FACULTY OF ENGINEERING

Syllabus for the

M.E. (Mechanical – Design Engineering)

(w.e.f. 2008-2009)

UNIVERSITY OF PUNE

THE SYLLABUS IS PREPARED BY:

BOS-Mechanical Engineering
University of Pune

PEER REVIEW BY:

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Note: This Syllabus is subjected to change without prior notice by the concerned BOS

Minutes of Meeting

Minutes of Meetings of the Peer View Committee on M. E. (Mechanical) in Design Engineering, Mechatronics and Heat Power Engineering courses held at Sinhgad College of Engineering, Pune and PVG College of Engineering dated 19th April 2007, 6th October 2007 and 10th January 2008

A separate peer view committees for these above courses were formed and long discussion on the syllabus framing was take place. Following points were discussed and following resolutions were resolved.

1. Mathematics and Management subjects are included for all courses as suggested by Dean Faculty Engineering and Academic Council.
2. Credit system and audit course concepts are incorporated.
3. Topics on Elastic behaviour of anisotropic material and introduction to fracture mechanics are added while plastic bending is being deleted from subject Advanced stress analysis.
4. Topics on 'Multi degree freedom system, transfer matrix method, impulse response' are included and 'Dunkerley's method, Stodola's method' are deleted in subject Vibration and Noise Control.
5. Cam shaft design with valve opening mechanisms, piston, and connecting rod are added in Advanced Machine Design.
6. Project evaluation should be carried out on following points.
    1. selection of Project
    2. Selection of components
    3. costing
    4. specification developments
    5. testing and verification
7. First should have general seminar and second & third seminar should be on project topic and evaluated as term work.
8. Industrial visits should be incorporated in Lab Practices.
9. Dissertation should not be accepted for evaluation until all theory subjects were cleared by the concerned candidate.
10. Topic on 'Onsager equation, energy analysis of thermal systems' is added in Advanced Thermodynamics.
11. 50 to 60% marks are kept for quantitative questions.

Date: 4th April 2008 — Coordinator

Place : Pune — M. E. Syllabus Coordination committee

Program Structure for
M.E. Mechanical (Design Engineering)
(For 2008 Course) (w.e.f. June – 2008)

Subject Code	Subject	Teaching Scheme		Examination Scheme				Credits
		Lect.	Pract.	Paper	TW	Pr/Or	Total	
Sem – I								
502201	Mathematical Modeling and Analysis	03	-	100	-	-	100	03
502202	Advanced Stress Analysis	03	-	100	-	-	100	03
502103	Technology and Financial Management	03	-	100	-	-	100	03
502204	Elective – I	03	-	100	-	-	100	03
502205	Elective – II	03	-	100			100	03
502206	Lab. Practice – I	-	06	-	50	-	50	03
502207	Seminar I	-	04	-	50		50	02
	Total	**15**	**10**	**500**	**100**	**-**	**600**	**20**
Sem – II								
502208	Vibration & Noise Control	03	-	100	-	-	100	03
502209	Advance Machine Design	03	-	100	-	-	100	03
502210	Analysis & Synthesis of Mechanisms	03	-	100	-	-	100	03
502211	Elective – III	03	-	100	-	-	100	03
502212	Elective – IV	03	-	100	-	-	100	03
502213	Lab. Practice – II	-	06	-	50	-	50	03
502214	Seminar – II	-	04	-	50	-	50	02
	Total	**15**	**10**	**500**	**100**	**-**	**600**	**20**

Sem – III

Subject Code	Subject	Teaching Scheme		Examination Scheme				Credits
		Lect.	Pract.	Paper	TW	Or	Total	
602215	Seminar – III	-	04	-	50	-	50	02
602216	Project Stage – 1	-	18	-	50	-	50	06
	Total	**-**	**22**	**-**	**100**	**-**	**100**	**08**

Sem- IV

Subject Code	Subject	Teaching Scheme		Examination Scheme				Credits
		Lect.	Pract.	Paper	TW	Or	Total	
602217	Project Stage – II	-	18	-	150*	50	200	12
	Total		**18**	**-**	**150**	**50**	**200**	**12**

*The term work of project stage II of semester IV should be assessed jointly by the pair of internal and external examiners, along with oral examination of the same.

Note- The Contact Hours for the calculation of load of teacher

Seminar- 1 Hr / week / student

Project - 2 Hr / week / student

CODE	**Elective – I**	CODE	**Elective – II**
502204 A	Instrumentation & Automatic Control	502205 A	Material Handling Equipment Design
502204 B	Advance Material Science	502205 B	Process Equipment Design
502204 C	Optimization Techniques	502205 C	Robotics

CODE	**Elective – III**	CODE	**Elective – IV**
502211 A	Reliability Engineering	502212 A	Vehicle dynamics
502211 B	Engineering Fracture Mechanics	502212 B	Industrial Tribology
502211 C	Computer Aided Engineering	502212 C	OPEN (SELF STUDY)**

**** Open elective subjects- BOS Mechanical Engineering will declare the list of subjects which can be taken under open elective.**

Mathematical Modeling and Analysis
(502201)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. Concept of State

System, Environment and Variables. The state of a system, mathematical models of continuous line linear lumped parameter time invariant systems, Discrete time systems, linear approximation of non-linear systems, Topological Models of system, Block diagram representation, signal flow graph, Mason's rule.

2. A Generalized Approach to Modeling

The principles of conservation and continuity. Physical laws. Mechanical systems, Electrical and Electro mechanical systems, Fluid systems, Thermal systems.

3. Modeling of Physical systems

The linear graph approach. Linear Graph Terminology, Formulation of system equations, systems with multi terminal components. Linear Graph Models: Skeletal structures, Mass Transfer Processes.

4. Input output approach

Discrete Signal Models, Discrete time-convolution, response of linear Discrete time systems, continuous (Analogue) signal models, continuous time convolution, Response of linear continuous time state equation - Discrete time systems, computation of state transition matrix by canonical Transformation, Computation of state transition matrix by technique based on Caley-Hamilton theorem, the solution of state equation-continuous time systems,

5. Numerical Analysis

Numerical method for solution of continuous time state. Ordinary differential equations: Explicit and implicit techniques. Adaptive step size control, Adaptive RK method. Numerical methods for partial differential equations.

6. The Laplace Transform:

Application of Laplace transforms to differential equations, stability in s domain. Linear system, Laplace transform analysis of causal periodic input to linear systems. Relationship of the Z-Transform to the Fourier and Laplace transforms.

7. The Fourier Transform

Fourier spectra of power signals, Fourier transform of periodic functions- Fourier series, Fourier analysis of sampled signals, modulation, discrete Fourier transforms.

8. The Z Transform

The inverse Z-transform, Z-transform analysis of linear discrete time systems, nature of response of linear discrete-time systems, Computation system, Deconvolution.

9. Wavelet Transform

Multi resolution Analysis and construction of wavelets. Representation of functions by wavelets. The characterization of MRA wavelets.

10 Simulation:

Introduction to simulation: Digital and Analogue simulation, Analytic and Monte Carlo simulation, Stochastic and Deterministic simulation.

Random and pseudo random number generation.

Designing a simulation experiment. Simulating basic stochastic models. Simulator technology. Applications.

Text/References

1. Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press.
2. Systems Modelling & Analysis, I.J. Nagarath & M. Gopal, Tata Me Graw Hill, New Delhi.
3. Jan Willen Polderman, Jan C. Willems -Introduction to Mathematical Systems Theory - A behavioural approach, 1998, Springer.
4. J.L. Shearer, A.T. Murphy, H.H. Richardson : Introduction to System Dynamics, 1971, Addison & Wesley.
5. T.H. Glisson : Introduction to System Analysis, 1987, Me Graw Hill.
6. W.J. Palm : Modelling Analysis and Control of Dynamic Systems, 2nd Ed., 1999, John Wiley.
7. Ernest O Doebelin, System Modelling and Response, theoretical and experimental approaches, 1980, Wiley.
8. Gray M. Sandquist: Introduction to System Science.
9. David K. Cheng: Analysis of Linear Systems.
10. James B. Reswick Charles K Taff: Introduction to Dynamic Systems.
11. Robert L. Woods, Kent L. Lawrence: Modeling & Simulation of dynamic system.
12. Robert A. Gabel & Richard A. Roberts: Signals and Linear Systems.
13. A First Course on Wavelets, 1996, Eugenio Hernandez, Guido Weiss: CRC Press.
14. Digital Sigal Processing, Alan V Oppenheim & Ronald W. Schafer, Prentice Hall of India, Pvt. Ltd.
15. Fast Algorithms for Digital Signal Processing, 1985, Richard E Blahut, Addis on-Wesley Publishing Co.
16. Fast Transforms Algorithms, Analysis and Applications, 1982, Dougllao F Elliott, K Ramamohan Rao, Academic Press Inc., Chapters i, 2 & 3.

Advanced Stress Analysis
(502202)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. Theory of Elasticity:-
Analysis of stress, Analysis of stain, Elasticity problems in two dimension and three dimensions, Mohr's circle for three dimensional stresses. Stress tensor, Airy's stress function in rectangular & polar coordinates. Energy method for analysis of stress, strain and deflection **T**he three theorem's -theorem of virtual work, theorem of least work, Castigliano's theorem, Rayleigh Ritz method, Galekin's method, Elastic behaviour of anisotropic materials like fiber reinforced composites.

2. Theory of Torsion:-
Torsion of prismatic bars of solid section and thin walled section. Analogies for torsion, membrane analogy, fluid flow analogy and electrical analogy. Torsion of conical shaft, bar of variable diameter, thin walled members of open cross section in which some sections are prevented from warping, Torsion of noncircular shaft.

3. Unsymmetrical bending :-
Concept of shear centre in symmetrical and unsymmetrical bending, stress and deflections in beams subjected to unsymmetrical bending, shear centre for thin wall beam cross section, open section with one axis of symmetry, general open section, and closed section.

4. Plate bending: -
Bending of plate to cylindrical surface, bending of a long uniformly loaded rectangular plate, pure bending in two perpendicular directions, bending of circular plates loaded loaded symmetrically w. r. t. center, Bending of circular plates of variable thickness, circular plate with circular hole at centre symmetrically loaded and load distributed along inner and outer edges.

5. Pressurized cylinders and rotating disks:-
Governing equations, stress in thick walled cylinder under internal and external pressure, shrink fit compound cylinders, stresses in rotating flat solid disk, flat disk with central hole, disk with variable thickness, disk of uniform strength, Plastic action in thick walled cylinders and rotating disc**.**

6. Contact stresses:-
Geometry of contact surfaces, method of computing contact stresses and deflection of bodies in point contact, stress for two bodies in line contact with load normal to contact area and load normal and tangent to contact area. Introduction to Analysis of low speed impact.

7. Introduction to Fracture Mechanics and Plastic Bending:-

Introduction to Linear Elastic Fracture Mechanics, Modes of fractures, Stress intensity factor, crack initiation and Crack opening phenomenon, stress distribution around crack tip under various loading conditions, Fracture toughness G_{Ic} Plastic bending of elastic materials, Post yield stress analysis, plastic flow process, shape factor, spring back effect.

8. Experimental stress analysis:

Dimensional analysis, analysis techniques strain gauges: configuration, instrumentation, characteristics of strain gauge measurement. Theory of photoelasticity and techniques used in photoelastic application

Term Work

Exercise / Assignments for Laboratory Practice – I

A) Study and report on:-

1. Study of strain Gauge Bridge.
2. Study of practical on photo elasticity
3. Study of plastic bending and spring back.

B) Mini project:-

On FEM analysis of machine members by using reputed commercial software for stress distribution, stress concentration and report writing on results of analysis.

Reference Books

1. Advanced Mechanics of Materials – Cook and Young, Prentice Hall
2. Advanced Strength and Applied Stress Analysis – Richard G. Budynas, McGraw Hill
3. Advanced Mechanics of Materials – Boresi, Schmidt, Sidebottom, Willey
4. Theory of Elasticity – Timoshenko and Goodier, Mc Graw Hill
5. Advanced Strength of Materials, Vol. 1,2 – Timoshenko, CBS
6. Advanced Strength of Materials – Den Harteg
7. Experimental Stress Analysis – Dally & Riley
8. Theory of Plates and Shells – Timoshenko Mc Graw Hill
9. Hertzberg, R. W. *Deformation and Fracture Mechanics of Engineering Materials*. 4th ed. John Wiley & Sons, Inc., 1996.

Technology and Financial Management
(502103)

Teaching Scheme:
Lecture: 3 hrs/week

Examination
Paper: 100 Marks
Paper Duration: 3hrs

Finance:

-Functions
-Source of finance
-National & International finance
-Benefits & Limitations
-Budgets & Budgeting Control

Costing:

-Significance of engineers
-Traditional absorption costing
-Marginal costing
-Contract costing
-Activity based costing
-Process costing

Engineering Economic Analysis:

-Basic concepts & price theory
-Supply & Demand
-Consumer behaviour
-Law of reducing returns
-Competition- types, equilibrium
-Inflation & unemployment
-Foreign trade
-Balance of payment

Quality Management:

-Fundamentals of TQM, Deming, Juran
-Kaizen
-JIT
-ISO 9000
-ISO 14000

Project Management:

-Project life cycle
-CPM
-PERT
-BOT
-Public Private Participation

HR Management:

-Difference between personnel management & HR management
-Role of HR Manager
-Manpower planning
-Merit rating
-Training & Development
-Retirement & Separation
-Organizational Development & Behaviour
-Management by objectives

Books:

1) S C Kuchal, Indian Economics
2) Prasad N K, Cost Accounting, Book Syndicate Pvt. Ltd., Kolkata 700 009
3) Collin Drury, Management & Cost Accounting, English Language Book Series, Chapman & Hall, London [ISBN 0412 341204]
4) E Dessler, Human Resource Management
5) R S Dwivedi, Managing Human Resporces
6) Chase Operations Management for Competitive Advantage
7) B S Sahay, World Class Manufacturing
8) Juran, Quality Control Handbook
9) K Ishikawa, Guide to Quality Control
10) Fred Luthans, McGraw Hill Publications, Organizational Behaviour
11) Robbins S P, Prentice Hall Publications, Organizational Behaviour

Instrumentation & Automatic Control (Elective – I)
(502204-A)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1) Introduction to measurements for scientific and engineering application need and goal. Broad category of methods for measuring field and derived quantities.

2) Principles of measurement, parameter estimation, regression analysis, correlations, error estimation and data presentation, analysis of data

3) Measurement of field quantities , thermometry, heat flux measurement, measurement of force, pressure, flow rate, velocity ,humidity, noise, vibration, measurement of the above by probe and non instructive techniques.

4) Measurement of derived quantities, torque, power, thermo physical properties, radiation and surface properties.

5) Analytical methods and pollution monitoring, mass spectrometry, chromatography, spectroscopy

6) Basics of P,PI,PID controllers, pneumatic and hydraulic controllers, electronic controllers, applications to machine tools, furnaces, material handling etc

Exercise/Assignment

1) Calibration of pressure gauge
2) Computer aided experimentation for temperature measurement.
3) Design of control system for boiler/compressor/pumps/turbines
4) Problem of analysis of data and error estimation.

Reference Books

1) Doebelin E.O:Measurement Systems-Application and Design, McGraw Hill Publication Co.
2) Beckwith TG. N. Lewis Buck and Marangoni R.D: Mechanical Measurements,Narosa Publishing House,New Delhi
3) Liptak B.G. Instrument Engineers' Handbook
4) Bolton W, Mechatronics-Electronics Control Systems in Mechanical and Electrical Engg.
5) Modern Electronic Instrumentation and Measurement Technique by A.D. Helfrick and W.D. Cooper
6) Johnson C.D., Process Control Instrumentation
7) J.P.Holman: Experimental Methods For Engineers, McGraw Hill International Edition, Seventh Edition

Advance Material Science (Elective –I)
(502204-B)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. Aspects of Physical Metallurgy:
   Crystal structure, systems and Barvias lattices, Indexing of lattice planes (Miller's Indices), Indexing of lattice directions, Co-ordination Number (Ligency), Density calculations and imperfections in crystals

2. Study of Equilibrium diagrams for Fe-C systems, Cu - Bronze alloys i.e. Cu:Zn, Cu:Sn, Cu:Al etc., Developments in metallic materials like HSLA state, maraging steels, dual phased steels, creep resisting steels, materials for high and low temperature applications, Nimerics, Inconels, Haste Alloys etc., Al, Ni alloys, Ti, Mg alloys.

3 Heat Treatment of Non ferrous alloys, Heat Treatment of Tool steels

4 Orthodental materials, Bio material, Prosthetic materials, Nano materials, super conducting materials, sports materials.

5 Composites, ceramics, cermets, shape memory alloys their manufacturing techniques, advantages and limitations.

6. Surface coatings and their tribological aspects. PVD, CVD, IVD ion implantation method.

Lab Practices:-

1. Study of effect of various coatings rates on steel samples by microscopy (Min. 4 studies)
2. Study of effect of various heat treatments on microstructures of non ferrous alloys (Min. 4 samples)

Reference Books

1. Engineering Metallurgy, R. A. Higgins, Viva Books Pvt. Ltd.
2. Elements of Material Science and Engineering, Lawrence H., Van Vlack Addison-Wesley Publishing Company
3. Principles of Material Science and Engineering, William F. Smith, McGraw-Hill Book Co.
4. Material Science, R. B. Gupta, Satya Publications, New Delhi.
5. A Text Book of Material Science and Metallurgy, O. P. Khanna, Dhanpat Rai and Sons, New Delhi.
6. Material Science and Engineering an Introduction, William D. Callister, Jr., John Wiley and Sons Inc.
7. Smithells Metals Reference Book, E. A. Brandes and G. B. Brook, Butterworth Heinemann.
8. Biomaterials and Bioengineering Handbook, Donald L. Wise, Marcel Dekker Inc.

Optimization Techniques (Elective –I)
(502204-C)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

Introduction to Optimization: Engineering applications of optimization, statement of optimization problem, classification of optimization problem

Classical Optimization Techniques: Introduction, single variable optimization, multi variable optimization with no constraint, equality constraint, in equality constraint, convex programming problems

Linear programming: Standard form of linear programming, geometry of linear programming, solutions of system of linear simultaneous equations, pivotal reduction of general system of reduction and simplex alogorithms

Non-linear programming: One dimensional Minimization methods, elimination methods, unrestricted search, exhaustive search, half interval method, golden section method, Interpolation methods, Newton method, Quasi Newton method, secant method

Non-linear programming (Unconstrained optimization techniques): Direct search method, random search method, grid search method, Powell's method, Simplex method. Indirect Search method, gradient of functions, descant method, conjugate gradient method, Newton's method, Quasi Newton method

Non-linear programming (Constrained Optimization): Direct methods, random search method, complex method, sequential linear programming, sequential quadratic programming and generalized reduced gradient method, Indirect method- Penalty function methods

Reference Books:

1. Engineering Optimization – Theory & practice, S.S. Rao, New Age Int. Publication
2. Optimisation concepts and application in engineering, Besequndle. A.D., Pearson, Edu.
3. Practical Methods of optimization, Fletcher, R., John Wiley
4. Principles of Optimisation Design, Paphlambros & Wilde

Material Handling Equipment Design (Elective – II)
(502205-A)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1.Elements of Material Handling System:-
Importance, Terminology, Objectives and benefits of better Material Handling; Principles and features of Material Handling System; Interrelationships between material handling and plant layout, physical facilities and other organizational functions; Classification of Material Handling Equipments.

2. Selection of Material Handling Equipments:-
Factors affecting for selection; Material Handling Equation; Choices of Material Handling Equipment; General analysis Procedures; Basic Analytical techniques; The unit load concept; Selection of suitable types of systems for applications ; Activity cost data and economic analysis for design of components of Material Handling Systems; functions and parameters affecting service; packing and storage of materials.

3. Design of Mechanical Handling Equipments:-
[A] Design of Hoists:-
Drives for hoisting, components, and hoisting mechanisms; rail traveling components and mechanisms; hoisting gear operation during transient motion; selecting the motor rating and determining breaking torque for hoisting mechanisms.

[B] Design of Cranes:-
Hand-propelled and electrically driven E.O.T. overheat Traveling cranes; Traveling mechanisms of cantilever and monorail cranes; design considerations for structures of rotary cranes with fixed radius ; fixed post and overhead traveling cranes; Stability of stationary rotary and traveling rotary cranes.

4. Design of load lifting attachments:-
Load chains and types of ropes used in Material Handling System; Forged, Standard and Ramshorn Hooks; Crane Grabs and Clamps; Grab Buckets; Electromagnet; Design consideration for conveyor belts; Application of attachments.

5. Study of systems and Equipments used for Material Storage:-
Objectives of storage; Bulk material handling; Gravity flow of solids through slides and chutes; Storage in bins and hoppers; Belt conveyors; Bucket-elevators; Screw conveyors; Vibratory Conveyors; Cabin conveyors; Mobile racks etc.

6. Material Handling / Warehouse Automation and Safety considerations:-

[A] Storage and warehouse planning and design; computerized warehouse planning; Need, Factors and Indicators for consideration in warehouse automation; which function, When and How to automate; Levels and Means of Mechanizations.

[B] Safety and design; Safety regulations and discipline.

Term Work:

- **Following assignments comprise the laboratory practice:-**

1. Design and development on Material Handling Equipments applicable to various process industries such as Sugar Industry, Power plants, Automobile manufacturing, Harbor, Foundries etc.

2. Repot based on visits to industries manufacturing or using various Material Handling Equipments.

Reference Books

1] N. Rudenko, 'Material Handling Equipments', Peace Publishers, Moscow.
2] James M. Apple, 'Material Handling System Design', John-Willlwy and Sons Publication, NewYork.
3] John R. Immer, 'Material Handling' McGrawHill Co. Ltd., New York.
4] Colin Hardi, 'Material Handling in Machine Shops'. Machinery Publication Co. Ltd., Landon.
5] M .P. Nexandrn, 'Material Handling Equipment', MIR Publication, Moscow.
6] C. R. Cock and J. Mason, 'Bulk Solid Handling', Leonard Hill Publication Co. Ltd., U.S.A.
7] Spivakovsy, A.O. and Dyachkov, V.K., 'Conveying Machines', Volumes I and II, MIR Publishers, 1985.
8] Kulwiac R. A., 'Material Handling Hand Book', 2nd edition, JohnWilly Publication, NewYork.

Process Equipment Design (Elective-II)
(502205-B)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1) **Process Design Parameters** : Basic concepts in process design, block diagrams for flow of processes, material flow balance. Design pressures ─temperatures, design stresses, factory of safety, minimum shell thickness and corrosion allowance, weld joints efficiency, design loading, stress concentration and thermal stresses, failure criteria, optimisation technique such as Lagrange's multiplier and golden section method, cost and profitability estimation. Introduction to design codes like IS-2825, ASME-SECT, EIGHT-DIV-II TEMA.API-650, BS-1500 & 1515.

2) **Design of Cylindrical and Spherical Vessels** : Thin and thick walled cylinder analysis, design of end closers, local stresses due to discontinuity or change of shape of vessel, vessel opening compensation, design of standard and non-standard flanges, design of vessels and pipes under external pressure, design of supports for process vessels.

3) **Design of Tall Vessels and Large Storage Tanks** : Determination of equivalent stress under combined loadings including seismic and wind loads application of it to vertical equipment like distillation column.

4) **Design of Thick Walled High Pressure Vessels** : Design by various theories of failure, construction of these vessels with high strength steel and other special methods.

5) **Process Equipment Design** : Storage vessels, reaction vessels, agitation and mixers, heat exchangers, filters and driers, centrifuges. Code practices, selection and specification procedures used in design. Selection of pumps, compressors, electrical equipments and auxiliary services, safety, etc.

6) **Process Piping Design** : Flow diagrams and pipe work symbols, design of layout of water, steam and compressed air pipes work, pipe fitting, linings and flanged connections. Types of valves used on pipe line. Fabrication of pipe lines, expansion joints and pipe supports.

7) Planning, manufacture, inspection and erection of process equipment like pressure vessels, chimneys, ducting, heat exchangers, pulverizing equipment, etc. protective coatings, lining of vessels.

8) **Process Control** : Fundamentals of process measurements and control modern control devics and other controls of major unit operation and processes.

9) Applications of CAD to process Equipment Design.

TERM WORK

Following assignments / experiments comprise the laboratory practice :-

1) Design and optimisation of tall vessels and large tanks.
2) Design of Heat exchangers used in industries.
3) Design of crystallisers.
4) Design and development of equipment useful to process industries such as sugar, cement, chemical industries.
5) Preparing flow diagrams of processes, piping layout, etc.
6) Report based on visit to industries such as sugar, cement, chemical industries.

REFERENCE BOOKS

1) Process Equipment Design : By Dr. M.V. Joshi, Mc-Millan.
2) Process Equipment Design : By Browell and Young, John Wiley.
3) Plant Design and Economics : Max and Timasulaus Kalus – McGraw Hill.
4) Industrial Instrumentation servicing Hand Book : Cannel Grady, McGraw Hill.
5) Handbook of Instrumentation and Control : Kellen Heward, McGraw Hill.
6) Chemical Engineering Handbook : Perry John, McGraw Hill.
7) Chemical Equipment Design : B.C. Bhattacharya.
8) Industrial Pipe Work : D.N.W. Kentish, McGraw Hill.
9) Chemical Engineering : J.M. Coulson, Richardson, Sinnott Vol. VII, Maxwell, McMillan.
10) Pressure Vessel Design Hand Book : H. Bedna.
11) Dryden's outlines of Chemical Technology for the 2 : By Roa M. Gopala, Sitting M., East West Press Pvt. Ltd., New Delhi.
12) Applied Process Design for Chemical and Petrochemical, Vol. I, II and III : By E.E. Ludwig, Gulf Publication Co., Houston.
13) Chemical Process Control : An Introduction to Theory and Practice : By Stephanopoulos G., Prentice Hall of India, New Delhi.
14) Chemical Process Equipment Selection and Design : By Stanley M.Walas, Butterworth-Heinemann Series in Chemical Engineering.
15) Process System Analysis and Control : By D.R. Coughanowr, McGraw Hill, New York.
16) Engineering Optimsiation : Theory and Practice : By Rao S.S., New Age Publishing Co., New Delhi.
17) Optmisation of Chemical Processes : By Edgar T.F., Himmelblau D.M., McGraw Hill Book Co., New York.
18) Control Devices, Vol. I and II : Liptak
19) Analysis, synthesis and design of Chemical Processes : Richard Turton, Richard C. Bailie, Wallace B. Whiting, Josheph A. Shaewitz, Prentice Hall Int. Series in Physical and Chemical Science.

Robotics (Elective – II)
(502205-C)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

Robot Fundamentals:-

Definitions, History of robots, present and future trends in robotics, Robot classifications, Robot configurations, Point to Point robots, Continuous Path robots, Work volume, Issues in design and controlling robots Repeatability, Control resolution, spatial resolution, Precision, Accuracy, Robot configurations, Point to Point robots, Continuous Path robots, Work volume, Applications of robots. Drives used in robots- Hydraulic, Pneumatic and Electric drives, Comparison of drive systems and their relative merits and demerits.

Manipulator Kinematics:-

Matrix Algebra, Inverse of matrices, rotational groups, matrix representations of coordinate transformation, transformation about reference frame and moving frame

Forward & Inverse Kinematics examples of 2R, 3R & 3P manipulators, Specifying position and orientation of rigid bodies Euler's angle and fixed rotation for specifying position and orientation Homogeneous coordinate transformation and examples D-H representation of kinematics linkages Forward kinematics of 6R manipulators using D-H representations Inverse kinematics of 6R manipulators using D-H representations, Inverse Kinematics geometric and algebraic methods.

Robotics Dynamics :-_

Velocity Kinematics, Acceleration of rigid body, mass distribution Newton's equation, Euler's equation, Iterative Newton –Euler's dynamic formulation, closed dynamic, Lagrangian formulation of manipulator dynamics, dynamic simulation, computational consideration.

Trajectory planning:-

Introduction, general considerations in path description and generation, joint space schemes, Cartesian space schemes, path generation in runtime, planning path using dynamic model point to point and continuous trajectory , 4-3-4 & trapezioidal velocity strategy for robots.

Robot Sensors:-

Internal and external sensors, position- potentiometric, optical sensors ,encoders - absolute, incremental ,touch and slip sensors velocity and acceleration sensors, proximity sensors, force & torque sensors, laser range finder, camera. Micro-controllers, DSP, centralized controllers, real time operating systems.

Robot Controllers:-

Essential components-Drive for Hydraulic and Pneumatic actuators, H-bridge drives for Dc motor Overload over current and stall detection methods, example of a micro-controller/ microprocessor based robot Controller.

Robot Vision:-

Introduction, Image acquisition, Illumination Techniques, Image conversion, Cameras, sensors, Camera and system interface, Frame buffers and Grabbers, Image processing, low level & high level machine vision systems.

Robot Programming languages:-

Introduction the three level of robot programming, requirements of a robot programming language, problems peculiar to robot programming languages.

Futuristic topics in Robotics:-

Micro-robotics and MEMS (Microelecto mechanical systems), fabrication technology for Micro-robotics, stability issue in legged robots, under-actuated manipulators, telecheirs.

Suggested References:

1) S.R.Deb, " Robotics Technology and Flexible Automation ", Tata Mc Graw Hill 1994.
2) M.P.Groover, M. Weiss R.N. Nagel, N.G. Odrey " Industrial Robotics (Technology , Programming and application s) , McGraw, Hill 1996
3) K.S.Fu, R.C.Gonzalez and C.S.G.Lee, " Robotics : Control , sensors , vision and inintlligence ", MCGraw-Hill.1987.
4) J.J.Craig , introduction to Robotics , Addision-wesely 1989.
5) Klafter , Richard D., et al " Robotics Engineering",PhI,1996.
6) Zuech,Nello,"Applying Machine Vision ",john Wiley and sons, 1988.

Vibration & Noise Control
(502208)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. (A) Multi Degree Freedom System:-

Free Vibration equation of motion. Influence Coefficient i) Stiffness Coeff. (ii) Flexibility Coeff. Generalized co ordinates, and Coordinate couplings. Langranges Equations Matrix Method Eigen Values Eigen Vector problems. Modal Analysis. Forced Vibrations of undamped system and modal analysis.

(B) Multi Degree System Numerical Methods:-

(i)Rayleigh`s Method, (ii)Rayleigh-Ritz Method (iii) Holzer`s Method (iv)Methods of Matrix iterations (v) Transfer Matrix Method, Impulse response and frequency response functions.

2. Continuous System: -

Vibrations of String, Bars, Shafts and beams, free and forced vibration of continuous systems.

3. Transient vibrations:-

Response of a single degree of freedom system to step and any arbitrary excitation, convolution (Duhamel's) integral, impulse response functions.

4. Vibration Control:-

Balancing of rotating machine, In-situ balancing of rotors, control of natural frequency introduction of damping, vibration isolation & vibration absorbers.

5. Vibration Measurement:-

FFT analyzer, vibration exciters, signal analysis. Time domain & Frequency domain analysis of signals. Experimental modal analysis, Machine Conditioning and Monitoring, fault diagnosis.

6. Random Vibrations:- Expected values auto and cross correlation function, Spectral density, response of linear systems, analysis of narrow band systems.

7. Non Linear Vibrations:-
Systems with non-linear elastic properties, free vibrations of system with non-linear elasticity and damping, phase-plane technique, Duffing's equation, jump phenomenon, Limit cycle, perturbation method.

8. Noise and Its Measurement :-

Sound waves, governing equation its propagation**,** Fundamentals of Noise , Decibel, Sound Pressure level, Sound Intensity, Sound fields, reflection, absorption and transmission .Noise measurement , Sound meter , Allowed exposure levels and time limit by B.I.S., Octave Band analysis of sound, Fundamentals of Noise control, source control, path control ,enclosures, noise absorbers, noise control at receiver.

Term Work

Any Three from Sr. No 1 to 5 & Sr. No 6 Compulsory

1. Determination of Natural Frequencies & Modal analysis of Machine Components, Equipments to be used: FFT Analyzer, with Impact Hammer or Exciter, Necessary Transducers etc.
2. Condition Monitoring & Fault finding of Machines by using FFT Analyzer, Vibration Meter, Vibration Pickups, Transducers etc.
3. Noise measurement & Analysis, Equipment to be used: Noise measurement & analysis Instruments.
4. In-situ (on-Line) balancing of rotors.
5. Problems of Numerical Methods of Vibrations.
6. Assignment on solving vibration problems using MATLAB.

Reference Books

1 **Theory of Vibrations with Applications**: W T Thomson CBS Publishers Delhi

2 **Mechanical Vibrations** : S S Rao Addison-Wesley Publishing Co.

3 **Fundamentals of Vibration** : Leonard Meirovitch , McGraw Hill International Edison.

4 **Principles of Vibration Control** : Asok Kumar Mallik, Affiliated East-West Press.

5 **Mechanical Vibrations** A H Church ,John Wiley & Sons Inc

6 **Mechanical Vibrations** J P Den Hartog ,McGraw Hill.

7 **Mechanical Vibration Analysis** : Srinivasan ,McGraw Hill.

8 **Mechanical Vibrations** : G K Groover.

9 **Vibration and Noise for Engineers**: Kewal Pujara , Dhanpat Rai & co.

Advanced Machine Design
(502209)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. **Engineering statistics**:-

Analysis of variance (ANOVA), factorial design and regression analysis. Reliability theory, design for reliability, Hazard analysis, fault tree analysis

2. **Fatigue and Creep:-**

Introduction, Fatigue strength, factors affecting fatigue behaviour, Influence of super imposed static stress, Cumulative fatigue damage, fatigue under complex stresses, Fatigue strength after over stresses, True stress and true strength, mechanism of creep of material at high temperature, Exponential creep law, hyperbolic sine creep law, stress relaxation, bending etc

3 **Optimization:-**

Introduction, multivariable search methods, linear & geometric programming, structural and shape optimization and simplex method.

4 Composite materials:-

Composite materials and structures, classical lamination theory, elastic stress analysis of composite material, Fatigue strength improvement techniques, stresses , stress concentration around cutouts in composite laminates, stability of composite laminate plates and shells, Hybrid materials, applications.

5 Design for Materials and Process:-

Design for brittle fracture, Design for fatigue failure, Design for different machining process, assembly & safety etc.

6 Design of Mechanical components :-

a) Gear Design:- Involute gears, tooth thickness, interference, undercutting, rack-shift etc. Profile modification, S and So spur, helical gears etc.

b) Spring Design:- Vibration and surging of helical springs, helical springs for maximum space efficiency , analysis of Belleville springs, ring spring, volute spring & rubber springs. Design for spring suspension.

c) Design of Miscellaneous components (to be detailed) Cam shaft with valve opening mechanism, piston, cylinder, connecting rod etc.

LAB PRACTICE

1 One complete design project considering all above concepts
2 Two assignments (Gear & spring)

REFERENCE BOOKS

1. Mechanical Design Analysis – M.F. Spotts
2. Machine Design - Robert Norton
3. Practical Gear design - D.W. Dudley
4. Optimum design - R.C.Jhonson
5. Mechanical Springs – A.M. Wahl.
6. An introduction to composite materials – D. Hull and T.W. Clyne

Analysis and Synthesis of Mechanisms
(502210)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. **Basic Concepts**: Definitions and assumptions, planar and spatial mechanisms, kinematic pairs, degree of freedom

2. **Kinematic Analysis Of Complex Mechanisms:** velocity-acceleration analysis of complex mechanisms by the normal acceleration and auxiliary point methods.

3. **Dynamic Analysis of Planar Mechanisms: -** Inertia forces in linkages, kinetostatic Analysis of mechanisms by matrix method. Analysis of elastic mechanisms, beam element, displacement fields for beam element, element mass and stiffness matrices, system matrices, elastic linkage model, equations of motion.

4. **Curvature theory**: Fixed and moving centrodes, inflection circle, Euler- Savy equation, Bobillier constructions, cubic of stationary curvature, Ball's point, Applications in dwell Mechanisms

5. **Graphical Synthesis of Planar Mechanisms**: Type, number and dimensional synthesis, function generation, path generation and rigid body guidance problems, accuracy (precision) points, Chebychev Spacing, types of errors, Graphical synthesis for function generation and rigid body guidance with two, three and four accuracy points using pole method, center point and circle point curves, Bermester points, Synthesis for five accuracy points, Branch and order defects, Synthesis for path generation.

6. **Analytical synthesis of Planar Mechanisms**:- Analytical synthesis of four-bar and slider- crank mechanism, Freudenstein's equation, synthesis for four accuracy points, compatibility condition, synthesis of four-bar for prescribed angular velocities and accelerations using complex numbers. Complex numbers method of synthesis, the dyad, center point and circle point circles, ground pivot specifications, three accuracy point synthesis using dyad Method, Robert Chebychev theorem, Cognates

7. **Kinematic Analysis of Spatial Mechanisms** : Denavit-Hartenberg parameters, matrix method of analysis of spatial mechanisms.

References:

1. Theory of Machines and Mechanisms, A. Ghosh and A.K.Mallik, Affiliated East-West Press.
2. Kinematic Synthesis of Linkages, R. S. Hartenberg and J. Denavit, McGraw-Hill.

3. Mechanism Design - Analysis and Synthesis (Vol.1 and 2), A. G. Erdman and G. N. Sandor, Prentice Hall of India.
4. Theory of Machines and Mechanisms, J. E. Shigley and J. J. Uicker, 2nd Ed., McGraw-Hill.
5. Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, Robert L.Norton, Tata McGraw-Hill, 3rd Edition.
6. Kinematics and Linkage Design, A.S.Hall, Prentice Hall of India.

Term Work:

The term work comprises of assignments on the following topics.

1. Complex Mechanism Analysis.
2. Dynamic Analysis.
3. Graphical and Analytical Synthesis.
4. Curvature Theory.

Use of softwares such as 'ADAMS' and 'Working Model' is recommended

Reliability Engineering (Elective-III)
(502211-A)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1) **Fundamental concepts:-**

Reliability definitions, failure, Failure density, Failure Rate, Hazard Rate, Mean Time To Failure, MTBF, maintainability, availability , pdf, cdf, safety and reliability, Quality, cost and system effectiveness, Life characteristic phases, modes of failure, Areas of reliability,Quality and reliability assurance rules, product liability, Importance of Reliability,

2) **Probability theory:-**

Set theory, laws of probability, total probability theorem, probability distributions- binomial, normal, poisson , lognormal, weibull , exponential, standard deviation, variance, skewness coefficient , chebyshev inequality, central limit theorem.

3) **System reliability and modelling**:

Series, parallel, mixed configuration, k- out of n structure, complex systems- enumeration method, conditional probability method, cut set and tie set method, Redundancy, element redundancy, unit redundancy, standby redundancy- types of stand by redundancy, parallel components single redundancy, multiple redundancy. Markov analysis.

4) **Maintainability and Availability:**

Objectives of maintenance, types of maintenance, Maintainability, factors affecting maintainability, system down time, Availability - Inherent, Achieved and Operational availability, reliability and maintainability trade-off.

5) **System reliability Analysis**:

Reliability allocation or apportionment, Reliability apportionment techniques – equal apportionment, AGREE, ARINC, feasibility of objectives apportionment, dynamic programming apportionment, Reliability block diagrams and models, Reliability predictions from predicted unreliability, minimum effort method.

6) **Strength based reliability**:

Safety factor, safety margin, Stress strength interaction,

7) **Failure Mode, Effects and Criticality Analysis-**

Failure mode effects analysis, severity/criticality analysis , FMECA examples, RPN, Ishikawa diagram for failure representation , fault tree construction, basic symbols development of functional reliability block diagram, Fau1t tree analysis, fault tree evaluation techniques, minimal cut set method, Delphi methods, Monte carlo evaluation.

8) **Design of Mechanical components and systems**:-

Material strengths and loads, Reliability testing and reliability growth testing.

Reference Books

- L.S. Srinath, Concepts of Reliability Engg., Affiliated East-Wast Press (P) Ltd., 1985.
- A.K. Govil, Reliability Engineering, Tata McGraw-Hill Publishing Co. Ltd., 1983.
- E. Balagurusmy, Reliability Engineering, Tata McGraw-Hill Publishing Co. Ltd., 1984.
- B.S. Dhillion, C. Singh, Engineering Reliability, John Wiley & Sons, 1980.
- M.L. Shooman, Probabilistic, Reliability, McGraw-Hill Book Co., 1968.
- P.D.T. Conor, Practical Reliability Engg., John Wiley & Sons, 1985.
- K.C. Kapur, L.R. Lamberson, Reliability in Engineering Design, John Wiley & Sons, 1977.
- A.Birolini , Reliability Engineering, Theory and Practice, Third Edition, Springer, 1999

Engineering Fracture Mechanics (Elective - III)
(502211-B)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

Review of - Mechanical properties of solid materials, Theory of elasticity Stress and strain, plane stress, plane strain, stress function, Theory of plasticity, yield stress, yield conditions (Mises & Tresca)

1. **Introduction**:-

Macroscopic failure mode, ideal fracture strength, energy release rate, Fracture Modes.

2. **Fracture Criteria** :-

Griffith criterion, **Irwin's Fracture Criterion, Stress Intensity Approach,** Stress intensity factor, crack tip plasticity, crack opening displacement, plastic constraint.

3. **Methods for Evaluating Fracture toughness** :-

   3.1 - Numerical Methods
   - a. Finite Elements (FE)
   - b. Finite Differences (FD)
   - c. Boundary Integral Equations (BIE)

   3.2. Experimental Methods
   - a. Compliance Method
   - b. Photoelasticity
   - c. Interferometry and Holography

4. **Experimental evaluation of Fracture toughness:**- Plane strain fracture toughness, J – Integral

5. **Fatigue mechanics** :- S-N diagram, fatigue limit, fatigue crack growth rate, Paris law.

6. **Creep mechanics**: - Creep deformation, creep strength, creep-fatigue interaction.

Special Note: – No question should be asked on review topic, derivations.

References :–

1. Anderson T.L., Fracture Mechanics, 2nd Edition, CRC Press, 1995
2. Hertzberg, R. W. *Deformation and Fracture Mechanics of Engineering Materials*. 4th ed. John Wiley & Sons, Inc., 1996.
3. ASTM standards

Computer Aided Engineering (Elective III)
(502211-C)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. **Introduction:–**
   a) Modeling and simulation as a design procedure and be able to apply this method to a wide range of problems.
   b) Analytical techniques for structural systems, system dynamics and thermo-fluid systems.
   c) Introduction to geometric modeling technology and associated computational geometry. A study of data exchange issues related to analysis and simulation.

2. **Computer aided Modeling :–**
   Modern features-based modeling system for the purposes of designing an assembly and use this geometry as the basis for analysis and simulation, utilizing available data-exchange mechanisms.

3. **Finite Element Analysis :–**
   Mechanical design criteria - Function, strength and cost. Introduction to FEM Software – meshing, mesh refinement, apply loads and constrains, assign material properties A machine component design exercise - use FEA software to determine dimensions and materials for all parts, modify, optimize and verify the design Numerical result analysis and assessment - von Misses stress, displacement.

4. **Computer aided Designing :–**
   Design of components and systems for stress analysis and heat transfer using fully featured commercial finite element software having linear & non-linear capabilities. (To be assessed through various course works). Verification of results for the component analyzed, with appropriate hand calculations.

5. **Computational Fluid Dynamics :–**
   Form of mass, energy and momentum equations, description of terms; boundary conditions and simple solution examples. Features of CFD Modeling for steady incompressible flow, pressure drop and heat transfer. Solution Methods - Solution algorithms, discritization schemes, solution convergence, and residuals. Model Formulation - Geometry and grid design, boundary conditions of the domain, choice of physical models for turbulence and heat transfer, modeling of fluid properties. Case Study Examples - Modeling pressure drop and heat transfer in a range of engineering examples.

Note:– No numerical, derivations & computer programs should be asked in theory examination.

Term work :–

1. Solid Modeling & Assembly modeling in CAE Software.
2. Engineering problem solving using FEA Software applied to a range of practical and industrially relevant stress analysis and heat transfer problems.
3. Use of FEA Software in linear elastic, non-linear and dynamic problems. Verification of models and analysis, post processing and checking of results. Model optimization. Case studies.
4. An insight into the analysis and simulation of plastic and composite components.

Reference Books

1. CAD/CAM Theory & Practice, Zeid, TMH
2. Finite Element Method, Belagundu & Chandrupatla, New Age Int. Pub.
3. Introduction to FEM, reddy, J. N., McGrawhill Int.
4. Introduction to FEM, K.J.Bathe, CRC press

Vehicle Dynamics (Elective-IV)
(502212-A)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

1. Vehicle Ride

Human response to vibration: ISO standards, Response of idealized suspension systems to stop and sinusoidal disturbances in bounce and to wheel out of balance. Combined pitch and bounce motion: application to multi wheel station vehicles. Random ground input excitation: Use of sinusoidal transmissibility function to predict mean square motion of spring mass.

2. Wheeled Vehicle Handling

Handling control loop, vehicle transfer function. Kinematic behaviour of vehicles with rigid wheels and with compliant tyres: neutral steer point, static margin, over and under-steer. Derivation of generalized equations of motion for a vehicle: stability derivative notation. Solution with two degree of freedom in the steady state: stability factor, characteristic and critical speeds.

3. Transient response:

Natural frequency and damping in yaw. Frequency response in yaw. Extension of two degree of freedom theory to include effects of traction and braking, aerodynamics, self-aligning torque, dual wheels and bogies, Handling of multi-axle vehicles. Development of equations of motion to include roll of sprung mass: Effect on steady state and frequency response.

4 Tracked Vehicle Handling

Analysis of sprocket torques and speeds, required to skid steer a tracked vehicle. Extension of theory to include three degrees of freedom. Modification of theory to allow for soil conditions and lateral weight transfer Application of theory of steering of articulated and half-track vehicles.

Texts/References

1. Vehicle Dynamics, 19&9,IR Ellis, Business Book.
2. Theory of Ground vehicles, 2001,JY Wong, Wily.
3. Vehicles & Bridging, igSs/Tytler, Brassey's.
4. Fundamental of vehicle dynamics: Thomas D Gillespie

Industrial Tribology (Elective – IV)
(502212-B)

Teaching Scheme
Lectures: 3 Hrs per week

Examination Scheme:
Paper: 100 Marks
Paper Duration: 3 Hrs.

Friction and Wear:-

Friction Control and Wear prevention, Boundary Lubrication, Tribological properties of Bearing Materials and Lubricants, Theories of friction and wear, instabilities and stick-slip motion.

Lubrication of Bearings:-

Mechanics of Fluid Flow, Reynold's Equation and its limitations, idealized bearings, infinitely long plane pivoted and fixed show sliders, infinitely long and infinitely short (narrow) journal bearings, lightly loaded infinitely long journal bearing (Petroff's solution).

Finite Bearings:-

Hydrostatic, Hydrodynamic and thrust oil bearings, heat in bearings.

Hydrostatic squeeze film:-

Circular and rectangular flat plates, variable and alternating loads, piston pin lubrications, application to journal bearings.

Elasto-hydrodynamic Lubrication:-

Pressure-viscosity term in Reynold's Equation, Hertz theory, Ertel-Grubin Equation, lubrication of spheres.

Air lubricated bearings:-

Tilting pad bearings, hydrostatic, hydrodynamic and thrust bearings with air lubrication.

Tribological aspects of rolling motion:-

The mechanics of tyre-road interaction, road grip and rolling resistance, Tribological aspects of wheel on rail contact, Tribological aspects of metal rolling, drawing and extrusion.

Tribo characteristics of different materials, Evaluation of friction & wear through experiments under influencing parameters, pV value of materials.

Term Work

Assignments –

Design of acoustic thrust bearings, Squeeze film lubrication of piston pin, Heat balance in bearings, Reynold's Equation

Practicals on:-

Journal Bearing Apparatus
Tilting pad and thrust Bearing Apparatus
Study of lubrication systems.
Friction in Journal Bearings.
Four Ball Tester
Coefficient of friction using pin on disc type friction monitor.
Brake line friction test rig.
Reference Books –

1. 1. Basic Lubrication Theory- A Camaron
2. Principles of Lubrication – A Camaron, Longman's Green Co. Ltd.
3. Theory and Practice for Engineers – D. D. Fuller, John Wiley and sons.
4. Fundamental of Friction and Wear of Metals – ASM
5. The Design of Aerostatic Bearings – J. W. Powell
6. Gas Bearings – Grassam and Powell
7. Theory Hydrodynamic Lubrication Pinkush and Sterrolicht
8. Tribology in Machine Design – T. A. Stolarski