TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

3rd Semester

S No	Course Code	Course Title	Periods			Credits	Pre-requisite
			L	T	P/D		
1.	IP-201	Machine Drawing	1	0	6	4	ME-101 Engineering Graphics
2.	IP-203	Strength of Materials	3	1	0	4	
3.	IP-205	Theory of Machines	3	0	2*	4	
4.	IP-207	Applied Thermodynamics	3	1	0	4	ME-102 Elements of Mech. Engineering
5.	MA-203	Probability & Statistics	3	1	0	4	
6.	PH-201	Material Science and Technology	3	0	0	3	
Laboratories							
7.	IP-211	Applied Thermodynamics Laboratory	0	0	2	1	
8.	IP- 213	Strength of Materials Laboratory	0	0	2	1	
TOTAL			16	3	12	25	

*****Practice Session------ Evaluation for practice session: 15 marks for regular evaluation+15 marks for end semester viva voce (In addition to 100 marks for three credits)

4th Semester

S No	Course Code	Course Title	Periods			Credits	Pre-requisite
			L	T	P		
1.	IP-202	Mechanical Measurements and Metrology	3	1	0	4	
2.	IP-204	Metallurgy and Heat Treatment	3	0	0	3	IP-101 Manufacturing Processes
3.	IP-206	Production Planning and Control	3	1	0	4	
4.	IP-208	Design of Machine Elements	3	0	2*	4	IP-203 S.O.M, IP-201 Machine Drawing
5.	IP-210	Casting, Forming & Welding	3	0	0	3	IP-101 Manufacturing Processes
6.	IP-212	Networks & Project Management	3	1	0	4	MA-203 Probability and Statistics
*****Practice Session------ Evaluation for practice session: 15 marks for regular evaluation+15 marks for end semester viva voce (In addition to 100 marks for three credits)							
Laboratories							
7.	IP-214	Mechanical Measurements and Metrology Laboratory	0	0	2	1	
8.	IP-216	Metallurgy and Heat Treatment Laboratory	0	0	2	1	
9.	IP-218	Casting, Forming & Welding	0	0	2	1	
TOTAL			18	3	8	25	

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

5th Semester

S. NO.	Course Code.	SUBJECT	PERIODS			CREDITS	PRE-REQUISITE
			L	T	P		
1	IP-301	Industrial Automation	3	0	0	3	
2	IP-303	Machine Tool and Machining	3	1	0	4	IP-101 Manufacturing Processes
3	IP-305	Work Study and Ergonomics	3	0	0	3	
4	IP-309	Industrial Quality Control	3	0	2*	4	MA-203 Probability and Statistics
5	--	ID-1	3	0	0	3	
6	--	Departmental Elective-1	3	0	0	3	
*Practice Session------ Evaluation for practice session: 15 marks for regular evaluation+15 marks for end semester viva voce (In addition to 100 marks for three credits)							
Laboratories							
1	IP-313	Machine Tool and Machining Lab.	0	0	2	1	
2	IP-315	Work Study and Ergonomics Lab.	0	0	2	1	
TOTAL			18	1	6	22	

6th Semester

S. NO.	Course Code	SUBJECT	PERIODS			CREDITS	PRE-REQUISITE
			L	T	P		
1	IP-302	Robotics	3	0	0	3	
2	IP-304	Operations Research	3	0	0	3	MA-203 Probability and Statistics
3	IP-306	Facilities Planning	3	1	0	4	IP-206 Production Planning and Control
4	--	Departmental Elective-2	3	0	0	3	
5	--	Departmental Elective-3	3	0	0	3	
6	--	ID – 2	3	0	0	3	
Laboratories							
1	IP-312	Industrial Automation & Robotics Lab.	0	0	2	1	
2	IP-314	Operations Research Laboratory	0	0	2	1	
TOTAL			18	1	4	21	

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

7th Semester

S. NO.	Course Code	SUBJECT	PERIODS			CREDITS	PRE-REQUISITE
			L	T	P		
1	IP-401	CAD/ CAM	3	0	0	3	IP-101 Manufacturing Processes, IP-301 Industrial Automation
2	IP-403	Jigs, Fixture and Tool Design	3	0	2*	4	IP-101 Manufacturing Processes, IP-201 Machine Drawing
3	IP-405	Materials Management	3	1	0	4	--
4	--	ID-3	3	0	0	3	--
5	--	Departmental Elective-4	3	0	0	3	--
Laboratories							
6	IP-411	CAD/ CAM	0	0	2	1	
7	IP-413	Practical Training				4**	
8	IP-400	Project (Phase-1)				2	
TOTAL			15	1	04	24	

*****Practice Session------ Evaluation for practice session: 15 marks for regular evaluation+15 marks for end semester viva voce (In addition to 100 marks for three credits)

** Industrial Practical Training will be held during summer vacation after sixth semester

8th Semester

S. NO.	Course Code	SUBJECT	PERIODS			CREDITS	PRE-REQUISITE
			L	T	P		
1	--	ID -4	3	0	0	3	--
2	IP-402	Management Information Systems	2	0	2*	3	CS-101 Computer Programming
3	IP-404	Maintenance and Reliability Engineering	3	1	0	4	MA-203 Probability and Statistics
4	--	Departmental Elective-5	3	0	0	3	--
5	--	Departmental Elective-6	3	0	0	3	
6	--	Departmental Elective- 7	3	0	0	3	---
7	IP-400	Project (Phase-2)				4	--
TOTAL			17	1	02	23	

*****Practice Session------ Evaluation for practice session: 25 marks for regular evaluation+25 marks for end semester viva voce (In addition to 100 marks for two credits)

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

List of Departmental Elective Courses

Sr. No.	Course Code	Course Title	L	T	P	C	Pre-requisite, if any
1.	IP -321	Occupational Health & Safety	3	0	0	3	-
2.	IP-322	Engineering Economics and Industrial Design	3	0	0	3	-
3.	IP-323	Plastics Engineering	3	0	0	3	-
4.	IP-324	Fracture Mechanics	3	0	0	3	IP-203 Strength of Materials
5.	IP-325	Productivity Engineering and Technology Management	3	0	0	3	-
6.	IP-326	Environmental Planning and Control	3	0	0	3	-
7.	IP-327	Composite Materials	3	0	0	3	-
8.	IP-328	Change Management for Competitiveness	3	0	0	3	-
9.	IP-329	Smart Materials & Nano Technology	3	0	0	3	-
10.	IP-330	Advanced Industrial Inspection and Non-destructive Testing	3	0	0	3	-
11.	IP-331	Mechatronics	3	0	0	3	-
12.	IP-332	Simulation and Modeling	3	0	0	3	MA-203 Probability & Statistics
13.	IP-423	Marketing and Financial Management	3	0	0	3	-
14.	IP-424	Industrial Instrumentation & Control	3	0	0	3	IP-202 Mechanical Measurements & Metrology
15.	IP-425	Finite Element Analysis	3	0	0	3	-
16.	IP-426	Geometrical Modeling for Manufacturing	3	0	0	3	-
17.	IP-427	Automobile Engineering	3	0	0	3	IP-205 Theory of Machines
18.	IP-428	Logistics and Supply Chain Management	3	0	0	3	-
19.	IP-429	Emerging Trends in Manufacturing Technology	3	0	0	3	-
20.	IP-430	T.Q.M. & Value Engineering	3	0	0	3	-
21.	IP-431	Computer Integrated Manufacturing	3	0	0	3	-
22.	IP-432	Advanced Operations Research	3	0	0	3	IP-304 Operations Research
23.	IP-433	Finite Element Plasticity & Metal Forming Analysis	3	0	0	3	-
24.	IP-434	Vibration & Noise Control	3	0	0	3	-
25.	IP -435	Flexible Manufacturing Systems	3	0	0	3	-
26.	IP-436	Design for Manufacturing and Assembly	3	0	0	3	IP-208 Design of Machine Elements

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

List of Interdisciplinary Courses

Sr. No.	Course Code	Course Title	L	T	P	C	Pre-requisite, if any
1.	IP-01	Industrial Engineering	3	0	0	3	-
2.	IP-428	Logistics and Supply Chain Management	3	0	0	3	-
3.	IP-02	Quality Management	3	0	0	3	-
4.	IP-429	Emerging Trends in Manufacturing Technology	3	0	0	3	-
5.	IP-329	Smart Materials & Nano Technology	3	0	0	3	-
6.	IP-202	Mechanical Measurements and Metrology	3	0	0	3	-
7.	IP-431	Computer Integrated Manufacturing	3	0	0	3	-
8.	IP-306	Materials Management	3	0	0	3	-
9.	IP-321	Occupational Health & Safety	3	0	0	3	-
10.	IP-304	Operations Research	3	0	0	3	-
11.	IP-212	Networks and Project Management	3	0	0	3	-

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

Syllabi for Third Semester Courses

IP–201 Machine Drawing [1 0 6 4]

Section A

Review of Principle of orthographic projections, symbols of standard tolerances machining symbols, sectioning and conventional representation, dimensioning, various types of screw fasteners.
Assembly and disassembly of the following:
Coupling: Pin type, flexible coupling, cone friction clutch
Pipe and pipe fittings

Section B

Boiler Mountings: Steam stop valve, feed check valve, Ramsbottom safety valve, blow off cock.
Bearings: Swivel bearing, thrust bearing, plumber block
Machine Tool Parts: Lathe tail stock, tool post

Section C

Miscellaneous: Screw jack, drill press vice, connecting rod, eccentric
CAD Practices: use of various application software like AutoCAD, 3D- studio etc. for drawing of the above machine components.
NOTE: First angle projection to be used. Drawings should contain bill of materials and should illustrate surface finish. The syllabus given above indicates the broad outlines and the scope of the subject to be covered.

Books Recommended

1. Narayanan Lakshmi and Mathur, "*Text-book of Machine Drawing*"
2. Gill P S, "*Machine Drawing*", S K Kataria and Sons, N. Delhi
3. Bhatt N D, "*Machine Drawing*"
4. Sidheshwar N, "*Machine Drawing*", Tata McGraw Hill Co.,New Delhi
5. Tanta C L, "*Mechanical Drawing*" Dhanpat Rai and Sons, N.Delhi

Based on the syllabus a number of sheets will be prepared by the students in practical classes as listed below:

Sheet No.1 : Types of lines, Conventional Representation for materials,
Assignment No.1 : Sectioning Practice on sketch book.
Sheet No. 2 :Various types of machine Components for sectioning.
Assignment No.2 : Tolerances, Limits and Fits, Practice on Sketchbook.
Assignment No.3 : Machining Symbols – Surface Texture and its importance.
Assignment No.4 : Screw threads practice on sketchbook.
Sheet No. 3 : Various Types of Nuts, Bolts, Studs and Setscrews etc.
Sheet No. 4 : Foundation bolts.
Assignment No. 5 : Coupling, its types and applications.
Sheet No. 5 : Pin type flexible coupling and cone friction clutch.
Sheet No. 6 : Assembly of various pipe joints and fittings.
Sheet No. 7 : Assembly of Screw Jack.
Sheet No. 8 : Assembly of Drill press vice.
Sheet No. 9 : Assembly of Steam stop valve.
Sheet No. 10 : Assembly of feed check valve.
Sheet No. 11 : Assembly of safety valve.
Sheet No. 12 : Assembly of Blow of cock.
Sheet No. 13 : Assembly of Tail Stock.
Sheet No. 14 : Assembly of Tool Post.
Sheet No. 15 : Assembly of Thrust bearing and Plummer block.
Assignment No. 6 : Sketch of Swivel bearing on the sketch book.
Sheet No. 16 : Assembly of connecting Rod and eccentric.
Assignment No. 7 : Drawing of machine parts using application softwares

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

IP-203 Strength of Materials [3 1 0 4]

Section A

Simple stresses and strains: Concept of stress and strain: St. Venants principle of stress and strain diagram, Hooke's law, Young's modulus, Poisson ratio, stress at a point, stresses and strains in bars subjected to axial loading, Modulus of elasticity, stress produced in compound bars subjected to axial loading, Temperature stress and strain calculations due to applications of axial loads and variation of temperature in single and compound walls.

Compound stresses and strains: Two dimensional system, stress at a point on a plane, principal stresses and principal planes, Mohr's circle of stress, ellipse of stress and their applications, Two dimensional stress-strain system, principal strains and principal axis of strain, circle of strain and ellipse of strain, Relationship between elastic constants.

Bending moment and shear force diagrams: Bending moment and shear force diagrams, S F and B M definitions. BM and SF diagrams for cantilevers, Simply supported and fixed beams with or without overhangs and calculation of maximum BM and SF and the point of contraflexure under Concentrated loads, Uniformity distributed loads over the whole span or part of span, combination of concentrated loads (two or three) and uniformly distributed loads, uniformly varying loads, application of moments.

Section B

Theory of bending stresses: Assumptions in the simple bending theory, derivation of formula: its application to beams of rectangular, circular and channel sections, composite/fletched beams, bending and shear stresses in composite beams.

Torsion: Derivation of torsion equation and its assumptions. Applications of the equation of the hollow and solid circular shafts, torsional rigidity, combined torsion and bending of circular shafts, principal stress and maximum shear stresses under combined loading of bending and torsion, analysis of close-coiled-helical springs.

Thin cylinders and spheres: Derivation of formulae and calculations of hoop stress longitudinal stress in a cylinder, and sphere subjected to internal pressures increase in Diameter and volume.

Section C

Columns and struts: Columns under uni-axial load, Buckling of Columns, Slenderness ratio and conditions. Derivations of Euler's formula for elastic buckling load, equivalent length, Rankine Gordon's empirical formula.

Strain energy: Energy of dilation and distortion, resilience stress due to suddenly applied loads, Castigliano's theorem, Maxwell's theorem of reciprocal deflection.

Theories of Failure: Maximum principal stress theory, maximum shear stress theory, maximum strain energy theory, maximum shear strain energy theory, graphical representation and derivation of equation for each and their application to problems relating to two dimensional stress systems only.

Books Recommended

1. Pytel A H and Singer F L, *"Strength of Materials",* 4th Edition, Harper Collins, New Delhi (1987).
2. Beer P F and Johnston (Jr) E R, *"Mechanics of Materials",* SI Version, Tata McGraw Hill, India (2001).
3. Popov E P, *"Engineering Mechanics of Solids",* SI Version 2nd Edition, Prentice Hall of India, New Delhi (2003).
4. Timoshenko S P and Young D H, *"Elements of Strength of Materials",* 5th Edition, East West Press, New Dlehi (1984).
5. Jindal U C, *"Introduction to Strength of Materials",* 3rd Edition, Galgotia Publishing Private Limited New Delhi (2001).

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

IP-205 Theory of Machines [3 0 2* 4]

Section A

Basic Concepts: Kinematics of machine, Kinematic link and their different types, types of kinematic pair, kinematic chain, mechanism and inversions of four bar chain and slider crank mechanism. Degree of freedom, synthesis of linkages – number synthesis, Grashof's criterion and introduction to dimensional synthesis.

Velocity Analysis: Motion of a link, velocity of a point on a link by relative velocity method, velocities of slider crank mechanisms, rubbing velocity at a pin joint, velocity of a point on a link by instantaneous center method, properties and types of I-Center, Kennedy theorem and methods of locating I-centers in a mechanism.

Acceleration Analysis: Acceleration of a point on a link, acceleration in slider crank mechanism, Coriolis component of acceleration, Quick-return mechanism.

Cams and Follower: Types of cams and followers, cam terminology, types of motion of the follower, analysis of motion of the follower, analysis of motion of the follower for cams with specified contours.

Section B

Gears: Classification of gears, terminology used in gears, law of gearing, velocity of sliding, forms of teeth, construction and properties of an involute, construction and properties of cycloidal teeth, effect of variation of center distance on the velocity ratio of involute profile tooth gears, length of path of contact, arc of contact, number of pairs of teeth in contact, interference, minimum number of teeth, interference between rack and pinion, undercutting, terminology of helical and worm gears.

Gear Trains: Definition of simple, compound, reverted and epicyclic gear trains, velocity ratio of epicyclic gear trains.

Belt, Rope and Chain Drive: Types of belt drives, velocity ratio, law of belting, length of belt, ratio of friction tensions, power transmitted, effect of centrifugal tension on power transmission, condition for maximum power transmission, concept of slip and creep. Chain drive, chain length and angular speed ratio.

Section C

Brakes and Dynamometers: Types of brakes, principle and function of various types of brakes, problems to determine braking capacity, different types of dynamometers.

Governors: Different types of centrifugal and inertia governors: hunting, isochronism, stability, effort and power of governor, controlling force.

Balancing: Static and dynamic balancing, balancing of several masses in different planes.

*** Practice Session**

In addition to the tutorials several studies related to mechanism, mechanism trains (Lathe, Milling Machines, and Shaper), automobiles mechanisms, automobile gearbox, differential mechanisms will be performed by the students.

Balancing of rotating masses, characteristics of governors, cam and cam profile experiments will be demonstrated during the Practice Session.

Books Recommended

1. Bevan T, "*The Theory of Machines",* 3rd Edition CBS Publishers and Distributors (2002).
2. Shigley J E and Vickar J J, *"Theory of Machines and Mechanism"*, 2nd Edition, McGraw Hill, New Delhi (1995).
3. Wilson C and Sadler J, *"Kinematics and Dynamics of Machine"*, 3rd Edition, Prentice Hall (2002).
4. Ratan S S, *"Theory of Machines",* 1st Edition, Tata McGraw Hill, New Delhi (1993).
5. Rao J S and Dukkipati R V, *"Mechanism and Machine Theory",* 2nd Edition, New Age International (P) Limited, Delhi (1992).

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

IP-207 Applied Thermodynamics [3 1 0 4]

Section A

Steam Generators: Review of steam generation process. Classification, Fire and water tube boilers, Description of Cochran, Locomotive, Lancashire Babcock and Wilcox boilers and Sterling Boiler, mountings and accessories: Economizer, super heater etc. Modern high pressure boilers, Characteristics of high pressure boilers, Advantages of forced circulation, steam accumulators, boiler performance, equivalent evaporation, boiler efficiency, Boiler Trial.

Steam Engine: Classification and working of steam engine, Simple Rankine cycle, methods of improving efficiency: Feed water heating (Bleeding), reheat cycle, combined reheat and regenerative cycle, Ideal working fluid – Binary vapour cycle, combined power and heating cycles.

Nozzle: Types of nozzles and their utility, Flow of steam through nozzles, Critical pressure and discharge, Area of throat and exit for maximum discharge, Effect of friction on Nozzle efficiency, Supersaturated flow.

Section B

Impulse Turbines: Steam turbines, description of components and advantages, Pressure and velocity compounding, Velocity diagram and work done, Effect of blade friction on velocity diagram, Stage efficiency and overall efficiency, Reheat factor and condition curve.

Reaction Turbine: Degree of reaction, velocity diagrams, blade efficiency and its derivation; calculation of blade height, backpressure and extraction turbines and cogeneration; Economic assessment.

Method of attachment of blades to turbine rotor, losses in steam turbines, Governing of steam turbines, Labyrinth packing.

Condensers: Function, Elements of condensing plant, types of condensers, Dalton's law of partial pressure applied to condenser problems, condenser and vacuum efficiencies. Cooling water calculations. Effect of air leakage, Methods to check and prevent air infiltration. Description of air pump and calculation of its capacity.

Section C

Reciprocating Air Compressors: Use of compressed air in industry. Classification of air compressors, Operation of single stage reciprocating compressors, Work input and the best value of index of compression. Isothermal and polytropic efficiency. Effect of clearance and volumetric efficiency, multistage compression and its advantages. Optimal multi-staging, work input in multistage compression, Reciprocating air motors.

I. C. Engines: Classification, Construction and working of 2 and 4- stroke SI and CI engines and their valve timing diagram, Combustion process in SI and CI engines, Performance of engines.

Books Recommended

1. Rogers and Mayhew, *"Engineering Thermodynamics",* Pearson Education New Delhi (1980).
2. Keartan W J, *"Steam Turbine Theory",* ELBS Series, London (1958).
3. Joel R, *"Basic Engineering Thermodynamics",* Addison Wesley Longman, New Delhi (1999).
4. Kostyuk A and Fralov V, *"Steam and Gas Turbines",* Mir Publishers, Moscow (1988).
5. Lee J F, *"Theory and Design of Steam and Gas Turbines",* McGraw Hill, New York (1954).

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

MA-203 Probability and Statistics [3 1 0 4]

Section A

Concept of statistics, collection and representation of data, frequency distribution, graphical representation of data, measure of central tendency and dispersion, coefficient of dispersion, moments, factorial moments, skewness and kurtosis.

Different approaches to probability, addition and multiplication theorem of probability, Boole's inequality, conditional probability, Bayes theorem and applications, Moment generating functions

Section B

Random variables – discrete and continuous, distribution function, probability mass function, probability density function, two dimensional random variables, mathematical expectation, expectation of discrete and continuous random variables, properties of expectation, conditional expectation.

Discrete and Continuous Probability Distribution: Binomial, Poisson, Normal, Exponential.

Section C

Correlation analysis, Regression analysis, Curve fitting using least square method.

Sampling and sampling distribution: chi-square, student-t and F-test.

Books recommended:

1. Bhattacharya G.K. and Johnson R.A.: Statistical Concepts and Methods, John Wiley, New Delhi, 2002.

2. Hogg R. V. And Elliot A.T," Probability and Statistical Inference", Pearson Education, 6th Edition.

3. Hogg R V, Craig A T ,"Introduction to Mathematical Statistics", Siixth Edition, Pearson Education, Delhi

IP-211 Applied Thermodynamics Laboratory [0 0 2 1]

1. To conduct a load test on a single cylinder, 4-stroke petrol engine and study its performance under various loads.
2. To conduct a load test on single cylinder speed diesel engine and to study its performance under various loads.
3. To conduct a performance test on single cylinder high-speed diesel engine and to study its performance under different loads.
4. To conduct the experiment on two stage Air Compressor and to find out its volumetric efficiency and isothermal efficiency.
5. To conduct Morse Test on 3-cylinder, 4-stroke petrol engine.
6. To conduct a load test on a 4-cylinder, 4-stroke, diesel engine and to study its performance under different loads.
7. To find the coefficient of performance of vapour compression refrigeration test rig using capillary tube as an expansion valve.
8. To find the coefficient of performance of vapour compression refrigeration test rig using thermostatic expansion valve.
9. To determine the thermal conductivity of a solid insulating material by slab method.
10. To study the parallel flow and counter flow heat exchanger.
11. To study the working and the construction of different types of fire tube and water tube boilers.
12. To study the various components of a thermal power plant namely turbines, condensers and nozzles. (Industrial visit)

IP-213 Strength of Materials Laboratory [0 0 2 1]

1. Determination of Young's modulus, tensile, strength and percentage elongation for steel, aluminum, brass and cast iron specimens on universal testing machine. Also plot the stress strain diagram.
2. To perform the compression test for cast iron specimen on universal testing machine.
3. To determine the deflection for mild steel specimen and verify the beam formula for specimen in bending.
4. To determine the stiffness of the following:
   (i) Cantilever beam (ii) Spring under compressive and tensile loading
5. To measure the total energy absorbed in fracturing of the ductile specimen on Charpy and Izod setup.
6. To plot and study the S-N curve for steel, aluminum and fibre reinforced composite material at 25%, 50%, 60% and 75% of ultimate tensile strength of the specimen.
7. Preparation of specimen for hardness test.
8. Testing of prepared specimens for Brinell hardness and Rockwell hardness.
9. To study the behavior of steel and aluminum specimen under torsion.

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

Syllabi for Fourth Semester Courses

IP-202 Mechanical Measurements and Metrology [3 1 0 4]

Section A

Basics of measurement: Characteristics of measuring instruments, elements of an instrument, calibration of instruments, types of error in instruments, selection of instruments.
Speed measurement: Revolution counter, Tachoscope, various types of tachometer, stroboscope.
Force measurement: Beam balance, various types of load cells.
Torque measurement: Various types of dynamometers, characteristics of dynamometers, direct power measurement systems.

Section B

Electromechanical transducers: Variable resistance transducers, variable capacitance transducers, pIPzo-electric transducers, photoelectric transducers, strain gauges, use of various transducers.
Measuring Standards: Classification of standards, basic standards used world wide, airy points for minimum deflection.
Length and Angle Measurement: Slip gauges, angle gauges, spirit level, bevel protector, sine bar.
Interchangeability: Meaning of interchangeability, types of interchangeability, and advantages of interchangeability.

Section C

Design of Gauges: Indian standard for design of fits and tolerances, Taylor's principle, design of limit gauges, advantages of limit gauges.
Comparators: Meaning of comparators, types of comparators, advantages of various types of comparators.

Books Recommended

1. Jain R K, "Engineering Metrology", Khanna Publishers, New Delhi (2003)
2. Kumar D S, "Mechanical Measurements and Control Engineering" Metropolitan Book Company, New Delhi (2001)
3. Sawney R, "Instrumentation and Mechanical Measurements", Dhanpat Rai and Sons, New Delhi (2003)
4. Holeman J P, "Experimental Methods for Engineers", Tata Mc Graw Hill Publishing Company, Delhi (1998)
5. Beckwith T H, "Mechanical Measurements", Addison Wesley, New York (1990).

IP-204 Metallurgy and Heat Treatment [3 0 0 3]

Section A

Creep: Introduction, time dependent mechanical behavior, creep curve, mechanism of creep, factors affecting creep, effect of alloys, creep under combined stresses, presentation of engineering creep data, fatigue creep interaction.

Equilibrium Diagrams for non-ferrous alloys: Review of cooling curves, phase rule, solid state transformation, phase diagram of non-ferrous alloys

Iron Carbon Diagram: Allotropic forms of carbon, solid and liquid state reactions, types of steels, types of cast irons, microstructures at various carbon percentages, properties as a function of microstructures, significance of IC diagram. Cooling curves and equilibrium diagrams for brass and aluminum alloys.

Section B

TTT Diagrams: Time temperature transformations diagram, transformations as a function of cooling rate, mechanism of various transformations, and significance of TTT diagram.

Heat Treatment Methods: Mechanism of annealing and advantages, mechanism of normalizing and advantages, mechanisms of tempering and advantages, mechanism of hardening and advantages, mechanism of case hardening and advantages, mechanism of induction hardening and advantages.

Section C

Chemical Heat Treatment Methods: Introduction to chemical heat treatment, mechanism and methods of carburizing, nitriding, cyaniding, introduction to flame hardening.

Hardenability: Meaning of Harden ability, tests of Harden ability, factors affecting Harden ability

Effect Of Alloying Elements: Effect on strength and hardness, effect on Harden ability, effect on transformation temperature

Books Recommended

1. Raghavan V, "Introduction to Material Science and Engineering", Prentice Hall of India.
2. Smith W F, "Principles of Material Science and Engineering", McGraw Hill, New York
3. Dieter G E, "Mechanical Metallurgy", McGraw Hill, New York.
4. Van Vlack L H, "Elements of Materials Science and Engineering", Addison Wesley publishers.
5. Lakhtin Y, "Metallurgy and Heat Treatment", MIR Publishers

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

IP-206 Production Planning and Control [3 1 0 4]

Section A

Production Processes: discrete and process types, mass, batch, unit flexible manufacturing types, manufacturing operations: selection of a process, difference between manufacturing and service operations, classification of manufacturing processes, 5 Ps in the organization.

Process Design: Systems approach to process planning and design, linkage between product planning and process planning, distinction between process planning and facilities planning, types of process design, product mix, process planning aids, process design procedure.

Forecasting: characteristics of demand over time, forecasting qualitative model: Delphi, naïve quantitative models: simple average, simple moving average, weighted moving average, exponential smoothing, smoothing coefficient selection, adaptive exponential smoothing, incorporating trend and seasonal components, linear regression, selection of forecasting models.

Section B

Aggregate Planning: Concept, strategies for aggregate planning: three pure planning strategies, graphical method for aggregate output planning, master production scheduling (MPS), and procedure for developing MPS.

Shop floor planning and control: Nature, factors determining production planning, factors determining production control, phases in production planning and control, limitations of PPC, measuring effectiveness of PPC, production activity control, operations planning and scheduling, scheduling process-focused production systems, scheduling techniques for job shop, stages in scheduling, load charts and machine loading charts, dynamic sequencing rules, scheduling product –focused systems, scheduling for flexible manufacturing system.

Section C

Resource Requirements Planning: Nature, resource requirement planning system, MRP-I, MRP-II, MRP Computational procedure, issues in MRP, implementation of MRP, evaluation of MRP, Introduction to ERP.

Manufacturing planning & Control systems: JIT, CIM and WCM.

Learning curves in services and manufacturing: Applying the learning curve, arithmetic approach, logarithmic approach, learning - curve coefficient approach; strategic implications & limitations of learning curves.

Books Recommended

1. Vollmann Thomas E, Bery William L, Why bark D Clay, "*Manufacturing Planning and Control Systems*" Galgotia Publications, New Delhi (2002).
2. Buffa, "*Modern Production/operations Management*", Wiley Eastern, New York (1999).
3. Muhlemann Alan, Oakland John and Lockyer Keith, "*Production and Operations Management*", Macmillan India Publications Ltd. (2001)
4. Panneer Selvan R,"*Production and Operation Management*", Prentice Hall India, New Delhi (2002).
5. Aswathappa K and Bhat K Shridhara, "*Production and Operations Management*", Himalaya Publishing House, Mumbai (2002).

IP-208 Design of Machine Elements [3 0 2 4]

Section A

Introduction: Basic requirements for machine elements, design procedure, system design cycle.
Designing for Strength: Theories for failure, factor of safety, stress-concentration, variable loading, impact or shock loading.
Joints: Strength of welded joint, design of welded joint for static loads, riveted joint, failure modes of riveted joints, efficiency of riveted joint, deign of cotter joint, designing the cotter and gib.
Knuckle joint and its design: Keys, types of keys, couplings, rigid and pin type flexible coupling design.

Section B

Springs: Helical springs design with axial loading, spring scale, erosion springs. Leaf springs, length of leaves, design procedure.
Shafts: Failure of shafts under simple loading conditions.
Bearings: Sliding bearings, hydrodynamic lubrication, hydrostatics bearing, and journal bearing design. Rolling contract bearing, ball bearing, roller bearing selection procedure under simple loading conditions.

Section C

Gear drive: Gear nomenclature, materials, types of gear tooth failures, design consideration of straight spur gears, helical spur gears, double helical gears.
Belt Drive: Flat belt drive, working stresses, slip and creep, stresses in belts, pulleys, and design procedure. V-belt drives, design procedure.

Books Recommended:

1. Sharma P C and Aggarwal D K, "*Machine Design*", Kataria Publishers (2002)
2. Spotts M F, "*Design of Machine Elements*", Prentice Hall of India Pvt. Ltd. (2000)
3. Sharma C S & Purohit Kamlesh, "*Design of Machine Elements*", Prentice Hall, New Delhi (2003)
4. Khurmi R S and Gupta J K, "*A Textbook of Machine Design*", Eurasia Publishing Housing (Pvt.) Ltd., New Delhi (2003)
5. Bhandari, "*Design of Machine Elements",* Tata Mcgraw Hill, New Delhi (2001)

IP-210 Casting, Forming and Welding [3 0 0 3]

Section A

Introduction to casting: Steps involved in casting, advantages, limitations and applications of casting process. Pattern types, allowances for pattern, pattern, materials color coding and storing of patterns.

Moulding methods: Molding methods and processes-materials, equipment, molding sand ingredients, essential requirements, sand preparation and control, testing, cores and core making. Design considerations in casting, gating and Risering, directional solidification in castings. Sand castings-pressure die casting-permanent mould casting-centrifugal casting-precision investment casting, shell moulding, Co2 moulding, continuous casting-squeeze casting-electro slag casting. Fettling and finishing, defects in Castings.

Foundry melting furnaces: Selection of furnace-crucibles oil fired furnaces, electric furnaces-cupola, calculation of cupola charges, hot blast, cupola-Degasifications, inoculation-pouring equipment, Inspection of castings. Need-Areas for mechanization-Typical layout-sand reclamation techniques-material handling, pollution control in Foundry, Computers in casting process.

Section B

Forming: Metallurgical aspects of metal forming slip, twining mechanics of plastic deformation-effects of temperature, strain rate-microstructure and friction in metal forming, yield criteria and their significance-classification of metal forming processes. Principle classification equipment, tooling-processes, parameters and calculation of forces during forging and rolling processes, Ring compression tests, Post forming heat treatment, Defects (cause and remedy) applications. Classification of extrusion processes, tool, equipment and principle of these processes, influence of friction, Extrusion force calculation, Defects and analysis: Rod/wire drawing-tool, equipment and principle of processes defects, Tube drawing and sinking processes-Mannessmann processes of seamless pipe manufacturing.

Classification of Forming Processes: Classification conventional and HERF processes, Presses-types and selection of presses, formability of sheet metals, Principle, process parameters, equipment and application of the following processes. Deep drawing, spinning, stretch forming, plate bending, press brake forming, Explosive forming, electro hydraulic forming, magnetic pulse forming. Super plastic forming, electro forming-fine blanking, P/M forging-Isothermal forging-high speed, hot forging high velocity extrusion.

Section C

Welding: Types of welding-gas welding-arc welding-shielded metal arc welding, TAW, GMAW, SAW, ESW-Resistance welding (spot, seam, projection, percussion, flash types)-atomic hydrogen arc welding-thermit welding soldering, brazing and braze welding. Welding symbols-Positions of welding-joint and groove design-weld stress-calculations-design of weld size estimation of weld dilution, heat input, preheat, and post heat temperature-computer applications in weld design. Electron beam and Laser beam welding-plasma arc welding-stud welding-friction welding-explosive welding ultrasonic welding-underwater welding-roll bonding-diffusion bonding-cold welding-welding of plastics, dissimilar metal. Gas welding equipments-welding power sources and characteristics-safety aspects in welding-automation of welding, seam tracking, vision and arc sensing-welding robots. Defects in welding-causes and remedies-destructive testing methods

Non Destructive Testing of weldments: Testing of pipe, plate, boiler, drum, tank-case studies-weld thermal cycle-residual stresses-distortion-relieving of stresses, weldability of cast iron, steel, stainless steel, aluminium alloys-effect of gases in welding-fatigue failure in weldments.

Books Recommended:

1. Taylor H.F Flemings M.C & Wulff J., Foundry Engineering, Wiley Eastern Limited, 1993.
2. Lindberg R.A, Processes and Materials of Manufacture , Prentice Hall of India (P) Ltd.,1996
3. Lancaster J.F., Metallurgy of welding, George Allen and Unwin, 1991.
4. Serope Kalpakjian, Manufacturing engineering and Technology, Edition III - Addision - Wesley Publishing Co., 1995.
5. William F. Hosford & Robert M. Caddel, Metal forming (Mechanics & Metallurgy), Prentice Hall Publishing Co., 1990.

IP-212 Networks & Project Management [3 0 0 3]

Section A

Introduction: Concept & definition of a project, categories of projects, project life cycle phases, project visibility, roles & responsibilities of project manager. Generation & screening of project ideas, selection of a project, project rating index, financial aspects, project cash flows, social cost-benefit analysis.

Project Planning: The statement of work, project specifications, work breakdown structure. Contract planning, Organization planning, project vs. non-project organization, matrix form of organization. Selection of personnel. Controlling, directing, coordination and delegation.

Project Scheduling: Gantt chart, milestone char. Network scheduling terminology. Path enumeration, Activity on node & activity on arc network precedence diagrams.

Section B

Project Scheduling (Contd.) Dummy activities, topological ordering, redundancy, cycles. Isolating critical path: multiple critical paths. Determination of float: total float, safety float, free float, and independent float. The CPM model.

The PERT Model: event orientation, uncertainty, the PERT assumptions, expected times for activities, variability of activity times, expected length of critical path, due date probability. Invoking central limit theorem. Time-cost trade-off and generation of the project cost curve in deterministic networks. Computerized project management. Other network-based techniques – minimal spanning tree technique, shortest route technique.

Section C

Time and cost considerations: cost versus time, straight-line approximation of variation of cost with reduction in time for activities, direct and indirect costs. Contracting the network: fixed project duration and corresponding total cost, optimum project duration and minimum project cost, project cost curve.

Controlling projects: cumulative costs for early and late start schedules, range of feasible budgets, graphic display of cost and time data, time and cost overrun or under run in projects.

Limited resources scheduling: the complexity of the project scheduling with limited resources, heuristic programs, resource leveling and resource allocation in project scheduling. Information requirements for projects, project management software based application.

Books Recommended:

1. Kerzner Harold, "Project Management - A Systems Approach to Planning, Scheduling and controlling", CBS Publishers Delhi, Second edition (2002).
2. Weist Jerome D and Ferdinand K. Levy, "A Management Guide to PERT/CPM with GERT/PDM/DCPM and other networks", Prentice-Hall of India New Delhi, Second edition (2003)
3. Parsanna Chandra, "Project Planning, Analysis, Selection, Implementation and Review", Tata McGraw Hill, Fourth Edition (2002)
4. L.S. Srinath, "PERT & CPM Principles and Applications", Affiliated East- West Press Pvt. Ltd., New Delhi, Third Edition (1993)
5. Ghattas R G and Sandra L Mckee, "Practical Project Management" Pearson Education Asia, First edition (2004)

IP-214 Mechanical Measurements and Metrology Laboratory [0 0 2 1]

1. To measure the acceleration of a vibrating body using strain gauges
2. To measure the acceleration of a rotating machinery using Piezo-electric sensors.
3. To measure the velocity of a rotating shaft using Tachometer.
4. To measure the angle of rotation of a rotating shaft using Photoelectric sensors.
5. To measure the dynamic power of a shaft using instantaneous power measuring dynamometer.
6. To measure the load of compressive nature using load cells.
7. To measure the angle of a taper rod using sine bar and slip gauges.
8. To measure the straightness of machine tool surface by sensitive spirit level.
9. To measure the angle and width of a V- groove
10. To measure the gear tooth thickness by using gear tooth vernier caliper.
11. To measure the elements of screw thread using tool makers microscope.
12. To measure the elements of screw thread using profile projecto

IP-216 Metallurgy and Heat Treatment Laboratory [0 0 2 1]

1. Analyzing the microstructure of steel and cast iron using Metallurgical Microscope.
2. Determining the grain size of the given specimen using Metallurgical Microscope.
3. Hardening of ferrous specimen by quenching in oil bath.
4. Annealing of ferrous specimen by slow cooling in the furnace.
5. Tempering of ferrous specimen in the furnace
6. Cyaniding a ferrous specimen in cyaniding bath.
7. Nitriding of ferrous specimen in nitriding bath.
8. Induction hardening of a given ferrous specimen.

IP-218 Casting, Forming and Welding Laboratory [0 0 2 1]

List of Experiments

1. Study of Tools and Equipments used in foundry.
2. Preparation of moulds of simple objects like flange, gear V- grooved pulley etc.
3. Study of Tools and Equipments used in welding
4. Arc Welding of butt joint, Tap Joint, Tee fillet etc.,
5. Demonstration of gas welding.
6. TIG and MIG welding Jobs
7. Spot welding job
8. Die design and manufacturing for forming.

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

Fifth Semester

IP-301 Industrial Automation [3-0-0-3]

Section A

Hydraulic System Elements: Pumps, types, working, characteristics, applications: Types of conductors, and connectors, their selection: Seals and packing, types, materials, applications.
Hydraulic Actuators: Linear and Rotary, types, working, cushioning effect, mounting, calculation of force and velocity of piston System components: Accumulators, Intensifiers, their types, working, applications.
Control Elements: Pressure control Valves, direct acting type, pilot operated, sequence, counterbalancing, unloading, pressure reducing, construction and working: Direction control valves, types, construction and working, spool actuation methods, spool center positions, Flow control valves – compensated and non compensated types, construction and working.
Hydraulic Circuits and their Applications: Speed control circuits, regenerative, sequencing, counterbalancing, synchronizing, interlocking, circuits with accumulator and intensifier.
Introduction to Fluidics and study of simple logic gates: Hydraulic clamping and braking systems.

Section B

Pneumatics: Air compressors, types, working, selection criteria; FRL unit , construction and working; Pneumatic cylinders and air motors, construction and working, types, calculation of force and air consumption, Comparison of air, hydraulic and electric motor.
Pneumatic System Control Elements: Direction control valves, types, control methods for spool working; Flow control valves, working of variable flow control, quick exhaust, time delay and shuttle valve; Pressure control valves, types and working.
Pneumatic Circuits: Basic circuit, impulse operation, speed control, sequencing, time delay circuits and their applications. Pneumatic clamping and braking systems, Pneumatic power tools.

Section C

Hydro pneumatic systems: concept, working and applications. Fluid power maintenance, troubleshooting and safety.
Automation devices: Feeders, orienters, catchment devices, PLC architecture and programming

Books Recommended

1. Espositio A., "*Fluid Power with Applications"*, Pearson, 2002.
2. Majumdar S. R. ,"*Oil Hydraulic Systems"* , Tata McGraw Hill 2000
3. Majumdar S. R. , "*Pneumatic systems-principles and Maintenance"*, TataMc Graw Hill 2000
4. Janakiraman P.A., "*Robotics and image processing"*, Tata McGraw Hill, 1995.
5. Yoram Koren, "*Robotics"*, McGraw Hill, 1992.

IP-303 Machine Tools and Machining [3 1 0 4]

Section A

Metal Cutting Theory: Introduction, tool materials, tool geometry, mechanics of metal cutting, tool failures, tool wear in metal cutting, tool life, cutting forces and power, mach inability, cutting fluids

Basic Machine Tool Elements: Introduction, machine tools, elements, motors, holding work pieces, handling work pieces, handling tools, and control systems.

Section B

Turning Operations: Introduction, constructional features of a center lathe, cutting tools, operations performed on a center lathe, taper turning methods, thread cutting methods, special attachments, limitations of a center lathe, capstan and turret lathes, turret indexing mechanism, machining time estimation.

Hole Making Process: Introduction, drilling, types of drilling machines, reaming, boring, tapping, other hole making operations, machining time estimation.

Section C

Milling Process: **I**ntroduction, types of milling machines, milling cutters, milling operations, dividing head, milling mechanics, machining time estimation, indexing

Reciprocating Machine Tools: Shaper, quick return mechanism, planner, slotter.

Abrasive process: Introduction, grinding wheel designation and selection, types of grinding machines, grinding process, grinding process parameters, honing, lapping.

Other Machine Tools: Broaching, gear cutting.

Introduction to NC, DNC and CNC machines

Books Recommended

1. Lindberg Roy A, "*Processes and materials of manufacture*", Fourth edition PHI, 1990.
2. Ostwald Phillip F, "*Manufacturing processes and systems*", John Wiley and Sons, ninth edition (1998).
3. Rao P N, "*Manufacturing technology*", Tata McGraw-Hill, 2002.
4. Gerling, "*All About Machine Tools*", New Age International (P) Limited, sixteenth edition, 2000.
5. Chapman W A J, "*Workshop Technology*", Part1, 2,3, CBS Publishers and distributors.,2000

IP-305 Work Study and Ergonomics [3 0 0 3]

Section A

Productivity: Definition, reasons for low productivity, methods to improve productivity, work-study and productivity

Human factor in work-study: Relationship of work-study man with management, supervisor & workers, qualities of a work-study man.

Method-study: Definition, objectives, step-by-step procedure, questioning techniques, charts and diagrams for recording data. Like outline process charts, flow process charts, multiple activity charts, two handed process chart, string diagram, travel chart, cycle graph, Chrono-cycle graph, therbligs, micro motion study and film analysis, Simo chart, principles of motion economy. Development and installation of new method.

Section B

Work–Measurement: Definition, various techniques of work-measurement work-sampling, stop-watch time study & its procedure, Job selection, Equipment and forms used for time study, rating, methods of rating, allowances and their types, standard time, numerical problems, predetermined – time standards and standard data techniques.
Incentive: Meaning, objectives of an incentive plan, various types of incentive plans.

Section C

Ergonomics: Introduction, history of development, man-machine system and its components. Introduction to structure of the body- features of the human body, stress and strain, metabolism, measure of physiological functions- workload and energy consumption, biomechanics, types of movements of body members, strength and endurance, speed of movements. NIOSH lifting equation, Lifting Index, Maximum acceptable Weights and Forces, Distal upper extremities risk factors, Strain Index, RULA, REBA, and Office Ergonomics. Applied anthropometry - types, use, principles in application, design of work surfaces and seat design. Visual displays for static information, visual displays of dynamic information, auditory, tactual and olfactory displays and controls. Effect of vibration, noise, temperature and illumination on performance.

Books Recommended

1. Barnes Ralph M., "*Motion & Time study: Design and Measurement of Work*", Wiley Text Books, 2001.
2. Marvin E, Mundel & David L, "*Motion & Time Study: Improving Productivity*", Pearson Education, 2000.
3. Benjamin E Niebel and Freivalds Andris, "*Methods Standards & Work Design*", Mc Graw Hill, 1997.
4. International Labour organization, "*Work-study*", Oxford and IBH publishing company Pvt. Ltd., N.Delhi, 2001.
5. Sanders Mark S and McCormick Ernert J, "*Human Factors in Engineering and Design*", McGraw-Hill Inc., 1993.

IP-309 Industrial Quality Control [3 0 2* 4]

Section A: Review of statistical concepts: Graphical representation of grouped data, continuous & discrete probability distributions, central limit theorem, skewness and kurtosis, tests of normality for a given data, chi-square test.

Introduction: Process control and product control, difference between SQC and SPC, chance and assignable causes of quality variation, advantages of Shewhart control charts.

Process Control: Charts for variables; for individuals, X bar, R and sigma charts; fixation of control limits; Type I and Type II error; theory of runs; Interpretation of ' out of control ' points. Initiation of control charts, trial control limits. Determination of aimed-at value of process setting. Rational method of sub grouping. Control chart parameters. Limitations of X bar and R charts,

Section B

Control limits verses specification limits: natural tolerances limits, relationship of a 'process in control' to upper & lower specification limits. Process capability studies, process capability indices for bilateral specifications & unilateral specification cases, remedial actions for indices less than one.

Control charts for Attributes: fraction defective chart and number of defectives chart, varying control limits, high defectives and low defectives, seriousness classification of defects, defects chart, U-chart. Quality rating, Average Run Length (ARL), Relative efficiency or sensitivity of control charts.

Product Inspection: 100% inspection, no inspection and sampling inspection. Application of hyper geometric, binomial & Poisson distributions in acceptance inspection. Operating Characteristic Curve (O.C.Curve); Effect of sample size and acceptance number, type A and type B O.C. curves. Single, Double and Multiple Sampling Plans.

Section C

Product Inspection (Contd.): Acceptance/ rejection and acceptance/ rectification plans. Producer's risk and consumer's risk. Indifference quality level, Average Outgoing Quality (AOQ) curve, AOQL. Quality protection offered by a sampling plan. Average Sample Number (ASN) curve, Average Total Inspection (ATI) curve. Design of single sampling plans.

Economics of Product Inspection: Use of Break-even analysis in decision for selection of economic acceptance plan option. Dodge - Romig Tables, MIL-STD-105D.

Introduction to surface response methodology and Taguchi methods.

***Practice Session**

The following exercises would be covered under the practice session:

1. To show that sample means from a normal universe follow a normal distribution.
2. To show that sample means from a non-normal universe (rectangular universe) also follow a normal distribution.
3. To show that sample means from a non-normal universe (triangular universe) also follow a normal distribution.
4. To verify binomial distribution of the number of defectives. (By mixing marbles of different colours & assuming say white marbles to be defectives or by any other suitably designed experiment).
5. To plot Operating Characteristics curve for single sampling attributes plan. (n = 20, c = 0, 1 & 2 at different fraction defectives or any other single sampling attributes plan). Use Poisson's distribution for calculation of probabilities of acceptance.

Books Recommended

1. Grant E L and Leavenworth R S, "*Statistical Quality Control*", McGraw Hill, Sixth Edition (2000)
2. Hansen Bertrand L and Ghare Prabhakar M, "*Quality Control and Applications*" Prentice Hall of India Pvt. Ltd., First Edition (1993)
3. Amitav Mitra, "*Fundamentals of Quality Control and Improvement*", Pearson Education Asia, First Edition (2004)
4. Besterfield Dale H [et…al.], "*Total Quality Management*", Pearson Education Asia, First Edition (2003)
5. Zaidi A., "*SPC: Concepts, Methodologies and Tools*", Prentice Hall of India, First Edition, (2003)

IP-313 Machine Tools and Machining Laboratory [0 0 2 1]

Students are required to perform various jobs in the machine shop as given below:

1 Practice on Lathe : 05 Jobs
(Jobs should cover various lathe operations like centering, facing, turning, stepped turning, parting, threading, taper turning, chamfering and knurling)
2 Practice on Shaper : 01 Job (Slot cutting)
3 Practice on milling machine : 01 Job (Slot cutting)
4 Practice on Surface grinder : 01 Job (Creating Flat surface)
5 Practice on Drilling Machine : 01 Job (Marking and drilling operations)
6 Practice on EDM 01 Job
7 Practice on wire cut – 01 Job

IP-315 Work Study and Ergonomics Laboratory [0 0 2 1]

List of Experiments

1. Method to improve the assembly and dis-assembly of a Bolt, a nut and three washers
2. Methods Improvement – Assembling pins on cardboard
3. Rating Practice –Walking on level grounds and dividing a pack of cards into four equal piles.
4. Rating Practice – Films and analysis.
5. Work sampling exercises
6. Stop watch time study on drilling machine, lathe machine and CNC machine
7. Calibration of an individual using Tread Mill as a loading-device.
8. To measure the autonomic tone of an individual using multichannel polygraph.
9. Measurement of anthropometrics data and analysis of data.
10. Audiometric examination a through pure tone audiogram of a subject using portable audiometer in a portable audiometric testing cabin.
11. To measure the middle ear latency response of an individual using BERA.
12. To measure the respiratory parameter of an individual.
13. To measure the ambience noise and to check the noise dose of an individual in industrial noisy environment using sound level meter and noise dosimeter.
14. To measure the heat stress of an individual using area heat stress monitor.
15. To measure the dust exposure of an individual using dust sampler.

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

Sixth semester

IP-302	Robotics	[3 0 0 3]

Section A

Fundamentals of Robotics: Definition of a robot, types and technology levels of robots, classification of robots, parts of a robot, applications.

Dynamic modeling of Rigid Manipulators: Kinematics modeling of manipulator arms, Denavit Hartenberg notations, inverse kinematics, kinematics modeling of instantaneous motions, inverse kinematics, Newton-Euler formulation for deriving the dynamics, Lagrangian formulation of manipulator dynamics, inverse dynamics, trajectory planning.

Section B

Dynamics of flexible structures: Euler – Bernoulli theory of beams, Raleigh beam theory, Timoshenko beam theory, free and forced vibrations of beams. Use of Lagrange methods to derive the dynamics of beams. Derivation of dynamics of single link flexible manipulators.

Section C

Conventional Sensors and Actuators for Robots: Linear and rotary encoders, resolvers, dynamic modeling of servo motors and stepper motors.

Smart Sensors and Actuators for Robots: Definition of a sensor, fiber optic sensors, definition of an actuator, intelligent actuators and smart actuators, piezoelectric actuators, magnetostrictive actuators, shape memory alloy actuators, electrorheological fluid actuators and magnetorheological fluid actuators.

Control of Robots: Open loop control and closed loop control of robot manipulators, open loop control by computed torque method, closed loop control for disturbance rejection and trajectory execution, individual joint PID control of single link manipulators.

Recommended Books

1. Asada and Slotine, Dynamics and control of robot manipulators , Wiley, New York.
2. JS Rao , Advanced theory of vibrations, Wiley Eastern New Delhi.
3. AK Sawhney,A course in Mechanical Measurements and instrumentation, Dhanpat Rai publication
4. H. Janocha , Adaptronics and Smart Structures, Springer, New York
5. JJ Craige, Introduction to Robotics, Pearson Education, New Delhi.

IP-304 Operations Research [3 0 0 3]

Section A

Nature and development of Operations Research: some mathematical preliminaries, OR and managerial decision making, OR applications in industrial and non-industrial fields.

Linear Optimization Models: formulation of linear programming problem, graphical solution, sensitivity analysis in graphical solution, comparison of graphical and simplex algorithm, simplex algorithm, computational procedure in simplex, penalty method, two phase method, degeneracy, duality and its concept, application of LP model to product mix and production scheduling problems.

Section B

The transportation model: solution methods, balanced and unbalanced problems, Vogel's approximation method, degeneracy in transportation problems. Assignment problem, methods for solving assignment problems. The traveling salesman problem. Numericals on transportation, assignment and traveling salesman method. Computer algorithms for solution to LP problems.

Dynamic programming problems: model formulation, computational procedures, solution in different stages. Decision making under conditions of risk, assumed certainty.

Section C

Waiting line models: queuing systems and concepts, various types of queuing situations, single server queues with poison arrivals and exponential service times, finite queue length model, industrial applications of queuing theory.

Simulation: advantages and limitations of the simulation technique: generation of random numbers, Monte-Carlo simulation, computer-aided simulation, applications in maintenance and inventory management.

Books Recommended

1. Taha,H A, "*Operations Research - An Introduction*", Sixth Edition, Prentice Hall of India Private Limited, N. Delhi, 2004.
2. Hillier, F S, "*Operations Research*", First Indian Edition, CBS Publishers & Distributors, Delhi, 1994.
3. Wagner H M, "*Principles of Operations Research*", Second Edition, Prentice Hall of India Private Limited, New Delhi, 2003.
4. Mustafi C K, "*Operations Research*", Third Edition, New Age International Pvt. Ltd., New Delhi, 1996.
5. Gupta P K, & Hira D.S., "*Operations Research*", Third Edition, S Chand & Company Ltd., New Delhi, 2005.

IP-306 Facilities Planning [3 1 0 4]

Section A

Introduction: Introduction to facilities planning and design, plant layout, material handling and their interrelationship.

Site Location: Importance of location, hierarchy of location problems, factors affecting site location; factors in heavy manufacturing location, light industry location, warehouse location, retail location. Various theories/models of site location like bid rent curves, Weber's isodapanes, Weber's classification of industries, Hoover's tapered transport rates, agglomeration, factor rating method, single facility location, load-distance model, break-even analysis, transportation method. New plant location and shut down under dynamic conditions.

Section B

Plant Layout: Objectives of a good plant layout, principles of a good layout, classical types of layouts like product layout, process layout, fixed-position layouts, cellular layouts and hybrid layouts. Factors affecting plant layout: man, material, machine, movement, waiting, service, building and change, features and considerations of each factor. P - Q chart, systematic layout planning, relationship (REL) chart, traditional layout configuration, production space requirements, manual CORELAP algorithm and examples, preparing process layouts and the considerations thereon.

Product Layouts: basic features of mass manufacturing, advantages & disadvantages of flow-line production, product-oriented layout – assumptions & types, assembly line layout, assembly line balancing. Design of an assembly line, layout heuristics for assigning tasks in assembly line balancing, assembly line balancing equations.

Section C

Computerized Layout: Evaluation of layout, computerized layout, flowcharts of various techniques like CRAFT, ALDEP and CORELAP.

Material Handling: Concept of material handling, principles of material handling, factors affecting material handling, objectives, material handling equation.

Material Handling Equipments: Selection of material handling systems and equipments: Automated Guided Vehicles, types, features, usage. Conveyors: basic functionality requirements, types of Conveyors, application considerations, operational considerations. Cranes, hoists and industrial trucks.

Books Recommended

1. James Apple, "Plant Layout & Material Handling", The Ronalt Press Co., New Delhi, 1998.
2. Francis, McGinnis and White, "Facilities Layout & Location –an analytical Approach" Prentice Hall of India Pvt Ltd., New Delhi, 2001.
3. Richards Muther, "Practical Plant Layout", McGraw Hill Book Co., New York, 1982.
4. Ronald H Ballou, "Business Logistics", Pearson Education, Inc. New Delhi, 2004.
5. Tompkins J A & J A White, "Facilities Planning", John Wiley & Sons, Inc. New York, 1984

IP-312 Industrial Automation & Robotics Laboratory [0 0 2 1]

List of experiments

1. Speed control circuits on hydraulic trainer
2. Sequencing circuit on hydraulic trainer
3. Counterbalancing circuit on hydraulic trainer
4. Synchronizing circuit on hydraulic trainer
5. Design of any hydraulic circuit and selection of components
6. Sequencing circuit using Pneumatics
7. Manual and automatic forward and reverse with solenoid control / pilot control
8. on pneumatic trainer
9. AND and OR logic circuits on pneumatic trainer
10. At least one industrial visit to study applications related to the subject and submission of the relevant report.
11. PLC program for control of control of various pneumatic cylinders
12. Robot Program

IP-314 Operations Research Laboratory [0 0 2 1]

In the practice session, students would be required to develop models and solve problems based upon case studies using solver tool or software what's best.

Group of students to undertake some real life problems involving queuing situations and analyze those problems to find out the optimal solution. Simulation problems to be solved by Monte Carlo method by developing models and solving these using suitable software.

TEACHING SCHEME FOR B.TECH "INDUSTRIAL & PRODUCTION ENGINEERING"

Seventh semester

IP-401 CAD/CAM [3 0 0 3]

Section A

The design process Morphology of design: Product cycle, Sequential and concurrent engineering, Role of computers, Computer Aided Engineering, Computer Aided Design, Design for Manufacturability, Computer Aided Manufacturing, Benefits of CAD.
Creation of Graphic Primitives: Graphical input techniques, Display transformation in 2-D and 3-D Viewing transformation, Clipping, hidden line elimination, Mathematical formulation for graphics, Curve generation techniques, Model storages and Data structure, Data structure organization, creation of data files, Accessing data files, Concepts of data processing and information system. Data Bank Concepts, Data bank information storage and retrieval, Data life cycle, integrated data processing, Information system, Engineering Data Management System. Hierarchical data structure. Network data structure - Relational data structure. Data storage and search methods.

Geometric Modeling: Wire frame, Surface and Solid models, CSG and B-REP techniques, Features of Soild Modeling Packages, Parametric and features, Interfaces to drafting, Design Analysis.

Section B

Finite Element Analysis: Introduction, Procedures, Element types, Nodal approximation, Element matrices, vectors and equations, Global connectivity, Assembly, Boundary conditions, Solution techniques, Interfaces to CAD, Introduction packages, Software development for design of mechanical components.

Computer Aided Manufacturing: Evolution of Computer Numerical Control, Components, Co-ordinate system, Working principle of CNC Lathe, Turning Centers, Milling Machine, Machining Center, Drilling Machine, Boring Machine, Punching and Nibbling Machines, Pipe-Bending Machine, Spot Welding Machine, Electro Discharge Machine, Grinding Machine, Laser and electron Beam Machining Equipment, DNC and adaptive control Machine structure, Slideways, Ballscrews, Accessories-Spindle drives-Axes feed drives, Open and closed loop control, Types of positional control, Machine Tool control, Control of Spindle speed, Control of slide movement and velocity.

Section C

Part Program Terminology: G and M Codes, Types of interpolation, Methods of CNC part programming, Manual part programming, Computer Assisted part programming: APT language, CNC part programming using CAD/CAM-Introduction to Computer Automated Part Programming.
Cutting tool materials: Hard metal insert tooling, Choosing Hard Metal tooling-ISO specification, Chip breakers-Non insert tooling, Qualified and pre-set tooling, Tooling System- Turning center-Machining center.
Factors influencing selection of CNC Machines: Cost of operation of CNC Machines-cost of Operation of CNC Machines-Practical aspects of introduction of CNC-Maintenance features of CNC Machines-Preventive Maintenance.
Rapid prototyping: - Introduction to rapid prototyping, need of RP in context of batch production, FMS and CIM and it's applications, Basic principles of RP, classification of different RP techniques, advantages of RP.

Books Recommended

1. Radhakrishnan P.and Kothandaraman C.P., "*Computer Graphics and Design*", Dhanpat Rai and Sons, New Delhi (1991).
2. Groover and Zimmers, "*CAD / CAM: Computer Aided Design and Manufacturing*", Prentice Hall of India, New Delhi (1994).
3. Zeid Ibrahim, "*CAD - CAM Theory and Practice*", Tata McGraw Hill Publishing Co. Ltd. (1991).
4. Steave Krar and Gill Arthur, "*CNC Technology and Programming*", McGraw-Hill Publishing Company (1990).
5. Gibbs David, "*An Introduction to CNC Machining*", Cassell (1987).

IP-403 Jigs Fixtures and Tool Design [3 0 2* 4]

Section A

Principles of jigs and fixture design: construction method and material used, the basic principles of location, locating methods and devices, radial or angular location, V-location, bush location, the basic principles of clamping, clamping devices, materials for locating and clamping elements. Drilling jigs, types, chip formation in drilling, general considerations in the design of drill jigs, drill bushings, methods of construction, drill jigs and modern manufacturing. Fixtures and economics, types of fixtures, milling fixtures, special vice jaws, design principles for milling fixtures, lathe fixtures, grinding fixtures, broaching fixtures, assembly fixtures, indexing jigs and fixtures, indexing devices, automatic clamping devices.

Section B

Tool materials and their properties: heat treatment of tools, basic requirements of a cutting tool, single point cutting tool, nomenclature, inserts, milling cutters, drills, types of drills, reamers, taps, carbide tools.

Press operations: types of power presses, press selection, cutting action in punch and die operations, die clearance, cutting forces, methods of reducing cutting forces, minimum diameter of piercing, blanking die design, piercing die design, bending dies, drawing dies.

Section C

Forging dies: open & closed die forgings, Principles of die design for forging operations, die material and processes of manufacture of dies, die maintenance, die block dimensions, Selection of forging equipments, die inserts, stock size for closed and open die forging.

Books Recommended

1. Grant Hiram E, "*Jigs & Fixtures*", Tata McGraw Hill Publishing Company, 1994.
2. Curtis Mark A, "*Tool Design for Manufacturing*", John Wiley & Sons, 1996.
3. Donaldson Cyril, "*Tool Design*", Tata McGraw Hill Publishing Company Limited, 1997.
4. Sharma P C, " *Production Engineering*", S Chand & Company,1997.
5. Kalpakjian S, "*Manufacturing Engineering & Technology*", Addison Wesley Longman, Pvt.Ltd., Low Price Edition, 2000.

IP-405 Materials Management [3 1 0 4]

Section A

Integrated approach to materials management: Introduction, materials productivity and role of materials management techniques in improved materials productivity. Cost reduction and value improvement, value analysis for right choice and rationalization of materials**.**

Purchasing function: Objectives, purchase requisitions, types of specification, centralized versus decentralized purchasing, timing of purchases. Purchasing research, identification of right sources of supplies. Make or buy decisions, vender selection and vender rating. Negotiations, purchase price analysis and price determination. Purchasing organization, procedures, forms, records and reports. Purchasing as a dynamic profession, transition to supply management, Reverse auctioning

Inventory management: Inventory concepts, reasons for holding inventory, types of inventory, inventory reduction tactics. Inventory turnover ratio. Selective Inventory management: ABC, VED, and FSN analysis etc., identifying critical items with selective inventory management.

Section B

Operating policies: continuous review system, periodic review system, comparative advantages and disadvantages of continuous and periodic review systems, hybrid systems. Inventory management across the organization.

Optimizing Inventory: Assumptions for Wilson's lot size model, inventory costs, hidden costs, composition of costs, estimation of inventory related costs, lead time, stock out point, number of time periods, calculating Economic Order Quantity (EOQ), sensitivity analysis of EOQ model.

Special inventory models: Finite replenishment rate model, lot size models with planned backlogging, generalized model with uniform replenishment rate, inventory model with lost sales, quantity discount model, one period decisions. Determination of safety stock, service level and uncertainty in demand. Information systems for inventory management.

Section C

Stores management: Introduction, stores functions, stores organization, stores systems and procedures, stores accounting and verification systems, stores address systems, stores location and layout, store equipment.
Discussion on modern materials management techniques like JIT, SMED, DBR & MRP

Books Recommended:

1. Arnold and Chapman "*Introduction to Materials Management*", Pearson Education Asia, Fourth Edition, (2001)
2. Narsimhan, Mcleavey & Billington, "*Production Planning & Inventory Control*", Prentice Hall of India, Second Edition (2003)
3. Dobler Donald W., Burt David N., "*Purchasing and Supply Management*", Tata McGraw Hill, Sixth Edition (2001)
4. Menon K S, "*Purchasing and Inventory Control*", Wheeler Publishing New Delhi, Third Edition (1997)
5. Krajewski L J and Ritzman L P, "*Operations Management*", Pearson Education Asia, Sixth Edition (2004)

IP 411 CAD/CAM Laboratory [0-0-2-1]

Creating component drawing and making sub assemblies of components using PRO/Engineer, UNIGRAPHICS and IDEAS choosing from the following components.

1. Steam stop valve
2. Tail stock
3. Plummer block
4. Check valve
5. Flange Coupling
6. Universal Coupling
7. Stuffing Box
8. Connecting Rod

Programming on CNC lathe and milling, demonstrating linear interpolation, circular interpolation, canned cycles.

Eighth Semester

IP-402 Management Information Systems [2 0 2* 3]

Section A

Managing the digital firm: Concepts, need and scope of Information system in business organization, the competitive business environment and the emerging digital firm, transformation of business enterprise, major business functions, approaches to the development of an organization's information system; technical approach, behavioral approach, socio – technical approach, new options for organization design, the Network revolution, Internet and its functions, World Wide Web, LAN etc., positive & negative impacts of information systems.

Information systems in the enterprise: Organizational levels, subsystems of information system; operational level, knowledge level, management level and strategic level information systems, transaction processing systems, office systems, knowledge work systems, MIS, DSS, ESS, relationship of systems to one another, systems from a functional perspective, life cycle of information system.

Managing data resources: Components of computer based information system (CBIS), file organization terms & concepts, problems with traditional file environment, Database Management System (DBMS), types of Databases, Relational DBMS, hierarchical & network DBMS, Object oriented databases. Datamining.

Section B

Logical database design: Entity relationship diagram, properties of tables, update anomaly, insertion anomaly, deletion anomaly, inconsistency anomaly, repeating groups, primary key and concatenated key, Normalisation, 1NF to 2NF to 3 NF steps.

Artificial intelligence: Expert system, features of an expert system, heuristic and algorithm, human expertise vs. artificial expertise, knowledge representation: rule-based methods & frame-based methods, tasks and stages of expert system development and difficulties in developing an expert system.

Section C

Computer simulation: concept of simulation, when is simulation an appropriate tool, when simulation is not appropriate, advantages and disadvantages of simulation, areas of application, systems & system environment, components of a system, discrete & continuous systems, model of a system, types of models, steps in a simulation study, simulation application examples, selecting simulation software.

*** Practice sessions:-** The students will be taught some DBMS language like Oracle, Foxpro or visual Basic. The students will be asked to develop software for various functional areas of an organization.

Books Recommended

1. Laudon Kenneth C and Laudon Jane P, "*Management Information Systems*", Pearson Education Asia, Eighth Edition (2004)
2. Donald A Waterman, "*A Guide to Expert Systems*", Pearson Education Asia, Third Indian Reprint (2002)
3. Banks Jerry…[et al.], "*Discrete Event System Simulation*", Pearson Education Asia, Third Edition (2001)
4. Davis & Olson, "*Management Information Systems*", McGraw Hill International Editions.
5. Parker & Case, "*Management Information Systems*", McGraw Hill International Editions.

IP-404 Maintenance and Reliability Engineering [3 1 0 4]

Section A

Concept of reliability, objectives, applications, area of use, use of reliability in industry.

The reliability functions, mean time between failures, hazard rate function, bath tub curve, conditional reliability, probability density function, failure rate, failure density, hazard rate, uncertainty measures.

Constant and time dependant failure models: Exponential, webull, normal and lognormal distributions

Reliability of systems, Series and parallel-connected systems, Concept of redundancy, objectives, applications, redundant standby systems, system structure functions, minimal cuts and minimal paths, common mode failures, three state devices.

Section B

Determination of reliability (state dependant systems), Markov analysis, load sharing system, standby systems, degraded systems.

Failure Analysis: Introduction to failure mode and effect analysis, FMEA and FMECA, criticality analysis, Fault tree diagram, event tree.

Availability: concept and definitions, availability model, system availability.

Section C

Introduction: Objectives and policies of maintenance, maintainability terms and definitions, maintainability organization functions and tasks.

Types of maintenance: breakdown, predictive, replacement, on-line, off-line, preventive maintenance, reconditioning and correction maintenance, Preventive maintenances v/s. repair,

Development of preventive maintenance schedule, top down bottom up approach, production maintenance integration.

Maintenance manpower planning, spare parts management, computerized maintenance system, condition based monitoring, on-line v/s off-line maintenance systems, maintenance devices, budgeting and cost control.

Introduction to TPM and RCM

Books Recommended

1. Clifton R H, "*Principles of Planned Maintenance*", McGraw Hill, New York, 2001.
2. Ebling CE, "An introduction to Reliability and .Maintainability Engineering" Tata Mc Graw Hill, Delhi, 2004.
3. Srinath L S "*Reliability Engineering*", Affiliated East-West Press Limited, New Delhi, 2002.
4. Dhillon B S, "*Engineering Maintainability*", Prentice Hall of India, New Delhi,2000.
5. Wireman Terry, "*Preventive Maintenance*", Reston Publishing Company, Reston Virginia,1998.

Departmental Elective Courses

IP-321 Occupational Health and Safety (3-0-0-3)

Section A

Introduction: Environmental law: Legal control of Hazardous substances and processes, Environmental Issues and judicial trends. Health and safety law, common liabilities and work place injuries, Health and safety at work- the principle legal requirements, Health and safety and Industrial relation law.

Health and safety Management: Safety Management and policy, Investigation reporting and recording of accidents, Health and safety monitoring, Comprehensive exposure assessment, Principles of evaluating workers exposure, Risk assessment in the work place, Major incidents and procedures, Health and safety training and communication, the cost of accidents. Principles of accident prevention, safe system of work, Surveys and audits.

Section B

Occupational Health and Hygiene: The organization of working environment, temperature, lighting and ventilation, welfare amenity provision, cleaning and hygiene. Toxicology and health, Occupational disease and conditions: Occupational Audiometry, NIHL, Cardiovascular Disease, Physiological and psychological parameters. Occupational health practice, Noise and vibration, Dust and fumes, radiation and radiological protection, personal protection, Occupational hygiene practice, prevention and control strategies in occupational hygiene, manual handling, first aid, human factor and safety, stress, safety technology.

Section C

Assessment of Exposure: Measurement of noise and vibration exposure. Noise and vibration and control, Heat stress monitoring, dust exposure and respiratory health. Work Posture, Musculoskeletal disorders, Strain Index, Lifting Equation, Maximum acceptable weight limits, Occupational Audiometry. Cardiovascular health, Occupational determinants of heart rate variability, pulmonary functions and respiratory health

Books Recommended

1. Jeremy W. Stranks, "Handbook of Health and safety Practice" Pitman Publishing, 1994.
2. Dharmendra S Sengar, " Environmental law" Prentice Hall of India, New Delhi.
3. Malcolm J Crocker, "Noise and Noise Control" CRC Press.
4. Marek Malik, " Clinical Guide to cardiac Autonomic Tests" Kulwer Academic Publishers.
5. Marek Malik,"Hear rate variability" Futura Publishing Co. NY
6. Cyril M Harris, "Handbook of Noise control" McGraw-Hill Book Company, NY
7. Maryanne Maltby, "Occupational Audiometry" Butterworth-Heinemann Immprint of Elsevier.

IP-322 Engineering Economics and Industrial Design [3 0 0 3]

Section A

Introduction: Definitions, what is industrial design, assessing the need for ID, product and process cycles, ethics, societal and economic considerations in engineering, technological forecasting, technological innovation and design process.

Design Process: Importance of product design, considerations of a good design, detailed descriptions of design process, role of marketing, organization for design and role of computers in design.

Concept generation & concept selection: Concept generation process, basic methods, information gathering and brain storming, conventional aids, brain ball, C-Sketch/6-3-5 method: advanced methods: Direct search, systematic search with physical principles and classifying schemes: Morphological analysis, factors that determine effective decision making, Estimating technical feasibility, concept selection process- basic and advanced methods.

Section B

Design for Robustness: Quality design theory, general robust design model, robust design model construction, taguchi's method; noise variable matrix, design variable matrix, experimental matrix, signal to noise ratio, selection of target design, optimization methods, finite element analysis, evaluation considerations in optimization, design optimization.

Design for manufacturing and assembly: Estimation of manufacturing costs, reducing the cost of components and assemblies, design for assembly, design for piece part production, cost driver modeling and manufacturing cost analysis.

Section C

Economic decision-making: Break-Even analysis, Applications of Break-Even Analysis, Investment Decisions, Payback Period, ARR, NPV and IRR methods, Depreciation, benefits - cost analysis.

Cost evaluation: categories of cost, method of developing cost estimates, cost indexes, cost capacity factors, estimation of plant cost, design cost, manufacturing costs, value analysis in costing, overhead costs, activity based costing, learning curve, cost models, life cycle costing.

Books Recommended

1. Ulrich Karl T and Eppinger Steven D, "*Product design and Development*", McGraw-Hill Inc, 2000.
2. Trott Paul, "*Innovation Management and New Product Development*", Financial Times Professional Ltd, London, 2000.
3. Dieter George E, "*Engineering Design*", McGraw-Hill Inc., 2000.
4. Otto Kelvin and Wood Kristen, "*Product Design*", Pearson Education, Delhi, 2001.
5. Bruce M and Cooper Rachel, "*Creative Product Design*", John Wiley & Sons Ltd., New York, 2000

IP-323 Plastic Engineering [3 0 0 3]

Section A

Introduction: Types of plastic materials **,** Introduction to extrusion process, different types of extruders: - single screw and twin screw extruder, vented barrel extruder, general principles of operation, die swell, function of various parts i.e. barrel, screw, screen pack, die, breaker plate, adaptor.

Section B

Types of screws in use for processing different plastics, Feed, Compression and Metering zone, Die zone, L/D ratio and its significance,Nip rolls, bubble casing, winding equipment, cutting devices, stretching and orientation. Extruder performance and their curves. Blown film extrusion, extrusion of pipes, wires and cables, sheets and filaments, Coextrusion of films and sheets.

Section C

Blow Moulding: Basic principles of blow moulding, Types of blow Moulding: - Extrusion blow moulding, injection blow moulding. Blow molding irregular containers Materials for blow moulding Production of parison, a). By extrusion b). By injection. Parison wall thickness control, Parison blowing systems, air requirement for blowing, effect of process variables on product design and properties. Parison programming, mould venting. Newer concepts including extrusion- stretch blow moulding, injection stretch blow moulding, multi layer moulding etc. Printing techniques – flexographic printing, gravure printing, pad printing, screen printing, hot stamping Conversion of plastic films into laminate e.g. metal plastic laminates, paper-plastic laminates, plastic-plastic laminates. Advantages of multi- layer packaging, disadvantages of multi layer packaging

Books Recommended

1. Frados Joel, "*Plastic Engineering Handbook"*, Van Nostrand Reinhold Company Publication, 2001.
2. Athalye AS , "*Processing of Plastics"* ,MultiTech Publishing Co, 2000.
3. Ghosh, Premamoy , "*Polymer science and technology of plastics and rubbers"*, Tata Mcgraw hill, 2000.
4. Lindberg R.A, "*Processes and Materials of Manufacture"* , Prentice Hall of India (P) Ltd.,1996
5. kalpakjian Serope, "*Manufacturing engineering and Technology"*, Edition III - addision - Wesley Publishing Co., 2002.

IP-324 Fracture Mechanics [3 0 0 3]

Section A

Energy Release Rate: Introduction, Dilemma of Griffith, Surface Energy, Griffith's Analysis, Energy Release Rate, Crack Resistance, Critical Energy Release Rate.

Stress Intensity Factor: Introduction, Linear Elastic Fracture Mechanics (LEFM), Stress and Displacement Fields in Isotropic Elastic Materials, Stress Intensity Factor, Approach of Westergaard; Mode-I, Mode-II & Mode-III.

Section B

Anelastic Deformation at the crack Tip: Further Investigation at the crack Tip, Approximate Shape and Size of the Plastic Zone, Effective Crack Length, Effect of Plate Thickness.

Elastic Plastic Analysis through J-Integral: Relevance and Scope, Definition of J-Integral, Path Independence, Stress-Strain Relation, Further Discussion on J-Integral.

Section C

Crack Tip Opening Displacement: Introduction, Relationship between crack tip opening displacement (CTOD), stress intensity factor and energy release rate.

Test Methods: Introduction, Test technique, Test method to determine Mode-I & Mode-II and Crack tip opening displacement.

Books Recommended

1. Kumar P, Elements of Fracture Mechanics. Wheeler Publishing, New Delhi
2. M. F. Kanninen and C. H. Popular Advanced Fracture Mechanics, Oxford, 1985.
3. T. A. Anderson, Fracture Mechanics, Fundamentals and application, CRC Press, 1994.

IP-325 Productivity Engineering & Technology Management [3 0 0 3]

Section A

Productivity Engineering: Productivity concept and definition, productivity and economic development, impact of productivity in macro-economic context, productivity and production, productivity and profitability, productivity and quality, productivity and technology, external environment and productivity, total, partial and total factor productivity.

Measurement of productivity: factors affecting the productivity of any nation, GDP and GNP, productivity at firm level, measurement approaches, total productivity model, product oriented model, computer algorithms for measuring total and partial productivity. Productivity measurement of services.

Section B

Productivity evaluation: Productivity evaluation and planning, methodologies for evaluation, the productivity evaluation tree, short-term and long-term productivity planning.

Technology management: Need for managing the technology, importance of technology and its management, role of technology in economic development, technological change in modern society.
Technology planning, technology forecasting, applications of technology forecasting and it's impact on business, technology life cycle and it's importance.

Section C

Technology transfer: Technology transfer at macro and micro level, need for technology transfer, modes of technology transfer, technology adaptation, factors affecting technology adaptation, technology absorption, technology diffusion, technology transfer agreements, negotiations in technology transfer, cultural differences, introduction to re-engineering, characteristics of technology in developing countries, role of R & D department in technology adaptation & development, implementation of acquired technology,

Books Recommended

1. Sumanth D J, "*Productivity Engineering & Management*", McGraw Hill (1995).
2. Sink S, "*Productivity Management, Planning, Measurement & Evaluation*", John Wiley, 1990
3. Smith E A, "*Productivity Manual*", Gulf Publisher, 1989.
4. Fredrick Betz, "*Technology Management*", McGraw Hill, 1990.
5. Coombs Rod & Richards Albert, "*Technological Collaborations*", Edward Elgar Publishing Ltd, 1996.

IP-326 Environment Planning and Control [3 0 0 3]

Section A

Introduction to environment management: Environment and its components, ecology and its divisions, structure of function of ecosystem, data base management for environmental appraisal, monitoring & warning system. environmental hazards, terminology and classification of natural resources, environmental impact analysis, environmental planning.

Environmental pollution: Concept and nature of pollution, sources and types of pollution and their effects, air, water, noise, thermal pollution monitoring and its parameters.

Section B

Environment and law: Environment legislations and its uses, water Act, air Act water Cess Act, hazardous waste handling Act, biomedical waste management Act, solid waste management Act, role of environmental enforcement organizations, kyoto protocol.

Systems of environment management: Management of air pollution control, management of water pollution, management of prevention of thermal pollution, management of waste heat.

Section C

Systems of environment management (**Contd.)** Management of solid waste disposal, hazardous wastes, management of noise pollution, biomedical waste management, management of agricultural pollution.

Environmental control: Introduction to ISO-14000, its parameters, importance of ISO 14000 in production and service sector various pollution control methods and devices.

Books Recommended

1. Della-Giustina Denial E, "*Safety and environment management*", Johan Wiley Publications.
2. Markman Howard J, "*Environmental Management and Cleaner Production*", John Wiley Publications.
3. Johnson Perry, "*ISO14000, The Business Managers Complete Guide to Environment Management*", John Wiley Publication.
4. Nemesow Nelson L, "*Zero Pollution for Industry*", John Wiley Publication.

IP-327 Composite Materials [3 0 0 3]

Section A

General introduction: Types of composite material, Design of composite materials, the concept of load transfer.

Fibres and matrices: Reinforcements: - Carbon fibres, Glass fibres, Organic fibres, Silicon carbide, Alumina and aluminosilicates. The strength of reinforcements:- Thermal stability, Compressive strength, Fibre fracture and flexibility. Matrices:- Polymer matrices, Metal matrices, Ceramic matrices.

Section B

Strength of composites: Failure modes of long-fibre composites, Failure of laminae under off-axis loads, strength of laminates, Failure of tubes under internal pressure.

Toughness of Composites: Fracture mechanics, contributions to work of fracture, Sub-critical crack growth.

Section C

Analysis of Laminated Composites: Introduction, Stress and strain variation in a laminate, Synthesis of Stiffness Matrix, Simplification of stiffness matrices. Determination of stresses and strains, Thermal stresses in laminates.

Fabrication: Polymer composites, Metal composites, ceramic composites, Applications.

Books Recommended

1. Hull & Clyne, An Introduction to Composite Materials, Cambridge University Press, New York, 1996.
2. Dr. A. Brent Strong, Fundamentals of Composites Manufacturing: Materials, Methods, and Applications, Society of Manufacturing Engineers, Dearbon, Michigan, 1989.
3. Agarwal B. D. & Broutman L. J., Analysis and Performance of Fiber Composites, John Willy & Sons, New York, 1979.

IP-328 Change Management for Competitiveness [3 0 0 3]

Section A

Problematizing organizations: Stakeholders, environment, structure, systems, culture and people, types of change- linear and nonlinear, incremental and radical, slow and fast, systems perspective of change, framework for conceptualizing change.

Section B

Organizational change- people, process and technology issues, restructuring of organizations, creative destruction, role of information technology in organizational change.

Reengineering and restructuring, self-regulating evolutionary and revolutionary changes, challenges of continuous and incremental changes, drivers of change, change agents, change process, total change.

Section C

Competitiveness: various measures of competitiveness, relationship between change and competitiveness, SWOT analysis, SAP-LAP analysis, tinkering and kludging, Matrix of change, Delphi study, implementing change: various issues and theories, impact of change, Case studies.

Books Recommended

1 Johnson A Edosomwan, *"Organizational Transformation and Process Reengineering"*, Kogan Page Limited, London, 2000.
2 Sushil, "*Flexibility in Management*", Vikas Publishing House, New Delhi, 2001.
3 Bernard Burnes, "*Managing Change*", Pitman Publishing Company, London, 1999.
4 John Storey, "*Human Resourse and Change Management*", Blackwell Publishers, UK, 1999.
5 Stephen P Robbins, "*Organizational Behaviour*", Pearson Education, New Delhi, 2002.

IP 329 Smart Materials and Nano Technology [3 0 0 3]

Section A

Introduction to Smart materials: Materials for both actuation and sensing: Piezoelectric Materials, Magnetostrictive Materials, Materials for actuation: Shape Memory alloys Magnetic shape memory material, Electro/Magneto rheological fluids; Materials for sensing: Optical fibre; Composite smart materials and micromodelling related issues; Intelligent system with integrated sensors & actuators; Self-sensing actuators; Placement of Smart Actuators/Sensors - Vibration damping.

Section B

Introduction to Nanotechnology: Characteristic scale for quantum phenomena, nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Drexler-Smalley debate - realistic projections. Electronic structure: quantum wells quantum dots, quantum wires. Nano clusters, clusters of rare gases, clusters of alkali metals.

Section C

Processing of Nano Materials: Si processing methods: Cleaning /etching, oxidation-oxides, Gettering, doping, epitaxy. Top-down techniques: Photolithography, other optical lithography's (EUV, X-ray, LIL), particle beam lithography's (e-beam, FIB, shadow mask evaporation), probe lithography's. Molecular-beam epitaxy, chemical beam epitaxy, metal-organic CVD (MOCVD). Bottom-up techniques: self-assembly, self-assembled monolayer, directed assembly, layer-by-layer assembly.

Books Recommended:-

1. Michelle Addington , Daniel L. Schodek "Smart Materials and Technologies in Architecture" John Wiley, 2008
2. Vijay K. Varadan, Ahsan Hariz, Olaf Reinhold "Smart Materials, Structures, & Integrated Systems", Springer, 1997
3. Bhushan, Bharat , "Handbook of Nano Technology" Springer, 2007
4. Di Ventra, Massimiliano; Evoy, Stephane; Heflin, James R. "Introduction to Nanoscale Science and Technology", Wiley, 2006
5. Mark J. Schulz , Ajit D. Kelkar , "Nanoengineering of Structural, Functional and Smart Materials" CRC Press, 2005

IP-330 Advanced Industrial Inspection and Non – Destructive Testing [3 0 0 3]

Section A

Radiography: Principle of radiography, types of radiography, equipments for neutron radiography, x-ray radiography, equipments for x-ray radiography, advantages and applications of fluoroscopy and photo fluoroscopy

Electromagnetic methods: Principle of electromagnetic testing, mathematical analysis, flaw detection in conductors, various types' of instruments used and advantages of various electromagnetic methods for crack detection etc.

Section B

Ultrasonic methods: Principle of ultrasonic testing, generation of ultrasonic waves, equipment details for ultrasonic checking, methods of wave propagation, methods of flaw detection, various methods of ultrasonic testing, advantages of ultrasonic methods for flaw detection and crack location

Holography: Principle of holography, method of holographic recording, method of holographic reconstruction, advantages of this technique and applications of holographic methods for non-destructive testing.

Section C

Liquid penetrant testing: Principle of liquid penetrates testing, types of dyes and penetrants used in this testing technique and application of liquids for detecting sub-surface defects.

Magnetic particle testing: Principles of magnetic particle testing, details of equipments used and methods of crack detection by magnetic particle testing Hardness testing: Brinnel hardness testing, Rockwell hardness tests, shore hardness testing, Vicker hardness testing and theory behind various hardness testing methods.

Books Recommended

1. Malhotra, "*Handbook on Non-destructive Testing of Concrete*", Publisher: CRC Press, 2002.
2. Mix, Paul E, "*Introduction To Nondestructive Testing: A Training Guide*", John Wiley and Sons Ltd, 1999.
3. Blitz and Jack, "*Electrical and Magnetic Methods of Nondestructive Testing*", Institute of Physics Publishing, 2001.
4. Achenbach, J D, "*Evaluation of Materials and Structures by Quantitative Ultrasonics*", Springer-Verlag Vienna, 2001.
5. Henrique L M, "*Non Destructive Testing and Evaluation for Manufacturing and Construction*", Hemisphere Publishers, New York, 2001.

IP-331 Mechatronics [3 0 0 3]

Section A

Introduction to Mechatronics Systems: Measurement Systems-Control Systems-Mechatronics Approach.

Sensors and transducers: Introduction-Performance Terminology-Displacement, Position and Proximity-Velocity and Motion-Fluid Pressure-Temperature Sensors-Light Sensors-Selection of Sensors-Signal Processing.

Section B

Microprocessor: Introduction-Architecture-Pin Configuration-Instruction set-Programming of Microprocessors using 8085 instructions-Interfacing input and output devices-Interfacing D/A converters and A/D converters-Applications- Temperature control-Stepper motor control-Traffic light controller.

Programmable Logic Controller: Introduction-Basic structure-Input/Output Processing-Programming-Mnemonics-Timers, Internal relays and counters-Data handling-Analog Input/Output-Selection of a PLC.

Section C

Design and Mechatronics: Stages in Designing mechatronic systems, Traditional and Mechatronic design, Possible design solutions, Case studies of mechatronic systems, Pick and place robot, automatic car park system , engine management system.

Books Recommended

1. Bolton W., "*Mechatronics"*,Longman,Second Edition, 2004.
2. Histand Michael B. and Alciatore David G., "*Introduction to Mechatronics and Measurement Systems"*, McGraw Hill International Editions, 2003.
3. HMT Ltd., "*Mechatronics*", Tata McGraw Hill Publishing Co. Ltd., 1998.
4. Bradley D.A., Dawson D., Buru N.C. and Loader A.J., "*Mechatronics*", Chapman and Hall, 1993.
5. Gaonkar Ramesh S., "*Microprocessor Architecture, Programming and Applications*", Wiley Eastern, 1997.

IP-332 Simulation & Modeling [3 0 0 3]

Section A

Introduction: Basic concepts of systems, Elements of systems, event driven models, simulation as a decision making tool, types of simulation, system modeling, types of modeling

Statistical models in Simulation: Review of terminology and concepts, useful statistical models, discrete distributions, continuous distributions, poisson process, empirical distributions.

Section B

Random Numbers: properties of random numbers, pseudo random numbers, techniques for generating random numbers, test for random numbers, techniques for random variate generation.

Analysis of simulation data: data collection, distribution fitting, parametric estimation, goodness of fit tests, verification and validation of simulation models

Markov processes: probabilistic systems, discrete time markov processes, random walks, simulating as a poisson process, continuous time markov processes

Section C

Recent advances and case studies/mini project: Development of simulation models using simulation languages studied for systems like queuing systems production, inventory, maintenance, material handlingand replacement systems-Investment analysis and network.

Books Recommended

1. Gray Beal, Wajne J and Pooch U W, "*Simulation Principles & Methods*", Winthrop Publishing Incorporate.
2. Severance Frank, "System Modelling and Simulation", John Wiley and
3. Hall, 2001.

IP-423 Marketing & Financial Management [3 0 0 3]

Section A

Introduction: Need, want, demand, production, product, selling, marketing and societal concepts of marketing, types of goods.

Marketing Process: Analyzing marketing opportunities, researching and selecting target markets, positioning the offer, designing marketing strategies, planning marketing program, organizing, implementing & controlling marketing efforts.

Consumer Behavior & Market Research: Factors affecting consumer behavior, stages in purchasing, market research, market segmentation and target market selection.

Organizational Buying: Salient features, factors affecting organizational purchase marketing mix, product, product levels, product hierarchy, product line, types of distributions, Channel management decisions, product mix, product life cycle, procedure for new product development, branding and packaging.

Section B

Price: Pricing objectives, price elasticity of demand, methods of pricing, discounts, discriminatory pricing.

Distribution: Need for middleman and their functions, vertical marketing system.

Promotion Mix: Advertising, media selection, frequency and timing of advertisement, steps in developing effective communication, sales promotion, personal selling, publicity.

Section C

Sales Force Management: Recruitment, training, motivating sales representatives, controlling and evaluating.

Basic Valuation Concepts: Time value of money, methods of dealing with time value of money, future value of a single cash flow, future value of annuity, present value of a single cash flow, present value of annuity, risk and return concept, valuation of bonds, securities and equities
Principles of accounting, balance sheet, income statement, financial ratios.

Books Recommended

1. Winer Russel S , "*Marketing Management*", Prentice Hall of India, 1998.
2. Guilitinan Joseph P , Gordon W Paul and Thomas J Maddaen, "*Marketing Management: Strategies and Programs*", Mc Graw Hill Publication, 1996.
3. Dolan Robert J, "*Marketing Management: Text & Cases*", McGraw Hill Publication, 2000.
4. Lamb Charles W and McDaniel Carl D., "*Marketing*", South Western College Publication, 2004.
5. Kotler Philip, "*Marketing management Analysis, Planning & Control*", Pearson Education Asia,2002.

IP-424 Industrial Instrumentation and Control [3 0 0 3]

Section A

Basic Concepts of Instrumentation: Accuracy and precision of measurement, types of error, statistical analysis of error, electrical standards, IEEE standards. Types of noises i.e. White noise, grey noise and colored noise.

Use of analysis tools of MATLAB, DFT, FFT, IFFT, Linear and Circular co-relation tools etc.

Windowing: Black Man Herris, Flat Top, Hamming, hanning, Co-efficicent windows. Use of windows to reduce leakage

Section B

Filters: Design of the analog filters like Butterworth, Bessel, Chebyshev, designing FIR/IIR filters.

Signal Processing: Auto/cross – correlation, discrete Fourier transform, convolution, power spectrum, inverse transforms, and signal amplification

Section C

Basic Sensors and Transducers: LVDT: Principle and applications, Signal conditioning of the signal measured by LVDT. Strain gauges: Principle and applications, Signal conditioning of the signal measured by strain gauges. Optical fiber based sensors: Principles of optical fiber technology, types of light emitters and absorbers etc.

Signal Measurement: Digital and analog data acquition, Types and architecture of data actuation cards. Interfacing: Methods of interfacing transducers to measurement system. Multiplexing: Meaning of multiplexing and types of multiplexing methods.

Basic Concepts of Control: Discrete and Continuous time control. Laplace and z- transform. Time domain control theories like Pole placement; Frequency domain control theories like Lead and Lag compensators.

Books Recommended

1. D S Kumar, "*Mechanical Measurement*", Metropolitan Books Company Ltd, 1998.
2. Haykin, "*Modern Filters*", Macmillan Publishers, 1989.
3. Ambardar, "*Analog and Digital Signal Processing*" Cole Publishing Company, 2001.
4. "*Measurement and Automation*" Manuals from National Instruments, 2002.
5. Lynn P A, "*Introduction to Digital Signal Processing*", John Wiley and sons, 1998.
6. Zhou K and Doyle j, "Robust and Optimal Control" Prentice Hall Publishers, 1998.

IP-425 Finite Element Analysis [3-0-0-3]

Section A

1**. Basic concepts:** Variational and Residual methods-Introduction - Different approaches in Finite Element Method - Direct Stiffness approach, simple examples Variational approach, Elements of variational calculus – Euler's-Lagrange equation, Rayliegh Ritz method , Weighted Residual methods, Point Collation method, Sub domain Collation method, Galerkins method - Steps involved in FEM.

Section B

2**.Elements and Interpolation Functions:** Elements and coordinate system -Interpolation Polynomials - Linear elements Shape function - Analysis of simply supported beam - Element and Global matrices - Two dimensional elements, triangular and rectangular elements - Local and Natural Co-ordinate systems.

3. **Finite Element Solution of Field Problems:** Field problems – Finite element formation of field problems - Classification of partial differential equations - Quasiharmonic equation - Steady state problems - Eigen value problems - Propogation problems - Examples, Torsional problem - Fluid flow and Heat transfer problems - Acoustic vibrations – Application in manufacturing problems – metal cutting and metal forming.

Section C

4. **Finite Element Solution of Structural Problems:** Solid mechanic problems – Finite element formulation of solid mechanic problems - Axial force member - element matrices for axial force members - Truss element analysis of pinned truss - Two dimensional elasticity problems.

5**. Higher Order Elements and Numerical Methods:** Numerical method and computer implementation –Numerical method in FEM and Computer implimentation. Evaluation of shape functions - One dimensional & triangular elements, Quadrilateral elements, Isoparametric elements - Numerical Integration, Gauss Legendre quadrature - Solution of finite element equations - Cholesky decomposition, Skyline storage - Computer implementation- Use of FEM software.

Recommended Books

1. Larry J Segerlind ," Applied Finite Element Analysis", John Wiley, 1984
2. Bathe, K.J., "Finite Element Procedures", Prentice Hall, 1994.
3. Huebner,K.H. and Thornton, E.A., "The Finite Element Method for Engineers", John Wiley, 1982.
4. Reddy,J.N., "Introduction to Finite Element Method", McGraw Hill, 1993
5. Zienkiewich . O.C., and Taylor . R.L., "The Finite Element Method", McGraw Hill,1991.
6. S.S.Rao, "Finite element method ", 1995.

IP-426 Geometrical Modeling for Manufacturing [3 0 0 3]

Section A

Introduction: Variational formulation, General field problems in Engineering, Modeling: Discrete and Continuous Models, Characteristics, the relevance and place of finite element method. Boundary and initial value problems, Gradients and Divergence theories, Functional Variational calculus, Variational formulation of B.V.P-The method of weighted residuals-The Ritz-Galesrkin, relaxation and finite difference method.

Finite elements formulation of one dimensional problem : One dimensional second order equations-discretization of domain in to elements-Generalized coordinate approach-Stiffness matrix-Extension of the method to fourth order equation, time dependant problems and their solutions-Examples from heat transfer, fluid flow and solid mechanics

Section B

Finite elements formulation of two dimensional problem: Second order equation involving variational formulation-Triangular elements and Quadrilateral elements-CST and LST models-Convergence criteria for chosen models-Element matricses and vectors-Solution techniques-Extension to three domain problem, Axisymmetric problems-Example from metal forming and metal cutting

Section C

Isoparamatric elements of formulation: Natural coordinate in 1, 2 and 3 dimensions-Use of area coordinates for triangular elements in 2 dimensional problems-Isoparamatric elements in 1,2 ,3 dimensional, Numerical integration.

Solution of large system of equations: Sparse and banded matrics-Memory requirements-Choleksy decomposition-Forward and backward substitution procedures-Gaussian elemination techniques-Eigen value problems-Iteration concepts.

Books Recommended

1. Chandrupatla T.R and Belegundu A.D., "*Introduction to Finite Elements in Engineering*", Prentice Hall of India, 1998.
2. Rao S.S., "*The finite element method in Engineering*", Pergaman process, 1993.
3. Segeriend L.J., "*Applied finite element analysis*", John Wiley and Sons, Inc 1989.
4. Reddy J.N., "*An Introduction to the Finite Element method*" , McGraw Hill International Student Edition, 1990.
5. Rajasekaran.S., "*Numerical methods for Initial and Boundary Value problems*", Wheelers and Co., Pvt Ltd. 1987.

IP-427 Automobile Engineering [3 0 0 3]

Section A

Introduction to automobile: Importance, applications, job opportunities, classification, types of vehicles, basic structure, general layout, hybrid vehicles.

Automotive electric and electronic systems: Electric and electronics principles, systems, and circuits, automotive batteries, construction, and operation, starting system, charging system, operation and service, ignition system, electronic ignition and fuel control, engine management, electric vehicles, electronic fuel injection system - monopoint and multipoint systems.

Section B

Automotive drive trains: Clutch - types and construction, fluid flywheel, gear boxes, manual and automatic - overdrives - propeller clutches, drive shafts, universal joints, drive axles.

Automotive chassis: Vehicle construction, chassis, frame and body, construction, operation, performance, steering system, wheel alignment, brakes, wheels and tyres.

Section C

Maintenance and Trouble Shooting: Automobile performance, drivability, emissions and emission norms, noise and vibration, engine tuning, equipment for measuring various vehicle parameters such as BHP, A/F ratio, noise, vibration and emission, comfort and safety.

Newer Fuels: Use of natural gas, LPG, hydrogen, bio- diesel in automobiles as fuels, electric and hybrid vehicles, fuel cells.

Other recent advances in automobiles and automotive components.

Books Recommended

1 Crouse – Anglin, "*Automotive Mechanics*", McGraw Hill, 10th Edition, Singapore.
2 Pulkrabek Willard W., "Engineering *Fundamental of the Internal Combustion Engine*", Prentice Hall of India, New Delhi, 2002.
3 Bosch, "*Automotive Handbook*", SAE Publication.
4 Denton Tom, "*Automobile Electrical and Electronics Systems*", Butterwoth, Heinemann, 2003.
5 Layne Ken, "*Automotive Engine Performance: Tune up, Testing and Service*", Englewood Prentice Hall of India, 1996.

IP-428 Logistics & Supply Chain Management [3 0 0 3]

Section A

Understanding supply chain: Objectives of supply chain, stages of supply chain, supply chain process cycles, customer order cycle, replenishment cycle, manufacturing cycle, procurement cycle, push/pull view of supply chain processes, importance of supply chain flows, examples of supply chain.

Supply chain performance: supply chain strategies, achieving strategic fit, product life cycle, the minimize local cost view, the minimize functional cost view, the maximize company profit view, the maximize supply chain surplus view.

Supply chain drivers and obstacles: Four drivers of supply chain – inventory, transportation, facilities, and information, a framework for structuring drivers, role of each driver in supply chain, obstacles to achieve strategic fit.

Network Design: Factors influencing distribution in network design, distribution networks in practice, framework for network design decisions, models for facility location and capacity allocation, making network design decisions in practice, impact of uncertainty on network design, discounted cash flow analysis, representation of uncertainty, evaluating networks using decision trees, illustration through practical examples.

Section B

Aggregate Planning in Supply Chains: Role of aggregate planning in a supply chain, aggregate planning strategies, aggregate planning using linear programming and problem solving using solver, practical problems concerning aggregate planning.

Managing economies of scale in a supply chain: Role of cycle inventory in a supply chain, economies of scale to exploit fixed costs, economies of scale to exploit quantity discounts, short term discounting, estimating cycle inventory related costs, determining appropriate level of safety inventory.

Transportation in a supply chain: Facilities affecting transportation decisions, modes of transportation and their performance characteristics, design options for a transport network, trade-offs in transportation decision, tailored transportation, routing and scheduling in transportation, making transportation decisions in practice.

Section C

Sourcing Decisions in Supply Chains: Role of sourcing in supply chains, supplier assessment, design collaboration, sourcing planning and analysis, market sourcing decisions in practice

Coordination in a supply chain: Lack of supply chain coordination and the Bullwhip effect, effect of lack of coordination on performance, obstacles to coordination, managerial levers to achieve coordination, achieving coordination in practice.

Books Recommended

1. Chopra Sunil, Meindl Peter, "*Supply Chain Management – Strategy, planning and Operation's"*, Pearson Education, Asia (2007).
2. Christopher Martin, "*Logistics and Supply Chain Management*", Pearson Education Asia, (2004).
3. Kapoor K K, Kansal Purva, "*Marketing logistics: A Supply Chain Approach*", Pearson Education Asia (2003).
4. Benjamin S Blanchard, *Logistics Engineering and Management*, Pearson Education, Asia (2005)
5. Buffa, "*Modern Production/Operations Management*", Wiley Eastern Ltd. (2000)

IP-429 Emerging Trends in Manufacturing Technology [3 0 0 3]

Section A

Introduction: classification of modern machining methods, consideration in process selection.

Mechanical process, ultrasonic machining, element of U.S.M., acoustic head & its design, tool feed mechanism, abrasive feed mechanism of cutting, effect of parameter on material removal rate and surface finish, economic consideration, application and limitations, recent development; abrasive jet marching, variable affecting material removal rate, application advantages and limitation; water jet machining, jet cutting equipment process details and practical applications.

Electro-chemical process:

Electro-chemical machining: elements of process, electrolytes & their properties, chemistry of process, metal removal rate. Thermal aspect, temperature rise & pressure-flow rate, tool design, accuracy & surface finish, advantages, application & limitations of the process, electrochemical grinding deburring & honing. Chemical machining: Elements of process, resists & echants, advantages & applications.

Section B

Thermal process: Electrical discharge machining, mechanism of metal removal, EDM equipment, generators & feed control devices, dielectric fluid, selection of electrode material, accuracy and surface finish, application & future trends. Plasma Arc Machining, mechanism of metal removal, PAM parameters, types of torches, accuracy and surface finish, economics and application of plasma jets, plasma arc spraying.Electro beam machining: generation and control of electron beam, theory of electron beam, process capability and limitations.

Laser beam machining: principles of working, thermal aspect, material removal, cutting speed and accuracy, advantages & limitations.

Section C

Emerging Trends in welding processes: Explosive welding, Cladding etc. Under water welding, Metallising, Plasma arc welding / cutting etc.

Emerging Trends in Forming processes: Principle, working and applications of High energy forming processes such as Explosive Forming, Electromagnetic forming, Electro-Discharge forming, water hammer forming, explosive compaction etc.

Books Recommended

1. Shan H S, "*Modern Machining Processes*", Tata McGraw Hill Publishing Co., 2002.
2. Ghosh Amitabh, "*Manufacturing Processes*", Tata McGraw Hill Publishing Co., 2001.
3. Kalpakjian Serope, "*Manufacturing Engineering and Technology*", Addison Wesley Longman Publishers, 2000.
4. Rao P N, "*Manufacturing Technology*", Tata McGraw Hill Publilishing Company, 2000.
5. Mishra P K,"*Non Conventional Machining*", Narosa Publishers, 2001.
6. Singh K K "Unconventional Manufacturing Processes" Dhanpat Rai & Company, New Delhi 2007.

IP-430 TQM & Value Engineering [3-0-0-3]

Section A

Total Quality Management

Basic concepts: Various approaches to understanding quality. Quality & competitiveness. The strategy of detection, prevention as a strategy, development of prevention, the economic benefits of prevention.

Basic analytical tools: check sheets, histogram, Pareto charts and cause & effect diagrams. Goal post view of Quality & Taguchi's loss- function approach. Steps in formation of Quality Circles.
Quality costs: Prevention, appraisal, internal failure & external failure costs.

Six sigma quality: 6σ introduction, comparison of 3σ / 6σ level company, CTQ: Critical to Quality, CTQP: CTQ Performance, CTQS: CTQ Specifications, theme selection (activity focusing). Process 6σ methodology: Define, measure, analyze, improve, and control.

Section B

Quality Function Deployment (QFD) approach: The voice of the customer, house of quality, what's, how's, building house of quality.

Quality assurance: Definition, characteristics of quality assurance system. ISO-9000: scope, application, terms & definitions, evolution of ISO-9000 series, process approach, PDCA methodology, documentation requirements, commentary on ISO-9000 requirements, guidelines for preparation of Quality Manual. Steps for certification, implementation schedule for certification. ISO - 14000 series standards, concepts & requirements of ISO –14001, benefits of ISO - 9000 & ISO - 14000.

Quality Audit: process audit & product audit, internal audit, second party, third party audit, pre-assessment, compliance audit. Procedure of auditing: Audit planning, audit execution, audit reporting, close out of corrective action. Minor & major non-conformities.

Business excellence models :- Malcom Balridge quality awards, Deming's philosophy, Juran's philosophy, EFQM

Value Engineering

Introduction: Introduction to value engineering & value analysis, methodology of value engineering.

Unnecessary cost: Unnecessary costs, reasons of unnecessary costs, results of unnecessary costs.

Value: Concept of value, types of value, use and prestige value, esteem value, estimation of product quality or performance.

Section C

Functional approach: Types of functions, functional cost and functional worth. Effect of value improvement on profitability, tests for poor value, aims and objectives of value engineering, systematic approach.

VE Job Plan: Value engineering, job plan- study of various phases of the job plan. Selection of projects: Selection of projects for value analysis. Primary and secondary functions work and sell functions, determining and evaluating functions, assigning equivalence, Evaluation techniques: Function-cost matrix evaluation. FAST approach. Other topics: Reporting, implementation & follow up.

Books Recommended

1. Mudge Arthur E, "Value Engineering -A Systematic Approach", McGraw Hill Book Co., New York, 2000.
2. R D Miles, "Techniques of Value analysis & Engineering", McGraw Hill, 2000.
3. Besterfield Dale H… [et al.], "Total Quality Management", Pearson Education Asia, 2001.
4. Goetsh & Davis, "Understanding & Implementing ISO 9000: 2000", Pearson Education Asia, 2002.
5. Sower, Savoie & Renick, "Introduction to Quality Management and Engineering", Pearson Education Asia, 1999.
6. Jeffrey Liker, David Meier" The TOYOTA way; Fieldbook " Prentice Hall

IP-431 Computer Integrated Manufacturing [3 0 0 3]

Section A

Modeling: automated modeling systems, Production economics, Nature role and development of CIM Architecture, computers in CIM, simulation software.

Process model formulation, control actions, optimal control structure model of a manufacturing process, steady state optimal control, adaptive control, sequence control and programmable controllers, computer process control, The computer process interface-interface hardware, direct digital control.

Section B

Group technology: part families, parts classification and coding, Production Flow analysis, cellular manufacturing cell design, benefits MRP I and II, computer aided quality control.

Process planning and concurrent engineering: logical design of a process plans election of machining processes, tools-work piece holders etc-sequencing of operations-geometric interpretation of technical drawings dimensioning and tolerancing-selection of detailed method of production

Section C

Computer aided process planning (CAPP): files management, variant approach, generative approach, development and trends. Architecture workstations, material handling and storage systems, computer controlled machines, automated work flow automated assembly systems, dead locks in automated manufacturing systems, PETRINET models applications, Development of software for FMS integration.

Books Recommended

1 Groover Micell P., "*Automation, Production System and computer integrated manufacturing"*, Prentice - Hall of India Pvt Ltd., 1995.
2 Radhakrishnan P and Subramanian S, "*CAD/CAM/CIM* ", Wiley Eastern Limited, 1994.
3 Gideon Halevi and Roland D.Weill, "*Principles of process planning* ", Chapman Hall, 1995.
4 Gu P and Norrie D.H, "*Intelligent Manufacturing Planning* ", Chapman and Hall, 1995.
5 Rehg James A., Kraebber Henry W, "*Computer Integrated Manufacturing*" Pearson,2002

IP-432 Advanced Operations Research [3 0 0 3]

Section A

The simplex algorithm, post optimality analysis, duality in l.p., dual simplex method, revised simplex method.

Transportation algorithm and optimality, assignment model, Hungarian method. decision making under certainty, risk and uncertainty, game theory, two-person zero-sum game, mixed strategy.

Section B

Elements of queuing model, single channel infinite population model, finite queue length, pure birth and death model, multi channel queuing model.

Goal programming, problem formulation, the weighting method, primitive method.

Integer programming, problem formulation, branch-and-bound algorithm, zero-one implicit enumeration algorithm.

Section C

Non-linear programming, direct search method, gradient method.

Evolutionary algorithms, introduction to genetic algorithms, Binary coded GAs for constrained optimization, introduction to real coded GAs. Introduction to simulated annealing, ant colonies, particle swarm optimization.

Recommended Books

1. Taha, H.A., Operations Research - An Introduction, Sixth Edition, Prentice Hall of India Private Limited, N. Delhi, 2004.
2. Hillier, F.S., Operations Research, First Indian Edition, CBS Publishers and Distributors, Delhi, 1994.
3. Wagner H.M., Principles of Operations Research, Second Edition, Prentice Hall of India Private Limited, New Delhi, 2003.
4. Deb K, Optimization for Engineering Design, Prentice Hall of India Pvt. Ltd., 2005.
5. Gupta P.K., and Hira, D.S., Operations Research, Third Edition, S. Chand and Company Ltd., New Delhi, 2005.

IP-433 Finite Element Plasticity & Metal Forming Analysis [3 0 0 3]

Section A

General introduction to the FEM: Introduction, Earlier theoretical methods for metal forming analysis, Basic finite-element approach, Discretisation, Interpolation, Stiffness matrices of the elements, Assembly of element stiffness matrices, Boundary conditions, Numerical solution for the displacements. Strains and stresses in the elements.

Section B

Basic formulation for elastic deformation: Types of elements, Size of elements, Continuity and equilibrium, Interpolation functions, Polynomials, Convergence, Plane elastic stress, Plane elastic strain, Boundary Conditions, Finite- difference method.

Finite- element plasticity on microcomputers: Microcomputers in engineering, A FORTRAN based system for non-linear finite-element plasticity. Applications of the non-linear systems, System improvements.

Section C

Finite- strain formation for metalforming analysis: Introduction, Governing rate equations, Elastic- Plastic formulation, Yield criterion, Elastic-Plastic flow rule, Elastic- Plastic constitutive relationship, Effect of plastic incompressibility, Element expressions, Incremental element-stiffness equations.

Books Recommended

1. Rowe G. W., Sturgess C. E. N., Pillinger I. Finite Element Plasticity and Metal forming analysis, Cambridge University Press, New York, 2005.
2. R Chandrupatla, "Finite Element Analysis for Engineering and Technology, Universities Press, 2001.
3. George E. Dieter "Mechanical Metallurgy" McGraw-Hill Book Company, 1988.
4. Dr. Sadhu Singh," Theory of Plasticity and Metal Forming Processes, Khanna Publication, New Delhi, 1999.

IP- 434 Vibrations & Noise Control [3 0 0 3]

Section A

Vibration concepts: Vibration of SDOF free, forced, damped and undamped vibration analysis. Energy based method of analysis: Lagrange's Equation and Hamilton's principal. Lumped parameter and distributed parameter modeling of mechanical vibratory systems.

Applications of numerical procedures to determine natural frequencies and mode shapes.

Section B

Finite Element Method for dynamic analysis. Distributed parameter models of rods, bars and beams.

Experimental and theoretical routes to vibration engineering. Introduction to Modal testing, Vibration Testing. Spatial, Modal and Response models of vibrating systems.

Design of vibration isolators. Auxiliary mass systems including tuned & untuned dampers for vibration control. Signal processing for noise and vibration.

Section C

Acoustics Concepts: Wave approach to sound, wave equation in two and three dimensions. Noise measurement and instrumentation standards. Sound pressure, power and intensity. Noise radiation from vibrating bodies. Various source models. Various types of sound fields. Sound Absorption and transmission. Some case studies

Books Recommended

1. Mechanical Vibrations (2nd Edition) H Benaroya, Marcel Dekker, New York, 2004
2. Mechanical Vibration, (4th Edition) S S Rao, Pearson Education, Delhi, 2004.
3. Theory and Practice of Mechanical Vibration, (2nd Edition) J S Rao and K Gupta, New Age International Publishers, New Delhi, 1999.
4. Advanced Theory of Vibration, J S Rao, Wiley Eastern Ltd. New Delhi, 1992
5. Inman D.J., "*Engineering Vibration*" 2nd Edition, Prentice Hall, 2001, ISBN 013726142X
6. Vibration: Fundamentals and Practice, (2nd Edition) de Silva, CRC Taylor & Francis, FL USA, 2007.
7. Fundamentals of Acoustics (4th Edition), Kinsler, Frey, Coppens & Sanders, John Wiley & Sons Inc, Delhi, 2000.

IP-435 Flexible Manufacturing Systems [3 0 0 3]

Section A

An overview: Definition of FMS – types & configurations concepts- types of flexibility & performance measures. Functions of FMS host computer – FMS host and area controller function distribution. Development and Implementation: Planning phases integration- system configuration – FMS layouts – simulation –FMS project development steps. Project management –equipment development – host system development - planning – hardware & software development.
Automated material handling and storage: Functions- types – analysis of material handling equipments, Design of conveyor & AGV systems. Storage system performance- AS/RS – carousel storage system – WIP storage system – interfacing handling storage with manufacturing.

Section B

Modeling and analysis: Analytical, heuristics, queuing, simulation and pertinent modeling techniques – scope applications and limitations. Application of Simulation software, manufacturing data systems- planning the FMS database.

Concepts of distributed numerical control: DNC system – communication between DNC computer & machine control unit – hierarchical processing of data in DNC system – features of DNC systems. Programmable Controllers: Control system architecture – elements of programmable controllers: languages, control system flowchart, comparison of programming methods .
Introduction to micro controllers Applications

Section C

Scheduling and loading of FMS Introduction, scheduling of operations on a single machine –2 machine flow shop scheduling – 2 machine job shop scheduling, 3 machine flow shop scheduling – scheduling 'n' machines – scheduling rules – loading problems – tool management of FMS, material handling system schedule, Knowledge based scheduling in FMC

FMS Relationale: Economic and technological justification for FMS – as GT, JIT- operation and evaluation – personnel and infra structural aspects – typical case studies – future prospects.

Books Recommended

1. Parrish D J, "*Flexible manufacturing*", Butter Worth – Heinemann Ltd, Oxford (1993).
2. Groover M P, "*Automation, Production system and computer Integrated manufacturing*", Prentice Hall India (P) Ltd (1989).
3. Kusiak A, "*Intelligent Manufacturing Systems*", Prentice Hall, Englewood Clitts, NJ (1990).
4. Considine D M and Considine G.D, "*Standard Handbook of Industrial Automation*", Chapman and Hall, London (1986).
5. Ranky P G, "The *Design and Operation of FMS*", IFS Pub. UK (1988).

IP-436 Design for Manufacturing and Assembly [3 0 0 3]

Section A

DFMN Approach and Process: Methodologies and tools, design axioms, design for assembly and evaluation, minimum part assessment taquchi method, robustness assessment, manufacturing process rules, designer's tool kit, Computer Aided group process rules, designer's tool kit, Computer Aided group Technology, failure mode effective analysis, Value Analysis. Design for minimum number of parts, development of modular design, minimising part variations, design of parts to be multi-functional, multi-use, ease of fabrication, Poka Yoka principles.

Section B

Geometric Analysis: Process capability, feature tolerance, geometric tolerance, surface finish, review of relationship between attainable tolerence grades and difference machining processes. Analysis of tapers, screw threads, applying probability to tolerences.

Form Design of Castings And Weldments: Redesign of castings based on parting line considerations, minimising core requirements, redesigning cast members using weldments, use of welding symbols.

Mechanical Assembly: Selective assembly, deciding the number of groups, control of axial play, examples, grouped datum systems - different types, geometric analysis and applications-design features to facilitate automated assembly.

Section C

True Position Theory: Virtual size concept, floating and fixed fasterners, projected tolerance zone, assembly with gasket, zero true position tolerance, functional gauges, paper layout gauging, examples. Operation sequence for typical shaft type of components. Prepration of process drawings for different operations, tolerence worksheets and centrality analysis, examples. Automatic assembly Transfer systems: Automatic Feeding and orienting –vibratory feeders, automatic feeding and orienting mechanical feeders, Feed tracks, parts placement mechanisms Performance and Economics of Assembly

Design for manual Assembly: Product design for high speed automatic assembly and robot assembly, printer circuit board assembly. Feasibility study for assembly automation.

Books Recommended

1. Biren Prasad, "*Concurrent Engineering Fundamentals - VOL II*", Prentice Hall, 1997.
2. Ulrich Karl.T, Eppinger Stephen D, "*Product design and development*", McGraw Hill, 1994.
3. Carter Donald E., "*Concurrent Engineering*", Addision Wesley, 1992.
4. Bralla James G., "*Hand Book of Product Design for Manufacturing*", McGraw Hill, 1986.
5. Beitz Paul, "*Engineering Design*", Springer Verlag, 1992.

Syllabi of Interdisciplinary Courses

IP-01 Industrial Engineering [3 0 0 3]

Section A

Work System Design: Definition, objectives, step-by-step procedure, charts and diagrams for recording data. principles of motion economy. Various techniques of work-measurement, work-sampling, time study & its procedure. Rating, methods of rating, allowances and their types, standard time, numerical problems. Introduction to Ergonomics, man-machine system and its components.

Facilities planning and design: Plant layout, material handling and their interrelationship, objectives of a good plant layout, principles of a good layout, classical types of layouts.
Value engineering: Value analysis, methodology of value engineering.

Section B

Quality Control: Process control and product control, difference between SQC and SPC, chance and assignable causes of quality variation, Shewhart control charts. 100% inspection, no inspection and sampling inspection. Application of hyper geometric, binomial & Poisson distributions in acceptance inspection.

Inventory Management: Introduction, materials productivity and role of materials management techniques in improved materials productivity, Wilson's lot size model, inventory costs, hidden costs, composition of costs, estimation of inventory related costs, lead time, stock out point, number of time periods, calculating Economic Order Quantity (EOQ), sensitivity analysis of EOQ model.

Section C

Project Management: Gantt chart, milestone char. Network scheduling terminology. Path enumeration, Activity on node & activity on arc network precedence diagrams.
Reliability: Concept of reliability, objectives, applications, area of use, use of reliability in industry.

Books Recommended

1. Krajewski L J and Ritzman L P, "*Operations Management*", Pearson Education Asia, Sixth Edition (2004)
2. Buffa, "*Modern Production/operations Management*", Wiley Eastern, New York (1999).
3. R Panneer Selvan, "*Production and Operation Management*", Prentice Hall India, New Delhi (2002).
4. Muhlemann Alan, Oakland John and Lockyer Keith, "*Production and Operations Management*", Macmillan India Publications Ltd. (2001)
5. Adam and Ebert "*Production and Operation Management*" Pearson Education Asia, Fifth Edition (2003)

IP-02 Quality Management [3-0-0-3]

Section A

Statistical process control: Introduction, review of statistical concepts, test of normality for a given data, causes of variation, chance and assignable causes, statistical basis for control charts, basic control charting principles.

Control charts and process capability: selection of control limits, Type-1 & Type II errors, effect of sample size on control limits, sample size, frequency of sampling. Revision of control limits. Control charts for mean and range, control charts for mean and standard deviation. Advantages and disadvantages of attributes charts, charts for proportion non-confirming (p-chart) and its derivatives, variable sample size. Charts for number of non-conformities (c chart) and its derivatives, classification of non-conformities**.** Process capability analysis: Introduction, specification limits and control limits, process capability indices, the C_p index, upper and lower capability indices, the C_{pk} index.

Section B

Acceptance Sampling: sampling inspection, 100% inspection, no inspection, acceptance sampling plans for attributes and variables, advantages and disadvantages of sampling, producer's risk and consumer's risk, operating characteristic curve. Types of sampling plans: single double, multiple and sequential sampling plans. Average outgoing quality, average total inspection, average sample number.

TQM: Philosophies and frameworks, pillars of TQM: Leadership, Customer satisfaction, Employee Involvement, Continuous Process Improvement. TQM Tools: Benchmarking, Quality Function Deployment (QFD) – House of Quality, Taguchi Quality Loss Function.

Section C

Six Sigma: Statistical basis for six sigma, DMAIC methodology, project selection for six sigma, tools and techniques.

Quality assurance & audit: definition, characteristics of quality assurance system. ISO-9000: scope, application, terms and definitions, evolution of ISO-9000 series, process approach, PDCA methodology, documentation requirement, guidelines for preparation of quality manual. Steps for certification, implementation schedule for certification, benefits of ISO –9000 implementation. Quality audit: definition, internal audit, second party, third party audit, pre-assessment and compliance audit, procedure of auditing, audit planning, audit execution.

Books Recommended:

1. Grant E L and Leavenworth R S, "Statistical Quality Control", McGraw Hill, Sixth Edition (2000)
2. Evans & Lindsay, "The Management and control of Quality," Thompson South-Western, Sixth Edition (2005)
3. Amitav Mitra, "Fundamentals of Quality Control and Improvement", Pearson Education Asia, First Edition (2001)
4. Besterfield Dale H [et…al.], "Total Quality Management", Pearson Education Asia, First Edition (2001)
5. A. Zaidi, "SPC: Concepts, Methodologies and Tools", Prentice Hall of India, First Edition, (1995)