Bachelor of Technology (Mechanical)

First Year (Autumn Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1.	MAN-001	Mathematics-I	BSC	4	3	1	0	3	0	25	-	25	50	-
2.	PHN-001	Mechanics	BSC	4	3	0	2	3	0	15	25	20	40	-
3.	CEN-105	Introduction to Environmental Studies	GSC	3	3	0	0	3	0	25	-	25	50	-
4.	HSN-001A	Communication Skills (Basic)	HSSC	2	1	0	2	2	0	25	-	25	50	-
5.	HSN-001B	Communication Skills (Advance)	HSSC	2	-	-	-	-	-	-	-			-
6	HSN-002	Ethics and Self Awareness	HSSC	2	1	1	0	2	0	25	-	25	50	-
7.	MIN-101A	Introduction to Mechanical Engineering	PCC	2	2	0	0	2	0	-	-		100	-
8.	MIN-103	Programming and Data Structure	ESC	4	3	0	2	3	0	15	25	20	40	-
			Total	23										
First Year (Spring Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	MAN-004	Numerical Methods	BSC	4	3	1	0	3	0	25	-	25	50	-
2	PHN-008	Electromagnetic Theory	BSC	4	3	1	0	3	0	25	-	25	50	-
3	MIN-104	Manufacturing Technology-I	PCC	4	2	0	4	3	0	-	25	25	50	-
4	MIN-106	Engineering Thermodynamics	PCC	4	3	1	2/2	3	0	20	20	20	40	-
5	MIN-108	Mechanical Engineering Drawing	PCC	4	2	0	4	3	0	-	25	25	50	-
6	MTN-106	Material Science	ESC	4	3	1	0	3	0	25	-	25	50	-
			Total	24										
Second Year (Autumn Semester)														
S. No.	**Code**	**TItle**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	CEN-102	Solid Mechanics	ESC	4	3	1	0	3	0	25	-	25	50	-
2	MIN-201	Kinematics of Machines	PCC	4	3	1	2/2	3	0	20	20	20	40	-
3	MIN-203	Manufacturing Technology-II	PCC	4	2	0	4	3	0	-	25	25	50	-
4	MIN-205	Fluid Mechanics	PCC	4	3	1	2/2	3	0	20	20	20	40	-
5	MIN-291	Engineering Analysis and Design	PCC	4	3	1	2	3	0	20	20	20	40	
6	HSN-ELE	HSS Elective Course	HSSMEC	3	3	2	1	0	3	0	50			50
			Total	23										

Second Year (Spring Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	EEN-112	Electrical Science	ESC	4	3	1	-	3	0	20	20	20	40	-
2	MIN-204	Machine Drawing	PCC	4	2	0	-	4	0	-	25	25	50	-
3	MIN-206	Mechanics of Materials	PCC	4	3	1	-	3	0	20	20	20	40	-
4	MIN-208	Theory of Production Processes	PCC	4	3	1	-	3	0	20	20	20	40	-
5	MIN-210	Energy Conversion	PCC	4	3	1	-	3	0	20	20	20	40	-
6	HSN-ELE	HSS Elective Course	HSSMEC	3	3	2	1	0	3	0	50	-	-	50
			Total	23										
Third Year (Autumn Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	MIN-301	Dynamics of Machines	PCC	4	3	1	2/2	3	0	20	20	20	40	-
2	MIN-303	Principles of Industrial Engineering	PCC	4	3	1	0	3	0	25	-	25	50	-
3	MIN-305	Heat and Mass Transfer	PCC	4	3	1	2/2	3	0	20	20	20	40	-
4	MIN-ELE 1	Departmental Elective Course-I	PEC	4	3	1	0	3	0	25	-	25	50	-
5	BM-ELE OEC	Management Studies/Open Elective Course	OEC/HSS M EC	3	3	2	-	0	2	25	-	25	50	-
6	MIN-391	Technical Communication	PCC	2	0	2	0	-	-	-	-	-	100	-
			Total	21										
Third Year (Spring Semester)														
S. No.	**Code**		**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	MIN-300	Lab based project	PCC	4	0	0	6	-	-	100	-	-	-	-
2	MIN-302	Machine Design	PCC	6	4	0	4	4	-	20	20	20	40	-
3	MIN-304	Fluid Machinery	PCC	4	3	1	2/2	3	0	20	20	20	40	-
4	MIN-ELE2	Departmental Elective Course-II	PEC	4	3	1	0	3	0	25	-	25	50	-
5	MSC1/ DHC1	Minor Specialization Course-I/ Departmental Honours Course-I	MSC/DHC	4	3	1	0	3	0	25	-	25	50	-
6	BM-ELE/ OEC	Management Studies/ Open Elective Course	OEC/ HSSMEC	3	3	2	1	0	2	0	25	-	25	50
7	MIN-399	Educational Tour	PCC	0	-	-	-	-	-	-	-	-	-	-
			Total	25										

Fourth Year (Autumn Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	MIN-400A	B.Tech. Project	PCC	4	0	0	3	-	-	-	-	-	-	-
2	MIN-ELE3	Departmental Elective Course-III	PEC	4	3	1	0	3	0	25	-	25	50	-
3	MIN-ELE4	Departmental Elective Course-IV	PEC	4	3	1	0	3	0	25	-	25	50	-
4	MSC2/ DHC2	Minor Specialization Course-I/ Departmental Honours Course-II	MSC/ DHC	4	3	1	0	3	0	25	-	25	50	-
5	MSC3/ DHC3	Minor Specialization Course-III/ Departmental Honours Course -III	MSC/ DHC	4	3	1	0	3	0	25	-	25	50	-
6	MIN-499	Training Seminar	PCC	2	0	2	0	-	-	100	-	-	-	-
			Total	22										
Fourth Year (Spring Semester)														
S. No.	**Code**	**Title**	**Area**	**Cr**	**L**	**T**	**P**	**TH**	**PH**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
1	MIN-400B	B.Tech. Project (Contd. from Autumn Semester)	PCC	8	0	0	12	-	-	-	-	-	-	-
2	MIN-ELE5	Departmental Elective Course-V	PEC	4	3	1	0	3	0	25	-	25	50	-
3	MIN-ELE6	Departmental Elective Course-VI	PEC	4	3	1	0	3	0	25	-	25	50	-
4	MSC4/ DHC4	Minor Specialization Course-IV/ Departmental Honours Course-IV	MSC/DHC	4	3	1	0	3	0	25	-	25	50	-
5	MSC5/ DHC5	Minor Specialization Course-V/ Departmental Honours Course-V	MSC/DHC	4	3	1	0	3	0	25	-	25	50	-
			Total	24										

Department ElectivesCategory-I (for III year students)

S. No.	Code	Title	Area	Cr	L	T	P	TH	PH	CWS	PRS	MTE	ETE	PRE
1	MIN-320	Automobile Engineering	PEC	4	3	1	0	3	-	25	-	25	50	-
2	MIN-321	Vibration and Noise	PEC	4										
3	MIN-322	Principles of Lubrication Technology	PEC	4	3	1	0	3	-	25	·	25	50	-
4	MIN-323	Design of Pressure Vessels & Piping	PEC	4	3	1	0	3		25	·	25	50	-
5	MIN-324	FEM applications in Mechanical Engg.	PEC	4	3	1	0	3	-	25	·	25	50	-
6	MIN-325	Numerical Methods in Manufacturing	PEC	4	3	1	0	3	-	25	-	25	50	-
7	MIN-326	Value Engineering	PEC	4	3	1	0	3	-	25	-	25	50	-
8	MIN-327	Reverse Engineering	PEC	4	3	1	0	3		25	-	25	50	-
9	MIN-328	Manufacturing System Analysis	PEC	4	3	1	0	3	-	25	·	25	50	-
10	MIN-329	Computer Integrated Manufacturing	PEC	4	3	1	0	3	-	25	-	25	50	-
11	MIN-330	Ergonomics	PEC	4	3	1	0	3		25	-	25	50	-
12	MIN-331	Total Quality Management	PEC	4	3	1	0	3		25	·	25	50	-
13	MIN-332	Industrial Hazards and Safety	PEC	4	3	1	0	3		25	-	25	50	-
14	MIN-333	Industrial Management	PEC	4	3	1	0	3	-	25	-	25	50	-
15	MIN-334	Facilities Design	PEC	4	3	1	0	3	-	25	-	25	50	-
16	MIN-335	Concurrent Engineering	PEG	4	3	1	0	3	-	25		25	50	-
17	MIN-336	Financial Management	PEC	4	3	1	0	3	-	25		25	50	-
18	MIN-337	Processing of Non-Metals	PEC	4	3	1	0	3		25	·	25	50	-
19	MIN-338	Measurement and Instrumentation	PEC	4	3	1	0	3	-	25	-	25	50	-
20	MIN-339	Design of Heat Exchangers	PEC	4	3	1	2/2	3	-	20	20	20	40	-
21	MIN-340	Refrigeration and Air-Conditioning	PEC	4	3	1	0	3		25	·	25	50	-
22	MIN-341	Thermal Systems Design	PEC	4	3	1	0	3	-	25	-	25	50	-
23	MIN-342	Environmental Pollution and Control	PEC	4	3	1	0	3	-	25	-	25	50	-
24	MIN-343	Power Plants	PEC	4	3	1	0	3	-	25	-	25	50	-
25	MIN-344	Industrial Combustion	PEC	4	3	1	0	3	-	25	-	25	50	-
26	MIN-345	Compressible Flow	PEC	4	3	1	0	3	-	25	-	25	50	-
27	MIN-346	Waste Heat recovery Systems	PEC	4	3	1	0	3	-	25	-	25	50	-
28	MIN-349	Fire Dynamics	PEC	4	3	1	0	3	-	25	-	25	50	-
29	MIN-350	Industrial Verification and Air Conditioning	PEC	4	3	1	0	3	-	25	-	25	50	-
30	MIN-351	Gas Dynamics	PEC	4	3	1	0	3	-	25	-	25	50	-
31	MIN-352	Experimental Methods in Thermal Engineering	PEC	4	3	1	2/2	3	-	20	20	20	40	-
32	MIN-354	Automatic Control	PEC	4	3	1	2/2	3	-	20	20	20	40	-

Department ElectivesCategory-II (for IV year students)

Machine Design Engineering

S. No	Code	Title	Area	Cr	L	T	P	TH	PH	CWS	PRS	MTE	ETE	PRE
1	MIN-411	Maintenance Technology for Rotating Components	PEC	4	3	1	0	3	-	25	-	25	50	-
2	MIN-412	Vehicle Dynamics	PEC	4	3	1	0	3	-	25	-	25	50	-
3	MIN-413	Micro Electro Mechanical Systems	PEC	4	3	1	0	3	-	25	-	25	50	
4	MIN-415	Piping Technology	PEC	4	3	1	0	3		25	-	25	50	-
5	MIN-416	Non Linear Dynamics	PEC	4	3	1	0	3	-	25	-	25	50	-
6	MIN-417	Energy and Variational Principles in Engineering Mechanics	PEC	4	3	1	0	3	-	25	-	25	50	-
7	MIN-500	Instrumentation and Experimental Methods	PEC	4	3	1	2/2	3	-	20	20	20	40	-
8	MIN-502	Robotics and Control	PEC	4	3	1	2/2	3	-	20	20	20	40	-
9	MIN-508	Advanced Automatic Control	PEC	4	3	1	0	3		25	-	25	50	-
10	MIN-509	Extended Finite Element Methods	PEC	4	3	1	0	3	-	25	-	25	50	-
11	MIN-553	Industrial Tribology	PEC	4	3	1	0	3	-	25	-	25	50	-
12	MIN-554	Computer Aided Mechanism Design	PEC	4	3	1	2/2	3		20	20	20	40	-
13	MIN-555	Experimental Stress Analysis	PEC	4	3	1	2/2	3	-	20	20	20	40	-
14	MIN-556	Dynamics of Road Vehicles	PEC	4	3	1	2/2	3		20	20	20	40	
15	MIN-558	Fracture Mechanics	PEC	4	3	1	0	3	-	25	-	25	50	-
16	MIN-559	Computer Aided Design	PEC	4	3	1	2/2	3	-	20	20	20	40	-
17	MIN-560	Mechanics of Composite Materials	PEC	4	3	1	0	3		25	-	25	50	-
18	MIN-561	Advanced Mechanical Vibrations	PEC	4	3	1	2/2	3	-	20	20	20	40	-
19	MIN-562	Noise Control in Mechanical Systems	PEC	4	3	1	2/2	3	-	20	20	20	40	-
20	MIN-563	Mechatronics	PEC	4	3	1	2/2	3	-	20	20	20	40	-
21	MIN-565	Smart Materials, Structures, and Devices	PEC	4	3	1	0	3	-	25	-	25	50	-
22	MIN-516	Artificial Intelligence	PEC	4	3	1	0	3	-	25	-	25	50	-
23	MIN-550	Advance Machine	PEC	4	3	1	0	3	-	25	-	25	50	-
24	MIN-551	Dynamics of Mechanical Systems	PEC	4	3	1	0	3	-	25	-	25	50	-
25	MIN-566	Computer Aided Analysis of Mechanical Systems	PEC	4	3	1	0	3	-	25	-	25	50	-
26	MIN-567	Computer Graphics	PEC	4	3	1	2/2	3	-	20	20	20	40	-
27	MIN-568	Advanced Robotics	PEC	4	3	1	2/2	3	-	20	20	20	40	-
28	MIN-548	Product and Process Optimization	PEC	4	3	1	0	3	-	25	-	25	50	-

Production and Industrial Engineering

S. No.	Code	Title	Area	Cr	L	T	P	TH	PH	CWS	PRS	MTE	ETE	PRE
1	MIN-573	Design for Manufacturability	PEC	4	3	1	0	3	-	25	-	25	50	-
2	MIN-574	Maintenance Management	PEC	4	3	1	0	3	-	25	-	25	50	-
3	MIN-575	Product Design and Development	PEC	4	3	1	0	3	-	25	-	25	50	-
4	MIN-576	Machine Tool Design and Numerical Control	PEC	4	3	1	0	3	-	25	-	25	50	-
5	MIN-577	Industrial Automation	PEC	4	3	1	0	3	-	25	-	25	50	-
6	MIN-578	Computer Aided Process Planning	PEC	4	3	1	0	3	-	25	-	25	50	
7	MIN-579	Information Systems and Data Management	PEC	4	3	1	0	3	-	25	-	25	50	-
8	MIN-580	Welding Science	PEC	4	3	1	2/2	3	-	20	20	20	40	-
9	MIN-581	Manufacturing Resources Management	PEC	4	3	1	0	3	-	25	-	25	50	-
10	MIN-562	Flexible Manufacturing Systems	PEC	4	3	1	0	3	-	25	-	25	50	-
11	MIN-5B3	Materials Management	PEC	4	3	1	0	3		25	-	25	50	-
12	MIN-584	Operations Research	PEC	4	3	1	0	3	-	25	-	25	50	-
13	MIN-585	Supply Chain Management	PEC	4	3	1	0	3	-	25	-	25	50	-
14	MIN-586	Metal Forming	PEC	4	3	1	0	3		25	-	25	50	-
15	MIN-587	Metal Casting	PEC	4	3	1	0	3	-	25	-	25	50	
16	MIN-588	Non-Traditional Machining Processes	PEC	4	3	1	2/2	3	-	20	20	20	40	-
17	MIN-593	Non-Conventional Welding Processes	PEC	4	3	1	2/2	3	-	20	20	20	40	-
1B	MIN-594	Safety Aspects of Welded Structures	PEC	4	3	1	0	3	-	25	-	25	50	-
19	MIN-595	Failure Analysis of Welding Joints	PEC	4	3	1	2/2	3	-	25	-	25	50	-
20	MIN-596	Automation & Application of Robots in Welding	PEC	4	3	1	0	3	-	25	-	25	50	-
21	MIN-597	Welding Procedures for Specific Applications	PEC	4	3	1	0	3	-	25	-	25	50	-
22	MIN-598	Weldeability of Metals	PEC	4	3	1	0	3	-	25	-	25	50	-
23	MIN-599	Surface Engineering	PEC	4	3	1	2/2	3	-	20	20	20	40	-

Thermal Engineering

S. No	Code	Title	Area	Cr	L	T	P	TH	PH	CWS	PRS	MTE	ETE	PRE
1	MIN-523	Gas Turbines &Compressors	PEC	4	3	1	0	3	-	25	-	25	50	-
2	MIN-524	Two Phase Flow &Heat Transfer	PEC	4	3	1	0	3	-	25	-	25	50	-
3	MIN-525	Solar Energy	PEC	4	3	1	2/2	3	-	20	20	20	40	-
4	MIN-526	Advanced Gas Dynamics	PEC	4	3	1	0	3	-	25	-	25	50	-
5	MIN-527	Computational Fluid Dynamics & Heat Transfer	PEC	4	3	1	0	3	-	25	-	25	50	-
6	MIN-528	Boundary Layer Theory	PEC	4	3	1	2/2	3	-	20	20	20	40	-
7	MIN-529	Turbulent Flows	PEC	4	3	1	2/2	3	-	20	20	20	40	-
8	MIN-530	Cold Preservation of Foods	PEC	4	3	1	0	3	-	25	-	25	50	-
9	MIN-531	Hydro-dynamic Machines	PEC	4	3	1	2/2	3	-	20	20	20	40	-
10	MIN-532	Renewable Energy Systems	PEC	4	3	1	2/2	3	-	20	20	20	40	-
11	MIN-533	Refrigeration &Air-Conditioning System Design	PEC	4	3	1	2/2	3	-	20	20	20	40	-
12	MIN-534	Air Conditioning and Ventilation	PEC	4	3	1	2/2	3	-	20	20	20	40	-
13	MIN-535	Cryogenic Systems	PEC	4	3	1	0	3	-	25	-	25	50	
14	MIN-536	Convective Heat and Mass Transfer	PEC	4	3	1	0	3		25	-	25	50	-
15	MIN-537	I. C. Engines	PEC	4	3	1	2/2	3	-	20	20	20	40	-
16	MIN-538	I. C. Engine Combustion Processes Modelling	PEC	4	3	1	2/2	3	-	20	20	20	40	-
17	MIN-539	Micro and Nano Scale Thermal Engineering	PEC	4	3	1	0	3	-	25	-	25	50	-
18	MIN-540	Combustion	PEC	4	3	1	2/2	3	-	20	20	20	40	-
19	MIN-541	Bio-Fluid Mechanics	PEC	4	3	1	0	3	-	25	-	25	50	-
20	MIN-544	Design of Heat Exchanger	PEC	4	3	1	0	3	-	25	-	25	50	-
21	MIN-545	Fuel Cell	PEC	4	3	1	2/2	3	-	20	20	20	40	-
22	MIN-542	Energy Management	PEC	4	3	1	2/2	3	-	20	20	20	40	-
23	MIN-543	Fluid Power Systems	PEC	4	3	1	0	3	-	25	-	25	50	-

Courses Offered by Department for Minor Degree

S. No.	Course Title		Semester		
			Autumn	Spring	Credit
1	MIN-206	Mechanics of Materials		✓	4
2	MIN-211	Theory of Mechanics	✓		4
3	MIN-212	Machine Design		✓	4
4	MIN-205	Fluid Mechanics	✓		4
5	MIN-304	Fluid Machinery		✓	4
6	MIN-305	Heat and Mass Transfer	✓		4
7	MIN-210	Energy Conversion		✓	4
8	MIN-106	Engineering Thermodynamics	✓	✓	4
9	MIN-208	Theory of Production Processes		✓	4
10	MIN-303	Principles of Industrial Engineering	✓		4

IMI-01Total Quality Management Pre-requisite**: Nil**

Fundamentals: Evolution of Quality: Inspection, Quality Control, Quality Assurance and Total Quality Management, Customer-Orientation: Internal & External Customer Concept, Quality Philosophies of Deming, Juran, Crosby, Ishikawa, Taguchi; Tools and improvement cycle (PDCA). Life cycle approach to quality costs prevention; Appraisal and Failure costs. Various TQM models. Relationship between quality and environment.

Human Resources Management: Organizational, Communicational and Team requirements. Types of teams, Quality circles, Empowerment, Human resource policies in TQM, Group dynamics.

Tools and Techniques: Seven QC tools (Histogram, Check sheets, Ishikawa diagrams, Pareto, Scatter diagrams, Control charts), Quality Function Deployment, Statistical process control, Process capability, JIT and Elimination of waste, Total Productive Maintenance, 5-S. Taguchi's concept of quality loss function.

Systems and Procedure: Importance, Standardization (National and International) Quality Systems, Quality Manuals, Quality Information Systems and documentation, Auditing, Basics of ISO-9000 and ISO 14000: Relevance and misconceptions.

Implementation: Quality strategy and policy, Motivation and leadership theories. Continuous vs breakthrough improvements, Management of change, Quality award models and role of self-assessment, Benchmarking, Implementation barriers, TQM practices.

Suggested Books:

- Besterfield, D. C. and Besterfield C., Total Quality Management, Pearson Education Asia, New Delhi, 1999
- Mohanty R. P. and Lakhe R. R .Handbook of Total Quality Management, Jaico Publishers, 2000.
- Berk, J. and Berk, S. Total Quality Management: Implementing Continuous Improvement. New York: Sterling Publishing, 1993
- Logothetis, N. Managing for Total Quality. New York: Prentice Hall, 1992
- Bossert, J. L. Quality Function Deployment – A Practitioner's Approach, NY: Marcel Dekker, 1994
- Taguchi, G., A. Elsayed, and T. Hsiang Quality Engineering in Production Systems, NY: McGraw Hill, 1989

PHN-001 Physics Department Pre-requisite**: Nil**

Statics of Particles: Vectorial representation of forces and moments- Vector Operation-Concepts of Particles and Rigid bodies – Composition of concurrent forces in plane free body Diagram – Equilibrium of Rigid bodies in Two and three dimensions-Moment of a force about a point and about an axis-Couple moment-Reduction of a force system to a force and a couple

Properties Of Surfaces, Moments And Products of Inertia: Definition Moment of Inertia for areas-Parallel axis theorem –Perpendicular axis theorem-Moment of inertia for composite area-product of inertia form an area-mass moment of inertia

Friction: Laws of coulomb friction- Coefficient of Friction-Dry Friction-sliding Friction-Ladder friction-Belt friction – Rolling Resistance.

Kinematics of Particles: Principle of virtual work for a particle and rigid body-condition for equilibrium for a conservative system, stability-particle dynamics in rectangular coordinate, cylindrical coordinate and in terms of path variables-General motion of system of particles-

Work Energy Methods, Impulse And Momentum: Work Energy Method-Conservation of Energy-Impulse and Momentum Relation-Impulsive Force-Impact force-Conservation of momentum – Moment of Momentum Equation.

Rigid Body Motion: Translation and rotation of rigid bodies- Derivative of a vector fixed in moving reference-General relationship between time derivative of a vector for different references-Moment of momentum equation-kinetic energy of rigid body-work and energy relations-Euler's equation of motion-Three dimensional motion about a fixed point

List of experiments:

1. Study of magnetic field of a pair of coils in Helmholtz arrangement
2. Determination of e/m
3. Determination of first excitation potential of a gas by Frank-Hertz experiment
4. Determination of Stefan's constant
5. Determination of Planck's constant by radiation
6. To study and verify Malus' law
7. Study of Polarization of light using quarter wave plate
8. Determination of Brewster's angle at glass-air interface
9. Determination of width of a slit by single-slit diffraction pattern
10. Four probe method of finding resistivity of semiconductor
11. Quinck's Method for determining mass susceptibility
12. Wavelength of Na light by Newton's ring method

Suggested Books:

- Shames I.H. and Rao G.K., "Engineering Mechanics-Statics and Dynamics",4 Edition, Pearson Education, 2006
- Beer F.P and Johnson E.R., "Vector Mechanics for Engineers- Statics and Dynamics" 9 Edition, Tata McGraw-Hill Publishing Company, 2010
- Pytel A. and Kiusalaas J., "Engineering Mechanics: Statics" 3rd Edition, Cengage Learing, 2010
- Pytel A. and Kiusalaas J., "Engineering Mechanics: Dynamics"3rd Edition Cengage Learing, 2010
- Hibberler R.C and Gupta A., Engineering Mechanics," 2th Edition, Pearson Education, 2012
- Meriam J.L. and Kraige L.G., "Engineering Mechanics: Statics", 6th Edition, John Willey and Son,s, 2012
- Meriam J.L., and Kraige L.G., "Engineering Mechanics: Dynamics", 6th Edition, John Willey and Son's, 2012

CEN-102 Solid Mechanics Pre-requisite: **Nil**

Analysis of Stresses and Strains: Concept of stress, normal stress and shear stress, nine Cartesian components of stress at a point, sign convention and notation, equality of shear stresses on mutually perpendicular planes and their planes of action, stress circle; concept of strain, normal and shear strain, two dimensional state of strain, Poisson's ratio, volumetric strain, strain circle, concept of strain energy

Stress-Strain Relationships: Hooke's law and its application to isotropic materials, elastic constants and their relationships, plane stress and plain strain conditions.

Mechanical Properties: Uniaxial tension test to determine yield and ultimate strength of materials, stress-strain diagram, proof stress, ductile and brittle materials, hardness and impact strength; conditions affecting mechanical behaviour of engineering materials

Members in Uniaxial State of Stress: Uniform cross-section and tapered bars subjected to uniaxial tension and compression, composite bars and statically indeterminate bars, thermal stresses; Introduction to plasticity; S.E. under axial loading.

Members Subjected to Axi-Symmetric Loads: Stresses and strains in thin cylindrical shells and spheres under internal pressure, stresses in thin rotating rings.

Members Subjected to Torsional Loads: Torsion of solid and hollow circular shafts, stepped and composting shafts, close-coiled helical springs subjected to axial loads, S.E. in torsion.

Members Subjected to Flexural Loads: Statically determinate beams, support reactions, relationship between load, shear force and bending moment, shear force and bending moment diagrams; theory of flexure for initially straight beams, distribution of bending stresses across the beam cross-section, principal stresses in beams; equation of elastic curve for the loaded beam, relationship between bending moment, slope and deflection; calculation of deflection by integration, moment area and unit-load methods, S.E. in flexure.

Members Subjected to Combined Loads: Short struts subjected to eccentric loads, shafts subjected to combined bending, torsion and axial thrust, concept of theory of failure.

Elastic Stability of Columns: Euler's theory of initially straight columns, critical loads for different end condition of columns, eccentric loading, columns with small initial curvature, empirical formulae.

Stresses in Beams (Advance Topics): Composite beams, Transformed section method, bending of unsymmetric beams, The shear-center concept.

Suggested Books:

- Gere, J.M. and Goodno, B.J., "Strength of Materials", Indian Edition (4th reprint), Cengage Learning India Private Ltd. 2009
- Beer, F.P., Johuston, Jr., E.R., Dewolf, J.T. and Mazureu, D.E., "Mechanics of Materials", Fifth Edition, McGraw Hill. 2009
- Hibbeler, R.C., "Mechanics of Materials", Sixth Edition, Pearson. 2005
- Crandall, S.H., Dahl, N.C. and Lardner, T.J., "An Introduction to the Mechanics of Solids", 2nd Edition, McGraw Hill. 1999
- Timoshenko, S.P. and Young, D.H., "Elements of Strength of Materials", Fifth Edition, (In MKS Units), East-West Press Pvt. Ltd. 2009 (reprint)

CEN-105 Introduction to Environmental Studies Pre-requisite: **Nil**

Overview: Environment and Natural Processes; Development (Resource Utilization & Waste Generation); Environmental issues; Concept of Sustainable Development; Issues affecting future development (population, urbanization, health, water scarcity, energy, climate change, toxic chemicals, finite resources etc.); Environmental units

Air – Water interaction: (Liquid phase-gas phase equilibrium) Henry's Law Constant with units, Dimensionless Henry's Law Constant

Water – Soil Interaction: Carbonate System (Alkalinity and buffering capacity); Major ions in water; Natural Organic Matter (NOMs); Water quality parameters; Physical processes (Mass Balance): Spatio-temporal variation in quality of river water, lake water, ground water; Water quality standards

Wetlands, water treatment and wastewater treatment .

Air resources: Atmosphere; Air pollutants; Emissions and control of air pollutants; Atmospheric meteorology and dispersion; Transport of air (global, regional, local); Air/ atmospheric stability; Plume shape; Gaussian modeling; Air quality standards

Land pollution and solid waste management

Ecosystem: Structure and function; Energy flow in ecosystem; Material flow in ecosystem; Biodiversity and ecosystem health; Bio-amplification and bio-magnification

Hazardous Waste: Definition; Classification; Storage and management; Site remediation; Environmental Risk: assessment, and management

Suggested Books:

- Davis M. L. and Cornwell D. A., "Introduction to Environmental Engineering", McGraw Hill, New York 4/e 2008
- Masters G. M., Joseph K. and Nagendran R. "Introduction to Environmental Engineering and Science", Pearson Education, New Delhi. 2/e 2007
- Peavy H. S., Rowe D.R. and Tchobanoglous G., "Environmental Engineering", McGraw Hill, New York 1986
- Mines R. O. and Lackey L. W. ""Introduction to Environmental Engineering", Prentice Hall, New Yark 2009
- Miheicic J. R. and Zimmerman J. B. " Environmental Engineering: Fundamentals, Sustainability, Design" John Wiley and Sons, Inc. 2010

MTN-106 Materials Science Pre-requisite: **Nil**

Introduction to crystallography: Bonding in Solids: Ionic, Amorphous and Crystalline, Single crystal and Polycrystalline material, Polymorphism, Lattice, Unit cell, Bravais lattice, Types of crystals, Linear and Planer densities, Voids in crystalline structures, Ceramic crystal structures, Crystal defects (Point, Line ,Surface and Volume defects)

Principles of alloy formation: Solid solution, Hume-Rothery rules, Binary phase diagrams: Gibbs phase rule, lever rule, cooling curves, Invariant reactions, Types of Binary phase diagrams (Isomorphous, Eutectic, Partial-Eutectic systems), Iron-Iron carbide phase diagram

Plastic deformation: Elastic and Plastic deformation and Strain hardening with respect to Stress-Strain Curve, Plastic deformation by Slip: Slip system, Critical resolved shear stress, Frank-Read source Work hardening and dynamic recovery, Strengthening Mechanisms, Recovery, Recrystallization and Grain growth, Cold and hot working

Mechanical Properties: Hardness Test (Brinell, Vickers, Rockwell and Microhardness Tests) Tensile Test (Engineering stress-strain curve: Y.S, U.T.S, work hardening, ductility, resilience and toughness, True stress-strain curve, Ductile and brittle fracture), Impact Test (Charpy and Izod specimens, Ductile – brittle transition, effect of carbon on ductile-brittle transition in plain carbon steels) Fatigue Test (Fatigue testing apparatus, S-N Curve for ferrous and non-ferrous, Fatigue fracture (transgranular fracture), Methods of improving fatigue life,

Creep Test: Creep curve, Creep fracture, Material consideration for high temperature use.

Heat Treatment: Purpose of Heat treatments, Equilibrium and Non-equilibrium cooling, Nucleation, Grain growth and Kinetics , TTT and CCT diagrams, Common heat treatments like Annealing, Normalizing,

Hardening and Tempering, Hardenability: Jominy end-quench test, Hardenability curves, Martempering and Austempering, Surface hardening (carburizing, Nitriding, Flame and Induction hardening).

Ceramic, Composite and Polymeric Materials: Ceramics: Types of ceramics, Fabrication and Processing of Ceramics: (i) Glass forming processes (ii) Particulate forming processes (iii) Cementation, Composites: Advantages of composites, Constituents of composites, Applications of composites ,Classification of composites: Based on matrix and reinforcement, Polymers: Hydrocabon and Polymer molecules, Molecular shape and structure, Molecular configuration, Thermoplastic and Thermosetting polymers

Suggested Books:

- Callister W.D., "Materials Science and Engineering" Wiley India (P) Ltd. ISBN: 978-81-265-21-43-2 , 2010
- Raghavan V.,"Materials Science and Engineering- A first Course," 5th edition, ISBN: 978-81-203-2455-8 **,** 2011
- Askeland D.R., "The Science and Engineering of Materials, 5th edition, ISBN: 978-81-315-0321-8, 2006

PHN-008 Electromagnetic Theory Pre-requisite: **Nil**

Vector Algebra: Cartesian, Cylindrical and Spherical coordinate Systems, Constant coordinate surfaces, Del operator, Gradient, Divergence of a Vector and Divergence Theorem, Curl of a vector and Stokes theorem, Gradient, Divergence, Curl and Laplacian in the three coordinate Systems, Laplacian of a scalar, Scalar & Vector Fields, Classification of Vector fields.

Electrostatics: Coulomb's law, electric field intensity due to continuous charge distribution, Gauss's law & its applications, electric potential, the line integral, electric dipole and flux lines, energy density in an electrostatic field, electrostatic discharge. Current and current density, metallic conductors, conductor properties and boundary conditions, polarization in dielectrics, nature of Dielectric materials and related boundary conditions, capacitance.Electrostatic boundary-value problems, Laplace's and Poisson's equations, Uniqueness theorem, General procedure for solving Laplace's and Poisson's equation.

Magnetostatics: Biot-Savart's law, Ampere's circuital law, Applications of Ampere's law, Magnetic flux and magnetic flux density, Scalar and vector magnetic potentials.Magnetic dipole, Force due to Magnetic field on a differential current element, force between two differential current elements, Force and torque on a closed circuit, The nature of magnetic materials, Magnetization and permeability, Magnetic boundary conditions, Inductors, inductances, Magnetic energy, Magnetic circuits, Potential energy and force on magnetic materials, magnetic levitation.

Time varying electric and magnetic fields and electromagnetic waves: Faraday's law, transformer, EMF, DC motors, displacement current, Maxwell's equations for time varying fields, electromagnetic wave equation in free space, plane waves in free space, polarization, Poynting vector and power associated with electromagnetic waves, plane waves in lossless, homogeneous, and isotropic dielectric, reflection and transmission of plane waves at dielectric interface, normal and oblique incidence, plane waves in good conductors, skin depth. Microwaves and their applications in telecommunication, radar, and heating.

Suggested Books:

- William H Hayt, Jr., and John A. "Engineering Electromagnetics", Buck, Tata McGraw Hill Publishing Company Ltd, New Delhi, 7th Ed., 2005
- Matthew N.O. Sadiku,"Elements of Engineering Electromagnetics", Oxford University Press, 3rd Ed., 2003
- Nannapaneni Narayan Rao, "Elements of Engineering Electromagnetics", Prentice Hall of India, New Delhi, 4th Ed., 2000
- D.J. Griffiths, "Introduction to Electrodynamics", Prentice Hall, 3rd Ed., 2000

EEN-112 Electrical Science Pre-requisite**: Nil**

Energy Resources and Utilization: Conventional and non-conventional energy resources; Introduction to electrical energy generation from different resources, transmission, distribution and utilization.

Network Fundamentals: Types of Sources and elements, Kirchoff's Laws, Mesh and Node Analysis of D.C. Networks, Network Theorems: Thevenin's Theorem, Norton's Theorem, Superposition Theorem, Maximum Power Theorem, Star-Delta Transformation.

A.C. Fundamentals: Concept of phasor, impedance and admittance; Mesh and Node analysis of AC networks; Network theorems in AC networks; Active and reactive power in AC circuits; Resonance in series AC circuits; Power factor correction.

Three-phase A.C. Circuits: Analysis of 3-phase balanced start-delta circuits, Power in 3-phase Circuits.

Measurement of Electrical Quantities: Measurement of Voltage, Current, and Power; Measurement of 3 phase power; Energy meters.

Single Phase Transformer: Introduction to magnetic circuit concepts, Basic constructional features, operating principle, phasor diagram, equivalent circuit, voltage regulation; Eddy current and Hysteresis losses, efficiency; Open circuit and Short Circuit tests.

D.C. Machines: Principle of operation, constructional features; Emf and torque equations; Types of excitation; Generator characteristics; Starting and speed control of D.C. motors.

AC Machines: Three-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting and speed control; Single-phase Induction Motor - Operating principle, constructional features, torque-speed characteristics, starting methods.

Industrial Applications and Control: Various industrial loads, traction, heating, lighting; Concept of power electronic control of AC and DC motors.

Suggested Books:

- Mukhopadhyaya P., Pant A.K., Kumar V. and Chittore D.S., "Elements of Electrical Science", Nem Chand & Brothers., 1997
- Vincent Del Toro, "Electrical Engineering Fundamentals", Prentice Hall of India., 2002
- Dubey G. K., "Fundamentals of Electric Drives", 2nd Ed., Narosa Publishing House., 2007
- Alexander C.K., Sadiku M.N.O., "Fundamentals of Electric Circuits", McGraw Hill, 5th Edition., 2012
- Chapman, Stephen, J., "Electric Machinery Fundamentals", McGraw Hill Book Company., 1985
- Hughes Edward, "Electrical & Electronic Technology", Pearson Publishing, 8th edition., 2002

HSN-001A Communication Skills (Basic) Pre-requisite**: Nil**

Understanding the Basics of Communication Skills: listening, Speaking, Reading & Writing, Scope and Importance Grammar & Composition: Time and Tense, Agreement, Active-Passive, Narration, Use of Determiners, Prepositions & Phrasal Verbs

Vocabulary Building & Writing: Word-formation, Synonyms, Antonyms, Homonyms, One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words Introduction to Sounds (Vowels & Consonants) Organs of Speech, Place and Manner of Articulation, Stress & Intonation, Listening Comprehension (Practical Sessions in Language Laboratory) Speaking, Countering Stage-fright and Related Barriers to Communication.

Reading and Comprehension: Two lessons to be identified by the department

List of Practicals:

1. Ice-breaking Exercises
2. Assignments on Time and Tense, Agreement, Active-Passive

3. Laboratory Session on Narration, Use of Determiners, Prepositions & Phrasal Verbs, Revisionary Exercises & Quiz
4. Laboratory Session on Synonyms, Antonyms, Homonyms
5. Assignments and Practice Sheets on One-word Substitutes, Idioms and Phrases, Collocations, Abbreviations of Scientific and Technical Words
6. Laboratory Session on Practice of sounds, Intonation and Stress, Listening Comprehension
7. Individual presentation, debates, Extempore & Turncoats
8. Exercises in Composition and Comprehension

Suggested Books:

- Murphy, Raymond. Intermediate English Grammar, New Delhi, Cambridge University Press., 2009
- Quirk, Randolph & Sidney Greenbaum. A University Grammar of English, New Delhi, Pearson., 2009
- McCarthy, Michael & Felicity O' Dell. English Vocabulary in Use, New Delhi, Cambridge University Press, 2010
- Jones, Daniel. The Pronunciation of English, New Delhi, Universal Book Stall., 2010
- Birchfield, Susan M. Fowler's Modern English Usage, New Delhi, OUP., 2004
- Llyod, Susan M. Roget's Thesaurus of English Words and Phrases. New Delhi: Penguin., 2010

HSN-001A Communication Skills (Advanced) Pre-requisite**: Nil**

Advanced Communication Skills: Scope, Relevance, & Importance

Soft Skills: Interpersonal Communication; Verbal & Non-verbal, Persuasion, Negotiation, Neuro-Linguistic programming Communication and Media (Social and Popular), The Social and Political Context of Communication, Recent Developments and Current Debates in Media

Cross-cultural and Global Issues in Communication: Race, Ethnicity, Gender & Diaspora Rhetoric and Public Communication, Audience Awareness, Emotionality.

List of Experiments:

1. Discussion on the Process of Communication in Personal and Professional Life
2. Group Discussion, Case Studies and Role-Play
3. Assignments on E-mail Etiquette, Social Networking, Blog Writing, Discussions on Current Issues
4. Non-Verbal Communication in Cross-Cultural Situations, Case Studies, Group Discussions and Readings on Topics Related to Race, Ethnicity , Gender and Diaspora
5. Individual Presentations (Audience Awareness, Delivery and Content of Presentation)

Suggested Books:

- Rentz, Kathryn, Marie E. Flatley & Paula Lentz. Lesikar's Business Communication CONNECTING IH A DIGITAL WORLD, McGraw-Hill, Irwin, 2012
- Bovee, Courtland L & John V. Thill. Business Communication Today. New Delhi, Pearson Education, 2010
- McMurrey, David A. & Joanne Buckley. Handbook for Technical Writing, New Delhi, Cengage Learning., 2009
- Jones, Daniel. The Pronunciation of English, New Delhi, Universal Book Stall., 2010
- Allan & Barbara Pease. The Definitive Book of Body Language, New York, Bantam, 2004

HSN-002 Ethics and Self-awareness Pre-requisite**: Nil**

Introduction: Definition of Ethics; Approaches to Ethics: Psychological, Philosophical, Social.

Psycho-social theories of moral development: View of Kohlberg; Morality and Ideology, Culture and Morality, Morality in everyday context.

Ethical Concerns: Work Ethics and Work Values, Business Ethics, Human values in organizations.

Self-Awareness: Self Concept: Johari Window, Self and Culture, Self Knowledge, Self-Esteem; Perceived Self-control, Self-serving bias, Self-presentation, Self-growth: Transactional Analysis and Life Scripts.

Self Development: Character strengths and virtues, Emotional intelligence, Social intelligence, Positive cognitive states and processes (Self-efficacy, Empathy, Gratitude, Compassion, and Forgiveness).

Suggested Books:

- Hall, Calvin S., Lindzey, Dardner., & Cambell, John B.,"Theories of Personality",Hamilton Printing Company., 1998
- Car Alan, "Positive Psychology: The Science of Happiness and Human Strengths", Brunner-Routledge., 2004
- Leary M.R., "The Curse of Self: Self-awareness, Egotism and the Quality of Human Life", Oxford University Press., 2004
- Louis P. P., "The Moral Life: An Introductory Reader in Ethics and Literature", Oxford University Press., 2007
- Corey, G., Schneider Corey, M., & Callanan, P., "Issues and Ethics in the Helping Professions", Brooks/Cole., 2011
- Snyder, C.R., Lopez, Shane, J., & Pedrotti, J.T., "Positive Psychology" Sage, 2nd edition., 2011

MAN-001 Mathematics I Pre-requisite**: Nil**

Matrix Algebra: Elementary operations and their use in getting the Rank, Inverse of a matrix and solution of linear simultaneous equations. Orthogonal, Symmetric, Skew-symmetric, Hermitian, Skew-Hermitian, Normal & Unitary matrices and their elementary properties. Eigen-values and Eigenvectors of a matrix, Cayley- Hamilton theorem, Diagonalization of a matrix.

Differential Calculus: Limit, Continuity and differentiability of functions of two variables, Euler's theorem for homogeneous equations, Tangent plane and normal. Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Error approximations. Extrema of functions of two or more variables,

Lagrange's method of undetermined multipliers

Integral Calculus:

Review of curve tracing and quadric surfaces, Double and Triple integrals, Change of order of integration. Change of variables. Gamma and Beta functions. Dirichlet's integral. Applications of Multiple integrals such as surface area, volumes, centre of gravity and moment of inertia..

Vector Calculus: Differentiation of vectors, gradient, divergence, curl and their physical meaning. Identities involving gradient, divergence and curl. Line and surface integrals. Green's, Gauss and Stroke's theorem and their applications.

Suggested Books:

- E. Kreyszig, Advanced Engineering Mathematics, 9th edition, John Wiley and Sons, Inc., U.K. 2011
- R.K. Jain and S.R.K. Iyenger, Advanced Engineering Mathematics, 2nd Edition, Narosa Publishing House. 2005
- M.D. Weir, J. Hass, F.R. Giordano, Thomas' Calculus, 11th Edition, Pearson Education. 2008

MAN-004 Numerical Methods Pre-requisite**: Nil**

Error Analysis: Exact and approximate numbers, Rounding of numbers, Significant digits, Correct digits, various types of errors encountered in computations, Propagation of errors.

Solution of system of linear equations: (i) Direct methods: Gauss elimination method without pivoting and with pivoting, LU-decomposition method. (ii) Iterative methods: Jacobi and Gauss-Seidel methods.

Roots of non-linear equations: Bisection method, Regula-Falsi method, Newton-Raphson method, direct iterative method with convergence criteria, Newton-Raphson method for solution of a pair of non-linear equations.

Eigen values and Eigen vectors: Dominant and smallest Eigen values/Eigen vectors by power method.

Interpolation: Finite difference operator and their relationships, difference tables, Newton, Bessel and Stirling's interpolation formulae, Divided differences, Lagrange interpolation and Newton's divided difference interpolation.

Numerical differentiation: First and second order derivatives by various interpolation formulae.

Numerical integration: Trapezoidal, Simpsons $1/3^{rd}$ and $3/8^{th}$ rules with errors and their combinations, Gauss Legendre 2-points and 3-points formulae

Solution of first and second order ordinary differential equations: Picard's method, Taylor's series method, Euler, Modified Euler, Runge-Kutta methods and Milne's method.

Case studies

Suggested Books:

- Gerald, C. F. and Wheatly, P. O.," Applied Numerical Analysis", 6^{th} Edition, Wesley. 2002
- Jain, M. K., Iyengar, S. R. K. and Jain, R. K., "Numerical Methods for Scientific and Engineering Computation", New Age Pvt. Pub, New Delhi. 2000
- Conte, S. D. and DeBoor, C., "Elementary Numerical Analysis", McGraw-Hill Publisher 1982
- Krishnamurthy, E. V. & Sen, S. K., "Applied Numerical Analysis", East West Publication. 1998

MIN-101A Introduction to Mechanical Engineering Pre-requisite**: Nil**

Overview of Mechanical Engineering: Role of mechanical engineers, tools in ME, skills and abilities, ethics in engineering, intellectual property.

History of machines and mechanisms.

Design as a creative problem-solving process: phases of design, design philosophy, design for success, materials in design.

Electromechanical systems: Fundamentals of electromechanical systems, the need for control systems.

Energy Conversion: History of energy conversion, overview of thermodynamics, mechanical energy, work and power, energy conservation and conversion, heat engines and efficiency, sustainable energy; Case Study 1: Internal-Combustion Engines; Case Study 2: Electrical Power Generation; Automobile Engineering.

Overview of Fluid Mechanics: Properties of fluids, pressure and buoyancy, laminar and turbulent flows, fluid flow in pipes, drag and lift.

Introduction to Manufacturing Processes: Casting, machining, welding.

Recent trends in mechanical engineering.

Suggested Books:

- Wickert, J. and Lewis, K., "An Introduction to Mechanical Engineering", 3^{rd} Edition, Cengage Learning 2012

- Kalpakjian, S., Schmid, S. R., “Manufacturing Engineering and Technology”, 7th Edition, Pearson Education 2013
- Groover, M. P., “Automation, Production Systems, and Computer Integrated Manufacturing”, 3rd Edition, Pearson Education 2008
- Bolton, W., “Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering”, 5th Edition, Pearson Education 2010
- Bautista Paz, E., Ceccarelli, M., Echávarri Otero, J., Muñoz Sanz, J.L., “A Brief Illustrated History of Machines and Mechanisms”, Springer 2010
- Shigley, J., Mischke, C., Budynas, R. and Nisbett, K., “Shigley's Mechanical Engineering Design”, 8th Edition, Tata McGraw Hill. **2008**
- Cengel, Y., “Introduction to Thermodynamics and Heat Transfer”, 2nd Edition, McGraw Hill**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. Subject Code: **MIN-102** Course Title: **Basic Manufacturing Processes**

2. Contact Hours: **L: 2** **T: 0** **P: 4**

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

4. Relative Weightage: **CWS: 15** **PRS: 15** **MTE: 30** **ETE: 40** **PRE: 0**

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

8. Pre-requisite: **Nil**

9. Objective: **To introduce fundamentals of manufacturing processes**.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Engineering materials, materials properties & selection of manufacturing process	**2**
2.	**Casting:** Fundamentals of casting process, pattern materials, pattern types, allowances, gating system, molding sand: composition and properties, cores, casting defects and their remedies	**8**
3.	**Joining**: Basic principle of welding, types of weld joints, classification of welding processes, gas welding, manual metal arc welding, welding defects and remedies, soldering and brazing	**6**
4.	**Machining:** Basic principle of machining, lathe, drilling, milling and grinding machines and their operations, cutting tools used	**6**
5.	**Forming:** Fundamentals of metal forming, forging, rolling, extrusion, wire drawing and tube drawing, relevant defects and remedies	**6**
	Total	**28**

11. **LIST OF PRACTICALS**

Sl. No.	Shop	Description
1.	CARPENTRY	Study of Different Carpentry Tools and Pattern Making of T-Joint
2.		Pattern Making of a Wooden Handle
3.	FOUNDRY	Study of Different Foundry Tools and Furnaces
4.		Making a Green Sand Mould of Half Bearing Block
5.		Making Green Sand Mold and Casting of Bearing Block
6.		Demonstration of Injection Molding process
7.	WELDING	Arc Welding of Butt Joint
8.		Gas Welding of Butt Joint

9.		Study of Other Welding/Joining Techniques
10.	MACHINE	Study of Lathe and Job Preparation on it – Lathe Job – 1 (step turning)
11.		Lathe Job – 2 (Threading and Knurling)
12.		Study of Milling Machine and Demonstration of Job Preparation on it
13.		Study of Different Drilling and Boring machines and Preparation of a job involving both operations
14.		Study of Shaping and Planning Machine and preparation of a job
15.		Study of Grinding Machines and Demonstration of Surface Grinding
16.	FITTING	Study of Various Fitting Hand Tools, Marking and Measuring Devices
17.		Preparation of a die (Turn – 1)
18.		Preparation of a die (Turn – 2)
19.	SMITHY	Study of Different Forming Tools and Power Presses
20.		Demonstration of Making of Bolt

12 . Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Kalpakjian, S. and Schmid, S. R, "Manufacturing Engineering and Technology", Pearson Education	2000
2.	DeGarmo, E. P, Black, J. T., Kohser, R. A., "Materials and Processes in Manufacturing",Prentice Hall of India Pvt. Limited	1997
3.	Groover, M. P., "Fundamentals of Modern Manufacturing", Mikell P. Groover, John Wiley and Sons Inc.	2002
4.	Rao, P. N., "Manufacturing Technology (Vol. 1&2)", 3rd Edition, Tata McGraw Hill	2009
5.	Lindberg, R. A., "Processes and Materials of Manufacture", Prentice Hall India Limited	1990

MIN-103 Programming and Data Structures Pre-requisite: **Nil**

Introduction to Programming: Introduction to computer systems; Data representation; Basic idea of program execution at micro level; Concept of flow chart and algorithms, algorithms to programs.

Basic Programming in C++: Constants, variables, expressions and operations; Naming conventions and styles; Conditions and selection statements; Looping and control structures; File I/O; Header files, string processing; Pre-processor directives such as #include, #define, #ifdef, #ifndef; Compiling and linking.

Programming Through Functional Decomposition: Functions (void and value returning); Parameters passing by value, passing by reference, passing by constant reference; Design of functions and their interfaces (concept of functional decomposition), recursive functions, function overloading and default arguments; Library functions; Scope and lifetime of variables.

Data Structures: Fixed size data structures --- arrays and structures; Pointers and dynamic data, relationship between pointers and arrays, function pointers, dynamic arrays; Introduction to dynamic data structures --- linked lists, stacks, queues and binary trees.

Object Oriented Programming: Data hiding, abstract data types, classes, access control; Class implementation – default constructor, constructors, copy constructor, destructor, operator overloading, friend function; Object oriented design, inheritance and composition; Dynamic binding and virtual functions; Polymorphism.

Suggested Books:

- Dietel, H.M. and Dietel, P.J., "C++ How to Program", 8th Edition, Prentice Hall, 2012
- Spephan Prata, "C++ Primer Plus", 6th Edition, Pearson Education, 2012
- Venugopal, K. R., Rajkumar, B. and Ravishankar, T., "Mastering C++", Tata-McGraw Hill, 1997
- Prinz, U.K. and Printz, P., "A Complete Guide to Programming in C++", Jones and Bartlett Learning, 2002

MIN-104 Manufacturing Technology – I Pre – requisite: **Nil**

Introduction: Classification of different manufacturing processes**,** application areas and limitations, selection of a manufacturing process

Sheet Metal Forming: Introduction to sheet metal forming operations, Types of presses, drives, Operations: shearing bending, spinning, embossing, blanking, coining and deep drawing. Die materials, compound and progressive dies and punches Construction details of die set Auxiliary equipments, safety devices.

Material Removal Processes: Classification of machining processes and machine tools. Tool's materials, different types of cutting tools, Nomenclature of single point and multi point cutting tool. Concept of cutting speed, feed and depth of cut. Coolants. Drilling, Boring and broaching machines. Indexing head, milling operations using simple, differential and compound indexing. Introduction to CNC Machines.

Abrasive Finishing: Operations and applications of surface, cylindrical and centreless grinding processes; dressing, truing and balancing of grinding wheels; grading and selection of grinding wheels.

List of Experiments:

1. Study of turret lathe
2. Study of grinding machines, attachments and accessories
3. External threading on a given job on lathe machine
4. Internal threading on a given job on lathe machine
5. Taper turning on a given job on lathe machine
6. V-groove cutting on a gven job on lathe machine
7. Profile turning on a given job on lathe machine

8. Cutting teeth on a spur gear on milling machine
9. Helical milling on a given circular job
10. Slot cutting on a given job on milling machine
11. Shaping operation on cast iron job
12. Keyway cutting on a given job on slotting machine

Suggested Books:

- DeGarmo, E. P, Black, J. T., Kohser, R. A. " Materials and Processes in Manufacturing", Prentice Hall of India Pvt. Limited, 1997
- Kalpakjian, S. and Schmid, S. R, "Manufacturing Engineering and Technology", Pearson Education, 2000
- Groover, M. P., "Fundamentals of Modern Manufacturing", John Wiley and Sons Inc., 2002
- Lindberg, R. A., "Processes and Materials of Manufacture", Prentice Hall India Limited, 1990
- Rao, P. N., "Manufacturing Technology (Vol. 1&2)", Tata McGraw Hill, 2009

MIN-106 Engineering Thermodynamics Pre-requisite: **Nil**

Introduction: Introduction to thermodynamic system, surrounding, state, process, properties, equilibrium, heat and work, Zeroth Law of Thermodynamics

Properties of Pure Simple Compressible Substance: PvT surface, Pv, Tv, TP diagrams. Equation of state for ideal and real gases. Virial equation of state, van der Waal equation, use of steam tables and Mollier diagram

First Law of Thermodynamics: First law application to non-flow processes such as isochoric, isobaric, isothermal, adiabatic and polytropic processes. Steady flow energy equation, flow work. Application to various practical systems viz. nozzles, diffuser, turbines, heat exchangers etc. Application of energy equation to transient flow problems.

Second Law of Thermodynamics: Second law, reversible and irreversible processes, Clausius and Kelvin Planck statements, Carnot cycle, corollaries of second law: thermodynamic temperature scale, Clausius inequality, entropy as a property, principle of increase of entropy. Calculation of entropy change.

Entropy and Exergy: Entropy and its generation, entropy balance for closed system and for control volume, basic concepts of exergy and irreversibility, exergy for closed system and control volume, exegetic efficiency.

Gas-Vapour Mixtures and Air-conditioning: Properties of gas-vapour mixtures, adiabatic-saturation and wet-bulb temperatures, psychrometric chart, human comfort and air conditioning, various air conditioning processes.

Gas and Vapour Power Cycles: Otto, Diesel, Dual, Stirling, Joule-Brayton cycle. Thermal efficiency and mean effective pressure, Rankine cycle.

Refrigeration Cycles: reverse Carnot cycle, vapour compression refrigeration cycle.

List of Experiments:

1. Study of P-V-T surface of H_2O and CO_2.
2. Determine P-T relationship for steam and verify Clausius Clapeyron equation.
3. Determine the calorific value of coal using Bomb calorimeter.
4. Analysing exhaust gases using Orsat apparatus.
5. Determine Relative Humidity and Specific Humidity of air using Sling Psychrometer and Psychrometric Chart.
6. Determine COP of a vapour compression refrigeration unit.

7. Analysing different processes on an air conditioning unit.

Suggested Books:

- Borgnakke, C. and Sonntag, R.E., " Fundamentals of Thermodynamics," Wiley India, 2011
- Cengel, Y.A. and Boles, M.A., "Thermodynamics an Engineering Approach", Tata McGraw-Hill, 2008
- Moran, M.J. and Shapiro, H.M., "Fundamentals of Engineering Thermodynamics", 4th Ed., John Wiley, 2010
- Russel, L.D., Adebiyi, G. A.," Engineering Thermodynamics", Oxford University Press, 2007
- Arora, C.P., "Thermodynamics", Tata-McGraw Hill, 2001
- Nag, P.K., "Engineering Thermodynamics", Tata-McGraw Hill, 2005

MIN-108 Mechanical Engineering Drawing Pre-requisite: **Nil**

General Instructions: Sheet Layout, Line Symbols and Groups, Preferred Scales, Technical Sketching

Types of projections: Reference Planes and Quadrants, Orthographic Projection Projection of point and lines Projection of plane figures Projection of solids Section of solid and development

Shape Description(External): Multiplanar Representation, Systems of Projection, Sketching of Orthographic Views from Pictorial Views, Conventional Practices, Precedence of Views , Precedence of Lines

Uniplanar Representation: Sketching of Pictorial Views (Isometric and Oblique) from Multiplaner Orthographic Views

Shape Description (Internal): Sectioning as an Aid to Understanding internal features, Principles of Sectioning, Types of Sections, Section Lines, Cutting Plane Lines and Conventional Practices

Size Description: Dimensioning, Tools of Dimensioning, Size and Position Dimensions, Unidirectional and Aligned Systems, Principle and Practices of Dimensioning,

Conventional Representation: Representation and Identification of Common Machine Elements and Features Introduction to Solid Modeling

Practical Exercises:

1. Projection of points and lines
2. Projection of plane figures
3. Projection of solids
4. Section and development
5. Sketching of Orthographic Views from Pictorial Views
6. Sketching of Pictorial Views (Isometric and Oblique) from Multiplanar Orthographic Views, Missing Lines Exercise, Missing Views Exercise
7. Sectioning Exercise
8. Dimensioning exercise
9. Identification Exercise
10. Solid Modeling, orthographic views from solid models

Suggested Books:

- Technical Drawing, Giesecke, Mitchell, Spencer, Hill, Dygdon and Novak, Macmillan Publishing Company, 2003
- Engineering Graphics, A. M. Chandra and Satish Chandra, Narosa Publishing House, New Delhi, 2003
- Engineering Drawing and Graphics Technology, T.E. French, C.J. Vierck and R.J. Foster, McGraw-Hill Inc, 1993

- Fundamentals of Engineering Drawing, W.J. Luzadder, J. Warren and J.M. Duff, Prentice Hall International Editions , 1989
- SP 46:1988 Engineering Drawing Practice for Schools and Colleges, Bureau of Indian standards, ---

MIN-201 Kinematics of Machines Pre-requisite**: Nil**

Introduction: Objective of kinematic analysis of mechanism, classification of links, pairs, Basic terminology and kinematic symbols, kinematic chains, plane motion; constraints and degrees of freedom, mechanism and machines, inversion of mechanisms along with their practical applications.

Motion Analysis of Mechanisms: Kinematic quantities and their relationships, absolute ad relative motions, and their vector representation, instantaneous centers of motion, Kennedy Arnold's theorem; relative velocity method, method of instantaneous centers, resolution and orthogonal velocity methods; Acceleration analysis, Significance of Coriolis component of acceleration in mechanisms and its determination, mathematical analysis of slider crank mechanism, special graphical methods

Motion synthesis: Introduction to synthesis of mechanisms, Graphical methods of Synthesis, Chebyshev spacing, two position synthesis, application to four bar mechanism , analytical synthesis using complex algebra , Freudensteins method.

Applied Linkages: Radial engines and master crank, straight line motion and indicator mechanisms, steering mechanism, quick return mechanism, intermittent motion generating mechanisms, Geneva mechanism, analog computing mechanisms, various types of ingenious mechanism and their functioning.

Cams: Classification of different types of cams, types of motion curves and their analytical expressions, graphical construction of cam profiles for different types of follower, pressure angle and cams with specified contours.

Gears: Classification and Basic terminology, Fundamental law of gearing, geometric and kinematic considerations for various tooth profiles, the cycloidal and involute profiles , standards in tooth forms, spur gears and other types of gears; Gear trains, Simple, compound and epicyclic gear trains and their applications.

Flexible connectors: Advantages and disadvantages of belt drives, Kinematic analysis of flat belt and V-Belt drives.

Suggested Books:

- Martin, G.H., "Kinematics and Dynamics of Machines", 3rd Ed., McGraw-Hill , 1982
- Ghosh, A, and Mallik, A.K., "Theory of Mechanisms and Machines", 2nd Ed., Affiliated East-West Press Pvt.Ltd., 2003
- Bevan, T., "Theory of Machines", 3rd Ed., CBS Publishers and Distributors, 2003
- Vicker, J.J., Shigley, J.E. and Penock, G.R., "Theory of Machines and Mechanisms", 3rd Ed., Oxford University Press, 2003
- Hannah, J., and Stephens, R.C., "Mechanics of Machines : Elementary Theory and Examples", 4th Ed., Viva Books, 2004
- Norton, R.L., Kinematics and Dynamics of Machinery", Mc Graw Hill, 2009

MIN-203 MANUFACTURING TECHNOLOGY – II Pre – requisite: **Nil**

Foundry: Sand casting process- Steps; Core; Sand Testing; Molding Processes, Gating system, Solidification Phenomena, Melting Furnaces, Special casting methods - Centrifugal casting; Permanent mold casting; Hot chamber and cold chamber die casting; Investment casting; Shell mold casting; Plaster mold casting; CO_2 mold casting.Casting design considerations, Casting defects and remedies.

Welding: Classification of welding processes, electric arc, ISI classification of coated electrodes, special welding methods: MMAW, GTAW, GMAW, welding, submerged arc welding, electro-slag welding, electron beam welding, laser beam welding, ultrasonic welding, resistance welding, welding defects, and arc blow.

None-destructive examination: Principle and application of common Non-Destructive Examination Methods DPT,MPT and UT of Castings and Weldments

Forming: Forging, Rolling, Extrusion, Wire Drawing and Tube drawing, Forging Defects and Remedies.

Suggested Books:

- DeGarmoE.Paul, Black J.T., Ronald A. Kohser,Materials and Processes in Manufacturing; Prentice Hall of India Pvt. Limited-Delhi, 1997
- Kalpakjian S., Schmid S.R. Manufacturing Engineering and Technology;; Pearson Education, Delhi , 2000
- GrooverMikell P.,Fundamentals of Modern Manufacturing; John Wiley and Sons Inc., 2002
- Lindberg R.A. Processes and Materials of Manufacture; Prentice Hall India Limited; 1990
- Rao P.N. Manufacturing Technology; Tata McGraw Hill, 1998

MIN-204 Machine Drawing Pre-requisite**: MIN-108**

Detachable Fasteners: Screw threads, approximate and conventional representations; Specifications; Threaded fasteners; Types, forms, standard, and specifications; Drawing of temporary connections; Foundation bolts; Locking Devices; Classification, principles of operation, standard types and their proportions. Shaft Couplings; Common types, standard proportions for some couplings.

Permanent Fastenings: Rivets; Standard forms and proportions, Riveted Joints, Common types of joints, terminology, proportions and representation; Welds; Types of welds and welded joints, edge preparation, specifications, and representation of welds on drawings.

Assembly Drawings: Review of sheet preparation, boundary lines, zones, title block, revision panel, Parts List; Numbering of components and associated detail drawings; Assembly drawings of various machine sub-assemblies and assemblies from detail drawings, sketched and actual machine components.

Components Drawing: Limits, Fits, and Tolerances of Size and Form; Types and Grade, Use of Tolerance tables and specification of tolerances, Form and Cumulative Tolerances; Tolerance Dimensioning; General Tolerances; Surface quality symbols, terminology and representation on drawings, correlation of tolerances and surface quality with manufacturing techniques.

Introduction to AUTOCAD, use of AUTOCAD for assembly and component drawings

Introduction to Solid modeling software, use of solid modeling software for assembly and component drawings, generation of different views from solid models.

Suggested Books:

- French, T.E., Vierck, C.J., Foster, R.J., "Engineering Drawing and Graphic Technology", 14th Ed., McGraw Hill Science/Engg./Math, 1993
- Giesecke, F.E., Mitchel, A., Spencer, H.C., Hill, I.L., Dygdon, J.T., Novak, J.E., and Lockhart, S.D., "Technical Drawing", 13th Ed., Prentice Hall, 2008
- Sidheswar, N., "Machine Drawing", McGraw Hill, 2004
- Goutam Pohit, Goutam Ghosh, Machine Drawing with AutoCAD, Pearson, 2007
- SolidWorks 2012: A Tutorial Approach, Prof. Sham Tickoo, CADCIM Technologies, 1988
- SP 46: 1988 Engineering Drawing Practice for Schools and Colleges, Bureau of Indian standards, 2012

MIN-205 Fluid Mechanics Pre-requisite**: Nil**

Introduction: Continuum concept, properties of fluids, Newtonian and Non-Newtonian fluids.

Fluid Statics: Pascal's law, hydrostatic pressure, pressure measurement, manometer and micro-manometer, pressure gauge; Forces on plane and curved surfaces, centre of pressure, equilibrium of submerged and floating bodies, buoyancy, metacentric height; Fluids subjected to constant linear acceleration and to constant rotation.

Kinematics of Fluid: Types of flow, Lagrangian and Eulerian approach, path line, streak line and stream line, stream tube, stream function and potential function, flownet; Deformation of fluid elements, vorticity and circulation.

Fluid Dynamics: Reynolds transport theorem; Conservation equations of mass, momentum and energy, Navier-Stokes, Euler and Bernoulli equations; Forces due to fluid flow over flat plates, curved vanes and in the bends, applications of Bernoulli equation.

Ideal Fluid Flow: Ideal flow identities, flow over half body, Rankine oval, stationary and rotating cylinders, Magnus effect, d'Alembert's paradox.

Viscous Flow: Reynolds experiment, laminar and turbulent flow, plane Poiseuille flow, Couette flow, Hagen-Poiseuille flow; Friction factor and Moody's diagram, losses in pipes and pipe fittings; Flow over aerofoil, lift and drag, flow separation.

Dimensional Analysis: Basic and derived quantities, similitude and dimensional analysis, Buckingham π – theorem, non-dimensional parameters, model testing.

Flow Measurement: Flow measuring devices, Pitot tube, obstruction flow meters, principles of hot wire anemometry and particle image velocimetry.

Compressible Flow: Propagation of sound waves, Mach number, isentropic flow and stagnation properties, one dimensional convergent-divergent nozzle flow, normal shock.

LIST OF EXPERIMENTS

1. Experimental verification of Bernoulli's theorem
2. Impact of jet of a fluid on vanes
3. Calibration and determination of coefficient of discharge for
   (i) Venturimter and (ii) Orificemeter
4. Calibrate V and rectangular notch (or weir) and compare their performances
5. Flow visualization/patterns
6. Flow field investigation by using educational PIV setup

Suggested Books:

- Munson, B.R., Young, D.F., Okiishi, T.H., and Rothmayer, A. P., "Fundamentals of Fluid Mechanics", 7th Ed., John Wiley & Sons, 2012

- Som, S. K., Biswas, G. and Chakraborty, S., "Introduction to Fluid Mechanics and Fluid Machines", 3rd Ed., Tata McGraw Hill, 2012
- Massey, B.S. and Ward-Smith, J., "Fluid Mechanics", 9th Ed., CRC Press, 2011
- White, F.M., "Fluid Mechanics", 7th Ed., McGraw-Hill, 2010
- Yuan, S.W., "Foundation of Fluid Mechanics", 2nd Ed., Prentice-Hall , 1988
- Streeter, V.L., Wylie, E.B., and Bedford, K.W., "Fluid Mechanics", 9th Ed., McGraw-Hill, 1998

MIN-206 Mechanics of Materials Pre-requisite**: CEN-102**

Three Dimensional State of Stress and Strain: Stress and strain tensor, stress and strain transformations, principal stress and strain, Octahedral planes and stresses.

Elastic Strain Energy and Energy Methods: Elastic strain energy due to normal and shear stress, strain energy of a three dimensional principal stress system, dilatational and distortional strain energy, strain energy due to axial, bending and torsional loads; Strain energy and complimentary energy theorems, Castigliano's theorems, theorem of virtual work, theorem of least work, reciprocal theorems, application of energy methods for determining slope and deflection in beams and twists in shafts, unit load method.

Theories of Elastic Failure: Modes of failure, the necessity and significance of a failure theory, statement of various theories of failure and their application, graphical representation, comparison and limitations of various failure theories, safety factors.

Curved Beams: Beams of large initial curvature, location of neutral axis, distribution of stresses across sections having rectangular, circular and trapezoidal shapes.

Statically Indeterminate Beams: Conditions of statical indeterminacy, degree of indeterminacy, analysis of built-in beams using integration, superposition and area-moment methods, application of energy methods.

Unsymmetrical Bending: Symmetrical and nonsymmetrical beam cross-sections and their properties, product and second moment of area, principal second moments of area, Mohr's circle of second moments of area, bending of symmetrical beam with skew load, bending of beams having unsymmetrical cross-section, location of neutral axis, shear center and its location determination for thin-walled open-sections.

Axi-symmetrical Problems: Stresses and displacements in thick cylindrical shells subjected to internal and external pressure, press fits and laminated construction, thick spherical shells. Stresses in rotating cylinders and thin rotating disc, disc having uniform strength in rotation.

Suggested Books:

- Boresi, A.P., and Schmidt, R.J., "Advanced Mechanics of Materials", 6th Ed., John Wiley & Sons, 2002
- Hearn, E.J., "Mechanics of Materials", 3rd Ed., Pergamon, 2003
- Timoshenko, S.P., and Gere, J.M., "Mechanics of Materials", 2nd Ed., CBS Publishers, 2002
- Srinath, L.S., "Advanced Mechanics of Solids", 3rd Ed., Tata McGraw Hill, 2009
- Ugural, A.C., "Advanced Strength and Applied Elasticity", 5th Ed., Pearson Education Inc., 2012

MIN-208 Theory of Production Processes Pre –requisite: **Nil**

Theory of Metal Cutting: Tool geometry, chip formation, chip control, mechanics of single point orthogonal machining, tool life, economics of metal cutting.

Non-Conventional Machining Methods: Comparison with conventional methods, principles and applications of ECM, EDM, ultrasonic, electron beam and laser machining.

Jigs and Fixtures: Usefulness of Jigs and Fixtures**,** Design principles of jigs and fixtures, Principles of location and clamping,Types locating and clamping devices, Few simple design of Jigs and Fixtures : lathe, milling, boring, shaping, broaching, grinding, assembly and welding fixtures, Economics of Jigs and Fixtures.

Metrology: Introduction, inspection types and principles, radius and taper measurement, measurement of screw threads and gears. Limits, fits, and dimensional and geometrical or form tolerances, computer vision system based measurement, coordinate measuring machines, measurement of form tolerances, measurement of surface roughness: surface roughness terminology, different methods of surface roughness measurement.

Foundry: Gating system design, Risering design, production of gray, malleable and spheroidal graphite iron castings.

Welding: Weldability, structure in weld and heat affected zones, distortion and residual stresses, welding of cast iron, stainless steel and aluminum, hard facing.

Forming: Introduction of forming process analysis methods (slab method, uniform deformation energy method, limit analysis), Analysis of extrusion, rolling and forging processes, forming defects, formability & workability, temperature & lubrication aspects in forming.

Suggested Books:

- Ghosh, A., and Mallik, A.K., "Manufacturing Science" Affiliated East-West press Pvt. Ltd. , 1985
- Lal, G.K., "Introduction to Machining Science" New Age International Publishers, 1996
- Gupta, I.C., "Text Book of Engineering Metrology" DhanpatRai Publishing Co., 2003
- Heine, R.W., Loper, C.R., and Rosenthal, P.C., "Principles of Metal Casting", 21st reprint, Tata McGraw-Hill , 1997
- Kuo, S., "Welding Metallurgy", John-Wiley & Sons Inc., 2003
- Dieter, G.E., "Mechanical Metallurgy", McGraw Hill Book Company , 1988

Laboratory Work Outline:

Experimental studies on the cutting tool angle measurement, cutting tool grinding, use of dynamometers, mechanical measurements etc.

MIN-209 Thermal Engineering Pre-requisite**: Nil**

Introduction: Introduction to Thermodynamics, examples of thermal power plants, refrigeration systems; Definitions: system, boundary, surroundings, closed and open systems, properties, processes, work and heat interactions.

Laws of thermodynamics: Zeroth law, concept of temperature, temperature scales, methods of temperature measurement; First law for cyclic process in closed system, internal energy; First law for open system, steady flow energy equation (SFEE), application of SFEE for simple devices.

Properties of pure substance: Properties of pure substance, *T-v, p-v* diagrams, properties of steam, use of steam tables, example problems for use of steam tables.

Second law of thermodynamics: Kelvin-Planck and Clausius statements of second law of thermodynamics, Carnot theorem, corollaries of Carnot theorem for absolute temperature scale, entropy.

Power Cycles: Rankine vapor power cycles on T-s diagrams, gas power cycles, Otto, Diesel and Joule cycles, simple problems.

Refrigeration & Air-conditioning: Working of simple vapor compression cycle, representation of various processes on p-h diagram, air-conditioning principles, definitions of humidity, relative humidity, wet-bulb and dry-bulb temperatures. Psychrometric chart, representation of various air-conditioning processes on psychrometric chart.

Heat Transfer: Introduction to different modes of heat transfer, conduction, convection and radiation.

Conduction: Fourier's law of heat conduction, 1D heat conduction equation, different types of boundary conductions, thermal resistance, composite wall for plane wall and cylindrical geometries.

Convection: Free and forced convection principles, important non-dimensional numbers, correlations for Nusselt number.

Radiation: Basic laws of radiation, black body concept, emissivity, absorptivity, reflectivity, transmissivity.

Suggested Books:

- Cengel, Y. A. and Boles, M. A., "Thermodynamics: An Engineering Approach", 7th Ed., Tata McGraw-Hill, 2011
- Van Wylen G.J. and Sonntag, R.E., "Fundamentals of Classical Thermodynamics", 4th Edn., John Wiley & Sons, 2002
- Rogers, G. and Mayhew, Y., "Engineering Thermodynamics and Heat Transfer", 4th Ed., Addison-Wesley, 2002
- Cengel, Y. A. and Ghajar, A. J., "Heat and Mass Transfer", 4th Edn., Tata McGraw Hill Education Pvt. Ltd., New Dehi, 2011
- Incropera, F.P., Dewitt, D.P., Bergman, T. L. and A. S. Lavine, "Principles of Heat and Mass Transfer", 7th Ed. (International Student Version), John Wiley & Sons, 2012

List of experiments:

I – Applied Thermodynamics

(i) Flash point and fire point of and lubricants and diesel
(ii) Calorific value of coal using Bomb Calorimeter
(iii) Performance test on single cylinder diesel engine

II – Heat Transfer

(i) Thermal conductivity of metal rod
(ii) Natural convection over a heated vertical wall
(iii) Forced convection over a heated cylinder
(iv) COP of vapor compression refrigeration system

MIN-210 Production Planning & Control Pre-requisite**: Nil**

Introduction: Manufacturing function; Elements of production systems; Types of production systems; Objectives and functions of production planning and control.

Product Design: Identification of product ideas and selection, product development and design, product analysis: marketing aspects, product characteristics, economic analysis, profitability and competitiveness, production aspects.

Forecasting: Concepts and applications, demand forecasting, principle of forecasting, forecasting techniques, quantitative and qualitative, Delphi technique.

Production Planning: Preplanning, selection of materials, methods, machines and man power, aggregate production planning, master production planning, Break Even Analysis, concepts, make or buy decisions.

Production Control: Dispatching rules, dispatching of work card, inspection card and reports, control boards and charts, expediting, progress reporting, corrective change in schedules.

Suggested Books:

- Buffa, E.S., Sarin, R.K., "Modern Production / Operations Management", John Willey and Sons, 1994
- Mukhopadhyaya, S.K., "Production Planning and Control – Text and Cases", Prentice Hall of India, 2004
- Adam, Jr., E.E., Ebert, R.J., "Production and Operations Management Concept, Models and Behaviour", 5th Ed., Prentice Hall of India, 2001

- Vollman, T.E., Berry, W.L., Whybark, D.C., “Manufacturing Planning and Control Systems” 4th Ed., McGraw Hill, , 1997
- Sipper, D., Buffin, R.L., “Production: Planning Control and Integration”, McGraw Hill, ., 1997

MIN-211 Theory of Machines Pre-requisite**: Nil**

Introduction: Objectives of kinematic analysis of mechanism, Plane motion, kinematic concept of links, kinematic chains, basic terminology and definitions, inversions of mechanisms along with their applications.

Motion and Force Analysis: Absolute and relative motions, kinematic and dynamic quantities and their relationships, vector diagrams; Instantaneous center of motion, velocity and acceleration polygons, concept of Coriolis component of acceleration; concepts of free body and its equilibrium, review of basic principles of statics, static force analysis, friction effects, dynamic force analysis, equivalent dynamical systems.

Power Transmission using Gears and Belts: Classification and basic terminology, Fundamental law of gearing, involute tooth profile and its kinematic considerations, spur gears, standards in tooth forms; Gear trains: Simple, compound and epicyclic gear trains; Kinematic design of pulleys, flat and V-belts, transmission, efficiency of power transmission.

Clutches and Brakes: Friction between pivot and collars, plate and cone clutches, analysis of band and block brakes.

Balancing: Balancing of rotating masses in one and different parallel planes

Mechanical Vibrations: Basic terminology related to vibrations, free and forced vibrations without and with damping

Suggested Books:

- Martin, G.H., "Kinematics and Dynamics of Machines", 2nd Ed., McGraw-Hill , 1982
- Norton, R.L., Kinematics and Dynamics of Machinery”, Mc Graw Hill, 2009
- Massie, H.H., and Reinholtz, C.F., "Mechanisms and Dynamics of Machinery, 4th Ed., John Wiley & Sons, 1987
- Vicker, J.J., Shigley, J.E., and Pennock, G.R., :Theory of Machines and Mechanisms:, 3rd Ed., Oxford University Press, 2003
- Hannah, J., and Stephens,R.C.,"Mechanics of Machines : Elementary Theory and Examples",4th Ed., Viva Books, 2004
- Vinogradov, O., “Fundamentals of Kinematics and Dynamics of Machines and Mechanisms”, CRC Press, 2000

MIN-212 Machine Design Pre-requisite**: MIN-108; CEN-102; MIN-211**

General: Introduction to design procedure, design requirements, review of force analysis concepts. Factor of safety concepts, concept and mitigation of stress concentration, motor selection.

Dynamic Loading: Cyclic loading, endurance limit, fatigue failure criteria.

Component Design: Rivets, welds and threaded fasteners, knuckle and cotter joints, design and force analysis of spur gears, design of shafts and shaft couplings.

Machine Drawing Practice

Detachable Fasteners: Specifications of screw threads and threaded fasteners, foundation bolts.

Permanent fastenings: Rivets and riveted joints, types of welds and welded joints, and representation of welds on drawings.

Assembly Drawings: Review of sheet preparation: Boundary lines, zones, title block. Revision panel; Parts List, Numbering of components and associated detail drawings. Assembly drawing practices.

Suggested Books:

- Shingley, J.E., Mischke, C.R., "Mechanical Engineering Design (in S.I. Units)", 6th Ed., Tata McGraw Hill, 2006
- Juvinall, R.C., Marshek, K.M., "Fundamentals of Machine Component Design", 4th Ed., John Wiley , 2006
- Mahadevan, K., and B., Reddy, "Design Data Hand Book", CBS Publishers, 2003
- Sidheswar, N., "Machine Drawing", McGraw-Hill , 2004
- Giesecke, F.E., Mitchell, A., Spencer, H.C., Hill, I.L., Dygdon, J.T., Novak, J.E., and Lockhart, S.D., "Technical Drawing", 13th Ed., Prentice Hall, 2008

MIN-214 Engineering Economy Pre-requisite**: Nil**

Introduction: Nature and purpose of engineering economy studies, functions of engineering economy, physical and economic laws, consumer and producer goods.

Interest and Depreciation: Productivity of capital, nominal and effective interest, interest factors, CAF, PWF, SPWF, SCAF, SFF, and CRF, deferred annuities, perpetuities and capitalized cost, equivalence, gradient factors GPWF and GUSF, Classification of depreciation, methods of computing depreciation, economic life and mortality data, capital recovery and return.

Industrial Costing and Cost analysis: Classification of costs: direct material, direct labour and overheads, fixed and variable cost, semi-fixed cost, increment, differential and marginal cost, sunk cost and its reasons, direct and indirect cost, prime cost, factory cost, production cost and total cost. Break-even analysis, two and three alternatives, graphical solution, break-even charts, effects of changes in fixed and variable cost, minimum cost analysis, economic order quantity, effect of risk and uncertainty on lot size.

Replacement Studies: Reason of replacement, evaluation of proposals, replacement because of inadequacy, excessive maintenance, declining efficiency, obsolescence; MAPI formula.

Cost Estimation and Risk analysis: Difference between cost estimation and cost accounting, qualifications of an estimator, estimating procedure, estimate of material cost and labour cost, Estimation of cost in machining, forging, welding and foundry operations. Introduction to risk analysis, measures of risk, techniques of risk analysis; RAD and CE approach.

Economy Study Patterns: Basic economy study patterns and their comparison, effect of taxation on economic studies.

Suggested Books:

- Ardalan, A., "Economic and Financial Analysis for Engineering and Project Management", CRC Press, 1999
- Grant, E.L., Grant, W., and Leavenworth, R.S., "Principles of Engineering Economy", 8th Ed., John Wiley & Sons Inc, 2001
- Eschenbach , T.G., "Engineering Economy by Applying Theory to Practice (Engineering Technology)", 2nd Ed., Oxford University Press, USA , 2003
- Blank, L.T., and Tarquin, A.J., "Engineering Economy", McGraw-Hill Inc., 2005
- Hartman, J.C., "Engineering Economy and the Decision-Making Process", Prentice Hall Inc., 2006
- Theusen Gerald J., Fabrycky W.J., Engineering Economy, PHI, 2008

MIN-216 Theory of Production Processes – I Pre –requisite: **Nil**

Theory of Machining: Single point and multi-point machining, chip formation: mechanism, chip types, chip control, tool geometry: single point, specifications in different systems, selection of tool angles, orthogonal and oblique machining, cutting tool geometry, mechanics of single point orthogonal machining: Merchant's circle, force, velocity, shear angle, and power consumption relations, cutting tool wear and tool life: wear mechanisms, wear criterion, Taylor's tool life equation, facing test, variables affecting tool life; Machinability and its measures, economics of machining.

Advanced Manufacturing Processes: Process principle, equipment, analysis and applications of advanced machining processes such as Abrasive Jet Machining, Ultrasonic Machining, Water Jet Machining, Electro Chemical Machining, Chemical Machining, Electro-Discharge Machining, Wire Electro Discharge Machining, Electron Beam Machining, and Laser Beam Machining, rapid prototyping and rapid tooling: introduction of solid-based (FDM, LOM), liquid-based (SLA, SGC), powder-based (3DP, BPM) RP processes.

Finishing and Superfinishing Processes: Principles and applications of honing, superfinishing, lapping, polishing, buffing, peening, and burnishing

Metrology: Introduction, inspection types and principles, radius and taper measurement, measurement of screw threads and gears. Limits, fits, and dimensional and geometrical or form tolerances, computer vision system based measurement, coordinate measuring machines, measurement of form tolerances, measurement of surface roughness: surface roughness terminology, different methods of surface roughness measurement

Jigs and Fixtures: Usefulness of Jigs and Fixtures**,** Design principles of jigs and fixtures, Principles of location and clamping, Types locating and clamping devices, Few simple design of Jigs and Fixtures : lathe, milling, boring, shaping, broaching, grinding, assembly and welding fixtures, Economics of Jigs and Fixtures..

Suggested Books:

- DeGarmo, E.P., Black, J.T., Kohser, R.A., "Materials and Processes in Manufacturing", Prentice Hall of India, 1997
- Ghosh, A., and Mallik, A.K., "Manufacturing Science" Affiliated East-West press Pvt. Ltd. , 1985
- Lal, G.K., "Introduction to Machining Science" New Age International Publishers, 1996
- Chua, C.K., and Leong, L.F., "Rapid Prototyping: Principles and Applications in Manufacturing" John Wiley & Sons Ltd., 1997
- Gupta, I.C., "Text Book of Engineering Metrology" Dhanpat Rai Publishing Co., 2003

MIN-291 Engineering Analysis and Design Pre-requisite**: Nil**

Introduction: Design, Mechanical Engineering Design, Different Phases of the Design Process

Engineering Analysis: role of analysis, the design spiral, Computer Aided engineering analysis: visualization, analysis and redesign, statistical considerations, safety and reliability

Reverse engineering: Introduction, applications

Learning from Failure: Various failure case studies, Failure of machine components

Engineering Design: projects for design of machine elements aesthetics in engineering design, written and oral presentation, posters engineering ethics, team work.

Suggested Books:

- J. L. Yowell, and D. W.Carlson,, Eds., Introductory Engineering Design: A Projects-Based Approach, Third Edition, 2011
- A. H. Burr and J. B. Cheatham, Mechanical Analysis and Design, 2nd Ed., Prentice Hall, , 1997
- J. R. Dixon, Design Engineering: Inventiveness, Analysis and Decision Making, TMH, New Delhi, , 1980.

- Budynas−Nisbett , Shigley's Mechanical Engineering Design, Eighth Edition, 2006
- Mike W. Martin, Roland Schinzinger, Ethics in Engineering, McGraw-Hill 4 edition, 2004

MIN-301 Dynamics of Machines Pre-requisite**: MIN-201**

Force Analysis of Mechanisms: Review of basic principles of statics, Concept of free body and its equilibrium, Transmission of forces in machine elements, static force analysis, friction effects, forces on gear teeth; D'Alembert's principle, dynamic force analysis of mechanisms, force analysis of cam and follower mechanism, equivalent dynamical systems, dynamic analysis of reciprocating engines, practical examples from actual machines.

Flywheels and Governors: Turning moment diagram, Fluctuation of energy and speed, coefficient of fluctuation of speed, use of crank effort diagram, calculation of flywheel size; Advantages of governors, Analysis of different types of governors, effect of sleeve friction, characteristic of governors, controlling forces curves, sensitivity, hunting phenomena in governors, stability, governor effort and power.

Balancing: Balancing of rotating masses in single plane and in different parallel planes, balancing of slider crank mechanisms, balancing of in-line, V- and locomotive engines, principles of balancing machine.

Friction Devices: Advantages and disadvantages of belt drives system, belt drive system, friction in pivots and collars, power screws, plate and cone clutches, band and block brakes.

Gyroscope: Motion of rigid body in three - dimensions, Angular momentum, Gyroscopic action, equation for regular precession and gyroscopic torque, applications of gyroscope

Mechanical Vibration: Basic terminology related to vibrations; Conservative systems; Free vibrations of systems without and with damping; Equilibrium and energy methods for determining natural frequency of vibratory system; Rayleigh's method, Free vibrations of system with viscous damping, over damped, critically and under damped systems, logarithmic decrement; Forced vibrations of systems with viscous damping, equivalent viscous damping; Impressed forces due to unbalanced masses and excitation of supports, vibration isolation, transmissibility, whirling of shaft; Introduction to multi degree of freedom system vibrations: Discrete and continuous systems.

Suggested Books:

- Vicker, J.J., Shigley, J.E., and Pennock, G.R., "Theory of Machines and Mechanisms", 3rd Ed., Oxford University Press, 2003
- Rao, J. S. "Theory of Machines", New Age pub, 2007
- Norton, R.L., Kinematics and Dynamics of Machinery", Mc Graw Hill, 2009
- Grover, G.K., "Mechanical Vibrations", 7th Ed., Nem Chand & Bros., 2003
- Thomson, W.T., "Theory of Vibration with Applications", 3rd Ed., CBS Publishers and Distributors, 2003
- Vinogradov, O., "Fundamentals of Kinematics and Dynamics of Machines and Mechanisms", CRC Press, 2000

MIN-302 Machine Design Pre–requisite: **MIN-206, MIN-301**

General: Introduction to design procedure; design requirements; review of force analysis concepts; materials selection for design.

Types of failures; theories of failures and their applications; factor of safety concepts, statistical considerations in design; Motor selection and matching of machinery.

Causes of stress concentration; stress concentration factors; mitigation of stress concentration.

Dynamic loading: Cyclic loading, endurance limit, effects of type of loading, size and surface finish; notch sensitivity; reliability considerations; Goodman and Soderberg diagrams; cumulative fatigue damage.

Design of Machine Elements: Design of keys, threaded fasteners and power screws, belt and chain drives; coil springs. Design of welded joints

Design of spur, helical and worm gears; design of shafts; analysis of forces and bearing reactions; selection of rolling elements bearings. Design of clutches and brakes.

Principles of Machinery Construction: Support and retainment of rotating assemblies, speed and motion changing devices, casting and weldment design, machine frame and housing design,

Self-Study: Design of keys and couplings; riveted and welded joints; design of bevel gears; corrosion and wear considerations in design

Suggested Books:

- Mechanical Engg. Design, Shigley and Mitchke, McGraw Hill, 2003
- Machine Design, Robert L. Norton, Pearson Education Asia, 2001
- Fundamentals of Machine component design, Juvinall and Marshek, John Wiley, 2002
- Design Data Hand book, Mahadevan and Balaveera Reddy, CBS Publishers, 2003
- Machine Design. Paul H. Black & O. E. Adams. McGraw Hill, 1981

MIN-303 Principles of Industrial Engineering Pre-requisite**: Nil**

Industrial Engineering: Introduction to industrial engineering.

Functions of organization, Elements of organization, Principles of organization, Types of organization and their selection.

Plant Layout and Material Handling: Site selection, types of layout, factors affecting layout, plant building, flexibility and expandability, Principles of material handling, types and selection of materials handling equipment's.

Production Planning and Control: Functions, forecasting, routing, operations planning; Gantt chart, work order, dispatching and follow-up; CPM and PERT techniques.

Inventory Control: Scope, purchasing and storing, economic lot size; ABC Analysis.

Quality Control: Statistical quality control, control charts for variables and attributes: X bar, R, p & c charts, Concepts &Scope of TQM and QFD.Acceptance Sampling: Consumers risk, Producers risk, LQL, AQL, OC curves, Types of sampling plans, AOQ, ATI.

Work Study: Scope, work measurement and method study, standard data, ergonomics and its industrial applications.

Suggested Books:

- Mitra, A., "Fundamentals of Quality Control and Improvement", John Wiley & Sons, Inc,, 2008
- Russell, R.S., Taylor, B.W.,"Operations Management", Pearson Education, 2003
- Jocobs, C.A., "Production and Operations Management", Tata McGraw Hill, 1999
- Groover,M.P.,"Automation, Production Systems and Computer- Integrated Manufacturing", Pearson Education, 2001
- Maynard, H.B.,"Industrial Engineering Handbook", McGraw Hill, 2001
- BesterfieldD.H. et al., "Total Quality Management:, Pearson Education, 1999

MIN-304 Fluid Machinery Pre-requisite**: Nil**

Introduction: Classification, Euler's turbomachinery equation, aerofoil and cascade theory, impulse and reaction principle, specific speed

Hydraulic Turbines: Classification, Pelton, Francis, Kaplan, propeller and bulb turbines, velocity triangles, power and efficiency calculations, draft tube, cavitation, Thoma's cavitation factor, governing of impulse and reaction turbines.

Rotodynamic Pumps, Fans & Compressors: Classifications, centrifugal, mixed and axial flow pumps, velocity triangles; Head, power and efficiency calculations, system losses and system head, impeller slip and slip factors, Hydraulic design of fans and compressors, internal and stage efficiency, stalling.

Performance Characteristics of Rotodynamic Machines: Head, capacity and power measurement, performance characteristics, operating characteristics, model testing, similarity laws, Muschal or constant efficiency curves.

Hydro-static Pumps: Principle of positive displacement pumps, working principle of reciprocating pumps, indicator diagram, slip, effect friction and acceleration, air vessels, two throw and three throw pumps. Constant and variable delivery, internal and external gear pumps, vane pumps, screw pumps, radial piston pumps, rotary piston pumps.

Hydraulic Transmission Devices: Fluid coupling and torque converter, hydraulic jack, press, crane, pressure accumulator and intensifier.

Suggested Books:

- Earl Logan, Turbomachinery: Basic theory and applications, CRC Press, 2009
- Lal, J., Hydraulic Machine; Metropolitan Book Co., 2007
- Gopal Krishnan & Prithviraj, A treatise on Turbomachines; scitech publications (India) pvt. Ltd, 2002
- Douglas, J., F., Fluid Mechanics, Pearson Education Ltd. , 2005
- Som & Bisswas, Introduction to fluid Mechanics, Tata McGrawhill 2nd Edition, 2004

List of Experiments:

1. Performance characteristics of Pelton Turbine
2. Performance characteristics of Francis Turbine
3. Performance characteristics of axial flow Turbine
4. Study of a jet reaction principle
5. Performance characteristics of ram pump
6. Performance characteristics of centrifugal pump

MIN-305 Heat and Mass Transfer Pre-requisite: **Nil**

Introduction: Mode of heat transfer, conduction, convection and radiation.

Conduction: Fourier, s, law, thermal conductivity of matter and other relevant properties, heat diffusion equation, boundary and initial conditions. One dimensional steady state conduction through plane wall, cylinder and sphere, conduction with thermal energy generation, heat transfer from extended surfaces. Two-dimensional steady-state conduction through plane wall.

Transient conduction- lumped capacitance method and its validity, plane wall and radial systems with convection, semi infinite solid.

Convection: Velocity, thermal and concentration boundary layers and their significance, laminar and turbulent flow, convection transfer equations, boundary layer similarity and normalized convection transfer equations, heat and mass transfer analogy, Reynolds analogy, effect of turbulence, convection in external and internal flow, free convection, boiling and condensation.

Heat exchangers: Heat exchangers types, overall heat transfer coefficient, analysis of parallel-flow, counter flow, multipass and cross- flow heat exchangers, effectiveness – NTU method, compact heat exchangers.

Radiation: Fundamental concepts, radiation intensity and its relation to emission, irradiation and radiosity, blackbody radiation, Planck distribution, Wien's displacement law, Stefan- Boltzmann law, surface emission,

surface absorption, reflection, and transmission, kirchhoff's law, gray surface. Radiation exchange between surfaces, view factor, blackbody radiation exchange, radiation exchange between diffuse gray surfaces in an enclosure.

Diffusion Mass Transfer: Fick's law of diffusion, mass diffusion equation, boundary and initial conditions, mass diffusion without and with homogeneous chemical reactions, transient diffusion.

Suggested Books:

- Fundamental of Heat and Mass Transfer, Incropera and Dewitt, 5th Edn., John Wiley & Sons, 2002
- Heat Transfer A Practical Approach, Cengel, 4th Edn, Tata McGraw-Hill, 2011
- Heat Transfer, Holman J.P., Ninth Edn. Tata McGraw –Hill, 2007
- Heat Transfer, Ozisik, 2nd Edn. Tata McGraw-Hill, 1987

MIN-309 Theory of Production Processes-II Pre–requisite: **Nil**

Theory of Casting: Cooling and solidification of castings, cooling curves, nucleation and dendrite formation, design of gating and risering system in ferrous and nonferrous foundry practice, production of gray, malleable, and spheroidal graphite iron castings, mechanization in foundry equipments.

Theory of Welding: Thermal effects in welding, structure in weld and heat affected zones, distortion and residual stresses, weldability, weld quality, welding of cast iron, stainless steel and aluminum, hard facing, brazing, soldering, and adhesive bonding.

Theory of Forming: Mechanics of materials: elastic and plastic behavior, concept of stress and strain and their types, Mohr's stress and strain circle in 2-D and 3-D, stress and strain tensor, hydrostatic and deviatoric components, elastic stress-strain relations, strain energy, anisotropy of elastic behavior; Theory of plasticity: true stress and strain, flow curve, concept of anelastic, hysteresis, and visco-elastic behavior, Bauschinger effect, Tresca and Von-Mises yield criteria, anisotropy in yielding, octahedral normal and shear stresses and strains, invariants of stress and strains, flow rules or plastic stress-strain relations.

Analysis of Forming Processes: Slab method, uniform deformation energy method, limit analysis, analysis of drawing, extrusion, rolling, forging, deep drawing, and bending, forming defects, formability & workability, temperature & lubrication aspects in forming.

Powder Metallurgy: Theory of powder metallurgy, manufacture of metal powders, sintering, secondary operations, properties of finished parts, design considerations and applications.

Suggested Books:

- DeGarmo, E.P., Black, J.T., Kohser, R.A., "Materials and Processes in Manufacturing", Prentice Hall of India, 1997
- Heine, R.W., Loper, C.R., and Rosenthal, P.C., "Principles of Metal Casting", 21st reprint, Tata McGraw-Hill , 1997
- Kuo, S., "Welding Metallurgy", John-Wiley & Sons Inc., 2003
- Dieter, G.E., "Mechanical Metallurgy", McGraw Hill Book Company , 1988
- Ghosh, A., and Mallik, A.K., "Manufacturing Science", Affiliated East-West Press Pvt. Ltd. , 1985

MIN-310 Quality Management Pre-requisite**: Nil**

Introduction: Different definitions, dimensions, and aspects of quality; Traditional and modern views of quality control; Different Philosophies by quality Gurus, seven basic and new quality control tools.

Statistical Process Control: Theory and applications of control charts, controls charts for variables: charts for averages, ranges, and standard deviation, control charts for attributes: p and c charts, fraction defective and number of defects per unit, different adaptations of control charts, manufacturing process variability, manufacturing process capability and tolerances.

Acceptance Sampling: Concept of acceptance sampling, sampling by attributes: single and double sampling plans; Construction and use of OC curves.

Total Quality Management: Concept and philosophy, scope, applications, implementation, quality function deployment, six sigma, process capability, just-in-time philosophy, quality circles, quality system and Introduction to ISO 9000 and ISO 14000.

Reliability: Concept and definition, measurement and test of reliability, design for reliability, concepts of maintainability and availability.

Suggested Books:

- Grant,E., and Leavenworth, R., "Statistical Quality Control", McGraw-Hill, 1996
- Mitra, A., "Fundamentals of Quality Control and Improvement", John Wiley & Sons, Inc,, 2008
- Juran,J.M., "Quality Control Handbook", McGraw-Hill, 1988
- Besterfield, D.H., Besterfield – Michna, C., Besterfield, G., and Besterfield-Sacre,M., "Total Quality Management",Pearson Education, 1999
- Montgomery, D.C.,"Introduction to Statistical Quality Control",John-Wiley & Sons Inc. , 1996

MIN-311 Operations Research Pre-requisite**: Nil**

Introduction: Origin and development of operations research, general methodology of operations research (OR), applications of OR to industrial problems.

Linear Programming: Different types of models, formulation of linear programming problems (LPPs), product-mix problems, deterministic models, graphical solution. Simplex algorithm, computational procedure in simplex method, applications of simplex technique to industrial problems. Duality and its concept, dual linear programming, application of elementary sensitivity analysis

Linear Optimization Techniques: Integer programming problems (IPPs), assignment models: mathematical formulation, methods of solutions, transportation problems: methods of obtaining optimal solution degeneracy in transportation problems, transshipment problems.

Game Problems: Introduction and scope of game problems in business and industry, min-max criterion and optimal strategy, solution of two-person zero-sum game, game problem as a special case of linear programming.

Queuing Problems: Queuing systems and concepts, classification of queuing situations; Kendall's notation, solution of queuing problems, single channel, single stage, finite and infinite queues with Poisson arrival and exponential service time, applications to industrial problems.

Suggested Books:

- Taha,H.A., "An Introduction to Operations Research", 6th Ed., Prentice Hall of India , 2001
- Panneerselvam R., Operations Research, PHI, 2011
- Hillier, F.J., Lieberman, G.J., "Introduction to Operations Research" 7th Ed., Holden Day Inc. , 2001
- Gross, D., and Harris, C.M., "Fundamentals of Queuing Theory", 2nd Ed., John Wiely & sons, NY, 1985
- Cheema, D.S., "Operation Research", Laxmi Publications (P) Ltd., 2005
- Wagner, H.M., "Principles of Operations Research", Prentice Hall of India, 1980

MIN-312 Operations Management Pre-requisite**: Nil**

Introduction: Types and characteristics of manufacturing systems, concept of manufacturing cell, system planning and design.

Operations Scheduling: Concepts, loading, scheduling and sequencing, single processor scheduling, flow shop scheduling, job-shop scheduling, scheduling criteria; Gantt charts

Project Management: Project management techniques; Introduction to CPM and PERT techniques, activities and events, conventions adopted in drawing networks, graphical representation of events and activities, dummy activities, identification of critical activities.

Materials Planning and Control: Field and scope, materials planning; Inventories-types and classification; ABC analysis, economic lot size, EOQ model, lead time and reorder point, inventory control systems, modern trends in purchasing, store keeping, store operations; Introduction to MRP and MRP-II, bills of material; Introduction to ERP.

Zero Inventory Systems: Introduction to the new manufacturing concepts; JIT, lean manufacturing and agile manufacturing, pull and push systems of production; Kanban system.

Capacity Planning: Definition of capacity, capacity planning, capacity requirement planning, capacity available and required, scheduling order.

Supply Chain Management: Introduction – understanding supply chain, supply chain performance, supply chain drivers and obstacles, planning demand and supply in a supply chain.

Suggested Books:

- Russell, R.S., and Taylor, B.W., 'Operations Management", Pearson Education, 2003
- Jocobs, C.A., "Production and Operations Management", Tata McGraw Hill, 1999
- Ramamurthy, P. "Production and Operations Management", New Age International, 2002
- Adam Jr., E.E., and Ebert, R.J., "Production and Operations Management Concept, Models, and Behaviour", 5th Ed., Prentice Hall of India , 2001
- Buffa, E.S., and Sarin, R.K., "Modern Production / Operations Management", John Willey & Sons, 1994

MIN-313 Work System Design Pre-requisite**: Nil**

Productivity: Concept, objectives, Factors affecting productivity, Productivity measurement, causes of low productivity, Tools and techniques to improve productivity, work study and productivity

Work Study: Purpose, scope and developments, human aspects, techniques of work study and their scope

Method Study: Objectives and scope, recording techniques: operation process charts, flow process charts, two hand process chart, activity chart, other charts, their analysis, flow diagram, string diagram, critical examination techniques, development, installation and maintenance of improved methods, Principles of motion economy, Micro Motion study, Therbligs, motion analysis, preparations of motion film and its analysis, SIMO charts, memo-motion study, cyclegraph and chronocyclegraph

Time Study: Scope and objectives, concepts of measurement of work in units of time, Techniques of work measurement, stop watch time study, allowances and calculation of standard time, standard time and its applications, Work sampling and introduction to Predetermined motion time systems

Ergonomics: Introduction to industrial ergonomics, constituents areas of ergonomics, man-machine system, anthropometry and ergonomics, metabolism and organization of work, ergonomic aspects in design of controls and displays and their layout, light and vibration consideration in ergonomically designed system, working conditions and environment, ergonomics and safety

Suggested Books:

- Introduction to Work Study by ILO., 2005
- Barnes, R.M., "Motion and Time Study", John Wiley & Sons., 1980
- McCormick, E.J., "Human Factors in Engineering and Design", TMH., 1976
- Bridger, R.S., "Introduction to Ergonomics", CRC Press., 2008
- Murrel, K.F.H., "Ergonomics", Longsman., 1971

MIN-320 Automobile Engineering Pre-requisite**: Nil**

Power Unit: Engine classification, engine performance characteristics, description of power unit, fuel supply system, hybrid vehicles, engine lubrication.

Transmission: Transmission requirement, standard transmission system, fluid transmission system, automatic transmission, performance requirements and gear ratios, tractive resistance.

Steering: Different types of steering systems, performance requirements, power steering.

Vehicle Dynamics: Stability analysis of vehicle, stability on curved path.

Braking Systems: General braking requirements, weight transfer during braking, mechanical brakes, hydraulic brakes, vacuum brakes, power brakes.

Chassis and Suspension: Loads on the frame, general consideration of strength and stiffness, engine mounting, various suspension systems including active suspension, shock absorbers.

Pneumatic Tyres: Tyre-pavement interaction forces and moments, SAE terminology, tyre wear.

Electrical System: Ignition system, conventional and electronic, lighting, auxiliary electrical equipment, wiring diagrams.

Maintenance: Preventive maintenance, trouble shooting, tuning and adjustment of power unit.

Air Pollution: Pollution due to vehicle emission, exhaust emission control systems, effect of design and operating conditions.

Suggested Books:

- Crouse, W.A., and Anglin, D.L., "Automotive Mechanics",10th Ed., McGraw-Hill , 2007
- Stockel, M.W., and Stockel, M.T., "Auto Mechanics Fundamentals", 5th Ed., The Good Heart – Willcon Company, 1982
- John B. Heywood, Internal combustion engine fundamentals, McGraw-Hill, 1988
- Heitner, J., "Automotive Mechanics", 2nd Ed., East-West Press, 1999
- Heisler, H., "Advanced Vehicle Technology", 2nd Ed., Butterworth-Hienemann, 2002
- Limpert, R., "Brake Design and Safety", 2nd Ed., SAE International , 1999
- Reimpell, J., Stoll, H., and Betzler, J.W., "The Automotive Chassis", 2nd Ed., SAE International, 2001

MIN-321 Vibrations and Noise Pre-requisite**: Nil**

Introduction: Simple Harmonic motion, Fourier analysis, Conservative systems.

Systems Having Single Degree of Freedom: Free vibrations of systems without damping, equilibrium and energy methods for determining natural frequency; Rayleigh's method; Equivalent systems, systems with compound springs, shaft of different diameters; Free vibrations of system with viscous damping, over damped, critically and under damped systems, logarithmic decrement; Coulomb and structural damping; Forced vibrations of systems with viscous damping, equivalent viscous damping, power consumption in vibrating system, impressed forces due to unbalanced masses and excitation of supports, vibration isolation, transmissibility, commercial isolators; Vibration isolation using ER fluids.

Vibration Measuring Instruments: Principle of frequency, displacement, velocity and acceleration measuring instruments, distortion effect.

Systems with two Degrees of Freedom: Free undamped vibrations, static and dynamic coupling, principal modes of vibration, undamped dynamic vibration absorber, centrifugal pendulum absorber.

Multi-Degree of Freedom Systems: Influence coefficients, eigen values and eigen vectors, matrix iteration; Dunkerley and Rayleigh's method.

Whirling of Shafts: Whirling of light flexible vertical/horizontal shaft with an unbalanced disc at the centre of its length with and without damping.

Continuous Systems: Vibration of strings, free longitudinal vibrations of prismatic bars, torsional vibrations of circular shafts, lateral vibrations of uniform beams.

Noise Control in Mechanical System: Review of fundamentals: Noise and vibration measurement units, levels, decibels, spectra. Objective/Subjective noise measurement-scales; Addition and subtraction of decibles; Frequency analysis bandwidths; Relationships for the measurement of free field sound propagation; The directional characteristics of sound sources; Sound power models.

Industrial Noise and Vibration Control: Basic sources of industrial noise and vibration, basic industrial noise and vibration control methods; The economic factor; Sound transmission from one room to another acoustic enclosures, acoustic barriers, sound absorbing materials; Vibration control procedures; Fault detection from noise and vibration signals.

Suggested Books:

- Grover, G. K., "Mechanical Vibrations", 3rd Ed., Nem Chand, 2003
- Rao, J. S. and Gupta, K., "Theory and Practice of Mechanical Vibration", 2nd Ed., New Age International Publishers, 1999
- Smith, J., and Whaley, W., "Vibration of Mechanical and Structural Systems with Microcomputer Applications", 2nd Ed., Harper and Row, 1994
- Thomason, W.T., "Theory of Vibrations with Applications", 5th Ed., Prentice Hall, 1997
- Timoshenko, "Vibration Problems in Engineering", 2nd Reprint Ed.,Wolfenden Press, , 2007
- Norton, M.P., and Karcazub, D.G., "Fundamentals of Noise and Vibration Analysis for Engineers", 2nd Ed., Cambridge University Press, 2003

MIN-322 Principles of Lubrication Technology Pre-requisite**: Nil**

Introduction: Brief history of tribology,Tribological Considerations in the design of machine elements, role of wear, friction and lubrication, geometrical properties of surfaces, method of studying surface; Contact of smooth surfaces, contact of rough surfaces; Role of friction, laws of static friction, cause of friction; Bowen & Tabor's theory of friction, laws of rolling friction, friction of metal and nonmetals, friction measurement; Wear definition, types of wear, wear mechanism, a brief introduction of wear test equipments, wear in plastics.

Industrial Lubricants and their Additives: Functions of lubricants; Types of lubricants and their industrial uses; Solid lubricants and their functions, liquid mineral lubricants, synthetic liquid lubricants, greases, properties of liquid and grease lubricants; Viscosity, Newtonian and non-Newtonian lubricants, Electrorheological, Magnetorheological and micropolar lubricants, temperature and pressure dependence of viscosity, other properties of lubricants; Lubricant additives, general properties and selection for machines and processes; Oil reclamation and preventive maintenance for lubricants.

Fluid-Film Lubrication: Equations of continuity and motion; Generalized Reynold equation with incompressible and compressible lubricants; lubrication regimes, Stribeck curve; Hydrodynamic lubrication; Tower's experiment, finite journal bearings, solution of finite bearing using Galerkin method, finite difference and FEM, significance of flow restrictors in compensated bearings.

Bearing Design and selection of Bearings: Comparative performance of various modes of lubrication, and bearing selection; Design of slider bearings and hydrostatic journal bearing, fixed type hydrodynamic and hydrostatic journal bearings, materials for sliding bearings; Bearing types, selection of rolling elements bearing, bearing life, dynamic load rating, bearing selection.

Some case studies related to tribological failures in machines

Suggested Books:

- Balling, J., "Introduction to Tribology", Wykeham, 1976
- Rowe, W.B., "Hydrostatic and Hybrid Bearing Design", 2nd Ed., Butterworth-Heinemann., 1983
- Khonsari, M.M., and Booser, E.R., "Applied Tribology: Bearing Design and Lubrication", 2nd Ed., John Wiley and Sons, 2001

- Gross, W., Matsch, L., Castelli, V., Eshel, A., Vohr, J., and Wildman, M., "Fluid Film Lubrication", John Wiley and Sons, 1980
- Hamrock, B.J., Jacobson, B.O., and steven, R.S., "Fundamentals of Fluid Film Lubrication", 2nd Ed., Marcel Dekker, 2004
- Mang, T., and Dresel, W., " Lubricants and Lubrication", 2nd Ed., John Wiley and Sons, 2007
- Cameron A., "The Principles of Lubrication", Longmans Green and Co. Ltd., London, , 1966

MIN-323 Design of Pressure Vessels and Piping Pre-requisite **: CEN-102**

Introduction: Industrial pressure vessels and piping systems. Type of failures of pressure vessels and piping systems. Safety of an Industrial plant.

Design Aspects of Pressure Vessel and Piping: General theory of membrane stresses, stresses in cylinders and spheres subjected to internal and external pressure.

Dilation of pressure vessels, auto-frettage and shrink fit stresses, mono-block and wire-wound cylinders, thermal stresses and their significance. Design of bottoms and roofs and cylindrical vessels, discontinuity stresses in vessels, deformation and stresses in flanges.

Fracture Mechanics Concepts and Design Application.

Construction Features of Pressure Vessels: Construction features of pressure vessels, localized stresses and their significance, welded joints, bolted joints, theory of reinforced openings.

Relevant National and International Design Codes and Their Limitations.

Importance of Stress and Flexibility Analysis of Piping System: Analysis of stresses due to static and dynamic loads, thermal stresses; Flexibility analysis for single and multi-plane configuration, Expansion joints and anchorages.

Design Features of Piping System: Pipe fittings, elbows and flange design, wall thickness determination, branched connections. Piping network analysis.

Selection of Pipe Materials and Economical Considerations in Piping Design.

Suggested Books:

- Harvey, "Pressure Vessel Design", Van Nostrand, 1963
- Gascoyne, "Analysis of Pipe Structures for Flexibility", Pitman, 1959
- Barsom, J.M., Rolfe, S.T., "Fracture and Fatigue Control in Structures", 3rd Ed., Butterworth Hcinemann, 1999
- Joshi, M.V., "Process Equipment Design", Macmillan India Ltd., 1985
- Smith, P. "The Fundamentals of Piping Design (Process Piping Design) (v. 1) , Gulf Publishing Company., 2007
- Smith, P. & Botermans, R., "Advanced Piping Design", Gulf Publishing Company., 2008

MIN-324 FEM Applications in Mechanical Engineering Pre-requisite**: CEN-102, MIN- 205**

Introduction: Underlying principles of the finite element analysis; application examples and versatility; basic steps in FEA.

Mathematical Preliminaries: Principle of virtual work; Ritz method; weighted residual; collocation and Galerkin methods; classification of partial differential equations and the corresponding mechanical engineering applications; Poisson's, Laplace's, diffusion and wave equation; review of governing equations in solid and fluid mechanics.

One Dimensional Problems: discretization, concept of shape functions, natural coordinates; element equations; assembly; boundary conditions; solution of assembled matrix equations; applications to solid mechanics, heat and fluid mechanics problems.

Trusses: Plane truss, local and global coordinate systems; stress calculations; temperature effect on truss members; solution of practical problems.

Beams: Euler-Bernoulli beam element

Two Dimensional Problems: Plane stress and plane strain formulation; triangular and rectangular elements; isoperimetric formulation; axisymmetric problems; computer implementation; steady-state heat conduction

Finite Element Analysis of Time-dependent Problems: Discretization of equation of motion; mass and stiffness matrices; eigenvalue problem; mode-shapes and natural frequencies; time-integration methods.

Computer Implementation of Finite Element Analyses: Introduction to commercial packages and their capabilities; demonstration of the modeling and solution process for representative cases.

Suggested Books:

- Cook, R.D., Malkus, D.S., and Plesha, M.E., "Concepts and Applications of Finite Element Analysis", 3nd Ed., John Wiley & Sons., 1989
- Bathe, K.J., "Finite Element Procedures", 2nd Ed., Prentice Hall. , 1996
- Seshu, P., "Textbook of Finite Element Analysis", 1st Ed., Prentice Hall of India Pvt. Ltd. , 2003
- Reddy, J.N., "An Introduction to the Finite Element Analysis", 3rd Ed., McGraw-Hill Education (ISE Editions)., 2005
- Zienkiewicz, O.C., and Taylor, R.L., "The Finite Element Method for Solid and Structural Mechanics", 6th Ed., Elsevier Ltd. , 2006
- Logan, D.L., "A First Course in the Finite Element Method", 4th Ed., Thomson Canada Ltd., 2007

MIN-325 Numerical Methods in Manufacturing Pre-requisite**: Nil**

Introduction to Numerical Methods: Introduction, Linear equations, Non-linear equations, Functional approximation, Numerical differentiation, Numerical integration, Ordinary differential equations, Partial differential equations, Finite difference method, Finite element method, Finite volume method, Orthogonal collocation, Boundary integral method, Optimization

Mathematical Model Development: Introduction, Fluid flow phenomenon, Heat transfer, Diffusion and mass transfer, Multiphase flow

Modeling of Casting & Solidification Process: Fundamentals of casting and solidification process, Heat flow in solidification, Solidification of mushy zones, Finite element simulation of solidification problems, Modeling and formulation of casting problems, case studies, Macro-modeling of solidification; Numerical approximation methods, Discretization of governing equations, Solution of discretized equations, Application of macro-modeling of solidification

Modeling of Metal Forming Processes: Introduction, Plasciticity fundamentals: von Mises yield criterion, Tresca yield criterion, Flow rule, Generalised stress & generalised strain increment, Plastic anisotropy, Anisotropic yield criterion, Plastic instability, Process modeling: Uniform energy method, slab method, slip-line field method, upper bound method, Visioplasticity method, Finite element method, Application of finite element method, Eulerian rigid-plastic FEM formulation for plane strain rolling, Governing equations

Modeling of Welding Processes: Weld pool heat & fluid flow, Modeling of fluid dynamics & coupled phenomenon in arch weld pools, finite element analysis of welding residual stress & distribution

Suggested Books:

- Ilegbusi, Olusegun J., Iguchi, M., Wanhsiedler, W., "Mathematical and Physical Modelling of Materials Processing Operations", Chapman & Hall/ CRC Press, 2000

- Stefanescu, D. M., “Science and Engineering of Casting Solidification”, Kluwer Academic/ Plenum Publishers, , 2002
- Lal, G. K., Dixit, P. M., Reddy, N. Venkata., "Modelling Techniques for Metal Forming Processes", Narosa Publishimg House, , 2011
- Gupta Santosh K, Numerical Methods for Engineers, New Age International (P) Limited Publishers, , 2009

MIN-327 Reverse Engineering Pre-requisite**: Nil**

Introduction: Scope and tasks of RE, Process of duplicating, Definition and use of Reverse Engineering, Reverse Engineering as a Generic Process

Tools and Techniques for RE: Object scanning: contact scanners, noncontact scanners, destructive method, coordinate measuring machine, Point Data Processing: preprocessing and post processing of captured data, geometric model development, construction of surface model, solid model, noise reduction, feature identification, model verification

Rapid Prototyping: Introduction, current RP techniques and materials, Stereo Lithography, Selective Laser Sintering, Fused Deposition Modeling, Three-dimensional Printing, Laminated Object Manufacturing, Multijet Modeling, Laser-engineered Net Shaping, Rapid Prototyping, Rapid Tooling, Rapid Manufacturing

Integration: Cognitive approach to RE, Integration of formal and structured methods in reverse engineering, Integration of reverse engineering and reuse.

Legal Aspects of Reverse Engineering: Introduction, Copyright Law

Suggested Books:

- Biggerstaff T. J., “Design Recovery for Maintenance and Reuse”, IEEE Corporation., 1991
- Katheryn, A. Ingle, “Reverse Engineering”, McGraw-Hill., 1994
- Aiken Peter, “Data Reverse Engineering”, McGraw-Hill., 1996
- Linda Wills,“Reverse Engineering” ,Kluiver Academic Publishers., 1996
- Donald R. Honsa , “Co-ordinate Measurement and reverse engineering”, American Gear Manufacturers Association, 1996

MIN-328 Manufacturing System Analysis Pre-requisite**: Nil**

Introduction: Definitions of manufacturing with input-output model, Definition of system, Basic problems concerning systems and system design procedure, Modes of manufacturing – job/batch/flow and multi-product, small-batch manufacturing.

System Modeling Issues: Centralized versus distributed control; Real-time vs. discrete event control; Forward vs. backward scheduling approaches with finite/infinite capacity loading; Modeling of absorbing states and deadlocks, conflicts, concurrency, and synchronization etc.

System Modeling Tools and Techniques: Introduction to mathematical modeling, optimization, and simulation; Issues related with Deterministic and Stochastic models, continuous and discrete mathematical modeling methods-Discrete event, Monte Carlo method; Basic Concepts of Markov Chains and Processes; The M/M/1 and M/M/m Queue; Models of manufacturing systems-including transfer lines and flexible manufacturing systems, Introduction to Petri nets.

Performance Analysis: Transient analysis of manufacturing systems, Analysis of a flexible machining center; Product flow analysis; Rank order clustering; Process flow charting; MRPI& II, Kanban, OPT, JIT-Pull and JIT-Push, Line of balance, Effects of machine failure, set-ups, and other disruptions on system performance; Calculation of performance measures-throughput, in-process inventory, due dates, MTL, Capacity, and Machine utilization etc.; Critique of high inventory, long lead time systems; Shop floor control issues.

Suggested Books:

- Askin, R.G., and Standridge, C.R., "Modeling and Analysis of Manufacturing Systems", John Wiley & Sons Inc. , 1993
- Gershwin, S., "Manufacturing Systems Engineering", Prentice-Hall Inc. , 1994
- Hitomi, K., "Manufacturing Systems Engineering", Taylor & Francis , 1998
- Viswanadham, N., and Narahari, Y., "Performance Modeling of Automated Manufacturing Systems", Prentice-Hall of India , 1992
- Hopp, W.J., and Spearman, M.L., "Factory Physics: Foundation of Manufacturing Management", McGraw Hill Inc. , 1996
- Chang, T.C.,Wysk, R.A., and Wang, H.P., "Computer Aided Manufacturing", Prentice Hall Inc. , 1998

MIN-329 Computer Integrated Manufacturing Pre–requisite: **Nil**

Introduction: Introduction to manufacturing systems and their performance analysis; Introduction to automation; Introduction to computer integrated manufacturing (CIM).

Numerical Control (NC): Introduction, numerical control – its growth and development, components of NC system, input devices, control systems – point to point, straight cut, and continuous path NC, open loop and closed loop NC systems, NC interpolations – linear, circular, helical, parabolic and cubic interpolation, applications of NC systems, merits and demerits.

Extensions of NC: Concepts of computer numerical control (CNC), machining center, and direct numerical control (DNC), and their advantages.

Robotics: Robot anatomy and related attributes, robot control systems – limited sequence, playback with point to point, playback with continuous and intelligent control; End effectors – gripper, tools; Sensors in robotics – tactile sensors, proximity, optical sensors and machine vision; Applications of industrial robots, robot programming.

Material Handling and Storage: Overview of material handling equipments, automated material handling equipments – AGVs, conveyor systems, performance analysis of material handling systems, automated material storage systems – ASRS and carousel storage, analysis of automated storage systems.

Manufacturing Support Functions: Introduction to group technology (GT), computer aided process planning (CAPP), material requirement planning (MRP), capacity planning, scheduling etc.

Suggested Books:

- Groover, M. P., "Automation, Production systems and Computer Integrated Manufacturing", 3rd Ed., Prentice-Hall., 2007
- Singh, N., "Systems Approach to Computer Integrated Design and Manufacturing", John Wiley & Sons., 1996
- Chang,T.-C., Wysk,R. A. and Wang, H.-P. "Computer Aided Manufacturing", 3rd Ed., Prentice Hall. , 2005
- Rembold,U., Nnaji,B. O. and Storr A., "Computer Integrated Manufacturing", Addison Wesley., 1994
- Besant,C. B. and Lui,C. W. K., "Computer Aided Design and Manufacture",
- Ellis Horwood Ltd., 1991
- Rao,P. N., Tiwari,N. K. and Kundra,T.K., "Computer Aided Manufacturing", Tata McGraw Hill., 1993
- Koren, Y. "Computer Control of Manufacturing Systems", McGraw Hill., 1983
- Lynch, M., "Computer Numerical Control for Machining", McGraw-Hill., 1992
- Sava,M. and Pusztai,J., "Computer Numerical Control Programming", Prentice Hall., 1990

MIN-330 Ergonomics Pre-requisite**: Nil**

Introduction: Introduction and relevance to work system design, importance of ergonomics in present day scenario, Definition & fundamentals of ergonomics:, historical perspectives, objectives and functions

Anthropometry: Human body, anthropometrics, postures; Stand, sitting, squatting and cross-legged postures, anthropometric measuring techniques, body supportive devices, vertical and horizontal work surface, design of an ergonomic chair

Human factors: Behavioral aspects, cognitive issues, mental work load, human error

Ergonomic Design: Design methodology and criteria for designing,design for improving occupational safety and reduction in fatigue and discomfort, work system design, environmental factors, visual issues in design, case studies

Case studies: Design modifications in existing products from the ergonomics point of view

Suggested Books:

- Singh, S (Edt), Ergonomics Interventions for Health and Productivity, Himanshu Publications, Udaipur, New Delhi, 2007
- Chakrabarti D., Indian Anthropometric Dimensions for ergonomic design practice, National Institute of Design, Ahmedabad, 1997
- Salvendy G. (edit), Handbook of Human Factors and ergonomics, John Wiley & Sons, Inc., 1998
- Dul, J. and Weerdmeester, B. Ergonomics for beginners, a quick reference guide, Taylor & Francis, 1993
- Green, W.S. and Jordan, P .W, Human Factors in Product Design, Taylor & Francis, 1999

MIN-331 Total Quality Management Pre-requisite**: Nil**

Fundamentals: Evolution of Quality: Inspection, Quality Control, Quality Assurance and Total Quality Management, Customer-Orientation: Internal & External Customer Concept, Quality Philosophies of Deming, Juran, Crosby, Ishikawa, Taguchi; Tools and improvement cycle (PDCA). Life cycle approach to quality costs prevention; Appraisal and Failure costs. Various TQM models. Relationship between quality and environment.

Human Resources Management: Organizational, Communicational and Team requirements. Types of teams, Quality circles, Empowerment, Human resource policies in TQM, Group dynamics

Tools and Techniques

Seven QC tools (Histogram, Check sheets, Ishikawa diagrams, Pareto, Scatter diagrams, Control charts), Quality Function Deployment, Statistical process control, Process capability, JIT and Elimination of waste, Total Productive Maintenance, 5-S. Taguchi's concept of quality loss function.

Systems and Procedure: Importance, Standardization (National and International) Quality Systems, Quality Manuals, Quality Information Systems and documentation, Auditing, Basics of ISO-9000 and ISO 14000: Relevance and misconceptions.

Implementation: Quality strategy and policy, Motivation and leadership theories. Continuous vs breakthrough improvements, Management of change, Quality award models and role of self-assessment, Benchmarking, Implementation barriers, TQM practices.

Suggested Books:

- Besterfield, D C and Besterfield C Total Quality Management, Pearson Education Asia, New Delhi, 1999
- Mohanty R P and Lakhe R R Handbook of Total Quality Management, Jaico Publishers, 2000
- Berk, J. and Berk, S. Total Quality Management: Implementing Continuous Improvement. New York: Sterling Publishing, 1993
- Logothetis, N. Managing forTotal Quality. New York: Prentice Hall, 1992

- Bossert, J. L. Quality Function Deployment – A Practitioner's Approach, NY: Marcel Dekker, 1994
- Taguchi, G., A. Elsayed, and T. Hsiang Quality Engineering in Production Systems, NY: McGraw Hill, 1989

MIN-332 Industrial Hazards and Safety Pre – requisite: **Nil**

Physical Hazards: Noise, properties of sound, occupational damage, risk factors, sound measuring instruments, noise control programmes. Ionizing radiation, types, effects, monitoring instruments, control programmes, OSHA standard - non-ionizing radiations, effects, types, radar hazards, microwaves and radio-waves, lasers, TLV- cold environments, hypothermia, wind chill index, control measures- hot environments, thermal comfort, heat stress indices, acclimatization, estimation and control.

Chemical And Nuclear Hazards: Recognition of chemical hazards- types, and concentration, Exposure vs. dose, TLV - Methods of evaluation, process or operation description, field survey, sampling methodology, Air Sampling instruments, Types, Measurement Procedures, Instruments Procedures, Gas and Vapour monitors, dust sample collection devices, personal sampling. Methods of Control - Engineering Control, Nuclear hazards, Disposal of nuclear wastes, Safety measures In nuclear plants

Biological And Ergonomical Hazards: Classification of Biohazardous agents – examples, bacterial agents, rickettsial and chlamydial agents, viral agents, fungal, parasitic agents, infectious diseases - Biohazard control Programmes, employee health Programmes-laboratory safety programmes-animal care and handling-biological safety cabinets – building design. Work Related Musculoskeletal Disorders –carpal tunnel syndrome (CTS) - Tendon pain-disorders of the neck- back injuries.

Occupational Health And Toxicology: Concept and spectrum of health - functional units and activities of occupational health services, pre - employment and post-employment medical examinations - occupational related diseases, levels of prevention of diseases, notifiable occupational diseases, their effects and prevention. Industrial toxicology, local, systemic and chronic effects, temporary and cumulative effects, carcinogens entry into human systems.

Occupational Physiology: Man as a system component – allocation of functions – efficiency – occupational work capacity – aerobic and anaerobic work – evaluation of physiological requirements of jobs – parameters of measurements – categorization of job heaviness – work organization – stress – strain – fatigue – rest pauses – shift work – personal hygiene.

Suggested Books:

- "Hand book of Occupational Safety and Health", National Safety Council, Chicago., 1982
- "Encyclopedia of Occupational Health and Safety", Vol. I and II, International Labour Office, Geneva,1985
- "Occupational Safety and Health Management" by Thomas J. Anton, 2nd Ed. , 1989
- "Occupational Safety Management and Engineering" by Willie Hammer and Dennis Price, ISBN: 0-13-896515-3, 2001

MIN-333 Industrial Management Pre-requisite**: Nil**

Introduction: Basic concepts of management, scientific management, types of management.

Organizational Structures: Types of organizations, Functions and objectives of industrial organizations, Ownership of Industries; Proprietorship, partnership, joint stock companies, public and private undertakings, co-operative organizations, comparison of different organization structures.

Personnel Management: Functions, wage and salary administration, job evaluation, satisfactory wage plan, merit rating and evaluation plans.

Industrial Safety: Occupational safety, engineering safety design and safety programmes; Safety aspects in work system design,

Suggested Books:

- J. Russell (Joseph Russell) Smith, "The Elements of Industrial Management", HardPress, 2012
- Rieske, David W., Asfahl and C. Ray, "Industrial Safety and Health Management", 6th Ed., Prentice Hall Professional Technical Ref., 2009
- Gavriel Salvendy, "Handbook of Industrial Engineering: Technology and Operations Management", John Wiley & Sons, Inc., 2001
- Herman B. Henderson, Albert E. Haas, "Industrial Organization and Management Fundamentals", Industrial Press, The University of California., 1961

MIN-334 Facilities Design Pre-requisite**: Nil**

Factory Planning: Introduction, factors to be considered

Plant Location and Site Selection: Levels of plant location, rural, urban and suburban location of plants, factors influencing the plant location, optimum plant location, location theories.

Plant Layout: Introduction of production system, scope, objectives, importance, and types of plant layout, characteristics of a good plant layout, factoring affecting plant layout, procedure of developing a plant layout, installation and evaluation of plant layout, optimum plant layout.

Group Technology: Definition, objectives, planning, part families and machine cell formation, evaluation of machine cells, types of GT layout, benefits of GT, implementation of GT.

Line Balancing: Definitions, heuristic and analytical methods of balancing the assembly and production line, single and mixed model line balancing, alternatives to line balancing.

Materials Handling: Definition, scope, objectives, principles, importance, factors in materials handling problem, analysis of materials handling, types and selection of materials handling equipment's, aids and techniques in materials handling equipment selection.Planning of material flow, advantages of planned material flow, flow planning principles, flow patterns, analysis of material flow.

Suggested Books:

- Francis, R.L., McGinnis, L.F., and White, J.A.,"Facility Layout and Location: An Analytical Approach", Prentice Hall of India, 2004
- Meyers, F.E., and Stephens, M.P., "Manufacturing Facilities Design and Material Handling", Prentice-Hall, Inc., 2000
- Groover,M.P.,"Automation, Production Systems and Computer-Integrated Manufacturing",2nd Ed., Pearson Education Inc. Delhi, 2001
- Sule,D.R.,"Manufacturing Facilities-Location, Planning, and Design", PWS Publishing Company, 1984
- Tompkins,J.A., White, J.A.,Bozer,Y.A.,Frazelle, E.H.,Tanchoco, J.M., and Tervino,J.,"Facilities Planning",2nd Ed., John Willey & Sons, 1996

MIN-335 Concurrent Engineering Pre-requisite**: Nil**

Introduction: Concurrent engineering concepts, sequential versus concurrent engineering, importance of concurrent engineering, benefits of concurrent engineering.

Design for Manufacturing and Assembly: Mathematical modeling between design and manufacturing, design for manufacturing and assembly approach, concurrent product design, material balance equation, cost equation, average manufacturing lead time.

Design for X: Design for quality, pseudo measure of product optimality, quality function deployment, improvement in unit cost and quality of manufactured products.

Implementation and Case Studies: Difficulties associated with performing concurrent engineering, life cycle costing, case studies.

Suggested Books:

- Andreasen, M.M., Kahler, S., Lund, T., and Swift, K., "Design for Assembly", Springer Verlag, 1988
- Molloy, O., Tilley, S., and Warman, E.A., "Design for Manufacturing and Assembly Concepts, Architectures and Implementation", Chapman & Hall, 1998
- Wang, B.,"Integrated Product, Process and Enterprise Design", Chapman & Hall, 1997
- Benhabib, B., "Manufacturing Design, Production, Automation and Integration", Marcel Dekker Inc., 2003
- Huang, G.Q., "Design for X Concurrent Engineering Imperatives", Chapman & Hall, 1996
- Boothroyd, G., Dewhurst, P., and Knight, W., "Product Design for Manufacture and Assembly", Marcel Dekker Inc., 2002

MIN-336 Financial Management Pre-requisite**: Nil**

Nature and Scope: Function of finance, jobs and objectives of a financial manager, various forms of business organizations,

Source of finances: short term finances- term credit, accrued expenses and deferred income, bank finance for working capital; long term finances- common shares, right issues, debentures, preference shares, lease financing, term loan.

Financial Accounting: Purpose, functions, difference between financial and management accounting, Purpose, objective of Financial Statement Analysis, ratio analysis: types of ratio, liquidity ratio, leverage ratio, profitability ratios, and activity ratios.

Cost: Nature and classification of costs in a manufacturing company, costing concepts, cost allocation, Break-even analysis, operating leverage, effect of change in profit, utility and limitation of Break-even Analysis.

Capital Budgeting (CB): Meaning, importance and difficulties of CB, kinds of capital budgeting decisions, cash in flow and out flow estimates. Capital structure, Concepts, needs, determination, and dimension of working capital management, estimation of working capital needs, financing current assets.

Financing and Dividend Decision: Meaning and measure of financial leverage, effect on the share holders return, dividends, dividend policy, practical consideration, constraints of paying dividends, advantages and disadvantages of bonus shares etc.

Suggested Books:

- Bose, D.C., "Fundamental of Financial Management", Prentice Hall, 2006
- Martin, K., Scott Jr., P., "Financial Management Principles and Applications", 10th Ed., Academic Internet Publishers , 2006
- Higgins, R.C., "Analysis for Financial Management", 8th Ed., McGraw-Hill/Irwin , 2005
- Brigham, E.F., and Ehrhardt, M.C., "Financial Management: Theory and Practice with Thomson ONE",11th Ed., South-Western College Pub., 2004
- Horne, J.C.V., "Financial Management Policy", Pearson , 2004

MIN-337 Processing of Non-Metals Pre-requisite**: Nil**

Introduction: Classification of engineering materials and processing techniques, structure and properties of non-metals

Processing of Glass and ceramics: Glass structure and properties, glass melting and forming, glass annealing, Ceramic powder preparation, synthesis of ceramic powders, fabrication of ceramic products from powders: pressing, casting, vapour phase techniques, sintering, finishing, machining. ceramic coatings

Processing of Plastics: thermoplastics and thermosets, Processing of Plastics: Extrusion. Injection moulding. Thermoforming. Compression moulding. Transfer moulding. General behavior of polymer melts, Machining of plastics

Processing of polymer matrix composites: Classification of composite materials, properties of composites hand lay-up, autoclaving, filament winding, pultrusion, compression molding, pre-pegging, sheet molding compounds etc., process capability and application areas of various techniques

Ceramic matrix composites: mechanical properties of ceramic matrix composites, different processing techniques for ceramic matrix composites, process capability and applications of various techniques

Secondary processing of composite materials: Need of secondary operations, different type of secondary operations, machining and drilling of non-metals, machining induced damage, different methods of reducing the damage on account of secondary processing

Suggested Books:

- Kalpakjian, S.,"Manufacturing Processes for Engineering Materials," 3rd Ed., Addison – Wesley, 1997
- Strong,A.B., "Plastics: Materials and Processing," Pearson Prentice Hall, 2006
- Mathews, F.L., and Rawlings,R.D., "Composite Materials: Engineering and Science," Woodhead Publishing, 1999
- Peters S.T. "Handbook of Composites", 2nd Ed., Chapman Hall, 1998

MIN-338 Measurement & Instrumentation Pre-requisite:**Nil**

Generalized Configuration of Measuring System: Functional elements of a basic measuring system; different types of measurands, description of functional elements. Input-output configuration of a measuring system. Interfering and modifying inputs; methods for correction for interfering and modifying inputs.

Characteristics of Instruments: Objective of studying the characteristics of the instruments. Static characteristics – accuracy, precision, error, sensitivity, hysterisis, threshold, drift, span, static stiffness etc. Dynamic Characteristics – time domain and frequency domain characteristics terms. Input-output Impedance's and meaning of impedance mismatching. Concept of mechanical loading.

Measurement System Behaviour: Description of mathematical model for the generalized configuration of a measurement system. Response characteristics of the system – Amplitude, frequency and phase response. Order of the systems, response of zero, first and second order systems to step, ramp and sinusoidal inputs. Transfer function method to study the response of the system.

Uncertainty Analysis: Classification of errors systematic errors, random errors, illegitimate errors and statistical analysis of experimental data, computation of maximum and rss error .

Principles of Transduction and Transducers: Description of various types of transduction principles. Transducers based on variable resistance, variable inductance, variable capacitance and piezo-electric effects. Displacement transducers - wire wound potentiometers, LVDT, strain gages, strain gage designation system. Diaphragm type Pressure Transducers and other pressure measuring techniques. Design of accelerometers and their applications. Temperature and flow measurement techniques, ultrasonic measurements. Signal conditioners - filters, low, high, band pass and charge amplifiers.

DAS and Signal Analysis: Data acquisition system via computers. The components of Data acquisition system, DAS Hardware, selection criteria for choosing a DAS. Techniques for signal analysis.

Suggested Books:

- Doeblin E O, and Dhanesh N M, "Measurements System Application and Design", 6th Ed., McGraw Hill, 2011,

- Mechanical Measurement; Beckwith and Buck; Wesley;, 2002,
- Theory and Design for Mechanical Measurements; Richard S. Figiliola, 4th Edn., Wiley India, 2005,
- Instrumentation for Engineering Measurements; James W. Dally, W.F. Rilley and K.G. McConnel; John Wiley (2nd Edn.), 2003,
- LAB View Manual, 2012,

MIN-339 Heat Exchangers Pre-requisite**: Graduate level course on Heat and Mass Transfer and Fluid Mechanics**.

Introduction: Heat exchanger types and construction,heat transfer and fluid flow fundamentals.

Types of heat exchangers: Derivations for counter flow and parallel flow heat exchangers, LMTD and ε-NTU method, double pipe heat exchangers, crossflow heat exchangers, shell-and-tube heat exchangers, TEMA standards.

Design Strategy: General design considerations and approaches, design strategies,material selection and fabrication processes, cost estimation,optimum design.

Design of Single Phase Heat Exchangers: Liquid to liquid, gas to gas and liquid to gas heat exchangers.

Design of Two Phase Heat Exchangers: Steam generators, condensers,principle of cooling towers.

Design of Compact Heat Exchangers: Definition, types, design parameters, design calculations for liquid-air heat exchangers.

Introduction to micro, nano and PCB type heat exchangers, familiarization with heat exchanger design softwares, computer aided design.

Suggested Books:

- Shah, R. K. and Seculic, D. P.,"Fundamentals of Heat Exchanger Design", Wiley India., 2012
- Kakac, S. and Liu, H., "Heat Exchangers: selection, rating and thermal design" CRC Press., 2012
- Hesselgreaves, J.E.,"Compact Heat Exchangers: selection, design and operation",Pergamon., 2001
- Kays, W. M. and London, A. L., "Compact Heat Exchangers", Krieger Publishing Company., 1998
- Webb,R. L. and Kim, N.H.,"Principles of Enhanced Heat Transfer", Taylor & Francis., 2005

MIN-340 Refrigeration & Air-conditioning Pre-requisite**: Nil**

Introduction: Review of basics thermodynamics and history of refrigeration and air-conditioning

Air cycle refrigeration: Carnot Cycle; Bell Coleman Cycle; Aircraft Refrigeration: Simple Cycle, Boot Strap cycle, Regenerative Cycle, Reduced Ambient cycle, DART.

Refrigerants: Important refrigerants and their properties; leak detection; charging of refrigerants, selection of refrigerant compressors. CFCs and Ozone Hole; Ozone-safe Refrigerants, Global Warming and refrigerants.

Vapour Compression Cycle: Carnot vapor compression Cycle; T-s and P-h diagrams of vapour compression refrigeration cycle; Departure of actual vapor compression cycle from theoretical cycle. Compressor volumetric efficiency. Analysis of actual cycle, second law analysis of vapour compression cycle. Effect of suction and discharge pressure, subcooling and superheating on performance. Compound vapour compression system with intercooling for single and multiple evaporator. Cascading.

Vapour Absorption Refrigeration Systems: Aqua-ammonia absorption refrigeration system; Lithium bromide-water absorption systems; properties of aqua-ammonia solution, p-t-x chart; enthalpy concentration chart. Three fluid Electrolux system.

Water Refrigeration: Introduction; Principle of Operation; Steam Jet Refrigeration; Centrifugal Refrigeration; Merits and Demerits of steam jet refrigeration; Characteristics of Steam Jet Refrigeration

Non-conventional Refrigeration Systems: Vortex and Pulse Tube Refrigeration Systems; Thermoelectric Refrigeration Systems

Psychrometrics: Introduction to Air conditioning; Psychrometric processes: evaporative cooling, humindifier efficiency; cooling and dehumidification by chilled water spray and cooling coils; bypass factor; chemical dehumidification; sensible heat factor; apparatus dew point. Elements of comfort air conditioning.

Infiltration and Ventilation: Basic concepts ant terminology; Driving mechanism of infiltration and ventilation; Indoor air quality; natural ventilation; Residential air leakage; Residential ventilation; Residential ventilation requirements.

Cooling Load Calculations: Introduction; Health and comfort criterion; Thermal Comfort; Design conditions; Estimation of heat loss and heat gain in a building: HB and RLF method.

Space Air Distribution: Room air distribution; total, static and velocity pressures; friction loss in ducts; dynamic loss in ducts; air duct design: equal friction method, static regain method, velocity reduction method.

Suggested Books:

- Stoecker, W.F., and Jones, J.W., "Elementary Refrigeration & Air conditioning", McGraw Hill, 2002
- Dossat, R.J., Principles of Refrigeration, Pearson Education Asia, 2002
- Arora, C.P.,"Refrigeration and Air conditioning", Tata-McGraw Hill , 2005
- Prasad, M., "Refrigeration and Air conditioning", New Age International, 2005
- ASHRAE Handbook (Fundamentals), 2013

MIN-341 Thermal System Design Pre-requisite**: Nil**

Introduction: Thermal systems, engineering design, workable and optimal designs.

Design Criteria: Maximum efficiency and energy conservation, minimum cost/losses, multi-criteria, functional reliability of system components.

Modeling and Simulation of Thermal Systems: Types of models with examples, mathematical modeling of processes and components, system models, identification of operating variables; simulation techniques.

Optimization: Maximum and minimum conditions, optimization parameters, levels of optimization, mathematical representation of problem, optimization procedures including introduction to some non-traditional methods.

Economic Considerations: Present and future work factors, gradient factors, rates of return, life cycle cost.

Suggested Books:

- Hodge, B. K.and Taylor, R. P.,"Analysis and Design of Energy Systems", Prentice Hall., 1999
- Suryanarayana, N. V. and Arici,O.,"Design and Simulation of Thermal Systems", Penguin Books Ltd., 2004
- Jaluria, Y.,"Design and Optimization of Thermal Systems", CRC Press., 2007
- Burmeister, L.C., "Elements of Thermal Fluid Systems", Prentice Hall.,1998
- Bejan, A., Tsaksaronic, G. and Moran, M.,"Thermal Design and Optimization", Wiley., 1996
- Stoecker, W. F., "Design of Thermal Systems", Tata McGraw Hills., 2011

MIN-342 Environnemental Pollution & Control Pre – requisite: **Nil**

Introduction: Nature and extent of pollution problem, types of pollution.

Air Pollutants: Air pollutants, oxides of nitrogen, sulphur oxides, particulate matter, oraganic compounds, carbon monoxide; their harmful effects.

Air Pollution Sources: Stationary sources, emission from stacks, mobile sources, pollutant formation in SI and CI engines and gas turbines.

Air Pollution Control: Stack emission control, inertial devices, electro-static propitiators, particulate scrubbers, dry and wet methods, filters. IC Engine pollution control devices, thermal reactors, catalytic converters, particulate traps.

Thermal Pollution: Nature of thermal pollution; effect of thermal pollution on ecology, thermal plume, regions of plume, parameters relevant to thermal plume and their limit. Mechanics of condenser water discharge from thermal power plants.

Global Atmospheric Changes: Green house effect, green house gases, Ozone depletion and control.

Suggested Books:

- Kenneth Wark, Cecil F. Warner, Wayne T. Davis; Prentice Hall (3rd Edn.); Air Pollution: Its Origin and Control; ISBN-10: 0673994163 ,
- ISBN-13: 978-0673994165, 1997
- John Benjamin Heywood; Internal Combustion Engine Fundamentals; McGraw Hill; ISBN-10: 0071004998, ISBN-13: 978-0071004992 , 1989
- Robert A. Ristinen, Jack P. Kraushaar; Energy and the Environment; Wiley; (2nd Edn.); ISBN-10: 0471739898, ISBN-13: 978-0471739890 , 2005
- Norman C. Pereira, Norman C. Pereira, Wei Yin Chen (Editors); Air Pollution Control Engineering; Springer-Verlag; ISBN: 1588291618,
- ISBN-13: 9781588291615 , 2004

MIN- 343 Power Plants Pre-requisite: **Nil**

Introduction: Energy sources for generation of electric power, energy policy of India, present status and future trends, major power plants in India.

Thermal Power Plants: Selection of site, general layout of the plant, major components- Boilers, Economisers, Super-heaters, Air pre-heaters, fuels, fuel and ash handling equipment's, High pressure Boilers, steam turbines, station heat balance and plant efficiency.

Diesel Power Plant: Diesel engine, engine performance and operation, super charging, Diesel Electric power plant layout.

Gas Turbine Power Plants: Gas turbine power plants, basic cycles, cycle calculation, the ideal and real operating cycles, components and layout.

Hydro Power Plants: Classification of hydro-plants, selection of site, rain fall and run off, calculation of storage capacity, plant layout, estimation of power available, selection of hydraulic turbines and their governing.

Nuclear Power Plants: Introduction, Atomic structure and radio-activities nuclear reactions, binding energy, Nuclear Reactors, Types of reactors, Pressurized water reactors, boiling heater reactors, Heavy water-cooled and moderated (CANDU) reactor, Gas-cooled reactors, Liquid metal cooled reactors, Indian Nuclear power installations, comparison between Nuclear and Thermal plants.

Non-Conventional Power Plants: Geothermal power plants, Tidal power plants, Wind power plants, solar power plants, M.H.D. Generators, OTEC

Power Plant Economics & environmental aspect: Plant investment costs, fixed charges, Operation cost, energy cost, depreciation and operating costs on the selection of equipments, incremental cost, comparison of fixed and operating costs, greenhouse effect, thermal pollution, other pollutants.

Suggested Books:

- Black & Veatch, "Power plant Engineering", CBS Publisher., 2005

- El-Wakil, M.M., “Power plant Technology”, McGraw-Hill Book Co., 2002
- Nag, P.K., “Power plant engineering”, Tata MacGraw Hill., 2008
- Modern Power Station Practical, CEGB, Pergamon Publisher., 1992
- Norris & Therkelsen, “Heat Power”, McGraw Hill., 1999
- Rust, J.H., “Nuclear Power Plant Engineering”, Haralson Pub. Co., 1999
- Potter, P.J., “Power Plant Theory & Design”, Kreiger Publishing Co., 1994

MIN-344 Industrial Combustion Pre-requisite: **Nil**

Introduction: Industrial Combustion, requirements and applications

Combustion Fundamentals:

i **Thermodynamics of Combustion:** Combustion Stoichiometry, evaluating enthalpy of reacting systems, enthalpy of formation, energy balance for reacting systems, enthalpy of reaction and heating values. Adiabatic flame temperature. Equilibrium criteria, chemical potential, equation of reaction equilibrium, equilibrium constant, equilibrium composition and flame temperature**.**

ii **Chemistry of Combustion:** Rate laws and reaction orders, elementary reactions, reaction Molecularity, temperature and pressure dependence of reaction rate, Arrhenius law, chain reactions, and reaction mechanisms. Combustion characteristics of hydrocarbons. NO_x formation and its control.

iii **Flame Processes:** Different types of flames, laminar flame structure, laminar flame speed, effect of various chemical and physical parameters on flame speed, Flammability Limits, Stability Limits.

Turbulent Premixed Flames: Applications, Turbulent Flame Speed, Structure of Turbulent Flames, Flame Stabilization, Turbulent Nonpremixed Flames.

Gas Fired Furnaces & Boilers: Gas fired furnaces, Energy Balance and Efficiency, Fuel Substitution, Gas burners, Classifications, Design factors, Heat Transfer From Burners

Oil fired Furnaces & Combustion Systems: Spray formation and droplet behavior, droplet size distribution, Fuel Injectors, Oil fired systems, Spray combustion in furnaces and boilers. Emissions from oil fired furnaces and boilers

Coal Fired Combustion Systems: Combustion mechanism of solid fuels, Grate burning systems, traveling vibrating grate spreader stokers, pulverized coal burning systems, Fluidized bed combustion, atmospheric pressure fluidized bed combustion systems, circulating and pressurized fluidized bed systems. Emissions from grate burning systems, pulverized coal and fluidized bed combustion boilers.

Suggested Books:

- Ragland, K. W. and Bryden, K. M., “Combustion Engineering,” CRC Press, 2011
- Baukal, C. E., “Industrial Burners Handbook” CRC Press; 2003
- Fawzy, E.M. and Saad, E. H., “Fundamentals and Technology of Combustion,” CRC Press, 2002
- Basu, P., K. C., Jestin Louis, “Boilers and Burners Design and Theory,” Springer, 1999
- Glassman, I. and Yetter, R. “Combustion 4th Edition”, Academic Press, 2008
- Oka S., “Fluidized Bed Combustion”, Marcel & Dekker, 2004

MIN-345 Compressible Flow Pre-requisite**: Nil**

Introduction: Velocity of sound, distinction between incompressible, compressible, subsonic, supersonic, transonic and hypersonic flows; Mach number, Mach angle and Mach cone.

One Dimensional Isentropic Flow: General features, adiabatic and isentropic flow of a perfect gas, choking in isentropic flow, operation of nozzles under varying pressure ratios, applications of isentropic flow.

Normal Shock Waves: Distinction between normal and oblique shock waves, governing relations of the normal shock, Rankine-Hugoniot relations, formation of shock waves, operating characteristics of convergent-divergent nozzles.

Viscous Compressible Flow: Governing equations, adiabatic viscous flow in constant area ducts, Fanno lines.

Frictionless Compressible Flow: Governing equations, full potential equation, flow through constant area ducts with heat transfer, Rayleigh lines.

Steady Isothermal Flow in Long Pipe-lines: Governing equations and features of steady isothermal flow in long pipelines.

Simulation: Introduction to CFD tools for simulation of compressible flows.

Suggested Books:

- Liepmann, H.W., and Roshko, A., "Elements of Gas Dynamics", Dover Publications, 2002
- John, J.E.A., and Keith, T.G., "Gas Dynamics", 3rd Ed., Prentice-Hall, 2006
- Anderson Jr., J.D., "Modern Compressible Flow: With Historical Perspective", 3rd Ed., Tata McGraw-Hill, 2012
- Zucrow, M.J., and Hoffman, J.D., "Gas Dynamics", John Wiley & Sons, 2001
- Rathakrishnan, E., "Gas Dynamics", 4th Ed., Prentice-Hall of India , 2012
- Oosthuizen, P. H. and Carscallen, W. E. "Introduction to Compressible Fluid Flow", 2nd Ed. , CRC Press, 2013

MIN-346 Waste Heat Recovery Systems Pre-requisite**: Basic course on Heat transfer**

Introduction: Waste Heat, Sources of waste heat, high temperature heat recovery applications, waste heat recovery calculations.

Recuperators: Gas to gas heat exchangers, recuperators, rotary regenerator, air pre-heaters, Heat pipe exchangers.

Regenerators: Gas or liquid to liquid Regenerators, Finned tube heat exchangers, shell and tube heat exchangers, waste heat boiler, Heat pumps..

Viscous Compressible Flow: Governing equations, adiabatic viscous flow in constant area ducts, Fanno lines.

Economics: Waste Heat recovery economics general concepts, case studies, examples

Case Studies: Case Studies of some industrial problems.

Suggested Books:

- Goldstick R.J.& Thumann A., "Principles of Waste Heat Recovery" Faimont Press, Digitised Version, 2008
- Ganapathy, V., "Industrial Boilers and heat recovery generators. Design applications and calculations." CRC, 2002
- Olszewski M., "Utilization of Reject Heat", Marcel & Dekker Inc., 1980
- Matsula K., Kanasha, Y., Fushimi, C., Sutsummi K and Kishimoto, A., "Advanced energy savings and its applications in Industry", Springer, 2013
- Goldstick R.J.& Thumann A., "Waste Heat Recovery Handbook," , Fairmont Press, 1986

MIN-349 Fire Dynamics Pre-requisite**: Nil**

Introduction: Fuels and combustion processes; physical chemistry of combustion in fires; summary of the heat transfer equations of conduction, conection and radiation

Premixed Flames: Limits of flammability; structure of premixed flame; heat loss and measurement of burning velocity; variation of burning velocity with composition, temperature, pressure, suppressant and turbulence.

Diffusion Flames and Fire Plumes: Laminar and turbulent jet flames; flames from natural fire: buoyant plume, fire plume, upward flow; interaction of fire plume with compartment boundaries; effect of wind on fire plume

Steady Burning of Liquids and Solids: Burning of liquids: pool fire, burning of liquid droplets; burning of solids: synthetic polymers, wood, dusts and powders

Frictionless Compressible Flow: Governing equations, full potential equation, flow through constant area ducts with heat transfer, Rayleigh lines.

Ignition and Spread of Flames: Ignition of liquids and solids; Flame spread over liquids and solids;.

Pre-flashover and Post-flashover Compartment Fire: Growth of flash-over: necessary conditions; ventilation requirements; factors affecting time to flashover and fire growth; fully developed fire behavior; temperature in fully developed fire; fire resistance and fire severity.

Production and Movement of Smoke: Production and measurement of smoke particles**;** test for smoke production potential; smoke movement; smoke control systems

Suggested Books:

- Drysdale, D.“Introduction to Fire Dynamics”, John Wiley , 2011
- Karlsson, B., Quintiere, J., “Enclosure Fire Dynamics”, James; CRC Press, 2000
- Quintiere, J.G.,., “Fundamentals of Fire Phenomena”,John Wiley, 2006
- Gorbet, G.E., and Pharr, J.L, Fire Dynamics; Pearson Education , 2010

MIN-352 Experimental Methods in Thermal Engineering Pre-requisite: **Nil**

Generalized Configuration of Measuring System: Functional elements of a basic measuring system; different types of measurands, description of functional elements. Input-output configuration of a measuring system. Interfering and modifying inputs; methods for correction for interfering and modifying inputs.

Characteristics of Instruments: Objective of studying the characteristics of the instruments. Static characteristics – accuracy, precision, error, sensitivity, hysterisis, threshold, drift, span, static stiffness etc. Dynamic Characteristics – time domain and frequency domain characteristics terms. Input-output Impedance’s and meaning of impedance mismatching. Concept of mechanical loading.

Measurement System Behaviour: Description of mathematical model for the generalized configuration of a measurement system. Response characteristics of the system – Amplitude, frequency and phase response. Order of the systems, response of zero, first and second order systems to step, ramp and sinusoidal inputs. Transfer function method to study the response of the system.

Uncertainty Analysis: Classification of errors systematic errors, random errors, illegitimate errors and statistical analysis of experimental data, computation of maximum and rss error .

Principles of Transduction and Transducers: Description of various types of transduction principles. Transducers based on variable resistance, variable inductance, variable capacitance and piezo-electric effects. Displacement transducers - wire wound potentiometers, LVDT, strain gages, strain gage designation system. Diaphragm type Pressure Transducers and other pressure measuring techniques.

Flow Measurement: Flow visualization,shadowgraph; schlieren and interferometric techniques;Pitot static tubes; hot wire anemometers; Laser Doppler velometer; flow measurements using coriolis effect.

Temperature and Heat Flux Measurement: Thermoelectric sensors; electric resistance sensors; thermistors; radiations pyrometers; Temperature measuring problems in flowing fluids, dynamic compensation.

DAS and Signal Analysis: Data acquisition system via computers. The components of Data acquisition system, DAS Hardware, selection criteria for choosing a DAS. Techniques for signal analysis. Signal conditioners - filters, low, high, band pass and charge amplifiers.

Suggested Books:

- Doeblin E O, and Dhanesh N M, "Measurements System Application and Design", 6th Ed., McGraw Hill
- 2011
- Mechanical Measurement; Beckwith and Buck; Wesley; 2002
- Theory and Design for Mechanical Measurements; Richard S. Figiliola, 4th Edn., Wiley India 2005
- Instrumentation for Engineering Measurements; James W. Dally, W.F. Rilley and K.G. McConnel; John Wiley (2nd Edn.) 2003
- Eckert R G and Goldstein R J, "Measurements in Heat Transfer", 2nd Ed., Springer 1986
- Goldstein, R. J.,"Fluid Mechanics Measurement", Hemisphere Publishing Company 1983
- LAB View Manual 2012

MIN-354 Automatic Controls Pre-requisite**: Nil**

Introduction: Introduction to automatic control systems, open loop and closed loop systems, servomechanism, design principles of control systems.

Mathematical Model of Physical System: Transfer functions, linearization of non-linear functions, linearization of operating curve, block diagrams and block diagram algebra, modeling in frequency and time domain, translation and rotational mechanical components, electrical components, series and parallel combinations, compactors for rotational and linear motions, integrating devices, hydraulic servomotor, temperature and speed control systems.

Transient Response Analysis: First and second order systems response to step, pulse, ramp and sinusoidal inputs, higher order systems, Routh's Criteria.

Error Analysis and Introduction to system Optimization: Steady state errors, Static error coefficient, dynamic error coefficients, error criteria, introduction to system optimization.

Control Action: Proportional control, integral control, derivative control, combination of control actions and their effect on system performance, two position control, industrial control systems using various control actions.

Control System Analysis: Stability of control systems, root locus techniques, root locus plots of simple transfer functions, stability analysis and transient response from root locus; frequency response analysis, logarithmic plots, stability and relative stability analysis on Bode plots, experimental determination of transfer function.

Design and Compensation techniques: Introduction of preliminary design consideration, lead and lag compensation, compensation, lag-lead compensation, summary of control system compensation methods, practical examples.

Control System Analysis Using State Variable Method: State variable representation, conversion of state variable model to transfer function, conversion of transfer function to canonical state of variable models, solution to state equations, concept of controllability and observability, signal flow graph, equivalence between transfer function and state variable representations.

Suggested Books:

- Katsuhiko, O., "Modern Control Engineering", 3rd Ed., Prentice Hall , 1996

- Raven, F.H., “Automatic control Theory”, 5th Ed., McGraw Hill , 1995
- Kuo, B.C., “Automatic Control System”, 5th Ed., Prentice Hall of India, 1995
- Nise, N.S., "Control Systems Engineering” 5th Ed., Willey, 2008
- Chen, C.T., “Linear System Theory & Design”, 3rd Ed., Oxford University Press, 1999
- Gopal, M., “Control System: Principles and Design”, 2nd Ed., Tata McGraw Hill, 1997

MIN-355 Building Ventilation & Air-conditioning Pre-requisite**: Nil**

Introduction: History of refrigeration and air-conditioning; trends in modern buildings for thermal comfort, pollution free environment and indoor traffic management

Vapour Compression Cycle: Carnot vapor compression Cycle; T-s and P-h diagrams of simple vapour compression refrigeration cycle; Compressor volumetric efficiency. Effect of suction and discharge pressure, subcooling and superheating on performance.

Psychrometery: Psychrometric properties, psychrometric chart, simple and computerized psychrometrics, psychrometric processes; Appreciation of indoor and outdoor conditions for a space in summer and winter.

Air Conditioning Processes: Summer and winter air-conditioning processes; Sources of thermal load in summer and winter using Load Estimation Chart; Sensible Heat Factor (SHF). Evaporative Cooling Systems.

Infiltration and Ventilation: Driving mechanism of infiltration and ventilation; Indoor air quality; natural ventilation; Residential air leakage; blower door test; Residential ventilation; Residential ventilation requirements.

Fenestration: Fenestration components; determination of energy flow; U-factor; solar heat gain and visible transmission; shading; visual and thermal controls; air leakage; day lighting; selecting fenestration: condensation resistance, occupant comfort and acceptance.

Building Cooling Load Calculations: Internal heat gain; system heat gain; ventilation load; cooling and heating load estimate; psychrometric calculations for heating and cooling load.

Transmission and Distribution of Air: AHU;Room air distribution; friction loss in ducts; dynamic loss in ducts; air duct design; space air diffusion.

Design Conditions: Comfort air conditioning and effective temperature; comfort chart; choice of supply design conditions; Climate design conditions; generating design day data; clean spaces.

Suggested Books:

- Stoecker, W.F., and Jones, J.W., “Elementary Refrigeration & Air conditioning”, McGraw Hill, 2002
- Dossat, R.J., Principles of Refrigeration, Pearson Education Asia, 2002
- Arora, C.P., “Refrigeration and Air conditioning”, Tata-McGraw Hill, 2005
- Prasad, M., “Refrigeration and Air conditioning”, New Age International, 2005
- ASHRAE Handbook (Fundamentals), 2013

MIN-357 Combustion Science & Technology Pre-requisite**: Nil**

Introduction: Importance of Combustion, applications, brief overview of combustion generated pollution

Thermodynamics of Combustion: Combustion Stoichiometry, enthalpy of formation, enthalpy of reacting systems, energy balance for reacting systems, enthalpy of reaction and heating values. Adiabatic flame temperature. Equilibrium criteria, equilibrium constant, equilibrium composition and flame temperature**.**

Chemistry of Combustion: Rate laws and reaction orders, elementary reactions, reaction Molecularity, temperature and pressure dependence of reaction rate, Arrhenius law, chain reactions, and reaction mechanisms. Steady state and partial equilibrium approximations. General oxidative and explosive

characteristics of fuels, chain branching and explosion criteria, Explosion limits of Hydrogen-O_2 CO-O, hydrocarbon –O_2 system, NO_x formation and its control

Flame Processes: Rankine Hugonoit Relations, Deflagration and Detonation Different types of flames, laminar flame structure, laminar flame speed, effect of various chemical and physical parameters on flame speed, Flammability Limits, Stability Limits. Quenching and Flash Back, Design of Burners

Turbulent Premixed Flames: Applications, Turbulent Flame Speed, Structure of Turbulent Flames, Flame Stabilization, Turbulent Non premixed Flames. Combustion Process in SI engines

Diffusion Flames: Applications of diffusion flames, structure of diffusion flames, Burke and Schumann development. Burning of condensed Phases, liquid droplet combustion in quiescent environment, effect of convection, spray combustion. Combustion in CI engines

Combustion Generated Emissions: Environmental consideration of combustion, Formation of NO_x and its control, Particulate matter, SO_x, Staged burner, catalytic converters, particulate traps

Suggested Books:

- Glassman, I. and Yetter, R. “Combustion,” 4th Edition, Academic Press, 2008
- Turns, S. R., “An Introduction to Combustion, concepts and applications,” 3rd edition, McGraw Hill , 2011
- Kuo, K. K., “Principles of Combustion,” 2nd edition, John Wiley , 2005
- Ragland, K. W. and Bryden, K. M., “Combustion Engineering,” CRC Press, 2011
- Baukal, C. E., “Industrial Burners Handbook”, CRC Press; , 1999
- Fawzy E. M., and Saad E. H., “Fundamentals and Technology of Combustion” , Elsevier, 2002

MIN–359 Fundamentals of Sound and Vibration Pre–requisite: **Nil**

Fundamental concepts: Fundamentals of applied mechanics, sound and vibration fields, longitudinal waves in gases and liquids, diffraction, models in room acoustics, geometrical acoustics, waves in solid media, frequency analysis of sound, levels and decibel, filters, band pass, octave and third octave filters, summation of sound fields, interference and frequency components, summary of important formulas.

Influence of Sound and Vibration: Ear and hearing, ear’s function, measures of hearing, measures of noise, speech and masking, influence of noise on man, hearing injuries, hearing protection, sound quality, effects of shock and vibration, machinery and vehicle vibration, effects on man, international standards, regulations and recommendations on machine, vehicles, work environment, buildings and on external noise, summary of important formulas.

Signal Analysis and Measurements Techniques: Mathematical fundamentals, fourier methods in sound and vibration, measurement systems, summary of important formulas.

Wave Equation in Fluids: Wave equation in a source free medium, general and harmonic solutions for free one dimensional wave propagation, sound intensity, energy and energy density, general and harmonic solutions for free spherical wave propagation, sound intensity, summary of important formulas.

Fundamentals of Vibrations: Mechanical power, linear systems of one, two and multi-degree of freedom systems, damping, frequency response, mechanical-electrical circuits.

Reflection, Transmission and Standing Waves: Reflection and transmission of plane waves, eigen-frequencies and eigen modes in enclosed spaces (rooms), summary of important formulas.

Wave Equation in Solids: Introduction, wave propagation in infinite and semi-infinite media, quasi-longitudinal waves in beams, bending waves in beams and plates, summary of important formulas.

Room Acoustics: Energy methods, room acoustics, acoustic absorbers, sound transmission through walls, summary of important formulas.

Sound Generation Mechanisms: Monopoles, dipoles, quadra poles, influence of boundaries, live source, sound radiation from vibrating structures, point excited plates, flow generated noise, summary of important formulas.

Vibration Isolation: Types, general comments, measures and prediction of vibration isolation, prediction models, rigid and flexible foundations, general expression, case studies.

Sound in Ducts: Principals for sound reduction, insertion and transmission loss, sound propagation in ducts, introduction to silencers, helmholtz resonator, case studies.

Suggested Books:

- Abom, M., "Sound and Vibration", KTH, Stockholm, 2006
- Rao, J.S., and Gupta, K., "Theory and Practice of Mechanical Vibrations", New Age International (Pvt) Ltd, 1999
- Fahy, F.J,. and Walker, J.G., "Fundamentals of Noise and Vibration", E and FN, Spon, 1998
- Kinsler, L.E., Frey, A.R., Coppens, A.B., and Sanders, J.V., "Fundamentals of Acoustics", John Wiley, 1982
- Grover, G.K., "Mechanical Vibrations", Nem Chand & Bros., 2003

MIN-411 Maintenance Techniques for Rotating Components Pre-requisite**: Nil**

Introduction to theory and practice of maintenance, operating policy and effective maintenance, operating practices to reduce maintenance work, reports from maintenance, operating characteristics of rotating equipments and the diagnostic techniques and inspections required for critical components of rotating equipment

Maintenance policies and strategies: Breakdown, preventive, predictive and proactive maintenance, components of effective preventive maintenance, predictive maintenance, economics of preventive maintenance

Maintenance of rotating equipment: Bearings - Plain bearings, rolling element bearings, gear drives and speed reducers, rotating shafts and flywheel, pumps – centrifugal and positive displacement, turbines – steam and gas

Advanced Maintenance: Condition monitoring and its types, techniques of condition monitoring – analysis of vibrations, temperature and lubricating oil

Testability and prognostics, Case studies.

Suggested Books

- Lindley R. Higgins, R. Keith Mobley, Maintenance Engineering Handbook, McGraw Hill, 7th Edition, 2008
- Lorenzo Fedele, Methodologies and Techniques for Advanced Maintenance, Springer , 2011
- Philip Kiameh, Power Plant Equipment Operation and Maintenance Guide, McGraw-Hill, 1st Edition, 2012
- Collacott, R.A., "Mechanical Fault Diagnosis and Condition Monitoring", Chapman & Hall, 1977
- Davies, "Handbook of Condition Monitoring- Techniques and Methodology", Springer, 2006

MIN-412 Vehicle Dynamics Pre-requisite**: Nil**

Introduction to Vehicle Dynamics: Various kinds of vehicles; motions; mathematical modelling methods; methods of investigations.

Mechanics of Pneumatic Tyre: Tyre construction; physics of tyre traction on dry and wet surfaces; tyre forces and moments; SAE recommended practice; rolling resistance of tyres; ride properties of tyres.

Performance Characteristics: Equation of motion and maximum tractive effort; aerodynamic forces and moments; vehicle transmission characteristics; prediction of vehicle performance; braking performance; antilock braking systems.

Handling and Stability Characteristics: Steering geometry; steady state handling characteristics; steady state response to steering input; transient response characteristics; directional stability.

Vehicle Ride Characteristics: Human response to vibration; vehicle ride models; road surface profile as a random function; frequency response function; evaluation of vehicle vertical vibration in relation to ride comfort criterion.

Experimental Testing: Instruments for vehicle measurements; recording and evaluation methods; test methods and measurement procedures for vehicle dynamics; interpretation of test results.

Suggested Books:

- Wong, J.Y., “Theory of Ground Vehicles”, John Wiley., 2008
- Gillespie, T.D., “Fundamental of Vehicle Dynamics”, S.A.E., 1992
- Rao V. Dukkipati, “Road Vehicle Dynamics”, SAE International , 2008
- Hans True, “The Dynamics of Vehicles on Roads and on Tracks”, 1st Ed., Taylor and Francis, 2003

MIN-413 MEMS Pre-requisite**: CEN-102**

Introduction: Introduction to MEMS; historical perspective; application examples; course motivation.

Preliminaries of Continuum Mechanics: Continuum hypothesis; governing equations of elasticity; thermo-elasticity; review of fluid dynamics principles; Navier-Stokes equation; Euler equation; fundamentals of electromagnetism; Maxwell's equations; electrostatics; magnetostatics; dimensional analysis and scaling laws of forces at the microscale; different actuation and sensing techniques used at the microscale.

MEMS Sensors and Actuators: Pressure sensors; accelerometers; gyroscopes; RF MEMS devices; MEMS resonators; switches; digital micro mirror devices: principle of operation and mathematical modeling.

Mechanical Analysis of Electrostatically Actuated MEMS Devices: Static analysis; spring constant for beams; electrostatic actuation; parallel-plates model; torsional plate actuator; comb drive actuator; shape of a deformed beam under electrostatic actuation; moderately large deflection analysis of fixed-fixed beams; dynamic analysis; mechanisms of energy dissipation; air damping fundamentals; squeeze film damping; Reynold's equation; dynamics response of beam-type actuators under electrostatic loading.

Introduction to Microfabrication Techniques: Basic process tools; oxidation; sputter deposition; chemical-vapor deposition; lithography; etching; advanced process tools: anodic bonding; silicon direct bonding; SU-8 photosensitive epoxy; Nonlithographic fabrication processes: laser machining, electrodischarge machining.

Suggested Books:

- Pelesko, J.A., and Bernstein D.H., "Modeling MEMS and NEMS", 1st Ed., Chapman and Hall CRC , 2002
- Beeby, S., Ensell, G., Kraft, M., and White N., "MEMS Mechanical Sensors", 1st Ed., Artech House, Inc., 2004
- Bao, M., "Analysis and Design Principles of MEMS Devices", 1st Ed., Elsevier B.V., 2005
- Mohamed Gad-el-Hak (Editor), "The MEMS Handbook", 2nd Ed., Taylor and Francis., 2006
- Adams, T.M., and Layton, R.A., "Introductory MEMS: Fabrication and Applications", Springer New York., 2010

MIN-415 Piping Technology Pre-requisite**: CEN-102**

Design/Analysis of Piping System: Industrial, sub-sea & underground piping systems. Design and stress analysis of piping system. Pipe fittings, elbows and flange design, stresses in elbows and flanges. Failure theories, National and International codes. Branched connections. Piping network analysis. Design calculation of wall thickness and working pressure. Use of FEM and software tools. Pipeline sizing, Design criterion; least annual cost criterion, velocity criterion, Pressure drop criterion,

Vibration Problem in Piping System; Experimental Tests on Piping System/Components: Vibration analysis of piping system, Determination of natural frequency, damping and mode shape. Design of experiments for piping system. Estimation of leakage of piping connections/joints.

Pipeline Machinery, Operation & Control: Description of various components, methods for control strategies. Field metering and regulating facilities, pressure surges, Anti-surge control, Coriolis mass flow measuring techniques, Pigging, examples of pigging operation. Linear and nonlinear pipelines. Pipeline installation and maintenance equipments. Structural supports of piping system.

Joining Techniques and Quality Control of Pipelines: Welding techniques/processes, welding procedures and equipments, Various techniques for inspection and testing, weld defects, Underwater welding in Offshore constructions, GMA welding, SMA welding, Shrouded metal arc welding, Dry under water welding, Visual and NDT techniques for inspection and tools for quality control of pipelines. Maintenance techniques. Cleaning of pipe internal surface.

Prevention of Corrosion in Pipelines: Corrosion process, Various types of corrosion in pipelines, Techniques for the prevention of corrosion, Anti-corrosive protective coatings, Cathodic protection of pipelines, Internal inspection and Corrosion monitoring. Recommended piping materials.

Well Head Installation & Water Injection: Introduction, definition, water injections, water sources, treatment for sea water injection, equipments, material for constructions, design specifications, sources of injected water, filters, de-oxygenation, Water injection pumps.

Suggested Books:

- Harvey,"Pressure Vessel Design", Van Nostrand, 1963
- Gascoyne,"Analysis of Pipe Structures for Flexibility", Pitman, 1959
- Joshi, M.V.,"Process Equipment Design", Macmillan India Ltd., 2009
- Sahu, G.K., "Handbook of Piping Design", New Age International Publishers., 2008
- Bausbacher, E. &Hunt, R."Process Plant Layout and Piping Design", Prentice Hall, ISBN: 0131386298., 1993
- Smith, P. & Botermans, R., "Advanced Piping Design", Gulf Publishing Company., 2008
- Smith, P. "The Fundamentals of Piping Design (Process Piping Design), Gulf Publishing Company., 2007

MIN-416 Nonlinear Dynamics Pre-requisite**: Nil**

Concepts in dynamical systems: phase space, fixed points, stability, Poincaré map etc.

Basic theorems in system dynamics: Poincaré-Lyapounov, Hartmann-Grobmann, Center Manifold, Review of KAM Theorem

Perturbation theory: secular terms, resonance in perturbation theory, Gronwall lemma, error estimation in approximation methods

Applications in ODE's: Duffing oscillator, forced oscillations, limit cycles; Lorentz equations

Applications in PDE's: nonlinear diffusion; amplitude equations; nonlinear wave equations - Burgers, KdV & NLS equations and their wave solutions, solitons, compactons

Chaos: The logistic equations and the route to Chaos

Fractals: Fundamental concepts in Fractals and Chaos

Nonlinear wave equations

Suggested Books:

- Nayfeh, A., Perturbation Methods, Wiley., 1978
- Wiggins, S., Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer-Verlag, NY, 1992., 1992
- Lichtenberg, A. J. & Lieberman, M. A., Regular and Chaotic Dynamics, Springer-Verlag, NY., 1992
- Hao Bai-Lin, Chaos, World Scientific, Singapore., 1984
- Kahn, P. B. & Zarmi Y., Nonlinear Dynamics – Exploration Through Normal Forms, Wiley, NY., 1998

MIN-417 Energy and Variational Principles in Engineering Mechanic Pre-requisite**: MAN-001, PHN- 001, CEN-102**

Motivation and Mathematical Preliminaries: Role of energy methods; historical perspective; review of vectors and vector calculus; basic equations in solid mechanics; index notation; conservation of linear and angular momentum; stress tensor; kinematics of deformation; strain tensor; constitutive laws.

Introduction to the Calculus of Variations: The variational operator; concept of a functional; extremum principles; functionals of one independent variable; functionals of two independent variables.

Basic Notions of Energy Methods: Virtual work; total potential energy and complementary potential energy; stability criteria; Castigliano's Theorem I; Castigliano's Theorem II; Betti and Maxwell reciprocity theorems.

Energy Methods for the Static Analysis of Deformable Solids: Analysis of deformable members such as longitudinal bars, Euler-Bernoulli beams, membranes and plates under static loading conditions using variational principles; separation of natural and essential boundary conditions; introduction to Ritz, weighted residual, and Galerkin methods; Introduction to the finite element method.

Energy Methods in Structural Dynamics: Hamiltonian and Lagrangian dynamics; principle of least action; Euler-Lagrange equation; conservative and non-conservative systems; dynamics of non-deformable bodies; stability criterion; dynamics of deformable bodies: longitudinal vibration of rod, transverse vibration of strings and Euler-Bernoulli beams.

Suggested Books:

- Langhaar, H.L., "Energy Methods in Applied Mechanics", 1st Ed., John Wiley and Sons, Inc., 1962
- Shames, I.H., and Dym, C.L., "Energy and Finite Element Methods in Structural Mechanics", 1th Ed., New Age International Publishers , 1991
- Reddy, J.N., "Energy Principles and Variational Methods in Applied Mechanics", 1st Ed., John Wiley and Sons, Inc., 2002
- Berdichevsky, V.L., "Variational Principles of Continuum Mechanics-I: Fundamentals", 1st Ed., Springer, 2009
- Berdichevsky, V.L., "Variational Principles of Continuum Mechanics-II: Applications", 1st Ed., Springer, 2009

MIN-445 Value Engineering Pre-requisite**: Nil**

Introduction: Value engineering concepts, advantages, applications in product development, process improvement, service improvement and system design, problem recognition, role in productivity

Analysis of Functions: Anatomy of function, use, antique, cost, esteem and exchange values, primary versus secondary versus tertiary/unnecessary functions, functional analysis: FAST (Function Analysis System Technique) and quantitative evaluation of ideas, case studies.

Value Engineering Techniques: Selecting products and operations for VE action, timing; VE programmes, determining and evaluating functions(s), assigning rupee equivalents, developing alternate means to required functions(s), decision making for optimum alternative, use of decision matrix, make or buy decisions, measuring profits, reporting results and follow up.

Implementation: Action plan, record progress, report progress, review meetings, problems in implementation, human factors.

Managing VE: Level of VE in the organization, size and skill of VE staff, small plant VE activity management supports; Audit of savings.

Suggested Books:

- Miles, L.D., "Techniques of Value Analysis and Engineering", Eleanor Miles Walker, 1989
- Park, R.J. "Value Engineering : A Plan for Invention", St. Lucie Press, 1999
- Michaels, J.V., and Wood, W.P., "Design to Cost", Wiley Interscience, 2004
- Tufty, H.G., "Compendium on Value Engineering", The Indo American Society, 1983
- Jagannathan, "Getting More at Less Cost", Tata McGraw Hill, 1992

MIN-500 Instrumentation and Measuring Systems Pre-requisite: **Nil**

Significance of Measurement and Instrumentation: Introduction; generalized configuration and functional stages of measuring systems. The transducer and its environment; an overview; sensing process and physical laws. Types of measurement problems. Transducer classification and their modeling; information, energy and incremental models

Characteristics of Instruments: Objective of studying the characteristics of the instruments. Static characteristics, Static Calibration, design and selection of components of a measuring system.

Dynamic Response of Instruments: Mathematical model of a measuring system, response of general form of instruments to various test inputs; time-domain and frequency domain analysis.

Errors in Measurement and Its Analysis: Causes and types of experimental errors; systematic and random errors. Uncertainty analysis; computation of overall uncertainty; estimation for design and selection for alternative test methods.

Transducers and Transduction Principles: Developments in sensors, detectors and transducer technology; displacement transducers; force, torque and motion sensors; piezoelectric transducers; capacity type transducers; Strain gage transducers; accelerometers, pressure transducers based on elastic effect of volume and connecting tubing.

Data Acquisition and Signal Processing: Systems for data acquisition and processing; modules and computerized data system; digitization rate; time and frequency domain representation of signals, and Nyquist criterion.

Flow Measurement: Flow visualization,shadowgraph; schlieren and interferometric techniques;Pitot static tubes; hot wire anemometers; Laser Doppler velometer; flow measurements using coriolis effect.

Temperature and Heat Flux Measurement: Thermoelectric sensors; electric resistance sensors; thermistors; radiations pyrometers; Temperature measuring problems in flowing fluids, dynamic compensation.

Suggested Books:

- Doeblin E O, and Dhanesh N M, “Measurements System Application and Design”, 6th Ed., McGraw Hill, 2011
- Theory and Design for Mechanical Measurements; Richard S. Figiliola, 4th Edn.; 2005, Wiley India, 2005
- Harry L T., “Transducers in Mechanical and Electronic Design”, Marcel Dekker, CRC Press,1986
- Marangoni R D and Lienhard J H, “Mechanical Measurements by Beckwith T G”, 6th Ed., Prentice Hall, 2006
- Eckert R G and Goldstein R J, “Measurements in Heat Transfer”, 2nd Ed., Springer 1986
- Goldstein, R. J.,"Fluid Mechanics Measurement”, Hemisphere Publishing Company 1983

MIN-501 Computer Aided Manufacturing Pre–requisite: **Nil**

Introduction: Introduction to manufacturing systems and their performance analysis; Introduction to automation; Introduction to computer integrated manufacturing (CIM).

Numerical Control (NC): Introduction, numerical control – its growth and development, components of NC system, input devices, control systems – point to point, straight cut, and continuous path NC, open loop and closed loop NC systems, NC interpolations – linear, circular, helical, parabolic and cubic interpolation, applications of NC systems, merits and demerits.

Extensions of NC: Concepts of computer numerical control (CNC), machining center, and direct numerical control (DNC), and their advantages.

Robotics: Robot anatomy and related attributes, robot control systems – limited sequence, playback with point to point, playback with continuous and intelligent control; End effectors – gripper, tools; Sensors in

robotics – tactile sensors, proximity, optical sensors and machine vision; Applications of industrial robots, robot programming.

Material Handling and Storage: Overview of material handling equipments, automated material handling equipments – AGVs, conveyor systems, performance analysis of material handling systems, automated material storage systems – ASRS and carousel storage, analysis of automated storage systems.

Manufacturing Support Functions: Introduction to group technology (GT), computer aided process planning (CAPP), material requirement planning MRP (MRP), capacity planning, scheduling etc.

Suggested Books:

- Groover, M. P., "Automation, Production systems and Computer Integrated Manufacturing", 3rd Ed., Prentice-Hall., 2007
- Singh, N., "Systems Approach to Computer Integrated Design and Manufacturing", John Wiley & Sons. , 1996
- Chang, T.-C., Wysk, R. A. and Wang, H.-P. "Computer Aided Manufacturing", 3rd Ed., Prentice Hall. , 2005
- Rembold, U., Nnaji, B. O. and Storr A., "Computer Integrated Manufacturing", Addison Wesley. , 1994
- Besant, C. B. and Lui, C. W. K., "Computer Aided Design and Manufacture",
- Ellis Horwood Ltd., 1991
- Rao, P. N., Tiwari, N. K. and Kundra, T.K., "Computer Aided Manufacturing", Tata McGraw Hill., 1993
- Koren, Y. "Computer Control of Manufacturing Systems", McGraw Hill., 1983
- Lynch, M., "Computer Numerical Control for Machining", McGraw-Hill., 1992
- Sava, M. and Pusztai, J., "Computer Numerical Control Programming", Prentice Hall. , 1990

MIN-502 Robotics and Control Pre–requisite: **Nil**

Introduction: Definition, Structure, Classification and Specifications of Robots, Industrial Robots.

Robot Elements and Control: Manipulators, Drives, Sensors, End Effectors, Configuration, Force/Torque Relationship, Trajectory Planning, Position Control, Feedback System, Digital Control

Modeling of Robots: Coordinate Frames, Mapping and Transformation; Direct Kinematic Model; Inverse Kinematics; Manipulator Differential Motion; Static Analysis; Jacobian

Manipulator Dynamics: Acceleration of a rigid body, mass distribution, Newtons equation, iterative Newton Euler dynamic formulation, Lagrangian formulation of manipulator dynamics, Bond graph modeling of manipulators, Trajectory Planning.

Linear and Non Linear Control of Manipulators: control law partitioning, trajectory following control, multi input multi output control systems, Cartesian based control scheme.

Force Control of manipulators: hybrid position/force control

Robot Programming: Robot Programming for Manufacturing and Other Applications, Robot Integration with CAD and CAM.

Suggested Books:

- Craig John J., "Introduction to robotics: Mechanics & Control", Addison-Wesley, 1986
- Niku Saeed B., Introduction to Robotics: Analysis, Systems, Applications, PHI, New Delhi, 2001
- Schilling R. J., "Fundamentals of Robotics Analysis and Control", Prentice Hall Inc , 1990
- Mittal R. K. and Nagrath I. J., "Robotics and Control", Tata McGraw Hill, New Delhi , 2003
- Ghosal Ashitava, "Robotics: Fundamental Concepts and Analysis", Oxford University Press, 2006

- Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer , 2013

MIN-508 Advanced Automatic Controls Pre-requisite: **Nil**

Mathematical Models of Linear Systems: Linear systems and state equations, linearization of non linear equations, linearizing functions, linearizing differential equations

Linear Algebra: Vector spaces, linear dependence and independence, bases, change of basis, rank and degeneracy, norms, Gram-Schmidt orthonormalization, subspaces and projection theorem

State Variable Analysis: State variable representation, conversion of state variable model to transfer function, characteristic equation, eigenvalues, eigen- vectors, conversion of transfer function to canonical state variable models, solution to state equations,

Stability of Control Systems: Bounded input, bounded output stability, zero input and asymptotic stability of continuous data system, Lyapunov stability, Lyapunov's direct method, external stability, relationship between stability types

Controllability and Observability: Controllability tests for LTI systems, modal controllability and observability, controllability and observability of time varying systems, discrete time systems

System Realizations: Minimal realization, specific realization, Markov parameters, balanced realizations

State Feedback and Observers: State feedback for SISO systems, multivariable canonical forms and feedback, observers, state estimator- multivariable case

Optimal Control and Estimation: The principle of optimality, optimal estimator

Pole Placement and Model Matching: Unity feedback configuration, implementable transfer function, multi variable unity feedback system, multivariable model matching

Suggested Books:

- Ogata, K., "Modern Control Engineering", Prentice Hall of India. **,** 2002
- Raven, F.H., "Automatic control Theory", McGraw Hill., 1995
- Kuo, B.C., "Automatic Control System", 5th, Prentice Hall of India. , 1995
- Chen, C.T., "Linear System Theory & Design", 3rd Edition, Oxford University Press., 1999
- Harrison, H.L. and Bollinger, J. G., "Automatic Controls", International Text Book Company., 1970
- Bay, J.S., "Fundamentals of Linear State Space Systems", McGraw Hill. , 1999
- Norman, S.N., "Control Systems Engineering", John Wiley and Sons., 2003

MIN-509 Extended Finite Element Methods Pre-requisite: **Nil**

Basic Concepts of Finite Element Methods: Introduction, weighted residual and weak formulations, variational methods, numerical problems.

Finite Element in 1-D: Basis steps of finite element analysis, Applications to solid mechanics, heat transfer and fluid flow problems.

Finite Element in 2-D: Single variable problems in 2-D, applications to solid mechanics and heat transfer problems, numerical integration, higher order shape functions, plane stress and plane strain problems.

Basics of Extended Finite Element Method (XFEM): Brief introduction, partition of unity finite element method (PUFEM), generalised finite element method (GFEM), introduction to XFEM, blending elements, concept of level sets and enrichment

Engineering Applications: XFEM on element level: shape functions, displacement, strain, element stiffness matrix, XFEM for weak and strong discontinuities e.g. static cracks, crack growth, bi-materials, phase change problems.

Advanced Concepts of XFEM: Concept of phantom nodes, tracking the crack path, embedded elements, interface elements, introduction to cohesive zone models, embedded elements, crack initiation/propagation, smeared cracks.

Suggested Books:

- Rao, S.S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science., 2005
- Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill., 2005
- Fish, J., and Belytschko, T., "A First Course in Finite Elements", John Wiley and Sons., 2007
- Chaskalovic J., Finite Element Methods for Engineering Sciences, Springer., 2008
- Mohammadi, S., "Extended Finite Element Method", Blackwell Publisher., 2008

MIN-511A Modeling and Simulation Pre-requisite: **Nil**

Introduction to Modeling: Concept of system, continuous and discrete systems, types of models, steps in simulation study.

Mathematical Preliminaries: Review of vector calculus, Cartesian tensors, vector spaces and linear transformations; Interpolation and extrapolation; Numerical differentiation and integration.

Discrete and Continuous systems: Continuous and discrete systems from fluid mechanics and heat transfer; Characteristics of discrete systems, eigenvalue problems; Characteristics of continuous systems based on differential equations; Inverse problems.

Mathematical Modeling of Thermal Processes: Conservation laws, mass, momentum and energy balance; Classification of governing equations, boundary conditions; Dimensional analysis, model development for various thermal processes and system; Dynamics of thermo-fluid systems.

Simulation of Thermal Systems: Numerical methods for solution of partial and ordinary differential equations; Numerical solution of linear and nonlinear algebraic equations; Numerical simulation of steady state and dynamic systems.

Optimization of Thermal Systems: Introduction to optimization, formulation of objective function, constrained single and multivariable optimization, dynamic integer and geometric programming.

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

Suggested Books:

- Jaluria, Y., "Design and Optimization of Thermal Systems", 2nd Ed., CRC Press., 2007
- Bejan, A., Tsatsaronic, G., and Moran, M., "Thermal Design and Optimization", John Wiley & Sons., 1995
- Close, C. M., and Frederick, D. K., "Modeling and Analysis of Dynamic Systems", John Wiley & Sons. , 2001
- Jaluria, Y. "Computer Methods for Engineering with MATLAB Applications", 2nd Edition, CRC Press., 2011
- Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P., "Numerical Recipes: The Art of Scientific Computing", Third Edition, Cambridge University Press, 2007

MIN-511B Modeling and Simulation Pre-requisite: **Nil**

Introduction: Systems and models, examples of models, models for systems and signals.

Physical modeling: Principles of physical modeling, basic relationship, bond graphs, and computer aided modeling.

Mathematical modeling: Estimating transient response, spectra and frequency functions, parameter estimation in dynamic models, system identification as a tool for model building.

Numerical methods: Ordinary differential equations (ODE); Euler's Method, Trapezoidal Method, Runge–Kutta Method, Predictor–Corrector Method, Boundary Value Problems, Shooting Method, Finite Difference Method, Elliptic partial differential equations (PDE), Parabolic PDE (Explicit Forward Euler Method, Implicit Backward Euler Method, Crank–Nicholson Method, Two-Dimensional Parabolic PDE), Hyperbolic PDE (Explicit Central Difference Method, Two-Dimensional Hyperbolic PDE)

Simulation and Simulation application: Numerical prototyping as modeling for design and synthesis using computational tools, Introduction to techniques for validation of models, Simulation of electromechanical, thermo-mechanical, hydraulic and pneumatic elements.

Modeling and Simulation for Optimization: Introduction to the concept of optimization, the basic terminology and notations; modeling process; and illustration with modeling of engineering problems. Graphical solution process; problems with – bounded (single or multiple) and unbounded solutions. Local and global optima; necessary and sufficient optimality conditions for unconstrained and constrained multivariate functions.

Suggested Books:

- Gordon, G., "System Simulation", Prentice Hall., 1978
- Lennart, L. and Torkel, G., "Modeling of Dynamic Systems" Prentice Hall., 1994
- Bhonsle, S.R. and Weinmann, K.J., "Mathematical Modeling for Design of Machine Components", Prentice Hall. , 1998
- D'Souza, A.F., and Garg, V.K., "Advanced Dynamics: Modeling and Analysis", Prentice-Hall. , 1983
- Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in Modeling, Simulation and Fault Identification", I & K International., 2007
- S. S. Rao; Engineering Optimization; 4th Edition, John Wiley & Sons., 2009
- K. Deb; Optimization for Engineering Design; Prentice Hall of India., 2005
- K. Deb; Multi-objective Optimization using Evolutionary Algorithms; John Wiley & Sons., 2003

MIN-515 Manufacturing Systems Analysis Pre–requisite: **Nil**

Introduction: Definitions of manufacturing with input-output model, definition of system, basic problems concerning systems and system design procedure, modes of manufacturing – job/batch/flow and multi-product, small-batch manufacturing.

System Modeling Issues: Centralized versus distributed control; Real-time vs. discrete event control; Forward vs. backward scheduling approaches with finite/infinite capacity loading; Modeling of absorbing states and deadlocks; Conflicts; Concurrency, and synchronization etc.

System Modeling Tools and Techniques: Introduction to mathematical modeling, optimization, and simulation; Issues related with deterministic and stochastic models; Continuous and discrete mathematical modeling methods - discrete event, monte carlo method; Basic concepts of Markov chains and processes; The M/M/1 and M/M/m queue; Models of manufacturing systems - including transfer lines and flexible manufacturing systems, introduction to Petri nets.

Performance Analysis: Transient analysis of manufacturing systems, analysis of a flexible machining center; Product flow analysis; Rank order clustering; Process flow charting; MRPI & II, kanban, OPT, JIT-pull and JIT-push, line of balance, effects of machine failure, set-ups, and other disruptions on system performance; Calculation of performance measures - throughput, in-process inventory, due dates, MTL, capacity, and machine utilization etc.; Critique of high inventory, long lead time systems;Shop floor control issues.

Suggested Books:

- Askin, R. G., and Standridge, C. R., “Modeling and Analysis of Manufacturing Systems”, John Wiley & Sons., 1993
- Gershwin, S. “Manufacturing Systems Engineering”, Prentice-Hall. , 1994
- Hitomi, K., “Manufacturing Systems Engineering”, Taylor & Francis. , 1998
- Viswanadham N. and Narahari Y. “Performance Modeling of Automated Manufacturing Systems”, Prentice-Hall , 1992
- Hopp, W. J., and Spearman, M. L., “Factory Physics : Foundation of Manufacturing Management”, McGraw Hill. , 1996
- Chang, T.-C., Wysk, R. A. and Wang, H.-P. “Computer Aided Manufacturing”, 3rd Ed., Prentice Hall. , 2005

MIN-516 Artificial Intelligence Pre–requisite: **Nil**

Overview of History and Goals of AI: Artificial Intelligence -- Definition, components, scope, and application areas; Turing's test; Review of AI success and failure.

State Spaces, Production Systems, and Search: State space representation of problems; Problem solving using search; Definition and examples of production systems; Heuristic search techniques i.e. generate-and-test, hill climbing, best-first search, constraint satisfaction and mean-ends analysis.

Knowledge Representation: Definition of knowledge; Issues in knowledge representation; Procedural vs declarative knowledge and their representation; Predicate logic, production rules, semantic nets, and frames; Meta-knowledge.

Reasoning and Inference Strategies: Forward vs backward reasoning; Depth first, breadth first, min-max etc.; Non-monotonic reasoning; Symbolic reasoning under uncertainty; Probability and Baye’s theorem; Certainty factors, Dempster-Shafer theory; Fuzzy logic etc.

Expert Systems and their Applications: Justification, structure, knowledge sources; Expert knowledge acquisition; Expert system languages; ES building tools/shells; Applications of AI in CAD, CAPP, process selection, GT, MRP II, adaptive control, robotics, process control, fault diagnosis, failure analysis, etc.

Suggested Books:

- Rich, E., Knight, K. and Nair, S. B., “Artificial Intelligence”, 3rd Ed., Tata McGraw Hill., 2010
- Russell, S. and Norvig, P., “Artificial Intelligence: A Modern Approach”, 3rd Ed.,Prentice-Hall., 2009
- Dean, T. L., Allen, J., and Aloimonos, Y. “Artificial Intelligence: Theory and Practice”, Benjamin/Cummings Publishing Company., 1995
- Genesereth, M. R. and Nilsson, N., “Logical Foundations of Artificial Intelligence”, Morgan Kaufmann., 1987

MIN-517 Automated Materials Handling Systems Pre–requisite: **Nil**

Introduction of Material Handling: Overview of MHE, consideration in MHS design, twenty principles of material handling, the unit load concept.

Material Transport Systems: Industrial trucks, automated guided vehicle systems, monorails and other rail guided vehicles, conveyor systems, cranes and hoists.

Evaluation and Selection of Material Handling Layout: Design of bins and hoppers – flow patterns, measurement of flow properties, design methods, feeders, dischargers, silos, chutes and gates; Bulk material sampling and weighing systems, blending of bulk materials, transportation interface – rail and water. monitoring and control.

Analysis of Material Transport Systems: Rate of deliveries, required number of vehicles, economics of material handling systems.

Automated Storage & Retrieval Systems (AS/RS): Functions of AS/RS, operations of AS/RS, AS/RS components, types of AS/RS, design of an AS/RS, system throughput, size parameters determination of AS/RS.

Suggested Books:

- Allegri, T. H., "Material Handling Principles and Practice", Krieger Publishing Company., 1992
- Meyers, F. E. and Stephens, M. P. "Manufacturing Facilities Design and Material Handling", Prentice Hall., 2000
- Adam, N. D., Brown, T. W., Rowland, V. D. and Misenheimer, F. P., "Warehouse & Distribution Automation Handbook", McGraw-Hill., 1996
- Tompkins, J. A., White, J. A., Bozer, Y. A. and Tanchoco, J. M, "Facilities Planning", 4th Ed., John Willey & Sons., 2010
- Sule, D. R., "Manufacturing Facilities-Location, Planning, and Design", 3rd Ed., CRC Press., 2008

MIN-520 Advanced Thermodynamics Pre-requisite:**Nil**

Review of I and II Laws of Thermodynamics: Transient flow analysis, entropy balance, entropy generation.

Exergy Analysis: Concepts, exergy balance, exergy transfer, exergetic efficiency, exergy analysis of power and refrigeration cycles.

Real Gases and Mixtures: Equations of state, thermodynamic property relations, residual property functions, properties of saturation states.

Thermodynamic Properties of Homogeneous Mixtures: Partial molal properties, chemical potential, fugacity and fugacity coefficient, fugacity relations for real gas mixtures, ideal solutions, phase equilibrium, Raulť's law.

Reacting Systems: I and II law analysis of reacting systems, absolute entropy and the third law, fuel cells, chemical energy, exergetic efficiency of reacting systems, chemical equilibrium, equilibrium flame temperature.

Suggested Books:

- Wark, K., "Advanced Thermodynamics for Engineers", John Wiley & Sons. , 1995
- Bejan, A., "Advanced Engineering Thermodynamics", 3rd Ed., John Wiley & Sons. , 2006
- Annamalai, K. and Puri, I.K., "Advanced Thermodynamics Engineering", CRC Press., 2001
- Moran, M. J., and Shapiro, H. N., "Fundamentals of Engineering Thermodynamics", 6th Ed., John Wiley & Sons , 2007

MIN-521 Advanced Fluid Mechanics Pre-requisite:**Nil**

Review of Basic Concepts: Concept of continuum, types of fluid, tensor analysis.

Basic Laws in Integral Form: Reynold's transport theorem, mass, momentum and energy equations in integral form and their applications.

Differential Fluid Flow Analysis: Continuity equation, Navier-Stokes equations and exact solutions, energy equation.

Ideal Fluid Flow Analysis: Two dimensional flow in rectangular and polar coordinates; Continuity equation and the stream function; Irrotationality and the velocity potential function; Vorticity and circulation; Plane potential flow and the complex potential function; Sources, sinks, doublets and vortices; Flow over bodies and d'Alembert's paradox; Aerofoil theory and its application.

Low Reynolds Number Flow: Approximation of Navier-Stokes equation, approximate solutions of Navier-Stokes equation, Stokes and Oseen flows, hydrodynamic theory of lubrication.

Large Reynolds Number Flow: Prandtl's boundary layer equations, Blasius solutions, Falkner-Skan solutions, momentum integral equation, Halstein and Bohlen method, thermal boundary layers.

Compressible Fluid Flow: One dimensional isentropic flow, Fanno and Rayleigh flows, chocking phenomenon, normal and oblique shocks.

Suggested Books:

- Kundu, P. K., and Cohen, I. M., "Fluid Mechanics", 4th Ed., Academic Press. , 2008
- Panton, R. L., "Incompressible Flow", 3rd Ed., John Wiley & Sons., 2005
- Murlidhar, K., and Biswas, G., "Advanced Engineering Fluid Mechanics", 2nd Ed., Narosa Publishing House. , 2005
- Batchlor, G.K., "Introduction to Fluid dynamics", Cambridge University Press., 2000
- White, F. M., "Viscous Fluid Flow", 3rd Ed., McGraw Hill., 2006
- Munson, B. R., Young, D. F., and Okiishi, T. H., "Fundamentals of Fluid Mechanics". 6th Ed., John Wiley & Sons., 2009

MIN-522 Advanced Heat Transfer Pre-requisite:**Nil**

Heat Conduction: Fourier's law, thermal conductivity of matter, heat diffusion equation for isotropic and anisotropic media, boundary and initial conditions; One-dimensional steady-state conduction through plane wall, cylinder and sphere, conduction with thermal energy generation, heat transfer from extended surfaces, radial fins and fin optimization; Multidimensional-dimensional steady-state heat conduction; Transient conduction – lumped capacitance method and its validity, plane wall and radial systems with convection, semi-infinite solid, muti-dimensional transient heat conduction.

Heat Convection: Boundary layers concepts, laminar and turbulent flows, conservation equation, non-dimensional analysis, boundary layer equations, Reynolds analogy for turbulent flows; Forced convection inside tubes and ducts – correlations for laminar and turbulent forces convection; Forced convection over exterior surfaces – bluff bodies, packed beds, tube bundles in cross flow, free jet; Natural convection; Combined free and forced convection; Combined convection and radiation.

Heat Transfer with Phase Change: Nucleate, film and pool boiling, boiling in forced convection; Filmwise and dropwise condensation; Heat pipes

Thermal Radiation: Fundamental concepts, radiation intensity and its relation to emission, irradiation and radiosity, blackbody radiation, Planck distribution, Wien's displacement law, Stefan-Boltzmann law, surface emission, surface absorption, reflection, and transmission, Kirchoff's law, gray surface; Radiation exchange between surfaces, Poljack's and Gehbart's methods and view factor, blackbody radiation exchange, radiation exchange between diffuse gray surfaces in an enclosure with absorbing and emitting media; Flame Radiation, solar Radiation.

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

Suggested Books:

- Kreith, F. and Bohn, M. S., "Principles of Heat Transfer", 6th Ed.,
- Thomson Learning., 2007
- Burmeister, L. C., "Convective Heat Transfer", 2nd Ed., John Wiley & Sons. , 1993
- Kays, W. M., Crawford, M. E., and Weigand, B., "Convective Heat and Mass Transfer", 4th Ed., McGraw Hill., 2004
- Ozisik, M. N., "Heat Conduction", 2nd Ed., John Wiley & Sons. , 1993

- Siegel, R., and Howell, J. K., “Thermal Radiation Heat Transfer”, Taylor & Francis., 2002

MIN-523 Gas Turbines and Compressors Pre-requisite: **Nil**

Introduction: Development, classification and field of application of gas turbines.

Gas Turbine Cycles: Ideal and actual cycles, multi-stage compression, reheating, regeneration, combined and cogeneration.

Energy Transfer and Fluid Flow Characteristics: Energy transfer between fluid and rotor, axi-symmetric flow in compressors and gas turbines.

Centrifugal Compressors: Principles of operation, compressor losses, adiabatic efficiency, slip factor, pressure coefficient, power unit, design consideration for impeller and diffuser systems, performance characteristics.

Axial Flow Compressors: Elementary theory, vortex theory, degree of reaction, simple design, elementary air-foil theory, isolated airfoil and cascade theory, three dimensional flow, stages, stage efficiency and overall efficiency, performance characteristics.

Turbines: Axial flow and radial flow turbines, impulse and reaction turbines, fundamental relations and velocity triangles, elementary vortex theory, limiting factors in turbine design, application of airfoil theory to the study of flow through turbine blades, aerodynamic and thermodynamic design considerations, blade materials, blade attachment and blade cooling.

Gas Turbine Power Plants: Fuel and fuel feed systems, combustion systems-design considerations and flame stabilization, regenerator types and design, gas turbine power plant performance and matching, applications.

Suggested Books:

- Saravanamuttoo, H.I.H., Rogers, G.F.C., Cohen, H. and Straznicky, P.V., “Gas Turbine Theory”, 6th Ed., Pearson Prentice Hall., 2008
- Bathie, W. W., “Fundamentals of Gas Turbines”, 2nd Ed., John Wiley & Sons., 1995
- Boyce, M. P., “Gas Turbine Engineering Handbook”, 3rd Ed., Gulf Professional Publishing., 2006
- Lefebvre, H. and Ballal, D. R., “Gas Turbine Combustion”, 3rd Ed., CRC Press. , 2010

MIN-524 Two Phase Flow and Heat Transfer Pre-requisite**: Nil**

Introduction: Types of flow; volumetric concentration; void fraction; volumetric flux; relative velocity; drift velocity; flow regimes; flow maps; analytical models.

Homogeneous Flow: One dimensional steady homogeneous equilibrium flow; homogeneous friction factor; turbulent flow friction factor.

Separated Flow: Slip; Lockhart-Martinelli method for pressure drop calculation; pressure drop for flow with boiling; flow with phase change.

Drift Flow Model: General theory; gravity flows with no wall shear; correction to simple theory; Armond or Bankoff flow parameters.

Boiling: Regimes of boiling; nucleation; gas nucleation in bulk liquid; growth of bubbles; motion at a heating surface; heat transfer rates in pool boiling; forced convection boiling; heat transfer correlations; maximum heat flux or burnout; metal boiling.

Condensation: Nusselt theory; boundary layer treatment of laminar film condensation; experimental results for vertical and horizontal tubes; condensation inside a horizontal tube, condensation outside a horizontal tube.

Suggested Books:

- Wallis, G.B., “One Dimensional Two Phase Flow,” McGraw Hill, 1969

- Butterworth, D. and Hewitt, G.F., “Two-phase Flow and Heat Transfer”, Oxford, 1977
- Collier, J.G., “Convective Boiling and Condensation,” McGraw Hill, 1982
- Rohsenow, W.M., Hartnett, J.P. and Ganic, E.N. (Ed.), “Handbook of Heat Transfer Fundamentals,” McGraw Hill, 1998
- Tong, L. S. and Tang, Y.S., “Boiling Heat Transfer and Two-phase Flow,” Taylor & Francis , 1997
- Whalley, P.B., “Two-Phase Flow and Heat Transfer,” Oxford Press, 1996
- Whalley, P.B., “Boiling, Condensation, and Gas-Liquid Flow,” Clarendon Press, Oxford, 1987
- Chisholm, D., “Two-phase Flow in Pipe Lines and Heat Exchangers,” Longman Inc. New York., 1969

MIN-525 Solar Energy Pre-requisite: **Nil**

Introduction: Energy demand and supply, energy crisis, conventional and non-conventional energy resources, solar energy applications.

Solar radiation: Sun, solar radiations, attenuation by atmosphere, solar radiation on earth, measurement, presentation and utilization of data.

Heat transfer concepts: Radiation characteristics of surface and bodies, absorbance, reflectance and transmittance, selective surface, sky radiation and wind convection.

Flat plate collectors: General description of flat plate collectors, general characteristics, performance, short term and long term performance, design.

Focusing collectors: General description of focusing solar collectors, concentrators, receivers and orienting systems, general characteristics, performance, materials, design.

Energy storage: Energy storage in solar process system, different types of storages, characteristics and capacity of storage medium, solar pond.

Solar heating and cooling: Passive heating and cooling, nocturnal radiations, green house concept, ponds, active heating and cooling, solar water heaters, absorption cooling, combined solar heating and cooling systems, performance, economics of solar heating and cooling.

Solar Process Modeling: Solar process systems and components, component models, system models.

Solar Photovoltaics: Description and principle of working, performance characteristics, efficiency of solar cells, module design, PV systems, applications.

Suggested Books:

- Duffie, J.A. and Beckman, W.A., “Solar Engineering of Thermal Processes”, 4th Ed., John Wiley & Sons, Inc., 2013
- Soteris A. Kalogirou, "Solar Energy Engineering: Processes and Systems", Academic Press, 2009
- Goswami, D.Y., Kreith,F., and Kreider J., “Principles of Solar Energy”, 2nd Ed., Taylor & Francis , 2000
- Sukhatme, S.P. and Naik, J.K., “Solar Energy: Principles of Thermal Collection and storage”, 3rd Ed., Tata McGraw - Hill Education, 2009
- Garg, H.P., & Prakash, J.,“Solar Energy : Fundamentals and Applications”, Tata McGraw - Hill Education, 2012
- Tiwari, G.N.,“Solar Energy Fundamentals, Design, Modelling and Applications”, Narosa publishing House, 2002

MIN-526 Advanced Gas Dynamics Pre-requisite**: Nil**

Basic Equations: Application of the general differential equation of continuity, momentum and energy to compressible inviscid fluids, compressible Bernoulli equation, irrotational flow, velocity potential and stream function.

Shock Waves in Supersonic Flow: A review of normal shock relations, Mach waves, equations for finite strength oblique shock waves, Rankine-Hugoniot relations, extended Prandtl relation, hodograph shock polars, reflection and interaction of shock, curved shocks.

Small Perturbation Theory: Linearization, small perturbation equation, pressure coefficient, subsonic flow past a wave shaped wall, general solution of supersonic flows, supersonic flow past a wave – shaped wall, elements of supersonic thin aerofoil theory.

Similarity Rules: Similarity rules between two-dimensional subsonic compressible flows and incompressible flows, Gothert rule, PrandtlGlauert rule, application to supersonic flows.

Hodograph Method for Subsonic Flow: Hodograph equations for two-dimensional subsonic flows, Chaplygin's equation, the tangent gas approximation of Karman and Tsien for subsonic flows, Karman-Tsien formula for pressure correction, comparison with Prandtl-Glauert rule

Method of Characteristics for Supersonic Flow: Method of characteristics for two dimensional supersonic flows, the characteristic curves, equation of hodograph characteristics, characteristics network, computational methods.

Suggested Books:

- Anderson Jr., J.D., "Modern Compressible Flow: With Historical Perspective", 3rd Ed., Tata McGraw-Hill, 2012
- Liepmann, H.W. and Roshko, A., "Elements of Gas Dynamics", Dover Publication., 2002
- Rathakrishnan, E., "Applied Gas Dynamics", John Wiley & Sons., 2010
- John, J. E. A. and Keith, T. G., "Gas Dynamics", 3rd Ed., Prentice Hall. , 2006
- Zucker, R. D. and Biblarz, O., "Fundamentals of Gas Dynamics", 2nd Ed., John Wiley & Sons., 2002
- Oosthuizen, P. H. and Carscallen, W. E. "Introduction to Compressible Fluid Flow", 2nd Ed. , CRC Press, 2013

MIN-527 Computational Fluid Dynamics and Heat Transfer Pre-requisite **: Nil**

Introduction: Conservation equations; Mass, momentum and energy equations; Conservative forms of the equations and general description.

Classification and Overview of Numerical Methods: Classification into various types of equations -- parabolic elliptic and hyperbolic; Boundary and initial conditions; Overview of numerical methods.

Finite Difference Method: Introduction, finite difference approximations, Taylor series expansion, polynomial fitting, approximation of boundary conditions, applications to conduction and advection-diffusion problems.

Finite Volume Method: Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods – central, upwind and hybrid formulations and comparison for convection-diffusion problem.

Finite Element Method: Introduction to Rayleigh-Ritz, Galerkin and least square methods, interpolation functions, one and two dimensional elements, applications.

Methods of Solution: Solution of finite difference equations, iterative methods, matrix inversion methods, ADI method, operator splitting, fast Fourier transform, applications.

Time integration Methods: Single and multilevel methods; predictor-corrector methods; stability analysis; Applications to transient conduction and advection-diffusion problems.

Numerical Grid Generation: Basic ideas, transformation and mapping, unstructured grid generation.

Navier-Stokes Equations: Explicit and implicit methods; SIMPLE type methods; fractional step methods

Phase Change Problems: Different approaches for moving boundary, variable time step method, enthalpy method.

Turbulence modeling: Reynolds averaged Navier-Stokes equations, RANS modeling, DNS and LES.

Suggested Books:

- Anderson, D.A., Tannehill, J.C. and Pletcher, R.H., "Computational Fluid Mechanics and Heat Transfer", 3rd Ed., Taylor & Francis , 2011
- Anderson, J.D., Jr., "Computational Fluid Dynamics", McGraw Hill., 1995
- Ferziger, J. H. and Peric, M., "Computational Methods for Fluid Dynamics", 3rd Ed., Springer., 2003
- Versteeg, H. and Malalasekra, M., "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", 2nd Ed., Pearson Education, 2007
- Reddy, J. N. and Gartling, D. K., "The Finite Element Method in Heat Transfer and Fluid Dynamics", 3rd Ed., CRC Press., 2010
- Chung, T. J., "Computational Fluid Dynamics". 2nd Ed., Cambridge University Press, 2010
- Patankar, S. V., "Numerical Heat Transfer and Fluid Flow", Taylor and Francis, 1980

MIN-528 Boundary Layer Theory Pre-requisite: **Nil**

Introduction: Ideal and real fluids, the concept of boundary layer; Navier- Stokes equations, the limiting cases of layer and small Reynolds number, energy equation; Exact solutions of N-S Equation

Laminar Boundary Layer Equation: Two dimensional equations; displacement and momentum thickness; general properties of the boundary layer equations; skin friction.

Similarity solutions: Wedge flow and its particular cases; flow past a cylinder; two dimensional flow in straight channel

Approximate Methods: Karman-Pohlhausen methods; Numerical methods; Axially symmetrical boundary layer: Circular jet; body of revolution; Manglers transformation

Stability of laminar flow: Transition to turbulence; Turbulent flow fundamentals

Boundary Layer Control: Different methods; flaw over a flat plate with uniform section

Turbulent Boundary Layer: Two-dimensional equation; Prandtl's mixing layer theory; Karman's hypothesis; Universal velocity distribution; flow over a flat plate; skin friction drag.

Thermal Boundary layer: Two-dimensional equations; forced and natural convection over flat plate; natural convective flow over a vertical plate; effect of Prandt'l number.

Suggested Books:

- Schlichting H., "Boundary Layer Theory", Springer-Verlag, 2004
- Rozenhead L., "Laminar Boundary Layers", Dover Publications, 1988
- Hinze J.O., "Turbulence", McGraw Hill, 1975
- Kays W.M. and Crawford M.E., "Convective Heat & Mass Transfer", McGraw Hill, 1993
- Wellty J., Wicks C.E. and Wilson R.E., "Fundamentals of Momentum Heat and Mass Transfer", John Wiley & Sons, 2007
- White F M, "Viscous fluid flow" 3rd Edition;McGraw hill co. , 2011

MIN-529 Turbulent Flows Pre-requisite:**Fluid Mechanics**

Introduction: Introduction to turbulence and equations of fluid motion.

Statistical descriptions of turbulent flows: random nature of turbulence, random variables, probability distributions, and averaging techniques.

Experimental techniques for measurement of turbulent flows: hot-wire and hot-film anemometry, laser Doppler Velocimetry, and Particle image velocimetry.

Dynamics of turbulence: scales of turbulent motion, energy cascade, Kolmogorov hypothesis, structure function, two-point correlations, Fourier modes and velocity spectra.

Homogeneous and isotropic turbulence: implications of isotropy, energy decay, energy spectrum, homogeneous shear flows.

Anisotropic turbulence: wall bounded flows (channel flow, pipe flow, boundary layers) and free shear flows (jets and mixing layers), coherent structures.

Turbulence modeling: RANS modeling, eddy viscosity models, algebraic Reynolds stress models and near-wall models.

Direct numerical simulation and large eddy simulation: filterning, subgrid scale models (smagorinsky and dynamic models), LES in wave number space.

Suggested Books:

- Pope, S.B., “Turbulent Flows”, Cambridge University Press., 2000
- Bernard, P., and Wallace, J.A., “Turbulent Flow“, John Wiley & Sons Inc., 2002
- Libby, P. A., “An Introduction to Turbulence”, Taylor & Francis., 1996
- Mathieu, J., and Scott, J., “Introduction to Turbulent Flow”, Cambridge University Press., 2000
- Biswas, G., and Eswaran, V., “Turbulent Flows”, Narosa Publishing House., 2002
- Piquet, J., Richards, J.A., Jia, X., “Turbulence Flows: Models and Physics”, Springer-Verlag., 2001
- Tennekes, H., and Lumley, J.L., “A First Course in Turbulence”, MIT Press., 1972

MIN-530 Cold Preservation of Food Pre-requisite**: Nil**

Introduction: Necessity of food preservation; general techniques; cold preservation of food.

Biological Aspects: Live and dead foods; biology of food products such as fruits, vegetables, milk, meat and fish; effect of temperature on food ingredients; respiration rates of food products; controlled atmospheric storage; diseases and deterioration of foods.

Cold Preservation of Food: Short and long term preservation; methods of chilling, freezing and freeze drying; heat and mass transfer analysis of cooling and freezing.

Cold Storages: Necessity and present status in the country ; site selection, building constructional features, load calculation, equipment, selection, safety consideration, insurance and management of cold storages; storage of some important food products; modem trends in cold storage practices.

Refrigerated Food Handling: Preparation for cooling/ freezing; packaging of foods; modes of transportation land, sea and air; their thermal, load and equipment; marketing of refrigerated food.

Suggested Books:

- Stoecker W.F.,”Refrigeration and Air-conditioning”, McGraw Hill, 2002
- Moravek J., “Air Conditioning Systems: Principles, Equipment, and Service”, AHRI, , Prentice Hall, 2000
- “ASHRAE Handbooks”, ASHRAE., 2013
- Wang, S. “Handbook of Air Conditioning and Refrigeration”, Tata McGraw Hill Education, 2000
- Arora, C.P., “ Refrigeration and Air conditioning”, Tata-McGraw Hill, 2005

MIN-531 Hydrodynamic Machines Pre-requisite **: Nil**

Introduction: Basic fluid mechanics of turbo-machinery; the torque-momentum and the head- momentum equations; one-dimensional theory and its limitations; two- dimensional theory of flow through axial and radial-flow machines; three-dimensional effects.

Classification of Hydrodynamic machines: Classification of turbines and pumps, various forms of runners.

Impulse Turbines: General theory of impulse machines; performance characteristics; design of runner; bucket shape and size; design of nozzles; regulation mechanisms; penstock design.

Reaction Turbines: General theory of reaction machines; performance characteristics; types; Francis and Kaplan turbines; runner design; blade design; design of the spiral casing; guide vanes and draft tube design; theory of cavitation flows in hydrodynamic runners.

Hydrodynamic Pumps: Classification of pumps and various forms of pump impellers; general theory of centrifugal pumps; performance characteristics; design of casings and diffusers; cavitation effects in impellers.

Hydrodynamic Transmissions: General features; primary and secondary units of the systems; fluid couplings and torque converters; general theory; performance characteristics; basic design considerations;

Suggested Books:

- Logan, E., Turbomachinery: Basic theory and applications, CRC Press, 2009
- Gopalakrishnan, G., A Treatise on Turbomachines, Scitech Publication, Chennai, 2002
- Dixon, S., L., Fluid mechanics and thermodynamics of turbomachinery, 5th Ed., Elsevier, 2005
- Stepanoff, A., J., Centrifugal & Axial Flow pumps: Theory, design and Application, John Wiley, 1957
- Daugherty, R., L., Hydraulic turbines with a chapter on Centrifugal pumps, McGraw-Hill, 1920
- Karassik, I., J., Pump Handbook, 3rd Edition, McGraw-Hill International Edition, 2001

MIN-532 Renewable Energy Systems Pre-requisite**: Nil**

Introduction: Energy and development, energy demand and availability, energy crisis, conventional and non-conventional sources, renewable and non-renewable energy resources, environmental impact of conventional energy usage, basic concepts of heat and fluid flow useful for energy systems.

Solar EnergySystems: Solar radiations data, solar energy collection, storage and utilization, solar water heating,solar air heating,solar power generation,solar refrigeration and air conditioning, solar energy system economics.

Micro And Small Hydro Energy Systems: Resource assessment of micro and small hydro power, micro, mini and small hydro power systems, economics, pump as turbine, special engines for low heads, velocity head turbines, hydrams, water mills.

Biomass Energy Systems: Availability of biomass- agro, forest, animal, municipal and other residues; Bioconversion technologies; cooking fuels, biogas, producer gas, power alcohol from biomass; Power generation,internal engine modifications and performance, system economics.

Wind Energy Systems: Wind data, horizontal and vertical axis wind mills, wind farms, performance and economics of wind energy.

Geothermal Energy Systems: Vapor dominated, liquid dominated and petrothermal systems; Hybrid systems.

Energy from the Oceans: OTEC systems, open and closed types; Wave energy conversion systems; Tidal energy conversion systems.

Integrated Energy Systems: Concept of integration of conventional and non-conventional energy resources and systems; integrated energy system design and economics.

Suggested Books:

- Duffie, J.A. and Beckman, W.A., “Solar Engineering of Thermal Processes”, John Wiley., 2006
- Bungay, H.R., “Energy, the Biomass Option”, John Wiley. , 1981
- Fowler, K.M., “Energy & Environment”,McGraw Hill. , 1984
- Sukhatme, S.P. and Nayak, J.K., ”Solar Energy: principles of thermal collection and storage”, McGraw Hill., 2009
- Boyle, G., “Renewable Energy – Power for a Sustainable Future”, 2nd Ed., Oxford University Press., 2010

MIN-533 Refrigeration & Air-conditioning System Design Pre-requisite**: Nil**

Load Calculations: Solar heat gains through structures; review of refrigeration and air conditioning load calculations.

Refrigeration Systems: Vapour compression; multiple evaporator and compound compression system with and without inter cooling; dual compressors; cascade systems; Vapour absorption system- analysis.

Solid carbon dioxide; principle of production; three stage system with water and flash inter-cooler; pressure snow chambers; regenerative liquid; binary system.

Compressors: Performance characteristics and capacity control of reciprocating, rotary and centrifugal compressors; screw compressors; hermetically sealed units; analysis of centrifugal compressors. Compressor Design.

Condensers: Water —cooled and air-cooled condensers; overall heat transfer coefficients; fouling factor; performance characteristics and design; performance and heat transfer processes in evaporative condenser.

Evaporators: Flooded and dry expansion type evaporators, liquid chiller, overall performance of evaporators and design of evaporators.

Expansion Devises: Capillary tubes; system design factors; pressure and temperature distribution; ASHRAE simplified calculation procedure.

Expansion valves; operation and performance calculation of thermostatic expansion valve; application of constant pressure expansion valve.

Thermal Comfort: Human thermoregulation; energy balance; thermal exchange with environment

Indoor Environmental Health and Air Contaminants: Airborne contaminants: particles, gaseous contaminants, outdoor air ventilation and health;

Pressure Drop and Heat Transfer: Two phase flow; flow regimes; maps; pressure drop in evaporator and condensers; Martinelli relation

Applications and System Design: Ice manufacture; Design of refrigerated ware houses. datacentre and clean room.

Suggested Books:

- Stoecker W.F., “Refrigeration and Air-conditioning”, McGraw Hill, 2002
- Moravek J., “Air Conditioning Systems: Principles, Equipment, and Service”, AHRI, , Prentice Hall, 2000
- “ASHRAE Handbooks”, ASHRAE., 2013
- Wang, S.“Handbook of Air Conditioning and Refrigeration”, TataMcGraw Hill Education, 2000
- Arora, C.P., “ Refrigeration and Air conditioning”, Tata-McGraw Hill, 2005

MIN-534 Air-conditioning and Ventilation Pre-requisite**: Nil**

Psychrometery: moist air properties; mass transfer and evaporation of water into moist air; theory of psychrometer; correlation of w.b.t. with temperature of adiabatic saturation; Lewis number; construction of psychrometric chart.

Physiological Principles: Comfort; thermal interchanges with environment; physiological body regulatory processes against heat or cold ; high and low temperature hazards; extreme environmental conditions; heat stress index; ASHRAE comfort standards.

Simultaneous Heat and Mass Transfer: Direct contact transfer equipment; simple air washer and indirect evaporative cooling contact mixture principle; enthalpy potential; basic equation for direct contact transfer equipment; graphical and analytical methods for heat and mass transfer analysis of air washers with heated and chilled water sprays; cooling towers.

Extended Surface Heat Transfer Apparatus: Cooling and Dehumidifying coils, Design of finned surfaces, Adsorption cooling systems.

Ventilation: Necessity; ventilation standards; natural and mechanical ventilation; forces for natural ventilation; general ventilation rules; advantages of mechanical ventilation; various methods; ejector systems; determining ventilation requirement; use of decay equation.

Air Cleaning: Physical and chemical vitiation of air; permissible concentration of air contaminants; mechanical and electronic air cleaners; dry and wet filters; air sterilization; odour control.

Steam Heating Systems: Elements of steam, water and warm-air heating systems; radiators and convectors. Design of an year-round air conditioning system.

Piping and Ducts: Pressure drops in piping and fittings; design of water and refrigerant piping; Air conditioning duct design methods.

Suggested Books:

- Stoecker, W.F., and Jones, J.W., “Elementary Refrigeration & Air conditioning”, McGraw Hill, 2002
- Dosset, R.J., Principles of Refrigeration, Pearson Education Asia, 2002
- Arora, C.P.,“Refrigeration and Air conditioning”, Tata-McGraw Hill, 2005
- Prasad, M., “Refrigeration and Air conditioning”, New Age International, 2005
- ASHRAE Handbook (Fundamentals), 2013

MIN-535 Cryogenic Systems Pre-requisite**: Nil**

Introduction: Introduction, Historical background, Present area involving cryogenics

Low Temperature Properties of Engineering Materials: Mechanical properties, Thermal properties, Electrical and Magnetic Properties, Properties of cryogenic fluids

Gas-Liquefaction System: Joule-Thomson effect, Adiabatic expansion, Simple Linde-Hampson system, Precooled Linde-Hampson system, Linde dual-pressure system, Cascade system, Claude system, Kapitza system, Collins helium liquefaction system,

Critical Components of Liquefaction System: Effect of heat exchanger effectiveness on system performance, Effect of compressor and expander efficiency on system performance, Effect of heat transfer to the system

Cryogenic Refrigeration System: Philips refrigerator, Importance of regenerator effectiveness for Philips refrigerator, Gifford-McMohan refrigerator

Measurement Systems for Low Temperatures: Temperature measurement, Flow rate measurement, Liquid level measurement.

Cryogenic Storage and transfer Systems: Cryogenic fluid storage vessels, insulations, cryogenic transfer systems

Vacuum Technology: Importance of Vacuum technology in cryogenics, Flow regimes in vacuum systems, Conductance in vacuum systems, Calculation of pump-down time for a vacuum systems, Components of a vacuum systems, Mechanical vacuum pumps, Diffusion pumps, Ion pumps, Cryopumping. Vacuum gauges and valves.

Suggested Books:

- Barron R.F.,"Cryogenic Systems", Oxford University Press 1985
- Timmerhaus K.D. and Flunn T M,"Cryogenic Process Engineering", Plenum Press 1989
- Fundamentals of Cryogenic Engineering, PHI 2010
- Cryogenic Heat Transfer, Taylor & Francis Ltd1999
- Cryogenic Mixed Refrigerant Processes, Springer-Verlag New York Inc.2008
- Kays, W.M., and London, A.L., "Compact Heat Exchangers", Krieger Publishing Company. 1998

MIN-536 Convective Heat & Mass Transfer Pre-requisite:**Nil**

Introduction: Concepts and Conservation Principles & Laws, Differential formulations of the basic laws: Equations of continuity, Equation of momentum, energy, mass & Entropy.

Approximate Solutions: Integral Equation, Laminar Boundary Layers, Laminar Heat Transfer in Ducts

Natural/Free convection: Internal & External Flow, Dimensional Analysis & Similarity Principles

Turbulence fundamentals & Turbulence Boundary layer flowBoiling & CondensationConvective Mass Transfer & Molecular DiffusionSimultaneous Heat & Mass Transfer

Suggested Books:

- Kays, W. M., Crawford, M. E., and Weigand, B. "Convective Heat and Mass Transfer", Tata McGraw Hill. , 2005
- Latif M Jiji, "Heat Convection", 2nd Edn,, Springer, 2009
- Bejan, A, Convection Heat Transfer, 3rd Edn, John Wiley & Son Inc , 2004
- Kakac, S and Yener, Y, Convective Heat Transfer, 2nd Edn, CRCPress, 1995
- Burmeister L.C., "Convection Heat Transfer", John Wiley & Son Inc. , 1993
- Arpaci, V. S.,and Larsen, P. S., "Convection Heat Transfer", Prentice Hall, Inc. , 1984

MIN-537 I.C. Engines Pre-requisite: **Undergraduate level course on Engineering Thermodynamics**

Introduction: Introduction and Historical Perspective.

Thermodynamic analysis of IC Engines Cycle: Properties of working fluid, thermodynamic charts, and unburned mixture charts burned mixture and, fuel air cycle analysis, Real cycles, availability analysis of engine processes.

Gas Exchange Processes: Inlet and exhaust processes in the four stroke cycle, volumetric efficiency quasi-static and dynamic effects, flow through valves.

Scavenging in the two - stroke cycle engines scavenging parameters and models, actual scavenging processes, flow through ports. Supercharging and turbocharging, basic relationships, compressors, turbines characteristics, matching of compressor, turbines and engine characteristics.

Combustion in SI Engines: Essential features of the process, thermodynamic analysis of SI engine combustion, combustion process characterization, cyclic variations in combustion.

Combustion in Compression: Ignition Engines: Essential features of process, types of diesel combustion systems, phenomenological model of compression- ignition engine combustion. Fuel spray behaviour, spray structure, atomization, spray penetration droplet size distribution, spray evaporation, ignition delay.

Pollutant Formation and Control: Nature and extant of problem, Nitrogen Oxides. Kinetics of NO formation, NO_x formation in spark- ignition engines, NO_x formation in CI engines. Carbon monoxide, Unburned hydrocarbon emissions. Particulate emissions exhaust gas treatment, catalytic converters, three way catalysts, particulate traps.

Suggested Books:

- Heywood J.B., "Internal Combustion Engine Fundamentals", McGraw Hill, 1988
- Stiesch, G., "Modeling Engine Spray and Combustion Processes", Springer-Verlag., 2003
- Ferguson C.R.,"Internal Combustion Engines", John Wiley, 2000
- Oppenheim, A.K., " Combustion in Piston Engines" Springer, 2004
- Pundir, B.P., " I C Engines Combustion and Emissions" Narosa, 2010

MIN-538 I.C. Engine Combustion Processes Modeling Pre-requisite : **Course on I.C Engines at U.G. level / MI 537**

Essential features of combustion process in S.I. and C.I. engines, Flame structure and speed, spray structure, auto ignition

Engine Combustion Modeling – An overview

Modeling Fluid Motions in Engines, intake jet flow, swirl generation during induction squish, prechamber flows, crevice flow and blow by

Modeling Flame Propagation and Heat Release in Engines, laminar burning speed, flame propagation relations, heat release in diesel engines, zero dimension burning rate function free gas jet theory, packet models

Knock, fundamentals, kinetic modeling of hydrocarbon combustion, autoignition, knock models

Modeling Spray, spray equation, droplet kinematics, spray atomization, droplet breakup droplet/droplet and spray wall interactions, fuel vaporization

Modeling pollutant formation in SI and CI engines, Models for NOx, CO and soot formation

Suggested Books:

- Wood, H., "Internal Combustion Engine Fundamentals", McGraw Hill Inc., 1988
- Stiesch, G., "Modeling Engine Spray and Combustion Processes", Springer-Verlag., 2003
- Merker, G. P, "Simulating Combustion," Springer, 2006
- Sirignano, W. A., "Fluid Dynamics and Transport of Droplets & Sprays", Cambridge University Press, 2000
- Warnatz, J., Mass, U., and Dirbble, R. W.,"Combustion: Physical and Chemical Fundamentals, Modeling and simulation, Experiments, Pollutant Formation", Springer-Verlag, 2001

MIN-539 Micro & Nano Scale Thermal Engineering Pre-requisite : **Course on Fluid Mechanics, Heat & Mass Transfer**

Introduction: Basic statistical thermodynamics, quantum theory, and kinetic theory, Photon and electron transport processes.

Thermal characteristics: Thermal properties at the nano scale –heat capacity & thermal conductivity, Thermoelectricity and applications.

Microfluidics: Intermolecular forces, states of matter, liquid and gas flows, continuum assumption, governing equations, Constitutive relations, slip theory, surface tension and interfacial energy, Young-Laplace equation, wetting and contact angles, capillary flows, Electrokinetic flows.

Convection heat transfer: Fundamentals, Laminar convection –Internal flow, Boiling and condensation, Single-phase heat transfer in micro channels, Two-phase flow heat transfer in micro channels continued.

Radiation heat transfer: Fundamentals of thermal radiation, Radiative properties of nano materials, Nano photonics and applications.

Sensors: Microscale thermal sensors and actuators, Nanofluids, Micro fluidic component: micro pump, micro valve, micro flow sensor, micro mixture

Micro Fabrications: Micro fabrication techniques, Photolithography, Etching, Oxidation, spin coating, micro molding, polymer micro fabrication

Suggested Books:

- Zhuomin, M.Z., "Nano/Microscale Heat Transfer", McGraw Hill. **,** 2007
- Nguyen, N.T., Werely, S.T., "Fundamental & application of micro fluidics", Artech House Inc., 2002
- Brian Kirby, "Micro- and Nano scale Fluid Mechanics: Transport in Micro fluidic Devices ", Cambridge University Press. , 2010
- Zhuomin, Z., "Microscale Energy Transport", MacGraw hill co.**,** 2007
- Tien, C.L., Majumdar, A., and Gerner, F.M., "Microscale Energy Transport", Taylor & Francis., 2003
- Celata, G.P., "Heat Transfer and Transport Phenomena in Microscale", Begell House., 2004
- Kakac, S., Vasiliev, L.L., Bayazitoglu, Y., Yener, Y., "Microscale Heat Transfer: Fundamentals and Applications", Springer-Verlag., 2005
- Madou, M.J.," Fundamental of Micro fabrication", CRC press., 2005

MIN-540 Combustion Pre-requisite: **Nil**

Introduction: Importance of combustion, combustion equipment hostile fire problems, pollution problems arising from combustion.

Thermodynamics of Combustion: Enthalpy of formation, enthalpy of reaction, heating values, first and second law analysis of reacting systems, chemical equilibrium, equilibrium composition, adiabatic and equilibrium flame temperature.

Kinetics of Combustion: Law of mass action, reaction rate, simple and complex reactions, reaction order and molecularity, Arhenius Law, activation energy, Chain reaction steady state and partial equilibrium approximations. Chain explosion, Explosion limits and oxidation characteristics ofhydrogen, carbon monoxide and hydrocarbons.

Flames: Premixed Flames: structure and propagation of flames in homogeneous gas mixtures; simplified Rankine Hugoniot relations; properties of hugoniot curve; analysis of deflagration and detonation branches, properties of Chapman Jouguet wave. Laminar flame structure; theories of flame propagation and calculation of flame speeds, flame speed measurements. Stability limits of laminar flames; flammability limits and quenching distance; bumer design. Mechanisms of flame stabilization in laminar and turbulent flows; flame quenching. Diffusion flames; comparison of diffusion with premixed flame. Combustion of gaseous fuel jets Burke and shumann development.

Burning of Condensed Phase: General mass burning considerations, combustion of fuel droplet in a quiescent and convective environment. Introduction to combustion of fuel sprays.

Ignition: Concepts of ignition, chain ignition, thermal spontaneous ignition, forced ignition.

Combustion Generated Pollution &its Control: Introduction, nitrogen oxides thermal fixation of atmospheric nitrogen prompt NO, thermal NO_x formation and control in combustors Fuel NO_x and control, post—combustion destruction of NO_x, Nitrogen dioxide carbon monoxide oxidation — quenching, hydrocarbons, sulphur oxides

Suggested Books:

- Glassman, I..,"Combustion", 4th edition Academic Press, 2008

- Turns, S. R., “An Introduction to Combustion, concepts and applications,” 3rd edition, McGraw Hill , 2011
- Kuo, K. K., “Principles of Combustion,” 2nd edition, John Wiley , 2008
- Law, C.K., “Combustion Physics,” Cambridge University Press, 2006
- Williams F.A.,”Combustion Theory”, Addison Wesley, 1993

MIN-541 Bio – Fluid Mechanics Pre-requisite:**Fluid Mechanics**

Introduction: Overview of basic anatomy and physiology from fluid flow perspective.

Review of basic equations and constitutive models: mass and momentum conservation, models for non-Newtonian fluids.

Blood rheology and mechanics of circulation: composition, structure and flow properties of blood, structure, flow and pressure characteristics of the blood flow in cardio-vascular system, flow of non-Newtonian fluids in elastic tubes.

Arterial wave propagation: oscillatory and pulsatile flow, pulse waves, behaviour at bifurcations, wave propagation in flexible tubes.

Flow through the pulmonary system: structure and function of pulmonary system, fluid exchange processes, fluid mechanics of breathing.

Flow and lubrication in musculo-sketetal system: hemodynamics of red blood cells, synovial fluid in joints.

Flow through the porous media: oxygen diffusion from blood to tissues, flow in ocular and renal system.

Computational biofluid mechanics: computational methods for flow and wave propagation through elastic tubes, flow through porous media

Suggested Books:

- Fung, Y. C., “Biomechanics: Circulation”, Springer-Verlag., 2010
- Chandran, K. B., Yoganathan, A.,and Rittgers, S., “Fluid Mechanics in the Human Circulation”, Pearson Education., 2005
- Humphrey, J. D., and Delange, S. L., “An Introduction to Biomechanics”, Springer-Verlag., 2004
- Fournier, R. L. L., “Basic Transport Phenomena in Biomedical Engineering, CRC press, 3rd Edition., 2011
- Mazumdar, J. N., “Biofluid Mechanics”, World Scientific., 1992
- Pedley, T. J., “Fluid Mechanics of Large Blood Vessels”, Cambridge University Press., 2008
- Caro, C. G., Pedley, T. J., Schroter, R. C., Seed, W. A., “Mechanics of the Circulation”, Cambridge University Press., 2012

MIN-542 Energy Management Pre-requisite: **Nil**

Introduction: Energy scenario, various forms of energy, energy management and its importance, recent trends in energy conservation.

Energy Auditing and Instrumentation: Definition, methodology, analysis of past trends (plan data), closing the energy balance, laws of thermodynamics, measuring instruments, portable and online instruments.

Energy Economics: Simple payback period, time value of money, IRR NPV, life cycle costing, cost of saved energy, cost of energy generated.

Monitoring and Targeting: Defining monitoring and targeting, elements of monitoring and targeting, data and information, analysis techniques, energy consumption, production, cumulative sum of differences.

Energy Efficiency in Thermal Utilities: Boilers, steam system, furnaces insulation and refractories, FBC boilers, cogeneration, waste heat recovery.

Energy Efficiency in electrical Utilities: Electrical systems, electric motors, compressed air system, HVAC and refrigeration systems, fans and blowers, pumps and pumping systems, cooling towers, lighting system, diesel generating system.

Suggested Books:

- Witte, L.C., Schmidt, P.S., Brown, D.R.,"Industrial Energy Management and Utilization", Hemisphere Publishing Corporation. Springer-Verlag, 1988
- Clive Beggs, "Energy: Management, Supply and Conservation", Routledge , 2012
- Capehart, B.L., Turner, W.C., Kennedy, W.J., "Guide to Energy Management", 7th Ed., Fairmont Press. , 2011
- Turner, W.C. and Doty, S., "Energy Management Handbook", 7th Ed., Fairmont Press., 2009
- Kreith, F. and Yogi Goswami, D., "Handbook of Energy Efficiency and Renewable Energy", CRC Press., 2007

MIN-543 Fluid Power Engineering Pre-requisite**: Nil**

Introduction: Types of Fluid power control systems and its components, Physical properties of hydraulic fluids and governing equations

Pumps and Valves: Classification, Working and performance of gear, vane, piston pumps and their selection, Pressure intensifiers, Direction control valves, Pressure control valves, Flow control valves, Servo valves, Pressure switches,

Hydraulic Actuators: Linear and rotary actuators, Gear, vane and piston motors, Performance of Hydraulic motors, Hydrostatic transmission

Hydraulic Circuit Design and Analysis: Control of single-acting and double-acting cylinders, Study of various circuits like regenerative, unloading counterbalance, speed control etc., maintenance of hydraulic circuits.

Pneumatic Control Systems: Air preparation and components, Compressors and conditioners, Air control valves and actuators.

Pneumatic Circuit Design and Analysis: Design considerations, Pressure and energy loss, Basic pneumatic systems, Vacuum and accumulator systems, Circuit analysis.

Fluid Logic Control System: Principles, Basic fluidic devices, fluid, sensors, Boolean algebra, fluidic control of fluid powers systems.

Electrohydraulic Servo Control System: Electric components and controls, Dual cylinder sequence circuits, Electro hydraulic servo system and their analysis, Programmable logic controllers.

Suggested Books:

- Anthony Esposito, Fluid Power with Applications, 6th Edition, Pearson Prentice Hall, New Delhi, 2007
- S. R. Mazumdar, Oil Hydraulic Systems- Principles and Maintenance, 25th Reprint, Tata McGraw Hill New Delhi, 2012
- Dudley A., Pippenger and John J. Pease, Basic Fluid Power, Prentice Hall Inc., New Jearsy., 1987
- S. R. Mazumdar, Pneumatic Systems- Principles and Maintenance, 28th Reprint Tata McGrawHill New Delhi, 2012
- Introduction to Fluid Logic - E.C. Fitch & J.B. Surjaatmadja, McGraw-Hill Inc, USA , 1978
- Pneumatic and Hydraulic Systems- W. Bolton, Butterworth and Heinemann, Oxford, 1997

MIN-544 Design of Heat Exchangers Pre-requisite**: Nil**

Introduction: Fundamentals ofheat transfer and fluid flow in heat transfer passages; Classification, constructional details, two and multi-fluid heat exchangers, extended surfaces.

Design of Heat Exchangers: Engineering design,steps for designing, feasible/workable design,optimum design, economics, probabilistic approach to design,sizing and rating problems; LMTD and ε-NTU approach of design,design of tubular, shell &tube, finned (radial and longitudinal), regenerative and compact heat exchangers.

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

Performance Behaviour: Design vs.simulation, steady state performance,effectiveness,transient performance, fouling, non-uniformities in temperature and flow,effect of property variation, three-fluid/ multifluid heat exchanger behavior.

Testing: Steady state and transient testing technique, j & f characteristics, empirical relations, experimental vs. numerical approach.

Suggested Books:

- Kays, W.M., and London, A.L., "Compact Heat Exchangers", Krieger Publishing Company. , 1998
- Rosenhow, W.M., Hartnett, J.P. and Cho, Y.I., "Handbook of Heat Transfer", McGraw Hill. , 1998
- Kraus, A.D., Aziz, A. and Welty, J.R., "Extended Surface Heat Transfer", WileyIndia. , 2013
- Rao, S.S., "Optimization theory and applications", 3rdEd. John-Wiley., 1996
- Hesselgreaves, J.E., "Compact Heat Exchangers: selection, design and operation", Pergamon Press. , 2001
- Webb,R. L. andKim,N. H., "Principles of Enhanced Heat Transfer", Taylor & Francis., 2005

MIN-545 Fuel Cells Pre-requisite: **Nil**

Introduction: Basic principle and operation of Hydrogen fuel cells, types of fuel cells.

Fuel Cell Thermodynamics: Free energy change of a chemical reaction, heat of reaction, reversible and net output voltage, theoretical fuel cell efficiency, effect of pressure

Fuel Cell Electrochemistry: Electrode kinetics, Butler-Volmer equation, voltage losses, cell potential-polarization curve, fuel cell efficiency.

Transport Mechanisms: Fuel cell charge transport, electron conductivity of metals, ionic conductivity of polymer electrolytes, fuel cell mass transport- fuel cell mass balance, diffusive and convective mass transports, heat transfer – fuel cell energy balance, heat management

Fuel Cell Components: Materials, properties, processes, membrane, electrodes, bipolar plates, stack design, hydrogen and oxygen supply systems, PEM fuel cell

Fuel Cell Applications: Automobiles, stationary power, fuel cells and hydrogen economy, medium and high temperature fuel cells

Suggested Books:

- Barbir, F., "PEM Fuel Cells: Theory and Practice", Academic Press., 2005
- Larminie, J. and Dicks, A., "Fuel Cell Systems Explained", John Wiley & Sons., 2003
- Spiegel, C., "PEM Fuel Cell Modeling and Simulation using MATLAB", Academic Press., 2008
- Sammes, N. M., "Fuel Cell Technology – Reaching towards commercialization", Springer., 2006
- Gregor, H., "Fuel Cell Technology Handbook", CRC Press., 2003
- Srinivasan, S., "Fuel Cells – From Fundamentals to Applications", Springer., 2006

MIN-546 Welding Metallurgy Pre – requisite: **Nil**

Fundamentals of physical metallurgy: Need, phase diagrams: Fe-C, Al-Cu, Cu-Zn system, Phase transformations in Fe-C system, TTT diagram and CCT diagram, Carbon equivalent, Schaffer diagram, relevance of above in welding.

Metal strengthen approaches: introduction, solid solution strengthening, grain refinement, precipitation hardening, transformation hardening, dispersion hardening, work hardening, strain aging

Heat treatment of weld joint: Need, Annealing; Normalizing; Quenching; Tempering; Austempering; Martempering and stress relieving of steel, Precipitation hardening of Al and copper alloys

Solidification of weld metal: principle of solidification of weld metal, modes of solidification, effect of welding parameter on weld structure, grain refinement principle of weld metal, method of weld metal refinement: inoculation, arc pulsation, external excitation

Heat affected zone and weld metal: transformations in HAZ of steel, factors affecting changes in microstructure and mechanical properties of HAZ, reactions in weld pool: gas-metal reaction, slag metal reaction.

Metallurgical issues in weld joint: Mechanisms, causes and remedy of cold cracking, solidification cracking, nonmetallic inclusions; lamellar tearing; hydrogen damage, banding, segregation

Suggested Books:

- Lancaster J F., “Metallurgy of Welding”, Allen & Unwin Co., 2000
- S D Avner, “Introduction to physical metallurgy”, TMH, 2011
- “Welding, Brazing and soldering”, Vol. 6, ASM International, ASM, Ohio., 1993
- Kou S., Welding metallurgy, 2nd edition, Wiley Publications , 2003
- K Esterling, “Introduction to Physical Metallurgy of Welding”, BH, 1991
- Gene Mathers, “Welding of Aluminium and alloys”, Wood Head Pub. UK., 2002

MIN-548 Product and Process Optimization Pre-requisite**: Nil**

Introduction to Design Optimization: The design process; basic terminology and notations.

Optimum Design Problem Formulation: The problem formulation process;and illustration with examples.

Graphical Optimization: Graphical solution process; problems with – bounded (single or multiple) and unbounded solutions.

Optimum Design Concepts: Local and global optima; necessary and sufficient optimality conditions for unconstrained and constrained multivariate functions.

Linear Programming Methods for Optimum Design: Basic concepts; simplex method; two-phase simplex method; post-optimality analysis.

Numerical methods for Unconstrained and Constrained Optimum Design: Gradient-based and direct search methods; Sequential linear and quadratic programming.

Multi-objective Optimization: Fundamental shift from single-objective optimization; Pareto-set and Pareto-optimal Front.

Evolutionary Techniques for Optimization: Genetic algorithms; Differential Evolution Algorithms; Ant colony Optimization; and Particle Swarm Optimization.

Advanced topics on Optimum Design: Meta models for design optimization; design of experiments; discrete design with orthogonal arrays; robust design approach; reliability-based design optimization.

Practical applications of optimization: Illustration on engineering problems with single and multiple objectives.

Suggested Books:

- S. S. Rao; Engineering Optimization; 4th Edition, John Wiley & Sons., 2009
- K. Deb; Optimization for Engineering Design; Prentice Hall of India. , 2005
- K. Deb; Multi-objective Optimization using Evolutionary Algorithms; John Wiley & Sons., 2003

MIN-550 Advanced Machine Design Pre-requisite: **Nil**

Introduction: Review of failure theories, their scope of applications under different loading and environmental conditions, Hertzian contact stresses and their effect on load carrying capacities of members, effect of small inelastic strains and residual stresses on load carrying capacity, theory of limit design; Machinery construction principles.

Designing against Fracture: Linear elastic fracture mechanics approach, theories of brittle fracture, fundamental aspects of crack growth and fractures, use of fracture in design.

Designing against Fatigue and Creep: Causes and interpretation of failures, influence of various factors, low cycle and high cycle fatigue, cumulative damage theories, acoustical and thermal fatigue, corrosion and fretting fatigue, pitting of gears, fatigue strength of joints, components and structures; creep behavior; the mechanical equation of state, an elastic and plastic creep, rupture theory, analysis of tensile creep data, creep in high temperature low cycle fatigue, creep analysis of thick walled cylinders and rotating discs.

Design for Reliability: Application of statistics to material properties, fatigue and reliability, early chance and wear out failures, reliability prediction against chance and wear out failures, probabilistic approach to design and its comparison with safety factor approach, reliability prediction of series, parallel and stand by systems.

Suggested Books:

- Faupel, J.H., and Fisher, F.E., “Engineering Design”, Wiley-Interscience. , 1981
- Burr, A.H., “Mechanical Analysis and Design”, Elsevier., 1982
- Smith, N., “Advances in Creep Design”, Applied Science., 1971
- Bazovsky, I., Reliability Theory & Practice, Courier Dover Publications. , 2004
- Haugen, E.B., Probabilistic Approach Design, John Wiley., 1968
- Yotaro Hatamura and Yoshio Yamamoto, “The Practice of Machine Design” Oxford University Press., 1999
- Kai Cheng, “Machining Dynamics: Fundamentals, Applications and Practices” Springer., 2008

MIN-551 Dynamics of Mechanical Systems Pre-requisite: **Nil**

Basic concepts: Inertial coordinate system, fundamental laws of motion, mechanics of particles and system of particles, principles of linear and angular momentum, work-energy principles.

Lagrangian dynamics: Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Lagrange’s equation from d’Alembert’s principles, application of Lagrange’s equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d’Alembert’s principle, Lagrange equation from Hamilton’s principle.

Multi-body dynamics: Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.

Stability of motion: Fundamental concept in stability, autonomous systems and phase plane plots, Routh’s criteria for stability, Liapunov’s method, Liapunov’s stability theorems, Liapunov’s function to determine stability of the system.

Control system dynamics: Open and close loop systems, block diagrams, transfer functions and characteristics equations, proportional integral and derivative control actions and their characteristics.

Suggested Books:

- Ginsberg, J.H., "Advanced Engineering Dynamics", Harper and Row., 1988
- Meirovitch, L., "Methods of Analytical Dynamics", McGraw Hill Inc. , 1970
- Harold Josephs and Ronald Huston, "Dynamics of Mechanical Systems", CRC Press., 2002
- Katsuhiko Ogata, "System Dynamics",4th Ed., Prentice Hall; , 2003
- Robert L. Woods and Kent L. Lawrence, "Modeling and Simulation of Dynamic Systems", Prentice Hall., 1997
- Ramin S. Esfandiari and Bei Lu, "Modeling and Analysis of Dynamic Systems", CRC Press., 2010
- Dean C. Karnopp, Donald L. Margolis, and Ronald C. Rosenberg, "System Dynamics: Modeling and Simulation of Mechatronic Systems", 4th Ed., Wiley., 2006
- Richard A. Layton, "Principles of Analytical System Dynamics" (Mechanical Engineering Series), Springer.,1998

MIN-552 Advanced Mechanics of Solids Pre – requisite: **Nil**

Mathematical Preliminaries: Scalars, vectors and matrix variables, index notation and the related rules, Cartesian tensors and their algebra, co-ordinate transformation, transformation rules for the n^{th} order tensors, elements of tensor calculus and the related theorems (divergence, Stokes' and Green's), principal value theorem, eigenvalues and eigenvectors, invariants of a 2^{nd} order tensor.

Kinetics of Deformation: Types of forces (point, surface and body), traction vector, state of stress at a point, Cauchy's relation and its proof, conservation of linear and angular momentum, stress equilibrium equations, symmetry of stress tensor, stress transformation, principal stresses and the associated planes, 3D Mohr's circle representation, planes of maximum shear, octahedral planes, hydrostatic and deviatoric stress, first and second Piola-Kirchoff stress tensors and their properties.

Kinematics of Deformation: Material and spatial co-ordinates, Eulerian and Lagrangian description of motion; deformation and displacement gradients, Green-Lagrange and Almansi strain tensor; Cauchy's small strain tensor and the rotation tensor, geometrical interpretation of strain components and sign convention, principal strains and directions, strain invariants, octahedral strain, maximum shear strain, volumetric strain, strain compatibility equations.

Constitutive Modeling: Thermodynamic principles, first and second law of thermodynamics, Generalized Hooke's law for isotropic materials, elastic constants and their relations, anisotropic, hyperelastic and viscroelastic material models, strain hardening, constitutive relations for elasto-plastic materials, flow and hardening rules.

Boundary Value Problems in Linear Elasticity: Field equations and boundary conditions, Navier equations, Beltrami-Michell stress compatibility conditions, 2D approximations (plane stress and plane strain) and solution strategies.

Variational Principles in Solid Mechanics: Elements of variational calculus, extremum of a functional, Euler-Lagrange equation and its application, types of boundary conditions, principle of virtual work, Principle of total potential energy and complementary potential energy, Ritz method, time-dependent problems and Hamilton's principle for continuum.

Suggested Books:

- Sadd, M.H., "Elasticity Theory Applications and Numerics", Elsevier Academic Press., 2005
- Boresi, A.P., Sidebottom, O. M., "Advanced Mechanics of Materials", 5th Ed., John Wiley and Sons, 2007
- Singh, A.K., "Mechanics of Solids", PHI Learning Private Limited, 2011
- Timoshenko, S.P., and Goodier, J.M., "Theory of Elasticity", 3rd Ed., McGraw Hill , 2004

- Srinath, L.S., “Advanced Mechanics of Solids”,Tata McGraw Hill Education Private Limited, 2009
- Fung, Y.C., “ Foundations of Solid Mechanics”, Prentice Hall Inc., 1965

MIN-553 Industrial Tribology Pre-requisite: **Nil**

Introduction: Tribological consideration, nature of surfaces and their contact. Introduction, physico-mechanical properties of surface layer; Geometrical properties of surfaces, method of studying surface; Contact of smooth surfaces, contact of rough surfaces. Role of friction, laws of static friction, causes of friction; Adhesion. Adhesion theory, laws of rolling friction, friction of metals and nonmetals, friction measurement; Wear definitions, types of wear, mechanism of wear, factors affecting wear behavior, measurement of wear a brief introduction of wear test equipments, wear in plastics.

Industrial Lubricants and Their Additives: Functions of lubricants, types of lubricants and their industrial uses; Solid lubricants and their functions, liquid mineral lubricants, synthetic liquid lubricants, greases, properties of liquid and grease lubricants, viscosity, Newtonian and Non-Newtonian lubricants, temperature and pressure dependence measurement, other properties of lubricants; Lubricant additives, general properties and selection for machines and processes; Oil reclamation and preventive maintenance for lubricants.

Fluid-Film Lubrication: Fluid mechanics concepts, equations of continuity and motion; Generalized Reynold’s equation with incompressible and compressible lubricants; Hydrodynamic lubrication, Tower’s experiment, finite bearings, partial journal bearings, solution of finite bearings using Galerkin, finite difference and FEM.

Dynamically loaded journal bearings: Solution of the generalized Reynold’s equation for infinite and short bearing, load carrying capacity, Sommerfield numbers, journal centre locus, whirling; Hydrostatic lubrication-- basic concepts, applications, compensated thrust and journal bearings and their solution using FEM, controlling flow with restrictors, design of restrictors for compensated bearings.

Gas Lubrication: Types of gas bearings and their characteristics; Reynolds equation for iso-thermal, polytropic and adiabatic supporting gas films; Introduction to porus bearing permeability, solution of thrust and journal bearings.

Bearing Design and Selection of Bearings: Comparative performance of various modes of lubrication, and bearing selection; Design of slideway bearing and hydrostatic thrust bearing, fixed type hydrodynamic and hydrostatic journal bearings, materials for sliding bearings; Bearing types, selection of rolling elements bearing, bearing life, bearing load, bearing selection.

Suggested Books:

- Conner, J.J. and Boyd, J., “Standard Handbook of Lubrication Engineering”, McGraw Hill., 1968
- Stachowiak, G. and A W Batchelor, A. W., “Engineering Tribology”, 3rd Ed, Butterworth-Heinemann., 2005
- Khonsari, M. M. and Booser, E. R., “Applied Tribology: Bearing Design and Lubrication”, 2nd Ed, Wiley., 2008
- Kudish, I. I. and Covitch, M. J., “Modeling and Analytical Methods in Tribology”, Chapman and Hall/CRC., 2010
- Bhushan, B., “Principles and Applications of Tribology”, Wiley., 1999

MIN-554 Computer Aided Mechanism Design Pre-requisite: **Nil**

Introduction: Review of concepts related to kinematic analysis of mechanisms, degrees of freedom, Grashof’s and Gruebler’s criteria, transmission and deviation angles, mechanical advantage.

Kinematic Synthesis of Mechanisms: Type, number and dimensional synthesis, spacing of accuracy points, Chebyshev polynomials, path motion and function generation, graphical synthesis with two, three, and four prescribed positions and points.

Analytical Synthesis Techniques: complex number modeling, dyad and standard form equation, Freudenstein's equation for three point function generation, coupler curves, Robert's law, cognates of linkages.

Path Curvature Theory: Fixed and moving centrode, inflection points and inflection circle, Euler-Savary equation, Bobillier and Hartmann's construction.

Dynamic Force Analysis: Introduction, inertia forces in linkages, kinetic-static analysis by superposition and matrix approaches and its applications, introduction to spatial mechanisms.

Software usages: Modelling, analysis and synthesis of various mechanisms using software packages

Suggested Books:

- Hall, A.S., "Kinematic and Linkage Design", Prentice Hall Inc. , 1978
- Sacks, E. and Joskowicz, L., "The Configuration Space Method for Kinematic Design of Mechanisms", MIT Press., 2010
- Erdman, A. G. and Sandor, G. N., "Mechanism Design: Analysis and Synthesis", 3rd Ed, Prentice Hall., 1996
- Shabana, A. A., "Computational Dynamics", 3rd Ed., Wiley., 2010
- Shabana, A. A., "Dynamics of Multibody Systems", 2nd Ed., Cambridge University Press., 2003
- Eckhardt, H. D., "Kinematic Design of Machines and Mechanisms", McGraw-Hill. , 1998
- Sandor G.N., and Erdman A.G., "Advanced Mechanism Design: Analysis and Synthesis Vol.2", Prentice Hall Inc, 1984

MIN-555 Experimental Stress Analysis Pre-requisite: **Nil**

Introduction: Importance of experimental methods and their scope, whole field and point by point methods.

Photoelasticity: Nature of light, photoelastic effect and polarized light, permanent and temporary birefringence, types of polariscopes and their basic elements, optics of plane and circular polariscope, isoclinics and isochromatics, stress optic law and secondary principal stresses; Photoelastic model materials their properties and selection, preparation of models, transition from model to prototypes, measurement of relative retardation and fringe order, compensation techniques, separation of principal stresses by oblique incidence, shear difference and numerical integration of Laplace's equation.

Photoelastic methods: Calibration methods and determination of stress trajectories from isoclinic data; Basic elements of three dimensional photoelasticity, stress freezing and slicing the model and interpretation of the resulting fringe patterns, fringe sharpening and fringe multiplication techniques; Photoelastic methods to determine stress intensity factors.

Birefringent Coatings: Surface stress determinations using birefringent coatings, sensitivity of biregringent coatings; Reinforcing, thickness and other effects of photoelastic coatings; Separation of principal stresses; Birefringent coating materials and applications; Photoelastic stress and strain gauges.

Scattered Light Photoelasticity: Scattering phenomenon and polarization associated with scattering, scattered light technique to solve general three dimensional problem; Scattered light polariscope.

Moire Method of Strain Analysis: Moire phenomenon and formation of Moire fringes; Geometric and displacement approach for in-plane problems, Moire grating production, printing and photography.

Brittle Coatings: Introduction, coating stresses; Brittle coating failure theories; Factors affecting analysis of coating data; Crack patterns due to direct and relaxation loading; Refrigeration technique, calibration methods and scope of application of brittle coating method.

Digital Image Processing: Fringe multiplication, fringe thinning and fringe clustering through data acquisition by DIP methods; Phase shifting, polarization stepping and Fourier transform techniques phase unwrapping and optical enhanced tiling, use of colour image processing techniques for data acquisition in digital photoelasticity.

Suggested Books:

- Phillips, E.A., Durelli, A.J. and Tsao, C.H., "Analysis of Stress and Strain", McGraw Hill., 1958
- Daily, J.W. and Riley, W.F., "Experimental Stress Analysis", McGraw Hill. , 1991
- Durelli, A.J. and Riley, W.F., "Introduction to Photomechanics", Prentice Hall. , 1965
- Frocht, M.M., "Photoelasticity (Vol. I and II)", John Wiley., 1948
- Ramesh, K., "Digital Photoelasticity: Advanced Techniques and Applications", Springer-Verlag. , 2000
- James W. Dally and William F. Riley, "Experimental Stress Analysis", College House Enterprises., 2005
- James F. Doyle, "Modern Experimental Stress Analysis: Completing the Solution of Partially Specified Problems", Wiley., 2004
- Pramod K. Rastogi, "Photomechanics"(Topics in Applied Physics),Springer., 2000

MIN-556 Dynamics of Road Vehicles Pre-requisite: **Nil**

Introduction to Vehicle Dynamics: Various kinds of vehicles,motions, mathematical modelling methods; Multibody system approach and Lagrangian formulations, methods of investigations, stability concepts.

Mechanics of Pneumatic Tyre: Tyre construction, physics of tyre traction on dry and wet surfaces, tyre forces and moments, SAE recommended practice, rolling resistance of tyres, ride properties of tyres.

Performance Characteristics: Equation of motion and maximum tractive effort, aerodynamic forces and moments, vehicle power plant and transmission characteristics, prediction of vehicle performance, operating fuel economy, braking performance, antilock braking systems.

Handling and Stability Characteristics: Steering geometry; steady state handling characteristics, steady state response to steering input, transient response characteristics directional stability, effects of tyre factors, suspension, braking and vehicle parameters on stability and handling.

Vehicle Ride Characteristics: Human response to vibration, vehicle ride models, road surface profile as a random function; frequency response function, evaluation of vehicle vertical vibration in relation to ride comfort criterion.

Experimental Testing: Instruments for vehicle measurements, recording and evaluation methods, test methods and measurement procedures for vehicle dynamics, interpretation of test results and correlation between measured values and subjective evaluation of the vehicle handling.

Suggested Books:

- Wong, J.Y., "Theory of Ground Vehicles", John Wiley., 2001
- Gillespie, T.D., "Fundamental of Vehicle Dynamics", S.A.E. , 1992
- Rao, V. D., "Road Vehicle Dynamics", SAE International. , 2008
- Rajesh, R., "Vehicle Dynamics and Control", Springer., 2005
- Hans, T., "The Dynamics of Vehicles on Roads and on Tracks", Taylor and Francis,, 2003
- Barnard, R. H., "Road Vehicle Aerodynamic Design: An Introduction", 2nd Ed., Mechaero Publishing., 2001
- Wong, J. Y., "Theory of Ground Vehicles", 4th Ed., Wiley., 2008

MIN-557 Finite Element Methods Pre–requisite: **Nil**

Basic Concepts: Introduction, Weak formulations, Weighted residual methods, Variational formulations, weighted residual, collocation, subdomain, least square and Galerkin's method, direct method, potential energy method

One-Dimensional Analysis: Basis steps, discretization, element equations, linear and quadratic shape functions, assembly, local and global stiffness matrix and its properties, boundary conditions, applications to solid mechanics, heat and fluid mechanics problems, axisymmetric problems

Plane Truss: Local and global coordinate systems, stress calculations, example problems

Beams: Introduction, Euler-Bernoulli beam element, numerical problems

Scalar Field Problems in 2-D: Triangular and rectangular elements, constant strain triangle, isoparametric formulation, higher order elements, six node triangle, nine node quadrilateral, master elements, numerical integration, computer implementation, Numerical problems

Plane Elasticity: Review of equations of elasticity, stress-strain and strain-displacement relations, plane stress and plane strain problems

Bending of Elastic Plates: Review of classical plate theory, plate bending elements, triangular and rectangular elements, Shear deformation plate theory, numerical problems

Suggested Books:

- Huebner K.H., Dewhirst, D. L., Smith, D. E., and Byrom, T. G., "The Finite Element Method for Engineers", 4th Ed., John Wiley and Sons, 2001
- Rao, S. S., "The Finite Element Method in Engineering", 4th Ed., Elsevier Science, 2005
- Reddy, J.N., "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill, 2005
- Fish, J., and Belytschko, T., "A First Course in Finite Elements", 1st Ed., John Wiley and Sons, 2007
- Chaskalovic J., "Finite Element Methods for Engineering Sciences", 1st Ed., Springer, 2008

MIN-558 Fracture Mechanics Pre-requisite: **Nil**

Introduction to Fracture Mechanics: Introduction to the realm of fracture and back ground history of development of fracture mechanics; Discrepancy between theoretical and real strength of materials, conventional failure criteria based on stress concentration and characteristic brittle failures, Griffith's work.

Linear Elastic Fracture Mechanics (LEFM) Based Design Concepts: Crack deformation modes and basic concepts, crack tip stresses and deformation, stress intensity factor (SIF) and its criticality in different modes, superposition of SIFs, LEFM design concept applications; Concept of energy release rate, equivalence of energy release rate and SIF.

Fracture toughness: Fracture toughness and its laboratory determination procedure, test specimen size requirement etc.; Effect of temperature and loading rate on fracture toughness; Fatigue and fatigue crack propagation laws, fatigue life calculations under constant and variable amplitude loading, mixed-mode fatigue crack propagation.

Strain Energy Density Failure Criterion: Introduction, volume strain energy density, basic hypothesis and application of energy density based failure criteria for two and three dimensional linear elastic crack problems.

Elastic Plastic Fracture Mechanics Based Design Criteria: Design criteria for non-brittle materials; plastic zone corrections, crack opening displacement (COD), J-contour integral and crack growth resistance (R-curve) concepts.

Suggested Books:

- Gdoutos, E.E., "Fracture Mechanics: An Introduction", 2nd Ed., Springer., 2005
- Broek, D., "Elementary Engineering Fracture Mechanics", 3rd Ed., Springer., 1982
- Kumar, P., "Elements of Fracture Mechanics", Wheeler Publishing., 1999
- Anderson, T. L., "Fracture Mechanics: Fundamentals and Applications", 3rd Ed., CRC Press., 2005
- Shukla, A., "Practical Fracture Mechanics in Design", 2nd Ed., CRC Press., 1989
- Bazant, Z. P. and Cedoliin, L., "Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories", World Scientific Publishers., 2010

MIN-559 Computer Aided Design Pre–requisite: **Nil**

Introduction: The design process, elements of CAD

Principles of Software Design: Characteristics of good software, data structures, algorithm design, flow chart, coding, top-down programming, modular programming, structural coding, testing of the software.

Computer Graphics: Graphics display, transformations, visualizations, computer animation.

3D Modeling and Viewing: Coordinate systems, sketching and sketch planes; Modeling aids and tools; Layers, grids, clipping, arrays, editing.

Curves Modeling: Analytical and synthetic curves, curve manipulations.

Surface Modeling: Surface representation and surface analysis, analytical and synthetic surfaces, surface manipulations, NURBS.

Solid Modeling: Geometry and topology, solid entities, solid representation, fundamental of solid modeling, half spaces, boundary representation, constructive solid geometry, sweeps, solid manipulations.

Features: Feature entities, feature representation, three dimensional sketching, parametrics, relations, constraints, feature manipulation.

Mass properties: Geometric and mass properties evaluation, assembly modeling, product data exchange

Optimization technique: Single variable optimization, multi-variable optimization, Johnson's method of optimum design, genetic algorithm.

Suggested Books:

- Zeid, I., "Mastering CAD/CAM", Tata McGraw Hill., 2007
- Onwubiko, C., "Foundation of Computer Aided Design", West Publishing Company., 1989
- Hsu, T. R. and Sinha, D. K., "Computer Aided Design: An Integrated Approach", West Publishing Company., 1991
- Dimarogonas, A. D., "Computer Aided Machine Design", Prentice Hall., 1988
- Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press., 2006

MIN-560 Mechanics of Composite Materials Pre-requisite: **Nil**

Introduction: Composite materials, characteristics, classification, advantages and typical problems.

Unidirectional Lamina: Introduction, longitudinal strength and stiffness, transverse strength and stiffness, failure modes, thermal expansion and transport properties.

Short Fibre Composites: Theories of stress transfer, modulus and strength of short fibre composites.

Analysis of an Orthotropic Lamina: Hook's law, stress-strain relation for lamina with an arbitrary orientation, strength of a lamina subjected to biaxial stress field.

Analysis of Laminated Composites: Classical lamination theory, thermal stress in laminates.

Special Design Considerations: Analysis after initial failure, inter-laminar stress, free edge effect, design of joints, elementary fracture mechanics concepts related to composite materials.

Experimental Characterization: Uni-axial tension test, compression test, in-plane shear test, three and four point bending test, determination of interlaminar shear strength.

Suggested Books:

- Agarwal, B.D. and Broutman, L.J., "Analysis and Performance of Fibre Composites", 3rd Ed., John Wiley & Sons., 2006
- Jones, R.M., "Mechanics of Composite Materials", Taylor & Francis., 1998
- Ashbee, K.H.G. and Ashbee, H.G., "Fundamental Principles of Fibre Reinforced Composites", 2nd Ed., CRC Press. , 1993
- Daniel, I.M. and Ishai, O., "Engineering Mechanics of Composite Materials", 2nd Ed., Oxford University Press., 2007
- Christensen, R.M., "Mechanics of Composite Materials", Dover Publications. , 2005
- Kaw, A. K., "Mechanics of Composite Materials", 2nd Ed., CRC Press. , 2005

MIN-561 Advanced Mechanical Vibrations Pre-requisite: **Nil**

Introduction: Review of free and forced vibrations with and without damping.

Isolation: Vibration isolation and transmissibility; Un-damped vibration absorbers.

Multi degree of freedom system: Generalized coordinates and coordinate coupling; Orthogonality of modes, Free and forced vibration of multi-degree of freedom systems with and without viscous damping; Lagrange's equation; Holzer's method. Solution of Eigen value problem, transfer matrix and modal analysis.

Stability criterion: Self excited vibrations; Criterion of stability; Effect of friction on stability.

Non linear vibration: Free vibrations with non-linear spring force or nonlinear damping; Phase plane; Energy curves; Lienard's graphical construction; Method of isoclines.

Vibration of continuous system: Vibrations of strings; Free and forced longitudinal vibrations of prismatic bars; Ritz and Galerkin methods.

Random vibration: Mathematical descriptions of stochastic processes; Stationary and ergodicity; Gaussian random process, correlation functions and power spectral density.

Diagnostic techniques: Introduction to diagnostic maintenance and signature analysis.

Suggested Books:

- Rao, S.S., "Mechanical Vibrations", 4th Ed., Pearson Education. , 2007
- Meirovitch, L., "Fundamental of Vibrations", Mc-Graw Hill., 2001
- Inman, D.J., "Vibration and Control", John Willey & Sons., 2002
- Tamadonni, S. and Kelly, G.S., "Mechanical Vibrations", Mc-Graw Hill., 1998
- Rao, J. S., "Vibration Condition Monitoring of Machines", Tata Mc-Graw Hill. , 2006

MIN-562 Noise Control in Mechanical Systems Pre-requisite: **Nil**

Introduction: Sound vs noise; Time and frequency domain representation, hearing mechanism -- assessment of noise, its units, human response to noise of different types- stead, fluctuating and impulsive, physiological effects of noise, control of noise, need, concepts and options, and its relation to vibrations.

Homogeneous Wave Equation: Linearized wave equation, acoustic velocity potential acoustic impedance, plane wave propagation, intensity, energy density and power, Simple Source models, monopole, dipole, quadrupole and linear, effect of proximity of rigid boundaries, directivity patterns.

Inhomogeneous Wave Equation and Aerodynamic Noise Theory: Effect of solid bodies in flow, vortex flow; Ray Acoustics-- propagation of sound outdoors, divergence, excess attenuation factors, effects of wind, temperature gradient and turbulence anomalous propagation, shadow zones, ground and terrain effects, harriers, cuttings and elevation.

Wave-Structure Interaction: Sound radiation from plates infinite and bounded; radiation ratio, sound transmission through layered media, behavior of infinite and finite panels, coincidence phenomena and design curves, sound transmission loss, fluid loading on structure, impact noise, introduction to statistical energy analysis.

Instrumentation: Sound measuring equipment, microphones, preamplifiers, sound level meters, recorders, frequency analysers statistical measurements, FFT analysers.

Noise Control Principles: Control strategies and limitations, integrated approach to low noise design, typical mechanical noise sources, mechanism of noise generation– vibration, impact, flow excitation, control of solid borne and air-home noise, concept of impedance mismatch, filters, silencers, damping, enclosure, absorbers, active noise control principle.

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

Suggested Books:

- Faulkner, L.L, "Handbook of Industrial Noise Control", Industrial Press. , 2001
- Lyon, R.H., "Machinery Noise and Diagnostics", Butterworths., 1995
- Norton, M.P., "Fundamentals Noise and Vibration Analysis", Cambridge University Press., 1989
- Rahn, C. D., "Mechatronic Control of Distributed Noise and Vibration", Springer., 2001
- Fuller, C. C., Elliott, S.J., and Nelson, P. A., "Active Control of Vibration", Academic Press., 1996
- Moser, M., Zimmermann, S. and Ellis, R., "Engineering Acoustics: An Introduction to Noise Control", 2nd Ed., Springer., 2009

MIN-563 Mechatronics Pre–requisite: **Nil**

Introduction: Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach.

Sensors and Transducers: Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches.

Actuators: Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems.

Signal Conditioning: Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems.

Microprocessors and Microcontrollers: Microcomputer structure, microcontrollers, applications, programmable logic controllers.

Modeling and System Response: Mathematical models, bond graph models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.

Design and Mechatronics: Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots.

Suggested Books:

- Bolton, W., “Mechatronics”, Longman., 1999
- Alciatore, D. G. and Histrand, M. B., “Introduction to Mechatronics”, Tata McGraw Hill., 2003
- Shetty, D. and Richard, A.K., “Mechatronics System Design”, PWS Pub. Boston., 1997
- Mahalik, N., “Principles, Concept and Applications: Mechatronics”, Tata McGraw., 2003
- Bishop, R.H. “Mechatronics Handbook”, CRC Press., 2002
- Bolton, W., “Mechatronics: A Multidisciplinary Approach”, 4th Ed., Prentice Hall., 2009
- Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer , 2013

MIN-565 Smart Materials, Structures and Devices Pre-requisite: **Nil**

Intelligent Materials: Primitive functions of intelligent materials; Intelligence inherent in materials; Materials intelligently harmonizing with humanity; Intelligent biological materials.

Smart Materials and Structural Systems: Actuator materials; Sensing technologies; Microsensors; Intelligent systems; Hybrid smart materials; Passive sensory smart structures; Reactive actuator-based smart structures; Active sensing and reactive smart structures; Smart skins.

Electro–Rheological Fluids: Suspensions and electro, reheological fluids; The electro- rheological phenomenon; Charge migration mechanism for the dispersed phase; Electro rehological fluid actuators.

Piezoelectric Materials: Background; Piezoelectricity; Industrial piezoelectric materials; Smart materials featuring piezoelectric elements.

Shape Memory Materials: Background on shape memory alloys; Applications of shape memory alloys; Continuum applications: structures and machine systems; Discrete applications; Impediments to applications of shape memory alloys; Shape memory plastics.

Fiber Optics: Overview; Light propagation in an optical fiber; Embedding optical fibers in fibrous polymeric thermosets; Fiberoptic strain sensors.

The Piezoelectric Vibrations Absorber Systems: Introduction; The single mode absorber, theory, design solution, extension including viscous modal damping, the electromechanical coupling coefficient, inductance,

experimental results; The multimode absorber, derivation of transfer function, design solution, self-tuning absorber, performance function, control scheme.

Modeling of Shells: Derivation of the basic shell equations, equation of motion, equations for specific geometries and cylindrical shell.

Modeling of plates and beams: Plate equations and beam equations.

Suggested Books:

- Gandhi, M. V. and Thompson, B. S., "Smart Materials and structures", Chapman & Hall., 1992
- Banks, H. T., Smith, R. C. and Qang, Y. W., "Smart Material structures: Modeling, Estimation and Control", John Wiley & Sons., 1996
- Gabbert, U. and Tzou, H. S., "Smart Structures and Structronic System", Kluwer Academic Publishers., 2001
- Preumont, A., "Vibration Control of Active Structures", Kluwer Academic Publishers., 2002
- Cheng, F. Y., Jiang, H. and Lou, K., "Smart Structures: Innovative Systems for Seismic Response Control", CRC Press., 2008

MIN-566 Computer Aided Analysis of Mechanical Systems Pre–requisite: **Nil**

Introduction: Introduction to mechanical systems analysis.

Kinematic Modeling: Modeling the kinematics of mechanical systems; Vector loop methods, vector chain methods.

Solution of Kinematic Models: Solution of kinematic models for displacements, velocities, accelerations; Direct analytical solutions of position, velocity, acceleration problems; Numerical solution of position problem; Matrix method solutions of velocity and acceleration problems.

Dynamic Modeling: Modeling the dynamics of mechanical systems; Newton-Euler methods to define dynamic constraints between forces, moments, and accelerations, energy methods to define dynamic constraints between input and output links.

Solution of Dynamics Models: Solution of inverse dynamics models for joint-link forces and torques, solution of forward dynamics models using numeric integration, model formulation into standard format for solution, Euler's method of integration, Runge-Kutta methods of integration, modeling and analysis of the Trebuchet mechanism.

Advanced Dynamic Analysis & Simulation: Bond graph modeling of dynamic systems, generation of system equations, causality, and simulation.

Suggested Books:

- Norton R., "Design of Machinery", McGraw-Hill, 1992
- Palm W. J., "Introduction to MATLAB 6 for Engineers", Mc Graw-Hill, 2000
- Nikravesh, P. E., "Computer-Aided Analysis of Mechanical Systems", Prentice Hall., 1988
- Haug, E. J., "Computer Aided Analysis and Optimization of Mechanical System Dynamics", Springer-Verlag., 1984
- Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in Modeling, Simulation and Fault Identification", I & K International., 2007

MIN-567 Computer Graphics Pre–requisite: **Nil**

Introduction: Role of Computer Graphics in CAD/CAM, configuration of graphic workstations, menu design and Graphical User Interfaces (GUI), customization and parametric programming.

Geometric Transformations and Projections: Vector representation of geometric entities, homogeneous coordinate systems, fundamentals of 2D and 3D transformations: Reflection, translation, rotation, scaling, and shearing, various types of projections.

Curves: Modeling planar and space curves, analytical and synthetic approaches, non-parametric and parametric equations.

Surfaces: Modeling of bi-parametric freedom surfaces, Coons, Bezier, B-spline, and NURBS surfaces, surface manipulation techniques.

Geometric Modeling: Geometric modeling techniques, wireframe modeling, solid modeling: B-Rep, CSG, hybrid modelers, feature based, parametric and variational modeling.

Data Structure in Computer Graphics: Introduction to product data standards and data structures, data-base integration for CIM.

Suggested Books:

- Rogers, D. F., and Adams, J. A., "Mathematical Elements for Computer Graphics", McGraw Hill., 1989
- Faux, I. D. and Pratt, M. J., "Computational Geometry for Design and Manufacture", Ellis Horwood Ltd., 1979
- Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press., 2006
- Zeid, I., "CAD/CAM: Theory and Practice", Tata McGraw Hill., 1998
- Choi, B. K., "Surface Modeling for CAD/CAM", John Wiley & Sons, 1991

MIN-568 Advanced Robotics Pre–requisite: **Nil**

Introduction: Review, forward and inverse kinematics, dynamics

Robots with Flexible Elements: Robots with Flexible Joints, Robots with Flexible Links

Parallel Mechanisms and Robots: Definitions, Type Synthesis of Parallel Mechanisms, Kinematics, Velocity and Accuracy Analysis, Singularity Analysis, Workspace Analysis, Static Analysis and Static Balancing, Dynamic Analysis, Design Mobile Robots:

Wheeled mobile robots: mobile robot kinematics, Mobility of Wheeled Robots, State-Space Models of Wheeled Mobile Robots, Wheeled Robot Structures, sensors for mobile robots, planning and navigation Legged robots: Analysis of Cyclic Walking, Control of Biped Robots Using Forward Dynamics, Biped Robots in the ZMP Scheme, Multilegged Robots, Performance Indices

Cooperative Manipulators: Kinematics and Statics, Cooperative Task Space, Dynamics and Load Distribution, Task-Space Analysis, Control

Advanced Robots: Modeling and control of space robots, underwater robots

Control of Manipulators: Manipulator control problem; Linear and non linear control schemes; PID control scheme; Force control.

Image Processing and Analysis with Vision Systems: Acquisition of images, digital images, image processing techniques, noise reduction, edge detection, image analysis, object recognition by features, application of vision systems

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

Suggested Books:

- Niku, S. B., "Introduction to Robotics: Analysis, Systems, Applications", Prentice Hall., 2001
- Angeles, J., "Fundamentals of Robotic Mechanical Systems: Theory, Methods and Algorithms", Springer , 2003

- Craig, J. J., “Introduction to Robotics: Mechanics & Control”, Addison Wesley., 1989
- Siegwart, R., Nourbakhsh, I. R., “Introduction to Autonomous Mobile Robots”, MIT Press., 2004
- Xu, Y. and Kanade, T., “*Space Robotics: Dynamics and Control”, Kluwer Academic Publishers.*, 1993
- Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer, 2013
- Siciliano, Bruno, Khatib, Oussama, Handbook of Robotics, Springer, 2008
- Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Springer , 2013

MIN-569 Expert Systems Design Pre–requisite: **Nil**

Introduction: Overview: Evolution and characteristics of knowledge-based systems.

Introduction to Expert System Languages: CLIPS (C language integrated production system) and JESS (java expert system shell).

Pattern Matching: Basic and advanced pattern matching techniques.

Modular Design and Control: Salience, phases and control facts, modules and execution control

Knowledge Representation: Productions, semantic nets, schemata, frames, logic and set.

Methods of Inferences: Inference rules, resolution system, forward and backward chaining.

Reasoning under Uncertainty: Hubert Dreyfus "From Socrates to Expert Systems: The Limits and Dangers of Computational Rationality" -- CSUS Library video collection, hypothetical reasoning and backward induction, temporal reasoning and Markov chains, uncertainty in inference chains; Probability-based techniques: Objective probability, experimental probability, subjective probability, Bayes' theorem, inexact or heuristic reasoning; Inexact reasoning: uncertainty and rules, certainty factors, Dempster-Shafer theory.

Design of Expert Systems: Approximate reasoning, fuzzy expert systems.

Suggested Books:

- Giarratano, J. C. and Riley, G. D., “Expert Systems: Principles and Programming”, 4th Ed., Course Technology., 2004
- Gonzalez, A., and Dankel, D., “The Engineering of Knowledge-Based Systems”, Prentice Hall., 1994
- Jackson, P., “Introduction to Expert Systems”, 3rd Ed., Addison Wesley., 1998
- Akerkar, R. and Sajja, P., “Knowledge-Based Systems”, Jones & Bartlett Publishers., 2009

MIN-570 Operations Management Pre – requisite: **Nil**

Introduction: Basic concepts of operations and production management, types of manufacturing systems and their characteristics.

Product and Process Design: System planning and design, long-range planning, product and process design and technological considerations.

Demand Forecasting: Role of demand forecasting in operations decisions; various demand patterns, qualitative and quantitative techniques of demand forecasting.

Production Planning and Scheduling: Aggregate production planning, operation scheduling, various scheduling criteria, lot sizing, job shop control; Mutli-stage manufacturing systems, their scheduling and management, capacity planning.

Materials Planning: Details of material requirement planning (MRP) and manufacturing resource planning (MRP-II) and their various techniques.

Facilities Planning: Plant design, types and considerations in the plant location, plant layout types, design, evaluation, principles and types of material flow, optimum plant layout.

Suggested Books:

- Buffa, E. S. and Sarin, R. K., "Modern Production/Operations Management", 8th Ed., John Wiley & Sons., 2003
- Adam, E., Jr. and Ebert, R. E., "Production Operations Management", 5th Ed., Pearson Education.,1992
- Brown, S., Blackmon, K., Cousins, P. and Maylor H., "Operations Management: Policy, Practice, and Performance Improvement", Butterworth-Heinemann., 2001
- Dervitsiotis, K. N., "Operations Management", 2nd Ed., McGraw Hill.,1987
- Starr M. K., "Production and Operations Management", Thomson Business Information.,2009
- Karjewski, L. J, Ritzman, L. P. and Malhotra, M. K., "Operations Management: Processes & Supply Chains, 9th Ed., Pearson Education., 2009

MIN-571 Quality Management Pre – requisite: **Nil**

Fundamentals of Quality Management: Quality of products, services and total quality control and its impact on the organization; Buyer, producer and market place demand for quality, quality cost and quality system economics; Quality management factors and jobs, system approach for quality management, commitment, leadership and team work.

Techniques of Quality Engineering: Quality policy, product reliability and life cycle, safety, product quality and process capability, evaluation of methods, processes and materials, quality cost optimization; Quality planning, implementation and inspection, quality information feedback, corrective actions, Taguchi's philosophy and robust product and process design.

Process Control Engineering: Machine and process capability analysis, multi-vary chart, vendor performance and their ratings, mechanization of process for quality.

Statistical Quality Control: Review on variables, attributes quantities and their measurements etc; Theory of control charts, brief review on X, R, P, C, charts; Different adaptation of control charts, viz, group control chart, control charts with variable subgroup sizes, moving average and moving range charts, acceptance control charts, charts for trended universe average, CUSUM charts, different control charts.

Acceptance Sampling: Acceptance sampling tables, acceptance sampling plans for attributes and variables.

Quality Improvement Techniques: Variance concept in manufacturing cycle; Fish bone diagrams; Pareto charts; Just in Time (JIT) - philosophy, evaluation and concept.

System Approach and Quality System Establishment: ISO-9000 pre-requisites, different quality systems and their structure, quality policies and objectives, management responsibility, documentation and methodology of implementation, quality audits and assessment.

Achieving Total Commitment to Quality: Participative approach and team work, training and motivation; quality circles, their characteristics, objectives and organization structure; Quality circle implementation structures and techniques; Communicating quality commitment to vendors and customers.

Suggested Books:

- Jackson, P. and Ashton, D., "Implementing Quality Through ISO-9000", Viva Book Pvt Ltd., 1993
- Grant, E. and Lavenworth, R., "Statistical Quality Control", 11th Ed., McGraw Hill., 1997
- Ross, P. J., "Taguchi Techniques For Quality Engineering", 2nd Ed., McGraw Hill. , 1995
- Gryna, F., Chua, R. and Defeo, J., "Juran's Quality Planning and Analysis for Enterprise Quality", 5th Ed., McGraw Hill., 2005

MIN-572 Advanced Manufacturing Processes Pre – requisite:**Nil**

Machining: Introduction: Review of mechanisms of machining, Advances in machining processes: Diamond turning, Hybrid machining, Micro machining

Newer Machining Processes: Introduction, process principle, process parameters and applications of processes such as ultrasonic machining (USM), abrasive water jet machining (AWJM), electrochemical machining (ECM), electro discharge machining (EDM), electron beam machining (EBM), and laser beam machining (LBM) processes, abrasive flow machining, biomachining

Metal Casting: Introduction to solidification, Nucleation and grain growth, Solidification of pure metals and alloys,

Advanced casting processes: Centrifugal and continuous casting processes, squeeze casting, vacuum mould casting, evaporative pattern casting, Semi solid metal working processes, ceramic shell casting

Rapid prototyping (RP): process chain in RP, layering techniques, steriolithography, fused deposition modeling, laminated object manufacturing, repetitive masking and depositing.

Metal Forming: Introduction:stress/strain, strain-rate characteristics of materials, yield criteria of metals, c1assification of metal working processes, various methods of analyzing the metal working processes (slip-line field theory; stab methods), Effect of strain rate and temperature in metal forming.

Advanced metal forming processes: Details of high energy rate forming (HERF) process: electro-magnetic forming, explosive forming, electro-hydraulic forming; stretch forming, contour roll forming, Microforming.

Suggested Books:

- Bhattacharya A., "Metal Cutting: Theory and Practices", 2nd Edition, New Central Book Agency., 1984
- Armarego E. J. A. and Brown R. H., "Machining of Metals", 1st edition, Prentice Hall Inc. Englewood Cliffs, New Jersey., 1969
- DeGarmo E. P., Black J. T. and Kohser R. A., "Materials and Processes in Manufacturing", 8th Edition, Prentice Hall of India, New Delhi., 1997
- Ghosh A. and Mallik A. K., "Manufacturing Science", Affiliated East-West Press Pvt. Ltd. New Delhi., 1985
- Benedict G.F., "Nontraditional Manufacturing Processes", Marcel Dekker, Inc. New York., 1987
- Pandey P. C. and Shan H.S., "Modern Machining Processes", Tata McGraw-Hill Publishing Company Ltd, New Delhi., 1980
- Jain V. K., "Advanced Machining Processes", Allied Publishers, New Delhi., 2002
- Heine and Roshenthal, "Principles of Metal Casting", Tata McGraw-Hill Publishing Company Ltd, New Delhi., 1983
- Chakrabarti, A. K., "Casting Technology and Cast Alloys" Prentice-Hall of India, New Delhi, 2005
- Dieter George E., "Mechanical Metallurgy", McGraw-Hill Book Company, London, 1988

MIN-573 Design for Manufacturability Pre-requisite**: Nil**

Introduction: Introduction to Design for Manufacturability (DFM), fundamentals of manufacturing technology and the interrelationship between design and manufacturing processes. Organizational changes in DFM.

Concurrent Engineering: Need for concurrent engineering, industrial practices of concurrent engineering.

Automation: Automation of design and manufacturing functions in CIM, computer aided process planning, Design for X, approaches to DFM.

Design Knowledge Representation: Design, manufacturing, and re- design considerations, Design and manufacturing knowledge representation.

Evaluation of Manufacturability: Evaluation of the manufacturability of a part design, various methods for defining manufacturability index, interpretation of MI value.

Suggested Books:

- Boothroyd G., Dewhurst P., and Knight W., "Product Design for Manufacture and Assembly", 2nd Edition, Marcel Dekker., 2002
- Bralla J. G., "Design for Manufacturability Handbook", 4th edition, McGraw Hill. , 1998
- Huang G. Q., "Design for X: Concurrent Engineering Imperatives", Chapman & Hall., 1996
- Kusiak A., "Concurrent Engineering: Automation, Tools, and Techniques", Wiley, 1993

MIN-574 Maintenance Management Pre – requisite: **Nil**

Introduction: Importance of maintenance, Objectives, duties, functions and responsibilities of maintenance engineering department, Organization and structure of maintenance systems.

Maintenance Policies and Planning: Maintenance strategies, advantages and disadvantages of each strategy, Planned maintenance procedure, advantage of planned maintenance, Scientific maintenance, Safety in maintenance.

System Reliability: Quantitative estimation of reliability economies of introducing a standby unit into the production system, Optimum design configuration of a series/parallel system, Breakdown time distribution.

Maintenance Activities: Optimal overhaul/repair or replacement policies for equipment subject to breakdown, Budgeting and control, Production maintenance integration.

Replacement Decisions: Economic models, block replacement policy, age replacement policy, replacement policies to minimize downtime, Economics of preventive maintenance.

Maintainability and Availability: Economics of maintainability and reliability, Maintainability increment, Equipment and mission availability.

Maintenance Organization: Computer applications in maintenance management, automatic chalk out equipment kits capabilities and limitations, Management information system for maintenance.

Suggested Books:

- Dhillon B.S., "Engineering Maintenance: a Modern Approach". 1 edition, CRC, 2002
- Kelly A., "Maintenance Planning and Control", Butterworth-Heinemann. Ltd, London. 1983
- Niebel B.W., "Engineering Maintenance Management", Marcel Dekker, New York, 1994
- Cliffton R. H.,"Principle of Planned Maintenance", McGraw Hill Inc. New York. 1983
- Heintzelman J. E., "Handbook of Maintenance Management", Prentice-Hall Inc., Englewood Cliffs, New Jersey. , 1976

MIN-575 Product Design and Development Pre–requisite: **Nil**

Product Design: Traditional and modern design processes; Organization objectives; Innovation, creation, and diffusion techniques; Evaluation of new product ideas – functional, technological, ecological, legal.

Product Modeling and Reverse Engineering: Wireframe modeling; Surface modeling – boundary representation; Solid modeling – CSG; Concept of reverse engineering.

Product Data Exchange: Neutral file formats for product data exchange–DXF, IGES, STEP.

Concurrent Engineering: Concept of concurrent engineering; Design for X; Design for manufacturability (DFM); Design for assemblability (DFA); Design for reliability (DFR); Design for quality (DFQ).

Rapid Prototyping Methods: Liquid based RP methods –stereolithography apparatus (SLA), solid ground curing (SGC), solid creation system (SCS), etc.; Solid based RP methods: Fused deposition modeling (FDM), laminated object manufacturing (LOM), etc.; Powder based RP methods– selective laser sintering (SLS), 3D printing (3DP), ballistic particle manufacturing (BPM), etc.

Suggested Books:

- Andrearsen, M. M., and Hein, L., "Integrated Product Development", Springer, **1**987
- Huang, G. Q., "Design for X: Concurrent Engineering Imperatives", Chapman and Hall, 1996
- Chitale, A. K. and Gutpa, R. C., "Product Design and Manufacturing", Prentice Hall, 1997
- ZeidI., "CAD/CAM: Theory and Practice", Tata McGraw Hill., 1998
- Mortenson, M. E., "Geometric Modeling", 3rd Ed., Industrial Press, 2006
- Boothroyd G., Dewhurst P., and Knight, "Product Design for Manufacture and Assembly", 2nd Ed., Marcel Dekker., 2002
- Chua, C. K and. Leong, K. F., "Rapid Prototyping: Principles and Applications in Manufacturing", John Wiley & Sons, 1997

MIN-576 Machine Tool Design and Numerical Control Pre – requisite: **Nil**

Machine Tool Design: General requirements; Electrical and hydraulic drives of machine tools ; Layout of gear boxes ; Hydraulic, electric and mechanical stepless speed regulations ; Designand analysis of guide ways; Bed; Column and Spindle.

Numerical Control (NC): Introduction to numerical control; Components of NC systems; Open and close loop NC; Types of numerical control: Point-to-point, straight cut, and continuous path NC; Drives andcontrols; NC-tape coding standards.

NC Part Programming Methods: Structure of NC part program; NC word formats; Introduction to G and Mcodes; Manual programming methods; Computer-assisted programming methods; APT part programming.

Extensions of NC: Concepts of CNC, machining center, and DNC; CNC and DNC efficiency; Tooling for NC/CNC.

CNC Part Programming: Tool motion commands; Tool length offset; Cutter diameter compensation command; fixed cyclecomm and; Scaling; rotation; Mirror image; Macros programming etc.

Suggested Books:

- Mehta N.K., "Machine Tool Design and Numerical Control", 3rdEdition Tata McGraw Hill McGraw-Hill,, 2012
- Koren Y., "Computer Control of Manufacturing Systems", McGraw HillInc., 1983
- Rapello R.G. "Essentials of Numerical Control", Prentice HallInc. Englewood Cliffs, 1986
- Chen S, and Lin J., "Computer Numerical Control: From Programming to Networking", Thomson Delmer Learning., 1994
- Sava M.,and Pusztai J.,"Computer Numerical Control Programming", Prentice Hall., 1990
- Rao P.N., Tewari N.K, and Kundra T.K., "Computer Aided Manufacturing", Tata McGraw Hill, 1993
- Steve K. and GillA., "CNC Technology and Programming", McGraw Hill., 1997

MIN-577 Industrial Automation Pre – requisite: **Nil**

Basic Concepts: Introduction of Mechanization and Automation, Classification and Strategies of Automation, Reasons for and Arguments against Automation. Mechanical, Electrical, Hydraulic, and Pneumatic Devices and Controls

High Volume Manufacturing or Hard Automation: Automated Flow Lines, Types of Automatic Transfer Mechanisms, Design and Fabrication Considerations, Analysis of Automated Flow Lines.

Assembly Automation: Assembly Systems and their Types, Manual Assembly Lines and Line Balancing, Automated Assembly Lines and their Types, Automatic Assembly Transfer Systems, Automatic Feeding and Orienting Devices:- Vibratory and Mechanical Feeders and their types, Orientation of Parts, Performance and Economics of Assembly Systems, Feasibility Study for Assembly Automation.

Design for Assembly: Design for Manual Assembly, Design for High-Speed Automatic Assembly, Design for Robot Assembly

Flexible Automation: Introduction of Group Technology (GT), Steps in Implementing GT, Part Families and Machine Cell Formation, Introduction of Flexible Manufacturing Systems (FMS).

Programmable Automation: Brief Introduction of Numerical Control (NC), Computer Numerical Control (CNC), Machining Centers, Programmable Robots, Direct Numerical Control (DNC), and Adaptive Control.

Suggested Books:

- Groover M.P., "Automation, Production systems and Computer Integrated Manufacturing", 2nd Edition, Prentice Hall. , 2005
- Boothroyd G.,"Assembly Automation and Product Design", 2nd Edition, Marcel Dekker CRC. , 1992
- Boothroyd G., Dewhurst P., Knight W. and Marcel Dekker, "Product Design for Manufacture and Assembly", 2nd Edition, Taylor & Francis., 2002
- Boothroyd G., Poli C., Murch L. E., "Automatic Assembly", Marcel Dekker, New York., 1982
- Tergan V., Andreev I. and Lieberman B., "Fundamentals of Industrial Automation", 1st Edition, Mir Publishers., 1986

MIN-578 Computer Aided Process Planning Pre– requisite: **Nil**

Introduction: traditional process planning, product design evaluation, various steps in process planning.

Group Technology: Introduction, advantages, part families, classification and coding systems, production flow analysis, design of machine cells.

Concepts Related to Process Planning: Machinability data system, cutting condition optimization.

Automated Process Planning: Advantages of automated process planning, various approaches to process planning; Variant process planning, its features and different stages, different variant systems; Generative and semi-generative process planning, its features, design strategies, planning, modeling and coding scheme, decision mechanisms; Process capability analysis, intelligent process planning system; Artificial intelligence -- overview and application in process planning; Various recent process planning systems; Case studies.

Interfaces of Process Planning: Integrating with loading, scheduling, MRP II, and capacity planning and other shop floor functions.

Suggested Books:

- Chang, T.C. and Wysk, R.A, "An Introduction to Automated Process Planning", Prentice-Hall., 1985
- Gallagher, C.C and Knight, W.A., "Group Technology: Production Method in Manufacturing", Ellis Horewood., 1986
- Nilsson, N.J., "Principles of Artificial Intelligence",Springer Verlag., 1982
- Cornelius,L.T, "Computer Aided and Integrated Manufacturing Systems: Manufacturing Processes", World Scientific Publishing Company., 2003

MIN-579 Information Systems & Data Management Pre – requisite: **Nil**

Introduction: role of information system, the function of information system, determination of informational need.

Information processing concepts: historical perspective, today's status, systems approach and analysis, concepts of data and information, data collection, data or information, data and information storage, data processing and information generation, transmission of data and information and the information economics of information.

Information system analysis: overview of system, management and formal information systems, hierarchical and system approach to information systems design and their applications, tailoring the information system to meet specific information requirements using filtering monitoring, interrogative and external methods.

Data base management system: introduction to data base concepts, difference between a file system and a data base systems, goals of DBMS including data independence consistency, data security and integrity; DBMS models, hierarchical network and relation, data description and query language, physical database design, case studies, system R, Ingress, IDMS etc.; introduction to distributed database, concurrency control bases recovery etc.

Suggested Books:

- Henry Luces C., "Information Systems Concepts for Management", McGraw Hill International Book Co. , 1978
- Burch J.G. and Strater F. R., "Information Systems Theory and Practice", Hamilton Publishing Co., 1989
- Walker D. W., "Computer Based Information System An Introduction", Pergamon Press., 1989
- Cardenas A. F., "Database Management Systems"., 1985

MIN-580 Welding Science Pre–requisite: **Nil**

Introduction: Welding as compared with other fabrication processes, Classification of Welding Processes

Physics of Welding Arc: Welding arc, arc initiation and maintenance, voltage distribution along the arc, cathode and anode drops, Arc column, Thermionic and non thermionic cathode, Theories of cathode and anode mechanisms, arc characteristics, arc efficiency, heat generation at cathode and anode Effect of shielding gas on arc, isotherms of arcs, arc blow.

Metal Transfer: Mechanism and types of metal transfer in various arc welding processes, factors controlling melting rate in various welding processes.

Welding Power Sources: Basic characteristics of power sources for various arc welding processes, arc length regulation in mechanized welding processes, Transformer, rectifier and generators, Duty cycle and power factor, Static and dynamic characteristics of power sources.

Welding Processes: Critical review of MMA; TIG. MIG and CO_2 welding processes, plasma arc, submerged arc welding, electro- gas and electro-slag welding; resistance welding. Theory and mechanism of solid state welding; technique and scope of friction welding, diffusion welding; cold pressure welding and ultrasonic welding, scope and application of electron beam and laser welding processes.

Heat Flow in Welding: Calculation of peak temperature; width of Heat Affected Zone; cooling rate and solidification rates; weld thermal cycles; residual stresses and their measurement; weld distortion and its prevention.

Weldability of Metals: Effects of alloying elements on weld ability, welding of plain carbon steel, stainless steel, Cast Iron and aluminium.

Suggested Books:

- "Welding Handbook", 7th Edition-Volume I to 5, American Welding Society., 1982
- Houdlecroft P.T., "Welding Process Technology", Cambridge University Press., 1977
- Udin H, Fruk F and Wulff J, "Welding for Engineers", John Wiley., 1978
- Rossi E., "Welding Technology", Mc-Graw Hill., 1969
- Baldev, R., "Welding Technology for Engineers", ASM International , 2006
- Bowditch, W.A., Bowditch M. A., Bowditch, K. E., "Welding Technology Fundamentals", 4th Edition, Goodheart-Willcox Pub., 2009

MIN-581 Manufacturing Resources Management Pre-requisite**: Nil**

Introduction: Production as input output system; Resources of production; Forecasting and resources planning.

Material Management: Definition and scope; Functions; Types of materials; Analytical structure of inventory models; Material requirement planning (MRP); Inventory control systems; Purchase management; Storekeeping and issue of materials; Material handling; Just in Time (JIT) and Kanban systems.

Human Resources Management: Objective; function; organizational planning and development; staffing policies and process; training and executive development; wage and salary policies and administration; motivation; employee services; employee record; labor relations; collective bargaining; personnel research.

Production Management: Direct and indirect; Machines and equipment planning; jigs and tools planning, material handling equipment planning; Planning of land, roads, building, warehouses etc.; General vs special purpose equipment; Economic analysis; Equipment replacement; Capital resources planning; Method of allocation of resources.

Production Information Management: Management of production technology; information systems; Management Information Systems (MIS); Strategic Information System (SIS); Information networking; Parts oriented production information systems.

Suggested Books:

- Hitomi K., "Manufacturing System Engineering", 2nd Edition, Viva Books., 1996
- Hitomi K, "Manufacturing Systems Engineering: A Unified Approach to Manufacturing Technology, Production Management and Industrial Economics", 2nd Edition, CRC Press., 1996
- Groover, M. P., "Fundamentals of Modern Manufacturing: Materials, Processes, and Systems",4th Edition, Wiley , 2010
- Gary Dessler, "Personnel Management", 4th Edition, Reston Publishing., 1988
- Nauhria R. N. and Rajneesh Prakash, "Management of Systems", Wheeler Publishing., 1995
- Thomas Vollman E., William Berry L. and Clay Whybark D., "Manufacturing Planning and Control Systems", 5th Edition, Galgotia Publishing., 1997

MIN-582 Flexible Manufacturing Systems Pre – requisite: **Nil**

Introduction: Definition and classification of manufacturing systems, fundamentals of automated production cycle, need of flexibility, concept of flexibility, various types of flexibility, measures of flexibility.

Flexible Manufacturing System (FMS) Type: Introduction of FMS, definition of FMS, types of FMS, applications of FMS, FMS configuration, FMS host operator interface.

FMS Planning and Control: Functional requirements of FMS equipments, functions of FMS host computer, host system design, planning, scheduling of FMS, FMS simulation, Databases in FMS, GT in FMS, cell design and layout design, CAPP in FMS.

Material handling in FMS: Material handling principles in FMS, applications of robots in FMS.

Case Studies: Cases on FMS installation and implementation –acceptance testing and maintenance

Suggested Books:

- Groover, M. P., "Automation, Production System and CIM", 2nd Ed., Prentice Hall., 2000
- Rankey, P., "Design and Operations of FMS", North-Holland Publishing., 1983
- Warnecke, H. J. (Ed.), "Flexible Manufacturing System", Springer. , 1985
- Bonetto, R., "FMS in Practice", North Oxford Academic Publishers., 1988

MIN-583 Materials Management Pre – requisite**: Nil**

Introduction: Operating environment:, scope, and issues

Material Requirement Planning**:** Introduction, Bills of material, Material requirement plans and planning process.

Capacity Management: Definition of capacity, capacity planning, Capacity requirement planning, capacity available and required, Scheduling order, make plan

Production Activity and Control: Data requirements, order preparation, scheduling, load leveling, Scheduling bottlenecks, production reporting.

Purchasing, forecasting, and Inventory fundamentals:

Establishing specifications, selecting suppliers, price determination, demand management, demand forecasting, principle of forecasting, forecasting techniques, seasonality, tracking the forecast, inventory and flow of materials, supply and demand pattern, functions of inventories, ABC, VED and FSN system of selective inventory, EOQ, variation of EOQ models, period order quantity, quantity discount.

Just in time Manufacturing: JIT philosophy, JIT environment, Manufacturing planning and control in JIT environment, MRP, Kanban, theory and constraints.

Suggested Books:

- Handfield R.B. and Nichols E.L., Jr "Introduction to Supply Chain Management", Prentice-Hall Inc., 1999
- Bowersox D. J. and Closs D. J., "Logistical Management: The Integrated Supply Chain Process", McGraw-Hill, New York., 1996
- Leenders M.R. and Fearon H.E., "Purchasing and Materials Management", 11th Edition, Irwin Burr Ridge, Illinois., 1997
- Arnold J. R. T. and Chapman S. N., "Introduction to Materials Management", 4th Edition, Pearson Education Asia., 2001

MIN-584 Operations Research Pre-requisite: **Nil**

Introduction: definition and scope of OR; techniques and tools; model formulation; general methods for solution; classification of optimization problems; optimization techniques.

Linear optimization models: complex and revised simplex algorithms; duality theorems; sensitivity analysis; assignment, transportation and transshipment models; traveling salesman problem as an assignment problem; integer and parametric programming; goal programming.

Game problems: minimax criterion and optimal strategy; two person zero sum game; games by simplex dominance rules.

Waiting line problems: classification of queuing situations; Kendall's notation, Poisson arrival with exponential or Erlang service time distribution; finite and infinite queues; optimal service rates; application of queuing theory to industrial problems.

Dynamic programming: characteristic of dynamic programming problems (DPPs); Bellman's principle of optimality; problems with finite number of stages; use of simplex algorithm for solving DPPs.

Non- linear programming: one dimensional minimization methods; unconstrained optimization techniques; optimization techniques- characteristics of a constrained problem; indirect methods; search and gradient methods.

Suggested Books:

- Taha H. A., "An Introduction to Operations Research", 6th Edition, Prentice hall of India;. , 2001
- Hillier F. J. and Lieberman G.J., "Introduction to Operations Research", 7th Edition Holden Day Inc., 2001

- Loomba N.P., “Linear Programming”, 2nd Edition, Mcmillan Publishing Inc. New York., 1976
- Wagner H. M., “Principles of OR with Applications to Managerial Decisions”, 2nd Edition, Prentice Hall., 1975
- Giffin, Walter G., “Queueing Basic Theory and Applications”, Grid Inc., Ohio., 1978

MIN-585 Supply Chain Management Pre – requisite: **Nil**

Introduction: Understanding supply chain, supply chain performance; supply chain drivers and obstacles.

Planning Demand and Supply in a Supply Chain: Demand forecasting in supply chain, aggregate planning in supply chain, planning supply and demand; managing predictable variability, Economic Order Quantity Models, Reorder Point Models, Multi-echelon Inventory Systems.

Planning and Managing inventories in a Supply Chain: Managing economies of supply chain, managing uncertainty in a supply chain, determining optimal levels of product availability.

Transportation, Network Design and Information Technology: Transportation aspects in a supply chain, facility Decision, Network design in a supply chain, Information technology and its use in supply chain.

Coordination in Supply Chain and effect of E- Business: Role ofCoordination and E-business in a supply chain; financial evaluation in a supply chain.

Suggested Books:

- Hopp W. J., Spearman M. L. and Irwin, “Factory Physics: Foundations of Manufacturing”, McGraw-Hill Inc. New York., 1996
- Viswanadham N., “Analysis of Manufacturing Enterprises”, Kluwer Academic Publishers, UK., 2000
- Sridhar Tayur, Ram Ganeshan and Michael Magazine (editors), “Quantitative Models for Supply Chain Management”, Kluwer Academic Publishers, UK., 1999
- Handfield R.B. and Nochols E.L.Jr., “Introduction to Supply Chain Management”, Prentice Hall Inc. Englewood- Cliff, New Jersey., 1999
- Viswanadham N. and Narahari Y., “Performance Modeling of Automated Manufacturing Systems”, Prentice Hall of India, New Delhi., 1998
- Chopra S. and Meindel P., “Supply Chain Management: Strategy, Planning, and Operation”, Prentice Hall of India, New Delhi., 2002
- Shapiro J. F., Duxbury Thomson Learning, “Modeling the Supply Chain”, Duxbury Thomson Learning Inc., Duxbury, Pacific Grove. , 2001
- Levi D. S., Kaminsky P. and Levi E. S., “Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies”, McGraw Hill Inc. New York., 2000

MIN-586 Metal Forming Pre – requisite: **Nil**

Introduction: stress/strain, strain-rate characteristics of materials, yield criteria of metals, c1assification of metal working processes, formability and theory of sheet metal working, friction and lubrication in metal working operation, theories of friction and lubrication; assessment of friction at interface.

Process analysis: various methods of analyzing the metal working processes (slip-line field theory; upper bound solution; stab methods).

Mechanics of forming processes: rolling- determination of rolling pressure, roll separating force, driving torque and power, and power loss in bearings; forging- determination of forces in strip forging and disc forging; drawing- determination of force and power, determination of maximum allowable reduction; deep drawing force analysis, analysis of tube drawing process with fixed and moving mandrel, tandem tube drawing; bending- determination of work load and spring back; extrusion- determination of work load from stress analysis and energy consideration, power loss, hydrostatic extrusion; punching and blanking- mode of

metal deformation and failure, two-dimensional deformation model and fracture analysis, determination of working force.

Hydrostatic extrusion: comparison with conventional extrusion; pressure required to extrude, variables affecting the process.

High speed forming: classification, comparison of low and high speed forming operation problems in high speed forming operation, introduction to high forming process such as explosive forming, electrical and mechanical high speed forming techniques.

Suggested Books:

- Rowe, and Geoffrey W, "An Introduction to Principles of Metal Working", St. Martin Press., 1965
- Avitzur B., "Metal Forming Analysis", Mc Graw Hill., 1980
- Polukhin V.P., "Mathematical Simulation and Computer Analysis of Thin Strip Rolling Mill", MIR Publishers., 1975
- Jhonson W.and Meller P.B., "Plasticity of Mechanical Engineers", Van Nostrand., 1983
- "High Velocity Working of Metals", ASTME., 1964
- Ghosh A. and Mallik A. K., "Manufacturing Science", Affiliated East-West., 2000

MIN-587 Metal Casting Pre – requisite: **Nil**

Introduction: Features of casting problem, a survey and scope of foundry industry.

Solidification: Solidification of pure metals and al1oys, nucleation and growth in alloys, solidification of actual castings, progressive and directional solidification, centerline feeding resistance, rate of solidification, Chvorinov's Rule, electrical analog of solidification problem; Fluidity- measurement of fluidity, effects of various parameters on fluidity

Risering and Gating System: Riser design, risering curves, NRL method of riser design, feeding distance, risering of complex casting, risering of alloy other than steel, recent developments in riser design by the application of geometrical programming; Gating systems and their characteristics, the effects of gates on aspiration, turbulence and dross trap, recent trends.

Pattern and Casting Design: Pattern design, recent developments in pattern design, materials and construction; Casting design considerations- review of casting design, recent trends.

Melting, Molding and Core Making Processes: Selection and control of melting furnaces, boiling, refining and pouring, recent trends in cupola design; Review and critical comparison of various established processes, recent developments e.g. low pressure and ferrous die casting, high pressure molding, full mold process, flaskless molding, hot and cold box molding, ceramic shell molding, V-process, continuous casting, squeeze and pressed casting, Nishiyama process, Shaw process, Anitoch process etc.

Internal Stresses, Defects and Surface Finish: Residual stresses, hot tears and cracks in castings, stress relief, defects and their causes and remedies, various parameters affecting surface finish and related defects e.g. rough casting, sand bum-on sand bum-in and metal penetration, facing and washes, mold wall movement, vapor transpol1 zones, expansion scabbing etc; Gases in metal- methods of elimination and control of dissolved gases in castings.

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

Suggested Books:

- Flinn R.A., "Fundamentals of Metal Casting", Addison Wesley Inc., Reading., 1963
- Heine R.W, Loper C.R. and Rosenthal P.C., "Principles of Metal Casting", Tata McGraw-Hill., 1997
- Niebel B.W., and Draper A.B., "Modern Manufacturing Process Engineering", McGraw Hill., 1990
- "Metals Handbook-Metal Casting", ASM., 1985

- Beeley, Peter R. , “Foundry Technology”, Butterworth-Heinemann., 2001
- Jain, P. L., “Principles of Foundry Technology”, Tata Mc. Graw-Hill., 1999

MIN-588 Non-Traditional Machining Processes Pre – requisite:**Nil**

Introduction: Types of advanced manufacturing processes; Evolution, need, and classification of advanced machining processes (AMPs).

Mechanical Type AMPs: USM, Rotary Ultra Sonic Machining (RUM), AJM, WJM, AWJM processes - Processprinciple and mechanism of material removal; Process Parameters; Process Capabilities; Applications; Operational characteristics; Limitations.

Advanced Fine Finishing Process: Abrasive Flow Machining (AFM), Magnetic Abrasive Finishing (MAF), Magneto Rheological Abrasive Finishing (MRAF) - Process principle; Process equipment; Process Parameters; Process Capabilities; Applications; Limitations.

Chemical Type AMPs: Process principle and details of Chemical Machining (CHM), Photo-Chemical Machining (PCM), and Bio-Chemical Machining (BCM) processes.

Electro Chemical Type AMPs: ECM -Process principle; Mechanism of material removal; Process Parameters; Process Capabilities; Applications

Thermal Type AMPs: EDM, Wire Electro Discharge Machining (WEDM), LBM, EBM, IBM, PAM processes – Process principle and mechanism of material removal; Process parameters and characteristics; Surface finish and accuracy, Process Capabilities; Applications; Limitations.

Derived and Hybrid AMPs: Electro Stream Drilling (ESD), Shaped Tube Electro Machining (STEM), Electro Chemical Honing (ECH), Electro Chemical Deburring (ECDE), Electro Chemical Discharge Machining (ECDM) - Process Parameters; Process Capabilities; Applications; Limitations, Introduction to form machining.

Suggested Books:

- Pandey P. C., Shan H. S. "Modern Machining Processes", ,
- Tata McGraw-Hill Publishing Co. Ltd, New Delhi (ISBN 0-07-096553-6), 1977
- Ghosh A., Mallik A. K., "Manufacturing Science",
- Affiliated East-West Press Ltd, New Delhi, 1985
- Benedict G. F., "Nontraditional Manufacturing Processes",
- Marcel Dekker, Inc. New York (ISBN 0-8247-7352-7), 1987
- McGeough J. A.,"Advanced Method of Machining",
- Chapman and Hall, New York (ISBN 8842-0412-31170-5), 1988
- Mishra P. K., "Nonconventional Machining",
- Narosa Publishing House, New Delhi (ISBN 81-7319-138-7), 1997
- Jain V. K.,"Advanced Machining Processes",
- Allied Publishers, New Delhi (ISBN 81-7764-294-4), 2002
- “Machining Data Handbook: Vol. 2”, Machinability Data Center, (3rd edition), Metcut Research Associates Inc., Ohio, 1980

MIN-590 Theory of Arc Welding Processes Pre – requisite:**Nil**

Introduction: Brief history of welding, classification of welding processes, heat sources and shielding methods; Physics of welding arc, voltage distribution along the arc, thermionic and non-thermionic cathodes, arc characteristics and its relationship with power source, arc efficiency, heat generation, effect of shielding gases on arc, isotherms of arcs, arc blow.

Metal Transfer: Classification, forces acting on the drop, metal transfer mechanisms, transition current, melting rate, effect of polarity, deposition efficiency, current and voltage oscillograms, high speed films.

Welding Power Sources: Conventional welding power sources, constructional features, static and dynamic characteristics, duty cycle, influence of inductance on arc and power source characteristics, internal and external regulation, specific power source requirements, special welding power sources.

Gas Metal Arc Welding Processes: Consumable electrode welding processes. Manual metal arc (MMA) welding: type composition and functions of flux covering, ISI and other international codes for electrodes, concepts of special electrodes, consumables, arc length control in pulsed MIG welding, selection of parameters, self shielded and gas shielded flux cored wire welding.

Submerged Arc and Electroslag Welding: Specific features, process variables, types and composition of fluxes and their manufacturing, arc length control, significance of flux-metal combination; Electroslag welding- heat generation, principle, wire and consumable guide technique, selection of parameters, nature of fluxes.

Non Consumable Electrode Welding Processes: Gas tungsten arc welding, electrodes, compositions, shielding gases, arc ignition and maintenance, selection of polarity, arc voltage rectification and remedy, cathode spot and normal mode operations; Plasma arc welding: transferred and non-transferred plasma arc welding,selection of gases,welding parameters, keyhole technique.

List of Experiments

1. Effect of welding parameters in SMAW, GMAW and GTAW processes.
2. Comparison of rutile, basic and cellulosic electrodes in MMAW process.
3. Effect of shielding gases on performance of GMAW process.
4. Effect of welding fluxes in submerged arc welding process.
5. Study of optical profile gas cutting.

Suggested Books:

- Lancaster J. F., “The Metallurgy of Welding”, 6th Ed., William Andrew Publishing., 1999
- “Welding Handbook” Volumes 1, 2 & 3, 9th Ed., American Welding Society. , 2001
- “Metals Handbook”, Vol. 6, ASM International Publication. , 1993
- “Procedure Handbook of Arc Welding”, 14th Ed., Lincoln Electric Co. , 2004
- Larry J. and Jeffus L., “Welding Principles and Application”, 5th Ed., Delmer Publication. , 2002
- Messler R. W., “Principles of Welding (Processes, Physics, Chemistry and Metallurgy)”, John Wiley & Sons. , 1999

MIN–591 Inspection and Quality Control of Weldments Pre – requisite:**Nil**

Introduction: Types and purposes of weldment testing, important welding terms, symbols for welding and testing.

Weld Related Discontinuities: Classification of discontinuities in weldment, occurrence, causes and prevention of discontinuities, location, orientation and extent of discontinuities, method for testing weld and base metal imperfections.

Destructive Testing of Welds: Chemical tests, metallographic tests, hardness tests, mechanical test for groove and fillet welds-full section, reduced section and all-weld-metal tensile tests, root, face and side bend tests, fillet weld break tests, fillet weld shear strength test.

Non-Destructive Testing (NDT) of Weldments: Visual inspection, dye-penetrant inspection, magnetic particle inspection; Ultrasonic inspection-principle of ultrasonic testing, types of ultrasonic probes, standard blocks for calibration; Radiographic inspection – principle of radiography, X-ray tubes, gamma-ray sources, interpretation of radiographs, defect discernibility, neutron radiography; Eddy current inspection; Proof test, leak tests: NDT AWS (American Welding Society) standards, safety in NDT.

Inspection of Weldments: Duties and requirement of an inspector before, during and after welding, codes governing welding inspection, ASME (American Society of Mechanical Engineers) Code.

Welding Procedure and Performance Qualifications: Standard procedure for specification and qualification of welding procedure, operator qualification, standard method of recording of qualification tests, welding procedure specification (WPS), procedure qualification record (PQR) and Welding performance qualification (WPQ).

Suggested Books:

- "Welding Inspection", 3rd Ed., American Welding Society., 2000
- "Welding Hand Book", Vol. 5, 7th Ed., American Welding Society., 1984
- "ASME Code Section IX ", ASME., 1998
- "Structural Welding Code – Steel", AWS D1.1:2000 AWS, 2000
- "Specifications for Welding Procedure & Performance Qualification",
- ANSI /AWS B2.1:1998, 1998
- Jeffus, L., "Welding: Principles and Applications", 6th Ed., Delmar Cengage Learning., 2007

List of Experiments:

1. Visual inspection for weld quality
2. Dye-penetrant inspection of surface defects in welded joints
3. Magnetic particle inspection surface defects in welded joints
4. Ultrasonic inspection for assessing sub-surface defects
5. Radiographic inspection of weld joints

MIN–592 Design and Analysis of Welded Structures Pre – requisite:**Nil**

Introduction: Introduction to design, engineering properties of steels, weldability of structural steels, carbon equivalent, fatigue and creep properties of welded joints, theories of failures.

Weld Joints and Connections: Type of welds and weld joints, description of welds terminology, welding symbols, edge preparation, sizing of welds in structure, type of connections in welded structures, combined groove and fillet weld connections.

Design for Static Loading: Weld calculations for lap, butt and fillet welds, analysis of connections for direct tension or compression and shear loading conditions, resistance to moment by combined tension and compression.

Design for Fatigue loading: Introduction to Fatigue, mechanism of fatigue fracture, residual fatigue strength, factors affecting fatigue life, design of welded joints for fatigue loading, fatigue behaviour of hollow section joints,methods for improving the fatigue strength of welded joints, reliability analysis and safety factors applied to fatigue design with reference to fracture toughness.

Industrial Applications of Weld Design: Design of tubular structure, circular and rectangular hollow sections under static loading; Introduction to design of weld joint for pressure vessel -- cylindrical and head section; Weld design for automobile applications: chassis and body design; Design of brazed and soldered joints.

Heat flow and Residual Stresses in Welds: Heat flow in welding, effect of welding parameters on heat distribution, calculation of peak temperature, weld thermal cycle, cooling rate and solidification time, residual stress distribution, influence of residual stress in static and dynamic loading, introduction to stress corrosion.

List of Experiments:

1. Study the effect of type of welds on tensile properties of weld joint
2. Development of weld thermal cycle during arc welding
3. Measurement of residual stress in welded joints

4. Measurement of hardness, toughness and fracture toughness of welded joints
5. Study stress corrosion cracking behaviour of stainless steel joints

Suggested Books:

- Fuchs, H. O. and Stephen, R I., "Metal Fatigue in Engineering", John Wiley & Sons., 2000
- Gray, T. G. F. and Spence, J., "Rational Welding Design", Butterworths., 1992
- "Welding Hand Book", Vol. 2 & 3, 9th Ed., American Welding Society., 2001
- Dieter, G., "Mechanical Metallurgy", McGraw Hill., 1988
- Messler, R.W. Jr., "Principles of Welding", John Wiley & Sons., 1999

MIN-593 Non Conventional Welding Processes Pre-requisite**: Nil**

Resistance Welding: Principle of contact resistance; calculation of current, time and voltage for spot welding, choice of electrode material; electrode shapes; shunt current; shop tests for soundness of spot welds, seam, projection, butt and flash welding; selection of welding and other process details; stud welding; power sources for resistance welding**.**

High Power Density Welding Processes: Electron Beam (EB) welding in different degrees of vacuum, applications; Laser welding; principle of operation; laser materials, applications.

Solid State Welding Processes: Fundamental principles of various non- conventional pressure welding processes and their applications; friction, explosive, diffusion and ultrasonic welding; induction welding.

Special Topics: Soldering; brazing and braze welding; welding of plastics.

Cutting and Surfacing: Plasma and thermal cutting and surfacing operations; parameters; consumables and equipment; arc and gas gouging.

Safety Measures in Welding: Various safety measures for conventional and non-conventional welding processes. Gas cylinder colour codes; storage and transportation of gases; protection from fire and explosions. Protection against electric shocks and short circuiting; chemistry and mechanism of formation of fumes; effect of fumes; radiations and noise on welder's health; eye flash, skin burn, heat exhaustion and other diseases; protective devices such as exhaust hoods, booths, shields, goggles, screens, clothing and ear covers; safety during welding in confined spaces.

Suggested Books:

- "Welding Handbook", Vol. 2 & 3, 9 th Edition, American Welding Society., 2003
- "Metals Handbook", Vol. 6, American Society of Metals., 1993
- "Procedure Handbook of Arc Welding", Lincoln Electric Co., USA., 2004
- Tylecote R.F., "The Solid phase welding of Metals", Edward Arnold Pub. Ltd., 1968
- Richard Little L., "Welding and Welding Technology", McGraw Hill. , 1976

MIN-594 Safety Aspect of Welded Structures Pre – requisite: **Nil**

Basis of Safety Concept: Definition of safety and definition of safety concept; Basic mechanism of failure of components; Brittle and ductile fracture; Collapse fatigue fracture mechanism and representations at sub-microscopic and macroscopic levels through Mohr's Circle; Specific problems of safety related to weldments; Definition and safety relevance of weld imperfections.

Conventional Methods for Safety Analysis: Concepts of strength and toughness of engineering materials; Determination and consequences of stress and strain state; Material - stress and strain state embitterment, their reasons and consequences; Effects of notches, stress state in notched component, safety analysis and assessment of notched components using notch theory; Semi quantitative Fracture Analysis Diagrams (Pellim's FAD); limitations of conventional methods.

Fracture Mechanics: Concepts of stress-strain state of cracked components; Introduction and basic principles of fracture mechanics; Linear Elastic Fracture Mechanics (LEFM); Stress intensity factor; Determination of fracture toughness.

Methods for Safety Analysis: ASTME:399 method; Limitations of LEFM; Modified LEFM (ASTME 1820); General yielding criterion; Plastic Limit Load Calculations (PLLC); Principles of Two Criteria Approach (TCA); Failure assessment diagram (CEGB Report R-6); Mechanism of cyclic crack growth; Paris law; Modifications of Paris law; Effects of temperature and environment; Elastic plastic fracture mechanics (EPFM); Stable crack growth; COD concept (CTOD BS: 5762); R-curve technique; Instability diagram.

Application of Safety Concepts to Welded Structures: Material imperfections and stress states in weldments; Quality - degradation in welded structures; CODE requirements; Case studies as examples of failures; Design and service requirements for engineering structures fabricated by welding i.e. welded structures.

Suggested Books:

- Anderson T. L., "Fracture Mechanics: Fundamentals and Applications", 3rd Edition, Taylor & Francis Group. , 2000
- Farahmand Bahram.,"Fracture Mechanics of Metals, Composites, Welds and Bolted Joints", Hardcover, Kluwer Academic Publishers ., 2000
- Broek D., "Elementary Engineering Fracture Mechanics", Martinus Nijhoff., 1982
- Latzko D.G.H, "Post Yield Fracture Mechanics", 2nd Edition, Elsevier Applied Science Publication., 1984
- Maddox S.J., "Fatigue of Welded Structures", 2nd Edition, Woodhead Publishing., 1991
- Gurney T.R.,"Fatigue of Welded Structures", Cambridge University Press., 1979
- Chell G.G.,"Development of fracture Mechanics", Elsevier Applied Science Publication., 1979

MIN-595 Failure Analysis of Welding Joints Pre-requisite**: Nil**

Fundamental Sources of Failure: Deficiencies in design, material and processing errors, improper service condition, residual stresses

Tools for failure analysis: Fault tree diagram, Failure mode and effective analysis, Weibull distribution, Pareto diagram

General Practice in Failure Analysis: Objective, collection of background data, selection of samples; Selection, cleaning and preservation of fractured surface, identification of mode of failure, approach for failure analysis, ascertaining causes of failure, reporting practice.

Examination of Fractured Components: Preliminary examination of fractured surface, equipment used for preliminary examination, preservation of failure records, Identification of Mode of Failure: Classification, specific characteristics, distinction between different type of fractures, factors affecting mode of fracture and defects.

Analysis of the Causes of Failure: Chemical analysis, optical microscopic examination, use of scanning electron microscope, micro probe analyser and X-ray diffraction etc. Correlation of weldment failure of different materials developed using various welding processes including repair welding.

Application of Fracture Mechanics in Failure Analysis: Physical meaning of K_{Ic}, J_{IC} and CTOD with reference to fracture control, fracture analysis in the light of fatigue crack growth rate behaviour of material, residual life assessment . Case studies of failure in different components such as pressure vessel and nuclear reactor.

Suggested Books:

- Becker, W. T. and Shipley, R. J. "Metals Handbook, Failure Analysis and Prevention", Volume 11, ASM International., 2002

- Hutchings, F. R. and Unterweiser, Paul M., "Failure Analysis, The British Engineering Technical Report", ASM International., 1981
- Robert H. and Bhadeshia H. H.K.D.H. "Steels: Microstructure and Properties", 3rd Edition, Butterworth-Heinemann., 1995
- "Metals Handbook, Fractography", Volume 12, ASM International., 1992
- Das A. K., "Metallurgy of Failure Analysis", Special Indian Edition, Tata McGraw- Hill., 1997
- Besterfield, D C and Besterfield C (1999), Total Quality Management, Pearson Education Asia,, 2002
- Andrew K. S. and Albert H. C. Tsang, "Maintenance, replacement, and Reliability", Taylor & Francis., 2006
- Dhillon B.S., "Engineering Maintenance: a Modern Approach". 1st Edition, CRC., 2002

MIN-596 Solid State Joining Processes Pre-requisite**: Nil**

Joining defined; Fundamental forces involved in joining; Mechanical fastening and integral attachment: using mechanical forces; Adhesive bonding: using chemical forces; Welding: using physical forces; Overview of fusion and solid state welds; Fundamental principles of solid state welding processes; Classification of solid state/non-fusion welding processes.

Adhesive bonding as a joining process; General description of adhesive bonding; Cementing and mortaring as an adhesive joining process; The functions of adhesives; Mechanisms of adhesion; Failure in adhesive-bonded joints; Adhesive joint designs; Design criteria and analysis of adhesive joints.

Friction welding process; application of friction welding process; friction welding process parameters; radial and orbital friction welding; direct drive and inertia drive friction welding; study of friction welds; joint quality of friction welds.

Overview of friction stir welding (FSW) process principles; welding tools used for FSW; Parameters' effects; Materials used with FSW; thermomechanical aspect of FSW; Plastic deformation in relation to material properties; Material flow and property relationships of the resultant FSW joint, friction stir processing (FSP), process parameters of FSP; Application of FSW and FSP processes.

Diffusion joining processes: conventional diffusion, deformation diffusion, resistance diffusion & continuous seam diffusion welding; diffusion brazing; braze welding, combined forming and diffusion welding; solid-state deposition welding processes. Pressure non-fusion welding processes: cold welding processes, pressure gas welding process, forge welding process; Roll welding; Explosion welding process.

Suggested Books:

- Messler Robert W. Jr., "Joining of Materials and Structures"Elsevier Butterworth–Heinemann., 2004
- Messler Robert W. Jr., "Principles of welding"WILEY-VCHVerlag GmbH & Co. KGaA**,** Weinheim., 2004
- "Friction stir welding From basics to applications" Edited by Daniela Lohwasser and Zhan Chen,Woodhead Publishing India Pvt. Ltd., 2010
- "Welding Handbook", Vol. 2 & 3, 9thEdition, American Welding Society., 2003
- Richard Little L., "Welding and Welding Technology", McGraw Hill. , 1976
- TylecoteR.F., "The Solid phase welding of Metals", Edward Arnold Pub. Ltd., 1968

MIN-597 Welding Procedure for Specific Applications Pre-requisite: **Nil**

Introduction and Economic Consideration: Groove geometry and weld metal deposition rates for different welding processes; Welding cost estimation; Standard data for cost estimation; Comparative cost study for various welding procedures.

Welding of Offshore Constructions: Requirement of offshore construction welding; Problems in underwater welding; Various underwater welding techniques.

Welding of Low Temperature Containment Plants: Materials used for cryogenic applications; Problems of welding; Welding processes and procedures used for cryogenic materials.

Welding of Pressure Vessels: Materials used for construction of pressure vessels; Processes and procedures for pressure vessels welding; Requirement of various codes.

Repairing of Castings: Specific problems in repairing of castings of various materials; Welding methods used for repairing and reclamation.

Micro joining Techniques: Various techniques used for joining of electronic circuitry and other micro joining applications.

Corrosion in Weldments: Various types of corrosion; Factors affecting corrosion; Minimization of susceptibility to corrosion; Corrosion testingand stress corrosion cracking.

Suggested Books:

- Peter Thomas, "Welding Process Technology", Houldcroft Technology., 1977
- "Developments in Micro joining", TWI, Abbington, Cambridge U.K, 1983
- "Welding Hand Book" Vol. 3 and 4, 9th Edition., AWS, 2001
- "Rules for Construction of Pressure Vessels", ASME, 1977
- Yahalom J. and Aladjan A., "Stress corrosion Cracking", SN Publishers, 1980
- Nixon, J.H.,"Underwater Repair Technology", Gulf Professional Publishing , 2000

MIN-598 Weldability of Metals Pre-requisite:**Nil**

Fundamentals: Weldability, definitions, factor affecting the weldability of steel Carbon equivalent, solidification of weld metal; heat affected zone (HAZ), factors affecting properties of HAZ, gas-metal, slag-metal and solid state reactions in welding and their influence on soundness of weld joint, common metal system and their weldability: work hardenable, precipitation hardenable and heat treatable alloys

Weldability of Plain Carbon Steels: Various grade of plain-C steels, factors affecting Weldability, viz., Carbon content, section thickness, Mn/S ratio, phosphorus concentration, microstructure of weld and HAZ, cold cracking and lamellar, tearing gas porosity, mechanism, causes and prevention of defects in plain –C steel welds,

Weldability of Stainless and Heat Resisting Steels: properties of stainless steels affecting weldability, common types of stainless steel austenitic, martensitic, ferritic and PH steel and their weldability, problems in welding of stainless steel and their remedy, weld decay, sigma phase formation, knife line cracking, stress corrosion cracking.

Weldability of HSLA Steels: Common grades of high strength low alloy (HSLA) steels, effect of various alloying elements on weldability, factors affecting weld-metal and HAZ Properties, problems and defects encountered in welding, post weld heat treatment of HSLA steels

Weldability of Cast Irons: Common grades of cast irons, carbon equivalent in cast irons, factors affecting weldability of cast irons, approaches for welding of cast irons common problems encountered during the welding of cast and their remedy.

Weldability of Aluminium Alloys: Physical metallurgy of heat treatable and work hardenable aluminium alloys, properties of aluminium alloys and weldability, solidification cracking, hydrogen induced porosity, partial melting zone and liquation cracking, HAZ softening, precautions in the welding of age hardenable alloy.

Weldability of Copper Alloys: Common copper alloys, properties of copper alloys and weldability, effect of various alloying element of weldability, problem in welding of heat treatable and none-heat treatable copper alloys and their remedy.

Suggested Books:

- Lancaster J F., “Metallurgy of Welding”, Allen & Unwin Co., 2000
- Castro R. and Cadenet J. J. de., “Welding Metallurgy of Stainless and heat-resisting steels”, Cambridge Uni. Press., 1975
- “Welding, Brazing and soldering”, Vol. 6, ASM International, ASM, Ohio., 1993
- Kou S., Welding metallurgy, 2nd edition, Wiley Publications , 2003
- Hrivnák, I., “Theory of Weldability of Metals and Alloys”, Elsevier Science , 1991
- Gene Mathers, “Welding of Aluminium and alloys”, Wood Head Pub. UK., 2002

MIN – 599 Surface Engineering Pre – requisite: **Nil**

Introduction: Concept and Importance, classification of surface modification techniques, advantages and their limitations.

Surface Degradation: Causes, types and consequences of surface degradation, Forms of wear – adhesive, abrasive, surface fatigue, corrosive, fretting and erosive wear, Classical governing laws related to wear, techniques to evaluate the wear damage.

Materials for Surface Engineering: Materials characteristics, their importance in surface engineering, wear resistant materials, selection of materials for engineering the surfaces for specific applications, New coating concepts including multi-layer structures, functionally gradient materials (FGMs), intermetallic barrier coatings and thermal barrier coating.

Coating based Surface Modification Techniques: Principles and application of weld surfacing: SMAW, SAW, GMAW, Thermal spraying – flame spraying, electric arc spraying, plasma spraying, detonation gun spraying and high velocity oxy fuel spraying Electro deposition and electro less coatings.

Diffusion based Surface Modification Techniques: Ion implantation, chemical vapour deposition (CVD) and physical vapour deposition (PVD), carburizing, nitriding, plasma nitriding, cyaniding.

Irradiation based and Laser Assisted Surface Engineering (LASE) Techniques: Laser cladding, alloying, glazing, laser and induction hardening, heat treatment of steel and remelting by laser / TIG. Microwave glazing.

Characterisation and Quality Assurance of Engineered Surfaces: Importance, Different characterisation techniques – physical, mechanical and functional characterisations, surface finish, microhardness, strength and tribological characterisations.

Suggested Books:

- Burakowski T. and Wierzchoń T., “Surface Engineering of Metals: Principles, Equipment, Technologies”, CRC Press, Boca Raton, Florida., 1999
- Burnell-Gray J.S. and Datta P.K. (eds.), “Surface Engineering Casebook”, Woodhead Publishing Limited, Cambridge, England., 1996
- Grainger, S. and Blunt J. (eds.), “Engineering coatings - design and application”, Abington Publishing, Cambridge, England. , 1998
- Rickerby D. S. and Matthews A. (eds), “Advanced Surface Coatings: a Handbook of Surface Engineering”, Blackie, London. , 1991
- Holmberg K. and Matthews A., “Coatings Tribology: Properties, Techniques and Applications in Surface Engineering”, Elsevier Science B.V., Amsterdam., 1994