: Gaussian elimination, tridiagonal matrix algorithm, Jacobi iteration, Gauss-Seidel iteration; numerical curve fitting and interpolation: exact fit with an *n*th order polynomial, uniformly spaced independent variable, Lagrange interpolation, Newton‘s divided-difference interpolating polynomial, linear regression, best fit with a polynomial.

Module 3: (13 hours)
Numerical integration: rectangular and trapezoidal rules, Simpson‘s rules, Richardson extrapolation, Romberg integration, higher-order Newton-Cotes formulae, unequally spaced data, adaptive quadrature, Gauss quadrature; numerical solution of ordinary differential equations: Euler‘s method, Heun‘s method, modified Euler‘s method, Runge-Kutta methods, predictor-corrector methods.

References:

1. Y. Jaluria, *Computer Methods for Engineering with MATLAB Applications*, 2nd ed. CRC Press, 2012.
2. S. C. Chapra and R. P. Canale, *Numerical Methods for Engineers*, 6th ed. McGraw-Hill, 2012.
3. D. V. Griffith and I. M. Smith, *Numerical Methods for Engineers: A Programming Approach*. CRC Press, 1991.

ME3030D NEWTONIAN AND ANALYTICAL MECHANICS

Pre-requisites: ZZ1001D Engineering Mechanics

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Formulate and solve engineering mechanics problems in system of particles and rigid body kinematics.
CO2: Solve 3-dimensional dynamics problems of rigid bodies.
CO3: Solve practical problems using the concepts of analytical mechanics.

Module 1: (14 hours)

Review of particle kinematics and dynamics: rectangular, path variables and cylindrical coordinate systems; Newton's Law for system of particles, work-energy equations for system of particles, work-energy expression based on center of mass, linear momentum considerations for a system of particles, impulsive forces, impact, moment-of-momentum method for a system of particles.

Kinematics of rigid bodies: translation and rotation of rigid bodies, Chasles' theorem, derivative of a vector fixed in a moving reference, applications of the fixed-vector concept, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of a particle for different references.

Module 2: (14 hours)

Moments and products of inertia: formal definition of inertia quantities, translation of coordinate axes, transformation properties of inertia terms, principal moments of inertia.

Energy and impulse momentum methods for rigid bodies: kinetic energy of rigid body, work-energy relations, angular momentum of a rigid body about any point in the body, impulse-momentum equations, impulsive forces and torques.

Dynamics of general rigid-body motion: Euler's equations of motion and applications, three-dimensional motion about a fixed point: Euler angles, equations of motion using Euler angles, introduction to gyroscope.

Module 3: (11 hours)

Introduction to analytical mechanics: principle of virtual work, D'Alembert's principle, Lagrange's equations of motion, applications in dynamics and vibrations.

Introduction to variational calculus: Euler-Lagrange equation, Hamilton's principle, introductory problems in variational calculus, analysis of simply supported beam with uniform load, elementary vibration problems.

References:

1. I. H. Shames, *Engineering Mechanics –Statics and Dynamics*, 4th ed. Prentice Hall of India, 2005.
2. F. P. Beer and E. R. Johnston, *Vector Mechanics for Engineers*, 10th ed. McGraw-Hill, 2013.
3. J. L. Meriam and L. G. Kraige, *Engineering Mechanics – Dynamics*, 7th ed. John Wiley & Sons, 2012.
4. L. Meirovitch, *Elements of Vibration analysis*, 2nd ed. McGraw-Hill, 2007.
5. K. B. M. Nambudiripad, *Variational Methods in Engineering*. Narosa, 2016.
6. L. Meirovitch, *Methods of analytical Mechanics*. McGraw-Hill, 1970.
7. F. B. Hildebrand, *Methods of applied mathematics*, 2nd ed. Prentice Hall of India, 1972.

ME3031D THEORY OF PLASTICITY

Pre-requisites: ME2003D Solid Mechanics / ME3023D Theory of Elasticity

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:
CO1: Develop general formulations of problems in plasticity based on fundamental concepts.
CO2: Perform elastic-plastic analysis of structural elements like beams and shafts.
CO3: Analyze metal forming problems using the fundamentals of theory of plasticity.

Module 1: (12 hours)
Review of theory of elasticity: mathematical preliminaries, stress and strain tensor, transformation laws, principal stress and strain, Mohr's circle, equilibrium equations, strain-displacement relations, compatibility conditions, stress-strain relations, general problem formulation and solution strategies.
Introduction to the theory of plasticity: experimental observations on behaviour of metals under uni-axial tension and compression, true stress-true strain relations, effect of work hardening, empirical stress-strain relations for work hardening materials.

Module 2: (12 hours)
Yield criterion: stress space representation of yield criterion, representation of Tresca and von Mises criterion, yield surface for work hardening materials,
Stress-strain relations in the plastic range: Prandtl-Reuss, Levy-Mises and St. Venant's stress-strain relations, plastic potential, principle of maximum work dissipation.
Classical methods for solution: slip line field theory, bound theorems and their applications.

Module 3: (15 hours)
Elastic-plastic analysis of mechanical components: pure bending of a beam, torsion of circular bar, thick spherical and cylindrical shells under internal pressure, rotating disks, Plane strain problems.
Application of theory of plasticity to analysis of metal forming operations: drawing and extrusion of strips and wires, rolling, deep drawing and forging.

References:

1. J. Chakrabarty, Theory of Plasticity, 3rd ed. Butterworth-Heinemann, 2011.
2. W. Johnson and P. B. Mellor, *Engineering Plasticity*. McGraw-Hill, 1987.
3. O. Hoffman and G. Sachs, *Introduction to the theory of Plasticity for Engineers*. McGraw-Hill, 1953.
4. R. Hill, *The Mathematical Theory of Plasticity*, 2nd ed. Oxford University Press, 2009.

ME3032D AUTOMOBILE ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Troubleshoot automobile engines.
CO2: Understand the latest transmission and other systems in automobiles.
CO3: Appreciate the significance of air pollution control and the use of electric vehicles.

Module 1: (13 hours)
IC Engines: two stroke and four stroke engines; SI and CI engines; constructional details; engine parts; cooling system: air cooling, water cooling; lubrication system and components; fuel system and components: types of carburettors, electronic fuel injection system, multi point fuel injection system, gasoline direct injection system, air-assisted fuel injection system, common rail direct injection system; air intake system: variable valve timing technologies, supercharger/turbo chargers; electronic ignition system, distributor less ignition system; starting systems and drives: alternators and charging circuits.

Module 2: (20 Hours)
Transmission: clutch, types of clutches; torque convertor; gear box: sliding-mesh, constant-mesh, synchro-mesh; planetory gear box transmission; dual-clutch transmission; CVT; electronics for automatic transmissions; cruise control; propeller shaft and joints; differential; LSD; axles.
Brakes: mechanical and hydraulic brakes, power-assisted brake, air brakes, anti skid braking system (ABS), electronic brake force distribution system (EBD).
Steering mechanism: steering geometry, steering gears, power-assisted steering.
Chassis and suspension: chassis lay out, active, semi active and passive suspension systems, dampers and springs, rigid axle and independent suspensions, air suspension systems, wheels, tyres and tubes

Module 3: (6 hours)
Air pollution: exhaust emissions, emission norms, exhaust treatment technologies, standards and regulations.
Hybrid and electric vehicles; electric drive-trains: DC motor drives, induction motor drives, drives and control circuits; energy storage: battery, fuel cell, super capacitor.

References:

1. K. Newton, W. Steeds, and T. K. Garret, *Motor Vehicle*, 13th ed. Butterworth-Heinemann, 2004.
2. W.H. Crouse and D. L. Anglin, *Automotive Engines*, 8th ed. McGraw-Hill, 1995.
3. H. Heisler, Advanced Vehicle Technology, 2nd ed. Butterworth–Heinemann, 2002.
4. W. H. Crouse and D. L. Anglin, *Automotive Transmission and Power Trains construction*, 10th ed. McGraw Hill, 2008.
5. W. H. Crouse and A. L. Anglin, *Automotive Emission control*. McGraw Hill, 1995.
6. W. H. Crouse and D. L. Anglin, *Automotive mechanics*, 10th ed. Tata McGraw-Hill, 2004.
7. V. Sajith and S. Thomas, *Internal Combustion Engines*, 1st ed. Oxford University Press, 2017.
8. M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*. CRC Press, 2004.
9. I. Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*. CRC Press, 2003.

ME3121D POWDER METALLURGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Describe the different powder production techniques used in P/M.
CO2: Explain the different compaction techniques used for shaping of P/M parts.
CO3: Analyze the different sintering mechanism and their effects on sintered parts.
CO4: Design the different P/M stages for making various engineering components.

Module 1: (12 hours)
Versatility and benefits of powder metallurgy; PM process; powder production techniques: mechanical, atomization, chemical reduction, carbonyl and electro-chemical processes; ceramic powder production; powder properties and their characteristics; sieve analysis, microscopy, sedimentation analysis; specific surface and other technological properties; powder conditioning.

Module 2: (15 hours)
Compaction and shaping; cold and iso-static compaction, die compaction, pressing equipments and tooling; powder injection moulding; extrusion and rolling; hot compaction techniques: hot iso-static pressing (hip), equipments, tooling and applications; explosive compaction; slip casting.
sintering stages, single component, material transport mechanisms; model studies: powder shrinkage experiments; sintering diagrams and sintering anomalies; multi-component sintering: solid phase and liquid phase, infiltration and reaction sintering; sintering atmospheres and equipments.

Module 3: (12 hours)
Powder metallurgy products: HSS and carbide tools, porous parts, sintered carbides, cermets, electric and magnetic parts; ceramic components, sintered friction materials; P/M parts of the year; research trends in powder metallurgy.

References:

1. F. Thummler and R. Oberacker, *An introduction to Powder Metallurgy.* The Institute of Materials, The University Press, 1993.
2. ASM Handbook (Vol 7), *Powder Metal Technologies and Application*, 1984.
3. F. Leander and W. G. West, *Fundamentals of Powder Metallurgy.* Metal Powder Industries Federation, 2002.
4. G. S. Upadhyaya, *Powder Metallurgy Technology,* 1st ed. Cambridge International Science Publishing Co, 2002.
5. A. K. Sinha, Powder *Metallurgy.* Dhanpat Rai Publications, 2003.
6. P. C. Angelo and R. Subramanian, *Powder Metallurgy,* 1st ed. Prentice Hall of India, 2008.

ME3122D INTRODUCTION TO MARKETING

Pre-requisites: ME2111D Essentials of Management / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Outline the fundamental concepts of marketing, marketing environment and marketing planning.
CO2: Segment and target a market with proper positioning of products and also to price the products.
CO3: Conduct market research and consumer research.
CO4: Price the products, communicate about the product and effectively utilize various sales promotion tools.
CO4: Understand the concepts of product development process, advertising and sales promotion.

Module 1: (13 Hours)

Introduction to marketing: marketing definitions, important terms in marketing, evolution of marketing; scope of marketing; value and satisfaction; philosophies of marketing; functions of marketing; marketing environment; auditing a marketing environment: SWOT, PEST, five force analysis.

Module 2: (13 Hours)

Product life cycle; marketing planning process; SBU, evaluation of SBUs; market segmentation: process of segmentation, basis of market segmentation, criteria for market segmentation; marketing mix variables; market targeting; positioning: types and errors; marketing research: marketing research process, research objectives, research plan development, collecting information, marketing analytics.

Module 3: (13 Hours)

Pricing: factors influencing pricing, types of pricing; consumer behavior: factors influencing consumer behaviour; new product development; advertising management, sales promotion.

References

1. P. Kotler, K. L. Keller, A. Koshy, and M. Jha, *Marketing Management*, 13th ed. Prentice Hall of India, 2009.
2. V. S. Ramaswamy and S. Namkumari, *Marketing Management*, 4th ed. Om Books, 2010.
3. W. J. Stanton, M. J. Etzel, and B. J. Walker, *Fundamentals of Marketing*, McGraw-Hill International Edition, 1991.

ME3123D DESIGN AND ANALYSIS OF MANAGEMENT INFORMATION SYSTEMS

Pre-requisites: ME2111D Essentials of Management / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Define the term data and information and illustrate the building blocks in information systems.
CO2: Understand the information system design and comprehend with various charting tools and designing forms.
CO3: Perform Verification and validation of a software system and understand capability maturity model.
CO4: Understand the software testing approaches and recent developments in information systems.

Module 1: (13 hours)

Concepts of data and information: producing information from data, economies of information, analysis of system, management and formal information system concepts; building blocks in information systems: system design forces, information development life cycle, information systems for strategic planning.

Module 2: (13 hours)

General steps in Information system design; systems investigation and requirements engineering; system analysis and general system design; charting tools for system analysis and design.
Introduction to database management: classification of data items, coding considerations, types of code structures, forms design; general file storage considerations: composition and classification of data files, selection consideration for file media and file organization methods; concepts of data structures, data association, sorting and searching techniques.

Module 3: (10 hours)

System implementation: verification and validation of software system, software metric and models, introduction to capability maturity model, software testing approaches, training and post implementation audit; recent developments in information systems; security features in global information systems.

References:

1. J. G. Burch Jr. and G. Grudnitski, *Information Systems: Theory and Practice*, 5th ed. John Wiley & Sons, 1989.
2. I. T. Hawryszkiewycz, *Introduction to Systems Analysis and Design*, Prentice Hall of India, 1989.
3. I. Sommerville, *Software Engineering*, 6th ed. Pearson Education Asia, 2001.
4. H. C. Lucas, *Analysis, Design, and Implementation of Information Systems*, 4th ed. McGraw-Hill, 1992.
5. J. A. O' Brien, *Management Information Systems*, 4th ed. Tata McGraw-Hill, 1999.

ME3124D WORK DESIGN AND MEASUREMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the fundamental concepts of productivity, work design and work measurement.
CO2: Apply various techniques of engineering work methods, work measurements, anthropometric data measurements.
CO3: Judge the application of fundamental principles in working conditions.
CO4: Devise solutions for the real-world problems in work environment design.

Module 1: (11 hours)

Productivity concept and definitions, measurement approaches at the enterprise, factors contributing to productivity improvement.

Work design: methods study, scope of work design, procedure for methods study: process analysis, process charts, operation analysis; manual work design, principles of motion economy, manual work and design guidelines: energy expenditure, heart rate, subjective ratings of perceived exertion, NIOSH lifting guidelines, multitask lifting guidelines.

Module 2: (13 hours)

Work measurement, objectives; time study equipment, time study elements; execution of study; allowances: constant and variable fatigue allowances, special allowances; atmospheric conditions: noise level, illumination levels, visual and mental strain; performance rating methods: calculation of standard time, synthesis of standard data, introduction to pre-determined time systems, Maynard Operation Sequence Technique (MOST); Work sampling, planning the work sampling study.

Module 3: (14 hours)

Work environment design: nature of man-machine systems, characteristics; working conditions: illumination, noise, temperature, vibration, radiation; shift work and working hours,

Design of cognitive work: information theory, human information processing model, perception and signal detection theory, memory, Hick-Hyman law, design principles for display of visual information: quantitative and qualitative displays, visual codes, symbols and signs, design principles for display of auditory information, human-computer interaction, hardware and software considerations.

Ergonomics: engineering anthropometry and work-space design, statistical basis of anthropometry, use of anthropometric data in design.

Text book:

1. A. Freivalds and B. W. Niebel, *Niebel's Methods, Standards and Work Design*, 12th ed. McGraw-Hill, 2008.

Reference:

1. R. M. Barnes, *Motion and Time Study: Design and Measurement of Work,* 7th ed. John Wiley & Sons, NY, 2002.
2. M. S. Sanders and E. J. McCormick, *Human Factors in Engineering and Design*, 6th ed. McGraw-Hill, 1987.
3. G. Salvendy, *Handbook of Human Factors & Ergonomics*. Inter-science, 1997.
4. M. P. Groover, *Work Systems and the Methods, Measurement, and Management of Work*. Pearson Prentice Hall, 2007.

ME3125D COST ANALYSIS AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Estimate and control the costs of goods manufactured and sold and the overheads cost.
CO2: Estimate the product and process costs applying different tools.
CO3: Analyse and control the variances to identify the problems.
CO4: Analyse the costs and variances for decision making process.

Module 1: (14 hours)
Accounting concepts: rules of debit and credit, journal entries, ledger posting; cost concepts: income measurement, profit planning, control, decision making; costing and control of materials: system of accounting for materials issued, inventory control techniques, economic order quantity, reorder point, safety stock; cost of inventory and costing methods; costing and control of labour: wage plans, labour turnover; costing and control of factory (manufacturing) overheads; costing and control of administrative, selling and distribution overheads.

Module 2: (12 hours)
Job-order and batch costing: accounting for manufacturing overheads, accounting for non-manufacturing overheads; process, joint and by-product costing: cost accumulation in process costing, determination of equivalent units, normal and abnormal losses; joint products: allocation of joint costs, sell or process further (by-product costing); variable costing and absorption costing, activity drivers, activity-based costing system.

Module 3: (13 hours)
Volume-cost-profit analysis: application of breakeven analysis, construction and interpretation of breakeven chart and volume-profit graph; standard costs and quality costs; cost variance analysis: material, labour and overhead variances; revenue and profit variance analysis; responsibility accounting, short-run decision analysis for different decision situations.

References:

1. M. Y. Khan and P. K. Jain, *Management Accounting: Text, Problems and Cases*, 4th ed. Tata McGraw-Hill, 2009.
2. C. T. Horngren, S. T. Datar, D. Foster, M. V. Rajan, and C. Ittner, *Cost Accounting: Managerial Emphasis*, 13th ed. Pearson, 2009.
3. M. Y. Khan and P. K. Jain, *Cost Accounting and Financial Management*. Tata McGraw-Hill, 2008.

ME3126D SUPPLY CHAIN MANAGEMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the fundamental concepts in supply chain management.
CO2: Analyze the role of logistical drivers in a supply chain.
CO3: Model a supply chain network and solve using solvers.
CO4: Perceive case studies on real world supply chain decisions and apply problem solving methods.

Module 1: (13 hours)
Introduction and a strategic view of supply chains: decision phases in a supply chain, process views of supply chain; enablers of supply chain performance; supply chain performance in India: challenges in maintaining supply chain in India; supply chain strategy and performance measures, supply chain performance measures, enhancing supply chain performance; supply chain drivers, framework for structuring drivers.

Module 2: (13 hours)
Introduction to inventory management: types of inventory, inventory related costs; managing inventories in a supply chain: single stage inventory control, inventory control policies, impact of service level on safety stock; transportation strategy: distribution network design options for a transportation network, vehicle scheduling in transportation.

Module 3: (13 hours)
Network design and operation decisions, framework for network design decisions; facility location and capacity allocation models: network optimization models, capacitated plant location models, gravity location models, network operations model, model building using Excel solver; innovations in supply chains; supply chain coordination: Bullwhip effect, quantifying the bullwhip effect, remedial strategies for coping with the bullwhip effect.

References:

1. J. Shah, *Supply Chain Management –Text and Cases*. Pearson Education, 2016.
2. S. Chopra and P. Meindel, *Supply Chain Management: Strategy, Planning, and Operation*. Pearson Prentice Hall of India, 2016.
3. D. S. Levi, P. Kaminsky, E. S. Levi, and R. Shankar, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*. Tata McGraw-Hill, 2008.
4. R. B. Chase, R. Shankar, F. R. Jacobs, and N. J. Aquilano, *Operation and Supply Chain Management*. Tata McGraw-Hill, 2010.
5. J. F. Shapiro, *Modeling the Supply Chain*. Thomson Learning, 2007.

ME3127D MANAGEMENT OF ORGANISATIONAL BEHAVIOUR

Pre-requisites: ME2111D Essentials of Management / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Summarize the foundations of organizational behavior and work related attitudes.
CO2: Ability to communicate and lead a group and understand group behavior.
CO3: Explain the organizational process and organizational culture.
CO4: Examine organizational change, stress management and decision making on stress in organizations.

Module 1: (13 Hours)

Introduction to Organizational Behaviour (OB): development and challenges, assumptions of contemporary OB; foundations of individual behaviour values: attitudes, personality, emotions, perception, abilities, motivation in organisations, work related attitudes.

Module 2: (13 Hours)

Group Process: foundations of group behavior, understanding team, communication, leadership, power, conflict and negotiation.

Module 3: (13 Hours)

Organisational Process: work design and technology, organisation structure and design, organisational culture; special topics: organisational change, stress management, decision making in organisations.

References

1. S. P. Robbins and T. A. Judge, *Organisational Behavior*, 16th ed. Pearson Education, 2014.
2. J. Greenberg and R. A. Baron, *Behavior in Organisations*, 9th ed. Pearson, 2008.
3. S. McShane and M. A. Von Glinow, *Organisational Behavior*, 7th ed. McGraw-Hill, 2014.
4. P. Hersey, K. H. Balaschard, and D. E. Johnson, *Management of Organisational Behavior*, 10th ed. Pearson Education, 2012.

ME3129D MANAGEMENT OF HUMAN RESOURCES

Pre-requisites: ME2111D Essentials of Management / Equivalent

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Explain the topology of companies and HR Planning.

CO2: Ability to recruit, select and train individuals in an organization and perform job evaluation and merit rating.

CO3: Examine industrial relations and grievance handling mechanisms.

CO4: Develop strategies of organizational design, dimensions and work organization.

Module 1: (13 Hours)

Human Resource Management: historical evolution, topology of companies, concept of an involved employee, HR issues, corporate and HR strategy, linking business and HR planning, HR instruments, diversity issues.

Module 2: (13 Hours)

Personnel Management: personnel functions, personnel management environment in India, manpower planning, recruitment, selection and Induction of employees, staff training and development, career planning, job analysis and design, compensation planning, salary administration, job evaluation, merit rating, incentive schemes.

Module 3: (13 Hours)

Industrial Relations: managing industrial relations; labour laws; trade union; employee discipline; grievance handling mechanisms; suspension, dismissal and retrenchment; industrial conflict resolution, collective bargaining; recent issues in industrial relations; turnover; organizational development: organizational design, dimensions, restructuring strategies; work organization; organizational development; change agents, process of organizational change.

References:

1. R. S. Dwivedi, *Manpower Management – An Integrated Approach to Personnel Management and Labour Relations*. Prentice-Hall of India, 1984.
2. D. Yoder and P. D. Staodohar, *Personnel Management and Industrial Relations*. Prentice-Hall of India, 1986.
3. A. Monappa and M.S. Saiyadain, *Personnel Management*. Tata McGraw-Hill, 1988.
4. N. D. Kapoor, *Introduction to Commercial and Industrial Law.* Sultan Chand & Sons, 1986.

ME3130D QUALITY PLANNING AND ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Estimate the process parameters applying statistical models.
CO2: Design the experiments and interpreting the results.
CO3: Design and Construct of control charts for quality control.
CO4: Design the sampling plans and understand the sensitivity of the plans.

Module 1: (13 hours)
Introduction to quality management, history, definition; responsibility for quality, cost of poor quality, TQM framework; customer satisfaction: customer perception of quality, voice of customer; continuous process improvement; describing variation: important discrete distributions, important continuous distributions, probability plots; point estimation of process parameters, statistical inference for a single sample, two samples.

Module 2: (13 hours)
Analysis of Variance: single factor experiment, two factorial experiment, linear regression models; chance and assignable causes; variable and attribute charts; rational subgrouping; control charts for variables: average, range chart, average, standard deviation chart; control charts for attributes; chart for fraction nonconforming; chart for count of non-conformities; construction of operating characteristic curves.

Module 3: (13 hours)
Process capability: Six Sigma; types of sampling plans: single sampling plan, double sampling plan; design of sampling plan; construction of operating characteristic curve; acceptance quality level; average time to inspection, average outgoing quality; reliability – life-history curve, system reliability, testing.

References:

1. D. C. Montgomery, *Statistical Quality Control*, 6th ed. Wiley, 2009
2. J. M. Juran, and F. M. Gryna, *Quality Planning and Analysis*, 3rd ed. Tata McGraw-Hill, 1995.
3. E. L. Grant and R. S. Leavenworth, *Statistical Quality Control*, 7th ed. Tata McGraw-Hill, 2000.
4. D. H. Besterfield, *Quality Control*, 7th ed. Pearson Education, 2006.

ME4021D INDUSTRIAL TRIBOLOGY

Prerequisites: 1. ME2001D Fluid Mechanics / ME2004D Fluid Mechanics and Fluid Machinery
2. ME2003D Solid Mechanics / ME3023D Theory of Elasticity

Total Hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:
CO1: Understand the significance of tribology in various industrial applications.
CO2: Learn the surface characteristics of various materials.
CO3: Understand modern friction theories and wear mechanisms.
CO4: Study the hydrostatic and hydrodynamic journal bearings by 2D analysis.
CO5: Develop new lubricants.

Module 1: (15 hours)
Lubrication: introduction, basic equations; derivation of Reynolds equation; energy equation; idealized hydrodynamic bearings; mechanism of pressure development; plane slider bearings; idealized journal bearings; infinitely long and short bearings; finite bearings: performance characteristics, numerical solution, hydrodynamic instability.

Module 2: (13 hours)
Design of journal bearings; analysis of externally pressurized and gas lubricated bearings.
Wear: costs of wear; surface topography; mechanics of contact.
Theories of friction: friction of metals and non-metals; stick-slip; rolling friction; temperature of sliding surfaces.

Module 3: (11 hours)
Wear of metals: adhesive wear; abrasive wear; corrosion and corrosion wear; erosion; surface fatigue and impact wear; wear of elastomers; wear of ceramics and composite materials; measurement of friction and wear.

References:

1. B. C. Majumdar, *Introduction to Tribology*, 4th ed. A.H. Wheeler, Bangalore, 1978.
2. O. Pinkus and B. Sternlicht, *Theory of hydrodynamic lubrication*. McGraw-Hill, New York, 1961.
3. D. F. Moore, *Principle and Application of Tribology*. Pergamon Press, New York, 1975.
4. E. Rabinowicz, *Friction and Wear of Materials*, 2nd ed. John Wiley & Sons, New York, 1995
5. K. L. Johnson, *Contact Mechanics*. Cambridge University Press, 1985.
6. T. R. Thomas, *Rough Surfaces*, 2nd ed. Imperial College Press, 1999.

ME4022D VEHICLE DYNAMICS

Pre-requisites: ZZ1001D Engineering Mechanics

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Estimate the various forces acting on a vehicle.
CO2: Design the suspensions and steerings for a vehicle for optimum dynamics
CO3: Analyse the dynamic behaviour of two-wheelers.

Module 1: (12 Hours)
Forces and moments affecting a vehicle, dynamic axle loads, equations of motion, transmission characteristics, vehicle performance, power‐limited and traction‐limited acceleration, braking performance, brake proportioning, braking efficiency.
Aerodynamics: mechanics of air flow around a vehicle, pressure distribution on a vehicle, aerodynamic forces, drag components, aerodynamics aids.

Module 2: (13 hours)
Tire Mechanics: tire construction, size and load rating, terminology and axis system, tractive properties, cornering properties, camber thrust, aligning moment, combined braking and cornering.
Suspensions: suspension kinematics, suspension types, solid axles, independent suspensions, anti-squat and anti-pitch suspension geometry, anti-dive suspension geometry, roll center analysis, suspension dynamics, body and wheel hop modes.
The steering system: steering linkages, steering system forces and moments, steering system models, steering geometry, understeer and oversteer, effect of tire camber and vehicle roll, transient handling and directional stability, effect of vehicle roll on transient handling, steady-state and transient handling of articulated vehicles.

Module 3: (14 hours)
Motorcycle dynamics: kinematic structure of motorcycle, geometry of motorcycles, importance of trail, resistance forces acting on motorcycle (tire rolling resistance, aerodynamic resistance forces, resistant force caused by slope), location and height of motor cycle's centre of gravity (CG), moments of inertia on Motorcycle; introduction to front and rear suspensions of motorcycle; self-stabilizing motorcycle, un-ridable bicycles.

References:

1. T. D. Gillespie, *Fundamentals of Vehicle Dynamics*. Society of Automotive Engineers, 1992.
2. J. Y. Wong, *Theory of Ground Vehicles*, 4th ed. John Wiley and Sons, 2008.
3. H. Pacejka, *Tyre and Vehicle Dynamics*, 3rd ed. Butterworth-Heinemann, 2012.
4. M. Blundell and D. Harty, *The Multi body Systems Approach to Vehicle Dynamics*, 1st ed. Butterworth-Heinemann, 2004.

Additional Reference:

NPTEL: Prof. R. Krishnakumar, Vehicle dynamics, Engineering design department, IIT Madras.

ME4023D INTRODUCTION TO ROBOTICS

Pre-requisites: ZZ1001D Engineering Mechanics

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the subsystems, types, applications and history of robots.
CO2: Model robots kinematically using geometrical and analytical methods.
CO3: Model robots statically and dynamically.
CO4: Describe trajectory planning, robot programming and controller.

Module 1: (12 hours)
Introduction to robotics: brief history, types and applications of robots, present status and future trends in robotics, overview of robot subsystems challenges in robotics, characteristics of robots, robot applications, robot configurations and concept of work space, types of actuators and sensors in robotics, types of grippers.

Module 2: (15 hours)
Introduction to manipulator kinematics: position and orientation of rigid bodies, planar and spatial mechanism description, homogenous transformations, Denavit-Hartenberg (DH) notation, forward and inverse kinematic analysis, examples, case studies of modeling on real robot mechanism; linear and rotational velocity of rigid bodies: velocity propagation from link to link, jacobian, singularities; static forces in manipulators: jacobians in force domain.

Module 3: (12 hours)
Dynamic modeling: Lagrangian formulation, examples, trajectory generation: general consideration in path description and generation, joint space schemes, collision free path planning; robot control; robot programming methods.

Text Books:
1. J. J. Craig, *Introduction to Robotics, Mechanics and control*, 2nd ed. Addison-Wesley, 1999.

References:
1. R. K. Mittal and I. J. Nagarath, *Robotics and Control*. Tata McGraw Hill 2003.
2. S. B Niku: *Introduction to Robotics, Analysis, Systems and applications*, 2nd ed. Prentice Hall India, 2010.
3. M. W. Spong and M. Vidyasagar, *Robot Dynamics and Control*. John Wiley & Sons, 1989.
4. K. S. Fu, R. C. Gonzales, and C. S. G. Lee, *Robotics Control, Sensing, Vision and Intelligence*. McGraw Hill 1987.
5. R. P. Paul, *Robot Manipulators Mathematics Programming, Control, The computer control of robotic manipulators*. The MIT Press, 1979.
6. R. J. Schilling, *Fundamentals of Robotics, Analysis and Control*. Prentice Hall of India, 1996.

ME4024D DESIGN FOR MANUFACTURABILITY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the benefits of DFM and the management structure required.
CO2: Describe the application of various tools in DFM.
CO3: Apply DFM concepts in assembly, machining, forming processes.
CO4: Apply DFM concepts in forging, coating, materials.

Module 1: (16 hours)
Introduction: design philosophy, implementing DFM, benefits of DFM; concurrent engineering : design for quality, design for life cycle, design for cost, enabling technology, concurrent engineering and the organization, improving the development process; management frameworks: architecture, management's concerns with manufacturability, team building and training; justification of DFM, viewpoints for DFM quality tools in DFM: problem solving tools, quality function deployment, benchmarking, supplier involvement, Taguchi approach; computer aided technology: CAD/CAM/CAE, rapid prototyping, group technology, CIM; creative thinking in DFM, tools; general product design: impact of design concept and early project decisions, evaluating manufacturability of conceptual designs, producibility, geometric tolerancing

Module 2: (12 hours)
Design for assembly: principles, improving serviceability, recyclability; design for machining: principles, modern machining; design for forming: principles, fine blanking, roll forming, precision forming, metal spinning, tube fabrication.

Module 3: (11 hours)
Design for forging, casting; design for coating: painting, powder coating, metal spraying; design for heat treatment; design for fastening & joining: design guidelines for fasteners, adhesive assembly, welded assemblies; design for materials: plastics, composites, ceramics, powder metallurgy

References:
1. A. K. Chitale and R. C. Gupta, *Product Design and Manufacturing*. Prentice Hall of India, 1997.
2. G. E. Dieter, *Engineering Design - A Materials and Processing Approach*. McGraw Hill International, 1991.
3. R. Bakerjian, Ed., *Design for Manufacturability*, *Tool and Manufacturing Engineers Handbook*. Society of Manufacturing Engineers, 1992.

ME4025D MECHATRONICS

Pre-requisites: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Identify the Key elements and various subsystems in mechatronics
CO2: Understand the measurements of system performance and control aspects/methodologies
CO3: Identify the sensors and actuators for various applications
CO4: Explain the advanced applications in mechatronics

Module 1: (12 hours)

Introduction to mechatronics: key elements in mechatronics, design process, types of design: traditional and mechatronics designs; advanced approaches in mechatronics; real time interfacing; elements of data acquisition system.

Module 2: (12 hours)

Introduction to signals, system and controls; system representation, linearization, time delays, measures of system performance; closed loop controller: PID controller, digital controllers, controller tuning, adaptive control; introduction to microprocessors, micro-controllers and programmable logic controllers components, PLC programming.

Module 3: **(15 hours)**

Actuator and Sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force and temperature, flow sensors-range sensors, ultrasonic sensors, fibre optic sensors, magnetostrictive transducer, selection of sensors.

Advanced applications in mechatronics: sensors for condition monitoring, mechatronics control in automated manufacturing; artificial intelligence in mechatronics: fuzzy logic application in mechatronics, microsensors in mechatronics; case studies of mechatronics systems.

Text Book:

1. D. Shetty and R. A. Kolk, *Mechatronics System Design*, 2nd ed. Thomson Learning, 2001.

References:

1. W. Bolton, *Mechatronics*, 4th ed., Pearson education Asia, 2004.
2. D. Necsulescu, *Mechatronics.* Parson Education Asia 2002.
3. HMT Ltd*, Mechatronics*. Tata McGraw-Hill, 1998
4. B. P. Singh, *Microprocessors and Microcontrollers*, 1st ed., Galgotia Pub, 1997.
5. F. D. Petruzella, *Programmable Logic Controllers*, 3rd ed., Tata McGraw-Hill, 2010.
6. K. Kant, *Computer Based Industrial Control*, 2nd ed. PHI, 1999.

ME4026D RENEWABLE ENERGY SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Estimate the renewable energy potential for a specified location
CO2: Illustrate the applications of various renewable energy systems
CO3: Compute the energy conversion efficiencies of typical renewable energy systems
CO4: Assess the techno-economic viability of representative renewable energy systems

Module 1: (13 hours)
Introduction to sustainable energy, energy and environment, energy scenario and role of renewables; solar energy option: measurement and estimation of terrestrial solar radiation, solar thermal systems, analysis and testing of flat plate and concentrator systems, industrial process heating and power generation; photovoltaic conversion, commercial solar cells and efficiencies, photovoltaic systems and applications.

Module 2: (13 hours)
Wind energy conversion: wind resource assessment, modern wind turbines and their characteristics, power extraction and control strategies; small hydro power: resource assessment for small installations, classification of hydro turbines, performance analysis, selection and sizing; ocean thermal energy conversion: types of OTEC systems, practical considerations; geothermal energy: types of geothermal power plants, environmental aspects.

Module 3: (13 hours)
Biomass and biofuels: biomass energy conversion routes, combustion, gasification, pyrolysis, fermentation, anaerobic digestion for biogas, bio-diesel, biomass based power generation systems; hybrid energy systems integrating renewable and conventional sources; energy storage options; economic analysis: indices for economic evaluation of energy projects, levelized cost of energy, process chain analysis and embedded energy, Energy Return on Energy Invested.

References:
1. S. P. Sukhatme and J. K. Nayak, *Solar Energy*, 4th ed. McGraw Hill Publications, 2017.
2. J. F. Manwell, J. G. McGowan, and A. L. Rogers, *Wind Energy Explained-Theory, Design and Applications,* 2nd ed. Wiley, 2010.
3. J. Twidell and T. Weir, *Renewable Energy Resources*, 3rd ed. Routledge, 2015.
4. F. Kreith, *Principles of Sustainable Energy Systems,* 2nd ed. CRC Press, 2014.
5. G. Boyle, *Renewable Energy: Power for a Sustainable Future*, 3rd ed. Oxford University Press, 2012.

ME4028D AERODYNAMICS

Pre-requisites: ME2001D Fluid Mechanics / Equivalent

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply basic criterion to model the flying devices.
CO2: Model the lift in airfoils and wings.
CO3: Design novel wings with least drag.
CO4: Analyze the effect of compressibility on lift and drag.

Module 1: (14 hours)
Basic fluid flow equations, Reynolds transport theorem, integral and differential formulations of continuity and momentum equations, Navier-Stokes equation; equations for incompressible inviscid flows; fluid circulation and rotation, vorticity; stream function; velocity potential; complex potential; Blasius theorem for force and moment on bodies; governing equations for irrotational incompressible flow; elementary flow patterns and their superposition.

Module 2: (14 hours)
Flow past a cylinder: lifting flow and non-lifting flow; Magnus effect; Kutta-Joukowski theorem; conformal transformation: Joukowski transformation; airfoils: nomenclature; Kelvin's circulation theorem; vortex sheet; Kutta condition; thin airfoil theory: symmetric airfoil, cambered airfoil; airfoil characteristics: flow over airfoil; comparison with the real case; aerodynamic center, pitching moment.

Module 3: (11 hours)
Incompressible flow over finite wings: downwash and induced drag; vortex filament; Biot-Savart Law; Helmholtz theorems; horseshoe vortex; ground effects; Prandtl's lifting line theory: elliptic lift distribution, general list distribution; effect of aspect ratio: swept and delta wings; airfoils in compressible flow; small-perturbation theory.

References:

1. J. D. Anderson, *Fundamentals of Aerodynamics*, 5th ed. McGraw Hill, 2010.
2. E. L. Houghton, P. W. Carpenter, S. H. Collicott, and D. T. Valentine, *Aerodynamics for Engineering Students*, 6th ed. Butterworth-Heinemann, 2013.
3. A. M. Kuethe and C. Chow, *Foundations of Aerodynamics*: *Bases of Aerodynamic Design*, 5th ed. John Wiley and Sons, 1998.
4. L. Katz and A. Plotkin, *Low Speed Aerodynamics*. Cambridge University Press, 2001.

ME4029D HEATING, VENTILATION AND AIR CONDITIONING

Pre-requisites: Nil

Total hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Apply principles refrigeration and air conditioning processes to real systems.
CO2: Estimate the cooling load/heating load with respect to a location for air conditioning.
CO3: Identify the processes required for air conditioning, and design of various components and systems.
CO4: Design the air distribution system for air conditioning and ventilating.

Module 1: (10 hours)

Principles of refrigeration; Carnot refrigeration cycle; unit of refrigeration; capacity; coefficient of performance; refrigeration systems: vapour compression system; theoretical and practical cycles, system components, compressors, condensers, expansion devices, evaporators; refrigerants; air refrigeration cycle; vapour absorption refrigeration system.

Module 2: (16 hours)

Psychrometry: psychrometric processes; determination of condition of air entering conditioned space.
Air conditioning systems: summer, winter and year-round air conditioning systems, central and unitary systems; requirement of air conditioning; human comfort; comfort chart and limitations; effective temperature; factors governing effective temperature; design considerations; cooling load calculations; various heat sources contributing heat load, solar load, equipment load, infiltration air load, duct heat gain, fan load, moisture gain through permeable walls and fresh air load; design of air conditioning systems.

Module 3: (13 hours)

Duct design: equal friction method; static regain method; velocity reduction method; air distribution systems; analysis for heating and cooling systems; insulation.
Heating systems: warm air systems, hot water systems, steam heating systems, panel and central heating systems; heat pump circuit; heat sources for heat pump.
Air conditioning equipments and control systems: air filters, humidifiers, fan, blowers, control systems for temperature and humidity, noise control.
Installation and charging of refrigeration unit; testing for leakage; cause for faults and rectification.

References:

1. N. C. Harris, *Modern Air Conditioning Practice,* 2nd ed. McGraw-Hill, 1974.
2. W. F. Stoecker, *Refrigeration & Air conditioning*, 2nd ed. McGraw-Hill, 1987.
3. C. P. Arora, *Refrigeration & Air conditioning*, 2nd ed. McGraw-Hill, 2000.
4. W. F. Stoecker, *Principles of Air conditioning*, 2nd ed. Industrial press, 1977.
5. J. M. Laub, *Heating & Air Conditioning of Buildings*. Holt, Rinehart and Winston, 1963.
6. J. R. Kell and P. L. Martin, *Air conditioning & Heating of buildings*, 6th ed. Architectural Press, 2007.
7. Carrier's *Handbook for Design of Unit Air Conditioners*, 14th ed. Kenrick Place Media, 1996.
8. J. L. Levenhagen and D. H. Spethmann, *Heating Ventilating and Air Conditioning Controls and Systems*. McGraw-Hill, 1993.

ME4030D FUNDAMENTALS OF COMBUSTION

Pre-requisites: ME2013D Thermodynamics / Equivalent

Total hours: 39

L	T	P	C
3	0	0	3

Course Outcomes:
CO1: Apply basic criterion to model the combustion systems.
CO2: Model the laminar and diffusion flames.
CO3: Design the combustors.
CO4: Model and analyze the fuel droplet properties in combustion process.

Module 1: (15 hours)
Introduction to combustion; review of thermodynamic laws; reactants and products mixtures; combustion stoichiometry; standard enthalpies and enthalpy of formation; enthalpy of combustion and heating; adiabatic flame temperatures; chemical equilibrium: Gibb‘s function; chemical kinetics: global and elementary reactions; reaction rates; mechanisms: unimolecular, chain and chain-branching reactions; H_2–O_2 chemical mechanisms; reaction orders; temperature and pressure dependence on rate coefficients; explosion limits.

Module 2: (14 hours)
Premixed laminar flames: laminar flame structure; physical description; structure of CH_4-air flame; flame velocity and flame thickness; simplified and detailed analysis of laminar flame; effect of equivalence ratio on flame speed and flame thickness; flame quenching and ignition; flammability limits; laminar diffusion flames: structure of diffusion flame.

Module 3: (10 hours)
Droplet combustion and its applications; simple model for evaporating and burning droplet: conservation of mass; energy and species; burning rate constant and droplet lifetime; D^2 law; one dimensional vaporization: physical model and analysis.

References:

1. R. T. Stephen, *An Introduction to Combustion: Concepts and Applications*, 2nd ed. McGraw-Hill, 2000.
2. K. K. Kuo, *Principles of Combustion*, 2nd ed. John Wiley and Sons, 2005.
3. J. Warnatz, U. Maas, and R. W. Dibble, *Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation*, 4th ed. Springer, 2006.
4. I. Glassman and R. A. Yetter, *Combustion*, 4th ed. Academic Press, 2008.
5. F. W. Williams, *Combustion Theory*, 2nd ed. CRC Press, 1994.

ME4031D REFRIGERATION AND AIR CONDITIONING SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the principles of various refrigeration systems and components.
CO2: Design and maintain components of different refrigeration systems.
CO3: Analyze various air conditioning processes and select components and systems according to the estimated cooling load.
CO4: Design air distribution components and system for air conditioning.

Module 1: (13 hours)

Principles of refrigeration: Carnot refrigeration cycle; various methods of producing cold; performance parameters; capacity; coefficient of performance (COP); refrigeration systems; vapour compression system: theoretical and practical cycles, simple and multi-pressure systems; system components; other refrigeration systems: vapour absorption system; air cycle refrigeration; steam jet refrigeration; thermo-electric cooling and magnetic refrigeration; introduction to liquefaction systems, cascading, simple Linde-Hampson system, Claude cycle liquefier.

Module 2: (13 hours)

Components of refrigeration system; compressors: reciprocating compressors, single and multistage compressors, work of compression, effect of clearance, effect of inter-cooling, optimum pressure ratio, efficiencies, rotary compressors, screw type and vane type compressors; hermetic, semi hermetic and open compressors; condensers: water cooled and air cooled condensers, evaporative condensers; expansion devices: capillary tube; constant pressure expansion valve; thermostatic expansion valve; float valve; evaporators; vapour absorption system: principle of operation of aqua-ammonia and lithium bromide water systems; electrolux system; comparison between vapour compression and absorption systems.
Refrigerants: thermodynamic, physical and chemical properties of refrigerants; selection criteria of refrigerants; designating refrigerants.

Module 3: (13 hours)

Air conditioning: human comfort; comfort chart and limitations; effective temperature; factors governing effective temperature; design considerations; inside design condition; ventilation standards.
Applied psychrometry: summer air conditioning processes; winter air conditioning processes; other air conditioning systems; summer–winter and round the year air conditioning systems; central and unitary systems.
Cooling load calculations: various heat sources, solar load, equipment load, infiltration air load, duct heat gain, fan load, moisture gain through permeable walls and fresh air load.
Design of air conditioning systems; duct design: equal friction; static regain and velocity reduction methods; distribution systems; insulation; analysis for heating and cooling systems, air conditioning equipment and control systems; air filters; humidifiers; fan; blowers; control systems for temperature and humidity; noise and noise control.

References:

1. W. F. Stoecker and J. W. Jones, *Refrigeration & Air Conditioning*, McGraw Hill, 1982.
2. R. J. Dossat, *Principles of Refrigeration*, 4th ed. Pearson Education India, 2002.
3. R. C. Jordan and G. B. Priester, *Refrigeration & Air Conditioning*, 2nd ed. Prentice Hall of India, 1985.
4. C. P. Arora, *Refrigeration & Air Conditioning*, Tata McGraw-Hill, 1995.
5. W. F. Stoecker, *Principles of Air Conditioning*, Industrial Press, 1968.
6. J. M. Laub, *Heating & air conditioning of buildings*, Holt, Rinehart and Winston, 1963.
7. J. R. Kell and P. L. Martin, *Air conditioning & Heating of buildings*, 6th ed. Architectural Press, 2007.
8. *Carrier's Handbook for Design of Unit Air Conditioners*, McGraw Hill, 1965.
9. N. C. Harris, *Modern Air Conditioning Practice*, 3rd ed., McGraw Hill, 1985.
10. J. L. Levenhagen and D. H. Spethmann, *Heating Ventilating and Air Conditioning Controls and Systems*, McGraw-Hill, 1993.

ME4033D INTRODUCTION TO COMPUTER GRAPHICS

Pre-requisites: ZZ1004D Computer Programming

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: Apply fundamental knowledge in mathematics for generating and transforming graphic entities using computers.

CO2: Represent curves and surfaces mathematically.

CO3: Develop computer programs for displaying and manipulating curves, surfaces and solids using a computer.

Module 1 (13 hours)

Introduction to computer graphics: overview of computer graphics; mathematics for computer graphics; representing and interfacing with pictures; description of graphic devices; raster scan graphics, algorithms for generating line, circle and ellipse: polygon filling; fundamentals of anti-aliasing; two-dimensional and three-dimensional transformations: scaling, shearing, rotation, reflection, translation; affine and perspective geometry: orthographic, axonometric and oblique projections, perspective transformations.

Module 2 (13 hours)

Plane curves; non-parametric and parametric curves; space curves: representation of space curves, cubic spline, Bezier curves, B-spline curves, NURBS.

Module 3 (13 hours)

Surface description and generation: surface of revolution, sweep surface, linear Coons surface, Bezier surface, B-spline surface, B-spline surface filling; introduction to solid modelling, hidden lines and hidden surfaces.

References:

1. D. F. Rogers and J. A. Adams, *Mathematical Elements for Computer Graphics,* 2nd ed. Tata McGraw-Hill, 2017.
2. D. F. Rogers, *Procedural Elements for computer Graphics,* 2nd ed. Tata McGraw-Hill, 1997.
3. D. Hearn and M. P. Baker, *Computer Graphics,* 2nd ed. Pearson Education India, 2002.
4. J. D. Foley, A. van Dam, S. K. Feiner, and J. F. Hughes, *Computer Graphics: Principles and Practice in C,* 2nd ed. Pearson Education India, 2002.
5. M. E. Mortenson, *Geometric Modeling,* 3rd ed. Industrial Press Inc., 2006.

ME4034D EXPERIMENTAL METHODS IN FLUID FLOW AND HEAT TRANSFER

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse and select suitable instruments for experimental thermal studies.
CO2: Perform error analysis in experimental studies.
CO3: Develop systematic experimental plan for applications in thermal studies.

Module 1: (15 hours)
Introduction to experimental methods: basic concepts, accuracy, precision, resolution; experiment planning; analysis of experimental data, error analysis, evaluation of uncertainties, propagation of uncertainties, statistical analysis, the normal distribution; pressure measurements, dynamic response considerations, dead-weight tester, Bourdon-tube pressure gage, diaphragm and bellows gages, Bridgman gage, Pirani thermal conductivity gage, Knudsen gage, ionization gage, Alphatron.
Flow measurement: positive-displacement methods, flow-obstruction methods, sonic nozzle, flow measurement by drag effects, pressure probes, hot-wire and hot-film anemometers, magnetic flow meters, flow visualization methods: smoke methods, shadowgraph, Schlieren photography, laser Doppler anemometer, laser-induced fluorescence, particle image velocimetry.

Module 2: (11 hours)
Temperature measurements: temperature scales, ideal-gas thermometer, temperature measurement by mechanical effects, temperature measurement by electrical effects, temperature measurement by radiation, transient response of thermal systems, thermocouple compensation, temperature measurements in high-speed flow, interferometric method.

Module 3: (13 hours)
Transport-property measurements: thermal conductivity measurements, measurement of viscosity, gas diffusion, calorimetry, convection heat transfer measurement, humidity measurement, heat flux meters, pH measurement; thermal-radiation measurements: emissivity measurement, reflectivity and transmissivity measurement; solar radiation measurement; detection of nuclear radiation; air pollution sampling and measurement; gas sampling techniques; combustion products measurement.
.

References:

1. J. P. Holman, *Experimental Methods for Engineers*, 8th ed. McGraw-Hill, 2012.
2. R. S. Figliola and D. Beasley, *Theory and Design for Mechanical Measurements*, 6th ed. John Wiley & Sons, 2015.
3. E. O. Doebelin, *Measurement Systems*, 6th ed. McGraw-Hill, 2015.
4. J. R. Taylor, *An Introduction to Error Analysis,* 2nd ed. University Science Books, 1997.

ME4036D SURFACE ENGINEERING AND COATING TECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Identify mechanism of surface degradation and select suitable surface protection techniques.
CO2: Explain mechanisms, reactions and process parameters involved in various coating techniques.
CO3: Assess the properties of coatings and perform characterization of coatings

Module 1: (12 hours)
Introduction to surface engineering; scope of surface engineering for different engineering materials; surface preparation methods: chemical; electrochemical; mechanical: sand blasting; shot peening; shot blasting; hydro-blasting; vapor phase degreasing; etc., coatings: classification; properties and applications of various coatings; surface dependent engineering properties; common surface initiated engineering failures; mechanism of surface degradation; mechanisms of wear: abrasive; adhesive wear; contact fatigue; fretting corrosion; importance and necessity of surface engineering; classification and scope of surface engineering in metals, ceramics, polymers and composites; surface protection and surface modification techniques: classification; principles; methods; and technology; surface modification by use of directed energy beams: plasma; sputtering; ion implantation; surface modification by friction stir processing; surface composites.

Module 2: (15 hours)
Review of diffusion coatings: carburizing; carbonitriding; siliconizing; chromizing; aluminizing; boronizing; boronitriding; chemical conversion coating: chromating; phosphating; anodizing; thermochemical processes: methods used, mechanisms, important reactions involved, process parameters and applications; metallic coating: hot dipping; galvanizing; electrolytic and electro less plating; coating from vapour phase: PVD and CVD; methods used, mechanisms, important reactions involved, Process parameters and applications; thermal spray coatings: processes; types of spray guns; comparison of typical thermal spray processes; surface preparation; finishing treatment; coating structures and properties; applications; recent advances in coating technology: Diamond Like Carbon (DLC) coating; Nano Crystalline Diamond (NCD) coating.

Module 3: (12 hours)
Testing of coatings and inspection of thickness; adhesion, corrosion resistance and porosity measurement; testing wear resistance; practical diagnosis of wear; scratch resistance testing; ASTM and other standards for the testing of engineering coatings; characterization of coatings: physical characterization; assessment of coating hardness; assessment of friction and wear of coating; assessment of surface roughness and thickness of coating; assessment of adhesion of coating; surface microscopy & topography by scanning probe microscopy; spectroscopic analysis of modified surfaces; case studies: case studies based on coatings and surface modification of important engineering components.

References:

1. K. G. Budinski, *Surface Engineering for Wear Resistances*. Prentice Hall, 1988.
2. M. Ohring, *The Materials Science of Thin Films*, 2nd ed. Academic Press, 2002.
3. N. V. Parthasaradhy, *Practical Electroplating Handbooks*. Prentice Hall, 1992.
4. *ASM Handbook Surface Engineering*, 10th ed. ASM International, 1994.
5. D. R. Gabe, *Principles of Metal surface treatment and protection*, 2nd ed. Pergamon, 1990.
6. A. Niku-Lari, *Advances in surface treatments*. Pergamon, 1990.
7. J. R. Davis, *Surface Engineering for Corrosion and Wear Resistance*. CRC Press, 2014.
8. L. Pawlowski, *The Science and Engineering of Thermal Spray Coatings*, 2nd ed. Wiley, 2008.
9. S. Zhang, *Nano structured Thin Films and Coatings*. CRC Press, 2010.
10. P. M. Martin, *Handbook of Deposition Technologies for Films and Coatings*. William Andrew Publisher, 2009.
11. S. C. Cha and E. Ali, *Coating Technology for Vehicle Applications*. Springer, 2015.

ME4037D GAS DYNAMICS

Pre-requisites: 1. ME2001D Fluid Mechanics / Equivalent
2. ME2013D Thermodynamics / Equivalent

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyze the compressibility effects in flow properties
CO2: Design a nozzle for supersonic flows
CO3: Analyze the effects of irreversible mechanisms in supersonic flows
CO4: Design ducts with realistic situations for supersonic flows.

Module 1: (13 hours)
Basic fluid flow equations; Reynolds transport theorem; integral and differential formulations: integral form of continuity, momentum, energy equations; differential form of these equations, Navier-Stokes equation; introduction to compressible flows: equations for one-dimensional compressible flows, speed of sound, Mach number; qualitative difference between incompressible, subsonic and supersonic flows; adiabatic flow ellipse.

Module 2: (15 hours)
Quasi one-dimensional flow equations; isentropic flow through a duct; area-velocity relation; use of gas tables and charts; nozzles, diffusers; choking; operation of convergent-divergent nozzles: off-design operating conditions; normal shocks in one-dimensional flow: normal shocks relations, Prandtl's relation, Rankine-Hugoniot relations; oblique shocks, oblique shock relations, θβM relations; supersonic flow over a wedges, shock polar; Prandtl- Meyer expansion waves, and relations.

Module 3: (11 hours)
One-dimensional flow with friction: Fanno curves, and Fanno flow relations; effect of friction on flow properties, frictional choking; isothermal flow; one-dimensional flow with heat addition: Rayleigh curves, effect of heat addition, thermal choking; generalized one dimensional flows: one-dimensional flow with effects like mass addition, friction and heat transfer.

References:

1. J. D. Anderson, *Modern Compressible Flow with Historical Perspective*, 3rd ed. McGraw-Hill, 2017.
2. P. H. Oosthuizen and W. E. Carscallen, *Introduction to Compressible Fluid Flow*, 2nd ed. CRC Press, 2014.
3. H.W. Liepmann and A. Roshko, *Elements of Gas Dynamics*. Dover Publications, 2002
4. R. D. Zucker and O. Biblarz, *Fundamentals of Gas Dynamics*, 2nd ed. John Wiley & Sons, 2002
5. M. J. Zuckrow and J. D. Hoffman, *Gas Dynamics*, Vol.1. John Wiley & Sons, 1976.
6. A. H. Shapiro, *The Dynamics and Thermodynamics of Compressible Fluid Flow*, Vol.1. John Wiley & Sons, 1953.

ME4122D MECHANICAL BEHAVIOUR AND TESTING OF MATERIALS

Pre-requisite: ME2101D Materials Science and Metallurgy

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Describe various plastic deformation mechanisms of metals.
CO2: Explain the various strengthening mechanisms.
CO3: Identify the various failure mechanisms.
CO4: Suggest suitable testing methods for given applications.

Module 1: (15 hours)
Concepts of crystals; plastic deformation by slip and twinning, slip systems in FCC,BCC and hcp lattices; critical resolved shear for slip; theoretical shear strength of solids; stacking faults and deformation bands; observation of dislocations, geometric properties of dislocations, edge and screw dislocations, climb and cross slip, dislocations in FCC and HCP lattice, partial dislocations, stress fields and energies of dislocations, forces between dislocations; strengthening from grain boundaries; grain size measurements, yield point phenomenon; strain aging; solid solution strengthening, strengthening from fine particles, fiber strengthening; cold working and strain hardening; annealing of cold worked metal.

Module 2: (12 hours)
Fracture in metals: Griffith theory of brittle fracture, metallographic aspects of fracture, fractography, dislocation theories of brittle fracture, ductile fracture, notch effects; fatigue of metals: S-N curve, low cycle fatigue, fatigue crack propagation; effects of metallurgical variables and fatigue, corrosion fatigue, effect of temperature on fatigue. creep and stress rupture, creep curve, mechanism of creep formation, stress rupture test, activation energy for steady state creep, fracture at elevated temperature; creep resistant alloys.

Module 3: (12 hours)
Tension test: stress-strain curves, Instability in tension, ductility measurement; effect of strain rate, temperature and testing machine on flow properties; stress relaxation testing; hardness test: Brinell, Rockwell and Vickers hardness; flow of metal under the indenter; relationship between hardness and flow curve; micro hardness testing; torsion test: torsion stresses for large plastic strains; types of torsion failures.

References:
1. G. M. Dieter, *Mechanical Metallurgy,* 3rd ed. McGraw-Hill Inc, 2017.
2. R. W. Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials,* 4th ed. John Wiley & Sons, 1995.
3. F. A. McClintock and A. S. Argon, Mechanical Behavior of Materials, 1st ed. Addison-Wesley Publications, 1966.
4. R. E. Reed-Hill, *Physical Metallurgy Principles,* 2nd ed. Affiliated East-West Press, 2008.
5. H. W. Hayden, W. G. Maffott, and J. Wulff, *The Structure and Properties Of Materials, Vol. 3: Mechanical Behaviour*. John Wiley & Sons, 1965.
6. R. W. K. Honeycombe, *Plastic Deformation of Metals,* 2nd ed. Edward Arnold, 1984.

ME4123D TECHNOLOGY MANAGEMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Comprehend the technology environment.
CO2: Analyze the implications of environment during the development and diffusion process.
CO3: Strategize the developed product for the integration of the technology with business.
CO4: Evaluate the commercial potential of a new technology.

Module 1: (14 hours)
Technology: scope, definition and characteristics, strategic, operational and management issues, classification of technology; technology environment: the long-wave cycle, evolution of production technology, evolution of product technology; critical factors in managing technology: technology-price relationship, the timing factor, managing change, productivity and competitiveness, leaders versus followers; types of innovation output, classification of innovation, technology life cycle curves; diffusion of technology: dynamics of diffusion, Bass model of diffusion, mechanisms of diffusion, factors driving diffusion; case discussion: market life-cycles, transition and disruptions.

Module 2: (12 hours)
Introduction to business architecture, research and technology phase, research and development, product development phase; business strategy and technology strategy: methods used in strategic analysis and decision making, product evaluation matrix, BCG matrix, X-Y coordinate positioning matrix, M-by-N matrix, SWOT matrix; formulation of technology strategy: concept of core competence, creating the product-technology-business connection; case discussion on product development.

Module 3: (13 hours)
Technology planning framework; methods of knowledge mapping: chronological mapping, co-word based mapping, cognitive mapping, conceptual mapping; forecasting technology: S-curves, Delphi technique, morphological analysis; critical technology and technology maps; technology audit model: technology roadmap, B-TECH approach, technology evaluation; definition of intellectual property, importance of IPR; TRIPS and its implications; patent, copyright, industrial design and trademark.

References:
1. T. Khalil, *Management of Technology*. Tata McGraw-Hill, 2009.
2. V. K. Narayanan, *Managing Technology and Innovation for Competitive Advantage*. Pearson Education Asia, 2001.
3. G. H. Gaynor, *Handbook of Technology Management*. McGraw-Hill, 1996.
4. R. A. Burgelman, C. M. Christensen, and S. C. Wheelwright, *Strategic Management of Technology and Innovation*, 4th ed. Tata McGraw-Hill, 2011.
5. S. Shane, *Technology Strategy for Managers and Entrepreneurs*. Pearson Education, 2009.

ME4125D MANAGEMENT OF LEAN PRODUCTION SYSTEMS

Pre-requisites: Nil

Total Hours: 39

L	T	P	C
3	0	0	3

Course outcomes:

CO1: Comprehend the issues associated with the lean production system design.
CO2: Explain the need for small lot production in lean production.
CO3: Develop SMED method, analyse production system for improved equipment availability and develop kanban-based pull production control.
CO3: Understand the use of workcell in pull production.

Module 1: (14 hours)

Evolution of manufacturing; Toyota Production System: features; fundamentals of continuous improvement: continuous improvement as tactics and strategy, finding improvements: PDCA cycles, value analysis / value engineering, basic problem solving and improvement tools, value stream mapping, Nemawashi; value adding and waste elimination: Toyota's seven wastes, Lean principles, Five Ss; customer-focused quality: Total Quality Management, Six Sigma, statistical process control.

Module 2: (16 hours)

Small lot production: lot size basics, lot sizing, lot-size reduction, effect of lot size reduction on competitive criteria, case of large process batches.
Setup-time reduction: traditional approaches for setups, set-up reduction methodology: SMED, techniques for setup reduction.
Maintaining and improving equipment: equipment maintenance and competitiveness, equipment effectiveness, preventive maintenance programme, total predictive maintenance.
Pull production systems: production control systems, pull systems and push systems, conveyance Kanban, production Kanban, other mechanisms for signal and control.

Module 3: (9 hours)

Focused Factories and Group Technology: ways of doing work, facility layouts, Group Technology, Focused Factory, production flow analysis.
Workcells and cellular manufacturing: Workcell concepts, Workcell applications, Workcell design, Workers in cells, equipment issues.

Text Book:

1. J. Nicholas, *Lean Production for Competitive Advantage: A comprehensive Guide to Lean Methodologies and Management Practices*, CRC Press, 2010

References:

1. J. M. Nicholas, *Competitive Manufacturing Management: Continuous Improvement, Lean Production, and Customer-Focused Qualities*. Tata McGraw-Hill, 2001.
2. R. G. Askin and J. B. Goldberg, *Design and Analysis of Lean Production Systems*. Wiley Student Edition, 2007.
3. N. Singh and D. Rajamani, *Cellular Manufacturing Systems: Design, Planning & Control*. Chapman & Hall, 1996.
4. M. G. Korgaonker, *Just In Time Manufacturing*. Macmillan Publishers, 2000.

ME4126D OPTIMIZATION METHODS IN ENGINEERING

L	T	P	C
3	0	0	3

Pre-requisites: Nil

Total hours: 39

Course Outcomes:
CO1: Formulate engineering problems as mathematical optimization problems.
CO2: Explain the techniques of optimization for engineering problems.
CO3: Apply computer software to solve engineering optimisation problems.
CO4: Explain the heuristic optimization methods.

Module 1: (13 hours)
Introduction: statement of an optimization problem, classification of optimization problems, mathematical formulation of optimization problems, engineering applications of optimization; fundamental concepts in optimization: concave functions, convex functions, local optima, global optima; principles of optimization of unconstrained and constrained problems, necessary and sufficient conditions of optimality.

Module 2: (15 hours)
Linear programming methods of optimization: Simplex method, two-phase method, duality concept, sensitivity analysis; integer programming: branch-and-bound algorithm.
Algorithms for non-linear optimization problems: algorithms for single variable optimization problems, golden section search method, Newton-Raphson method; algorithms for multi-variable optimization problems: steepest descent method, quadratic programming; solving optimization problems using solvers (Excel, LINGO, AMPL).

Module 3: (11 hours)
Heuristic optimization methods: working principles of Genetic Algorithm, Simulated Annealing, Ant Colony Optimization, and Particle Swarm Optimization; multi-objective optimization: concept of Pareto-optimality, analytic hierarchy process for multi-criterion decision problems.

References:

1. J. S. Arora, *Introduction to Optimum Design*, 3rd ed. Academic Press, 2011.
2. A. D. Belegundu and T. R. Chandrupatla, *Optimization Concepts and Applications in Engineering,* 2nd ed. Cambridge University Press, 2011.
3. K. Deb, *Optimization for Engineering Design*, 2nd ed. Prentice-Hall of India, 2011.
4. D. Nagesh Kumar, *Optimization Methods*. [online] Available: http://nptel.ac.in/course.php .
5. S. S. Rao, *Engineering Optimization*, 3rd ed. New Age International, 2013.
6. A. Ravindran, K. M. Ragsdell, and G. V. Reklaitis, *Engineering Optimization: Methods and Applications*, 2nd ed. Wiley India, 2006.
7. H. A. Taha, *Operations Research: An introduction*, 8th ed. Prentice-Hall of India,1998.
8. W. L. Winston, *Operations Research: Applications and Algorithms*, 4th ed. Brooks/Cole Cengage Learning, 2004.

ME4127D ACCOUNTING AND FINANCE FOR ENGINEERS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1**:** Explain the basic accounting concepts and construction of financial statements.
CO2: Analyze and interpret the financial statements.
CO3: Evaluate the time value of money and its applications to capital market.
CO4: Apply the tools of capital planning and budgeting.

Module 1: (14 hours)
Financial Accounting: need, accounting concepts, classification of items in balance sheet, formats of balance sheet, construction of balance sheet, accounting equation technique; inventory valuation methods: depreciation valuation techniques; construction of profit and loss account; statement of changes in financial position, working capital basis (funds flow statement); cash flow statement; recording of transactions: classification of accounts, rules of debit and credit, journal entries, ledger postings; trial balance and work sheet

Module 2: (13 hours)
Finance and related discipline; role of financial manager: scope, function; sources of corporate finance: capital market, primary market and secondary market; financial statement analysis: ratio analysis, liquidity ratios, leverage ratios, profitability ratios, activity ratios, integrated analysis of ratios; time value of money; stocks and bond valuation: basic bond valuation, yield to maturity, valuation of ordinary shares, constant growth model, variable growth model; relationship among financial decisions, return, risk and share values.

Module 3: (12 hours)
Financial planning: budgeting, types of budget, preparation of budget; working capital computation; capital budgeting principles: effect of depreciation, effect of working capital, identifying relevant cash flows; capital budgeting techniques: traditional (payback, accounting rate of return) and discounted cash flow techniques (net present value, internal rate of return, profitability index); resolving the conflict of net present value: internal rate of return differences.

References:

1. N. Ramachandran and R. K. Kakani, *Financial Accounting for Management*, 4th ed. Tata McGraw-Hill, 2017.
2. M. Y. Khan and P. K. Jain, *Financial Management*, 7th ed. Tata McGraw-Hill, 2017.
3. M. Y. Khan and P. K. Jain, *Management Accounting*, 6th ed. Tata McGraw-Hill, 2013.
4. J. Lal and S. Srivastava, *Financial Accounting*, 3rd ed. S. Chand, 2014.

ME4128D SIMULATION MODELLING AND ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply simulation approach to model static and dynamic systems, with an understanding of the principles of generating random numbers and random variates.

CO2: Develop input data models for simulation and conduct verification & validation tests on simulation models.

CO3: Evaluate the performance of systems by analysing the output of the simulation models.

CO4: Develop simulation models using simulation software and develop insightful reports.

Module 1: (15 hours)

Systems and system environment: components of a system, discrete and continuous systems, model of a system, types of models; steps in simulation study: technique of simulation, comparison of simulation and analytical methods; Monte Carlo simulation: simulation of queuing systems, simulation of inventory systems; concepts in discrete event simulation; random number generation: techniques for generating random numbers, tests for random numbers, random variate generation, inverse transform method.

Module 2: (14 hours)

Input modelling for simulation: data collection, identifying the distribution with data, parameter estimation; goodness of fit tests: Chi square and Kolmogorov-Smirnov tests; verification and validation of simulation models; output analysis for a single model: measures of performance and their estimation, output analysis for terminating simulations and steady state simulations.

Module 3: (10 hours)

Simulation modelling and analysis of manufacturing systems; introduction to simulation software: simulation model building and analysis using Excel and ARENA.

References

1. J. Banks, J. S. Carson, B. L. Nelson, and D. M. Nicol, *Discrete-Event System Simulation*, 5th ed. Pearson Education, 2009.
2. A. M. Law and W. D. Kelton, *Simulation Modelling and Analysis*, 5th ed. McGraw-Hill Education, 2014.
3. G. Gordon, *System Simulation*, 2nd ed. Prentice Hall of India, 1995.
4. S. M. Ross, *Simulation*, 3rd ed. Academic Press, 2002.
5. G. S. Fishman, *Concepts and Methods in Discrete Event Digital Simulations*. Wiley,1973.
6. L. Oakshott, *Business Modelling and Simulation*. Pitman Publishing, 1997.
7. A. S. Carrie, *Simulation of Manufacturing Systems*. John Wiley & Sons Ltd., 1988.
8. M. D. Rossetti, *Simulation Modeling and ARENA*, 2nd ed. Wiley, 2015.

ME4129D MODELING OF MANUFACTURING SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Classify the manufacturing systems, modelling methods and performance measures.
CO2: Explain the transportation and storage systems for material handling.
CO3: Apply Group Technology principles for manufacturing systems.
CO4: Analyze manufacturing systems using Markov models and queuing models.

Module 1: (11 hours)
Modelling automated manufacturing systems: role of performance modelling; performance modeling tools: simulation models, analytical models; automated manufacturing systems: input-output model, plant configurations, performance measures; computer controlled machines: NC machines, pallets and fixtures, machining centers, automated inspection systems.

Module 2: (13 hours)
Material handling systems: conveyors, industrial robots, automated guided vehicles; storage and retrieval systems; facility layout: quadratic assignment problem; Group Technology: coding schemes, production flow analysis, mathematical models; flexible manufacturing systems: architecture of flexible manufacturing systems, automated work piece flow, automated assembly systems, deadlocks, performance measures.

Module 3: (15 hours)
Markov chain models, geometric and exponential random variables; stochastic processes: Poisson process; discrete-time Markov chains, continuous-time Markov chains, Markov model of a transfer line.
Basic queuing models: M/M/1, M/M/m models, queues with breakdowns, queuing networks: open, closed, product-form, queuing networks with blocking; application of queuing models for manufacturing systems; simulation models for serial lines and flexible manufacturing.

References:
1. N. Viswanadham and Y. Narahari, *Performance Modeling of Automated Manufacturing Systems*. Prentice-Hall of India, 1996.
2. R. G. Askin and C. R. Standridge, *Modeling and Analysis of Manufacturing Systems*. John Wiley & Sons, 1993.
3. T. Altiok, *Performance Analysis of Manufacturing Systems*. Springer, 1997.
4. P. Brandimarte and A. Villa, *Performance Modeling of Automated Manufacturing Systems*. Prentice-Hall of India, 1996.
5. G. L. Curry and R. M. Feldman, *Manufacturing Systems Modeling and Analysis*. Springer, 2011.
6. M. P. Groover, *Automation, Production systems and Computer-Integrated Manufacturing*, 4th ed. Pearson Education, 2016.

ME4130D HUMAN FACTORS IN ENGINEERING AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Comprehend the principles and applications of ergonomics/human factors in system design.
CO2: Identify the human capabilities and limitations for a system design.
CO3: Estimate the work physiology and devise strategy for improvement.
CO4: Adapt design principles in human factors to real-world systems through exercises.

Module 1: (15 hours)
Introduction to Human factors and Ergonomics: systems description, nature of man-machine systems and characteristics, design of cognitive work: information theory, human information processing model, displaying information: coding of information, information input and processing: perception, attention, mental workload; display of visual information: specific design principles, display of auditory information, specific design principles, tactual and olfactory displays; cutaneous senses: speech communication.

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Module 2: (12 hours)
Biomechanical bases of ergonomics: static biomechanical analysis and models; work physiology: energy and energy sources of the body, categories of work, respiration, circulatory system, metabolism, physical work capacity: aerobic capacity, assessment of aerobic capacity, fatigue and its evaluation.
Manual work and design guidelines: energy expenditure, heart rate, subjective ratings of perceived exertion, NIOSH lifting guidelines, multitask lifting guidelines.

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Module 3: (12 hours)
Engineering anthropometry and work-space design: statistical basis of anthropometry, use of anthropometric data in design; principles of work design: workplace, machines, tools and equipment; design of work surfaces: science of seating, cumulative trauma disorders, fundamental risk factors and prevention; work environment design: illumination, noise, temperature, ventilation, vibration, radiation; shift work and working hours, work rest scheduling.

References:

1. M. S. Sanders and E. J. McCormick, *Human Factors in Engineering and design*, 7th ed. McGraw-Hill, 1992.
2. A. Freidvalds, *Niebel's Methods, Standards, and Work Design*, 12th ed. Mc-Graw Hill Education, 2013.
3. F. Tayyari, and J. L. Smith, *Occupational Ergonomics: Principles and applications*. Kluwer Academic Publishers, 1997.
4. S. Gavriel, *Handbook of Human Factors & Ergonomics*. Inter-science, 1997.
5. K. F. H. Murrell and H. Schnauber, *Ergonomics.* Econ, 1986.

ME4131D MACHINE LEARNING FOR DATA SCIENCE AND ANALYTICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Outline the basic concepts and techniques of Machine Learning for data science.
CO2: Illustrate the techniques of well-known supervised and unsupervised learning algorithms.
CO3: Analyze the various algorithmic techniques in machine learning.
CO4: Apply machine learning algorithms for solving practical problems.

Module 1: (12 hours)
Sampling distributions: central limit theorem, distributions of the sample mean and the sample variance for a normal population; test of hypothesis: mean of normal population, one-tailed and two-tailed tests, F-test and Chi-Square test; analysis of variance (ANOVA): one-way and two-way classifications; relation between machine learning and statistics: introduction to R, working with programming language.

Module 2: (13 hours)
Introduction to algorithms in machine learning: classification, tools to analyze algorithms, algorithmic technique: divide and conquer, randomization in algorithms, supervised machine learning, linear regression, multiple linear regression: cost function and gradient descent, logistic regression: model representation, multi-class classification, problem of over fitting; linear discriminant analysis, quadratic discriminant analysis, regression and classification trees.

Module 3: (14 hours)
Introduction to unsupervised learning; clustering methods: partitioned based clustering, K-means; hierarchical clustering, agglomerative-, divisive- distance measures; density-based clustering: DBScan; spectral clustering; objective function (cost function for clustering algorithm), random initialization for K-Means, choosing number of clusters: dimensionality reduction, principal component analysis (PCA) algorithm, factor analysis.
Prescriptive analytics: creating data for analytics through designed experiments, creating data for analytics through active learning, creating data for analytics through reinforcement learning.

References:
1. D. M. Levine, D. F. Stephan, and K. A. Szabat, *Statistics for Managers Using Microsoft Excel*, 8th ed. Pearson, 2016.
2. D. C. Montgomery and G. C. Runger, *Applied Statistics and Probability for Engineers*, 6th ed. Wiley, 2013.
3. J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 7th ed. Pearson New International, 2015.
4. S. Addicam, S. Malik, and P. Tian, *Building Intelligent Systems – Utilising Computer vision, Data Mining and Machine Learning*. Intel Press, 2012.
5. T. Hastie, R. Tibshirani, Friedman, *The elements of statistical learning*, Vol. 2, No. 1. Springer, 2009.
6. M. Gardener, *Beginning R: The statistical programming language*, Wiley India, 2012.
7. R. A. Johnson and D. W. Wichern, *Applied Multivariate Statistical Analysis*, 6th ed. Pearson New International, 2015.