

UNIVERSITY OF MUMBAI



Bachelor of Engineering

Mechanical Engineering

Third Year (Sem. VI)

Revised Syllabus (REV- 2012) w. e. f.
Academic Year 2014 -15

Under

FACULTY OF TECHNOLOGY

(As per Semester Based Credit and Grading System)

**T. E. Mechanical -
(Semester VI)**

Subject Code	Subject Name	Teaching Scheme (Contact Hours)		Credits Assigned					
		Theory	Pract.	Theory	Pract.	Total			
MEC601	Metrology and Quality Engineering	3	2	3	1	4			
MEC602	Machine Design I &	4	2	4	1	5			
MEC603	Mechanical Vibrations &	4	2	4	1	5			
MEC604	Thermal and Fluid Power Engineering &	4	2	4	1	5			
MEC605	Mechatronics	4	2	4	1	5			
MEC606	Finite Element Analysis &	3	2	3	1	4			
Total		22	12	22	6	28			
Subject Code	Subject Name	Examination Scheme							
		Theory					Term Work	Pract. /oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
MEC601	Metrology and Quality Engineering	20	20	20	80	03	25	25	150
MEC602	Machine Design I &	20	20	20	80	03	25	--	125
MEC603	Mechanical Vibrations &	20	20	20	80	03	25	25*	150
MEC604	Thermal and Fluid Power Engineering &	20	20	20	80	03	25	--	125
MEC605	Mechatronics	20	20	20	80	03	25	--	125
MEC606	Finite Element Analysis &	20	20	20	80	03	25	25	150
Total		--	--	120	480	--	150	75	825

& Common with Automobile Engineering

* Only ORAL examination based on term work and syllabus

Course Code	Course/Subject Name	Credits
MEC601	Metrology and Quality Engineering	3+1

Objectives

1. To study the fundamentals of modern quality concepts and statistical techniques.
2. To study fundamentals of inspection methods and systems.
3. To acquaint with operation of precision measurement tools and equipment's.

Outcomes: Learner will be able to...

1. Apply inspection gauge and checking systems.
2. Demonstrate the understanding of purpose of critical dimensions in manufacturing.
3. Analyse simple parts for dimensional accuracy and functionality.

Module	Details	Hrs.
01	1.1 Introduction to Metrology, Fundamental principles and definitions, measurement standards / primary and tertiary standards, distinction between precision and accuracy. 1.2 Limits, fits and tolerances, Tolerance grades, Types of fits, IS919, GO and NO GO gauges- Taylor's principle, design of GO and NO GO gauges, filler gauges, plug gauges and snap gauges.	04
02	2.1 Comparators: Constructional features and operation of mechanical, optical, electrical/electronics and pneumatic comparators, advantages, limitations and field of applications. 2.2 Principles of interference, concept of flatness, flatness testing, optical flats, optical interferometer and laser interferometer. 2.3 Surface texture measurement: importance of surface conditions, roughness and waviness, surface roughness standards specifying surface roughness parameters- Ra, Ry, Rz, RMS value etc., surface roughness measuring instruments – Tomlinson and Taylor Hobson versions, surface roughness symbols.	09
03	3.1 Screw Thread measurement: Two wire and three wire methods, floating carriage micrometer. 3.2 Gear measurement: Gear tooth comparator, Master gears, measurement using rollers and Parkinson's Tester. 3.3 Special measuring Equipments: Principles of measurement using Tool Maker's microscope, profile projector & 3D coordinate measuring machine.	09
04	Quality Control Introduction, definition and concept of quality & quality control, set up policy and objectives of quality control, quality of design and quality of conformance, compromise between quality & cost, quality cost and planning for quality.	05
05	SQC and SQC tools Importance statistical methods in QC, measurement of statistical control variables and attributes, pie charts, bar charts/ histograms, scatter diagrams, pareto chart, GANT charts, control charts, X chart, X bar charts, R charts, P charts, np charts their preparation, analysis and applications. Elementary treatment on modern SQC tools.	06
06	Sampling Techniques Sampling inspection and basic concepts, OC curves, consumer & producer risk, single & double sampling plans and use of sampling tables.	03

List of Experiments

1. Use of comparators.
2. Thread measurement.
3. Gear measurement.
4. Use of Profile projectors.
5. Use of linear and angular measuring instruments.
6. Measurement of surface roughness.
7. Measurement of flatness.

Term Work

Term work shall consist of minimum 5 experiments from the list and presented with inferences and one assignment on each module

The distribution of marks for term work shall be as follows:

- Laboratory work (Experiments) : **10 marks**
- Assignments : **10 marks**
- Attendance (Theory and Practical) : **05 marks**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Practical/Oral examination

1. Experiment for the examination shall be based on the list of experiments mentioned in the term work.
2. The distribution of marks for practical/oral examination shall be as follows:
 - i. Practical performance: 15 marks
 - ii. Oral: 10 marks
3. Evaluation of practical examination to be done based on the experiment performed and the output of the experiments during practical examination.
4. Students work along with evaluation report to be preserved till the next examination

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

References

1. *Practical Engineering Metrology*, K.W.B.Sharp, Pitman Publication
2. *Engineering Metrology*, K.J.Hume, Kalyani publication
3. *Engineering. Metrology*, I.C. GUPTA, DhanpatRai Publications.
4. *Statistical quality control*, A.L. Grant, McGraw Hill International, New York.
5. *Engineering. Metrology*, R.K.Jain, Khanna Publisher.
6. *Metrology*,Taher.
7. *Statistical Quality control*, R.C. Gupta
8. *I.S. 919/1963*.
9. *I.S. 2709/1964*.
10. *Engineering. Metrology*, Hume K.G., M C Donald, Technical &Scientific ,London.
11. *Quality Control and Industrial Statistics*, – Duncon A.J., D.B. Taraporevela& Co. Bombay.
12. *Statistical quality Control*, Mahajan M., DhanpatRai& Sons, Delhi.
13. *Engineering Metrlogy*-2nd Ed.,P. Narayana, Scitech Publication.
14. *Metal working & Metrology*, P. Narayana et.al ,Scitech Publication.
15. *Quality control* 7 ed.,D.H. Besterfield Pearson education.
16. *Juran's Quality Control Handbook*.

Course Code	Course/Subject Name	Credits
MEC602	Machine Design-I^{&}	4+1

& Common with Automobile Engineering

Objectives

1. To study basic principles of machine design
2. To acquaint with the concepts of strength design related to various components.
3. To familiarize with use of design data books & various codes of practice.
4. To make conversant with preparation of working drawings based on designs.

Outcomes: Learner will be able to...

1. Demonstrate understanding of various design considerations
2. Apply basic principles of machine design
3. Design machine elements on the basis of strength concept
4. Use design data books and various standard codes of practices.
5. Acquire skill in preparing production drawings pertaining to various designs.

Modules	Details	Hrs.
01	Mechanical Engineering Design, Design methods, Aesthetic and Ergonomics consideration in design Material properties and their uses in design Manufacturing consideration in design Design considerations of casting and forging Basic principles of Machine Design, Modes of failures, Factor of safety, Design stresses, Principal stresses and strains, Theories of failures Standards, I. S. codes, Preferred Series and Numbers.	06
02	Curved Beams: Assumptions made in the analysis of curved beams. Design of curved beams: Bending stresses in curved beams, such as crane hook, C-frame, etc. Thick cylinders: Design of thick cylinders subjected to an internal pressure using Lamé's equation.	06
03	Design against static Loads: Cotter joint, knuckle joint, Turn Buckle Bolted and welded joints under eccentric loading. Power Screw - Screw Presses, C- Clamps along with the Frame, Screw Jack	12
04	Design against Fluctuating Loads: Variables stresses, reversed, repeated, fluctuating stresses Fatigue Failure: Static and fatigue stress concentration factors Endurance limit - estimation of endurance limit Design for finite and infinite life, Soderberg and Goodman design criteria, Fatigue design under combined stresses	06
05	Design of shaft - power transmitting, power distribution shafts Module (excluding crank shaft) under static and fatigue criteria. Keys - Types of Keys and their selection based on shafting condition. Couplings- Classification of coupling. Design of Split muff couplings, Flange couplings, Bush pin flexible couplings	11

06	Design of Springs: Helical compression, tension springs under static and variable loads, Leaf springs.	07
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List of Assignments

Design exercises in the form of design calculations with sketches and or drawings on following machine system

1. Knuckle joint,
2. Turn Buckle
3. Screw Jack
4. Flexible flange couplings

Term Work

Term work shall consist of

- A. Minimum 3 design exercises from the list which may include computer aided drawing on A3 size sheets
- B. Stress analysis of any machine element mentioned in the syllabus using any application software and programming language

The distribution of marks for term work shall be as follows:

- Part A : **15 marks**
- Part B : **05 marks**
- Attendance (Theory and Practical) : **05 marks**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

NOTE:

Use of standard design data books like PSG Data Book, Design Data by Mahadevan is permitted at the examination and shall be supplied by the college.

References

1. Design of machine elements -- V. B. Bhandari. Tara Mc-Graw Hill Pub.
2. Design of machine elements -- Sharma, Purohil. Prentice Hall India Pub.
3. Machine Design - An Integrated Approach -- Robert L. Norton – Pearson Education.
4. Machine Design - Pandya & Shah- Charotar Publishing.
5. Mechanical Engineering Design - J. E. Shigley - McGraw Hill
6. Recommended Data Books - PSG, K. Mahadevan
7. Machine Design - Reshetov - Mir Publication
8. Machine Design - Black Adams-Mcgraw Hill
9. Fundamentals of Machine Elements - Hawrock, Jacobson McGraw Hill
10. Machine Design - Patel, Pandya, Sikh, Vol. - I & II, C.
11. Jamnadas & Co. Educational & Law Publishers
12. Design of Machine Elements - V.M. Faires
13. Design of Machine Elements - Spotts.

Course Code	Course/Subject Name	Credits
MEC603	Mechanical Vibration^{&}	4+1

& Common with Automobile Engineering

Objectives

1. To study basic concepts of vibration analysis
2. To acquaint with the principles of vibration measuring instruments
3. To study balancing of mechanical systems

Outcomes: Learner will be able to...

1. Develop mathematical model to represent dynamic system
2. Estimate natural frequency of mechanical element/system
3. Analyze vibratory response of mechanical element/system
4. Estimate the parameters of vibration isolation system

Modules	Details	Hrs
01	<p>1.1 Basic Concepts of Vibration Vibration and oscillation, causes and effects of vibrations, Vibration parameters – spring, mass, damper, Damper models, Motion – periodic, non periodic, harmonic, non- harmonic, Degree of freedom, static equilibrium position, Vibration classification, Steps involved in vibration analysis.</p> <p>1.2 Free Undamped Single Degree of Freedom Vibration System Longitudinal, transverse, torsional vibration system, Methods for formulation of differential equations by Newton, Energy, Lagrangian and Rayleigh’s Method,.</p>	08
02	<p>2.1 Free Damped Single Degree of Freedom Vibration System Viscous damped system – under damped, critically damped, over damped; Logarithmic decrement; Coulomb’s damping; Combined viscous and coulomb’s damping.</p> <p>2.2 Equivalent Single Degree of Freedom Vibration System Conversion of multi-springs, multi masses, multi – dampers into a single spring and damper with linear or rotational co-ordinate system</p>	08
03	<p>3.1 Free Undamped Multi Degree of Freedom Vibration System Eigen values and Eigen vectors for linear system and torsional two degree of freedom; Holzer method for linear and torsional unbranched system; Two rotors, Three rotors and geared system; Dunkerley’s and Rayleigh’s method for transverse vibratory system</p>	09
04	<p>4.1 Forced Single Degree of Freedom Vibratory System Analysis of linear and torsional systems subjected to harmonic force excitation and harmonic motion excitation (excluding elastic damper)</p> <p>4.2 Vibration Isolation and Transmissibility Force Transmissibility, Motion Transmissibility Typical isolators& Mounts</p> <p>4.3 Rotor Dynamics: Critical speed of single rotor, undamped and damped.</p>	09

05	5.1 Vibration Measuring Instruments: Principle of seismic instruments, vibrometer, accelerometer - undamped, damped 5.2 Introduction to Conditioning Monitoring and Fault Diagnosis.: At least two case studies in detail based on Conditioning Monitoring and Fault Diagnosis.	06
06	6.1 Balancing Static and dynamic balancing of multi rotor system, Balancing of reciprocating masses In - line engines, V - engines (excluding radial engines)	08

List of Experiments

1. Experimental prediction of natural frequency of compound pendulum, prediction of equivalent simple pendulum system.
2. Experimental prediction of natural frequency for longitudinal vibrations of helical springs, and springs in series and parallel
3. Experimental prediction of natural frequencies, and nodal points for single rotor and two-rotor vibratory system, and comparison with theoretical results
4. Experimental and theoretical investigation of whirling of shaft (i.e. . comparison of experimental and theoretical natural frequency and justification of discrepancy between experiment and theory)
5. Experimental investigation of viscous and coulomb damping, prediction of system parameter (spring stiffness, damping coefficient) from damped oscillations
6. Experimental and theoretical investigation of frequency response of mechanical system, and comparing both and justification of discrepancy between theory and experiments
7. Experiments' on distributed parameter system: Transverse vibrations of beam (Dunkerley's Rule Expt.)
8. Experimental balancing of single and multi-rotor system.
9. Introduction to FFT analyzer, and prediction of spectral response of vibrating machine from workshop.
10. Experiments on vibration isolation system and prediction of force transmissibility, motion transmissibility of system.
11. Vibration analysis of mechanical system using MATLAB

Term Work

Term work shall consist of minimum 8 experiments from the list and one assignment on each module containing at least 5 numerical.

The distribution of marks for term work shall be as follows:

- Laboratory work (Experiments) : **10 marks**
- Assignments : **10 marks**
- Attendance (Theory and Practical) : **05 marks**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Oral examination

1. Oral examination shall be conducted based on term work and syllabus content
2. Examiners are expected to give small task or ask questions either to evaluate understanding of basic fundamentals or to evaluate their capability of applying basic theory to practical applications.

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

References

1. Mechanical Vibrations 4th ed- S. S. Rao - *Pearson Education*
2. Mechanical Vibrations - G. K. Grover
3. Fundamentals of Mechanical Vibration - S.Graham Kelly - *Tata McGraw Hill 4.*
4. Vibration Analysis - P. Srineevasan - *Tata McGraw Hill*
5. Mechanical Vibrations - Schaum's outline series - S.Graham Kelly- *McGraw Hill*
1. Mechanical Vibrations - Schaum's outline series - William W. Seto- *McGrmvHill .*
2. Theory and Practice of mechanical vibrations - J. S. Rao, K. Gupta - *New Age International Publications.*
3. Mechanical Vibrations - Den; Chambil, Hinckle
4. Mechanical Vibrations, J.P. Den Hartog, McGrawhill Book Company Inc.
5. Leonard Meirovitch, Introduction to Dynamics and Conti'oJ. *Wiley, New York,*
6. Leonard Meirovitch, Elements of Vibration Analysis. *McGrmv-Hill, New York,*
7. Leonard Meirovitch, Dynamics and Control of Structures. *Wiley, New York. 4.*
Antony J. Pettofrezzo, Matrices and Transformations. *Dover, New York.*
8. Benson H. Tongue, Principles of Vibration. *Oxford University Press.*
9. W. Thomson, Theory of Vibrations with Applications, Second Edition, *Pearson Education*
10. Vibrations-BalakumarBalachandan, Edward Magrab, *CENGAGAE Learning.*

Course Code	Course/Subject Name	Credits
MEC604	Thermal and Fluid Power Engineering^{&}	4+1

Common with Automobile Engineering

Objectives

1. To study boilers, boiler mountings and accessories
2. To study utilization of thermal and hydraulic energy
3. To study gas turbine and its applications

Outcomes: Learner will be able to...

1. Identify utilities of thermal and hydraulic energy
2. Differentiate impulse and reaction turbines
3. Analyze performance of turbines

Module	Detailed Contents	Hrs.
01	Steam Generators Fire tube and Water tube boiler, Low pressure and high pressure boilers, once through boiler, examples, and important features of HP boilers, Mountings and accessories. Layout of a modern HP boiler. Equivalent evaporation of boilers. Boiler performance. Boiler efficiency	08
02	Steam Nozzle and Turbines Flow through steam nozzle-velocity at exit and condition for maximum discharge, nozzle efficiency Steam Turbine- Basic of steam turbine, Classification, compounding of turbine, Impulse turbine – velocity diagram. Condition for max efficiency. Reaction turbine - velocity diagram, degree of reaction, Parson's turbine. Condition for maximum efficiency	10
03	Impact of Jets and Water Turbines Impact of jet on flat and curved plates Types of hydro turbines - impulse and reaction, definition of various turbine parameters like gross head, discharge, work done, input power, output power, efficiencies etc., Eulers' equation applied to a turbine, turbine velocities and velocity triangles, expression for work done. Pelton Turbine: Components of Pelton turbine, definition of design parameters like speed ratio, jet ratio, and estimation of various parameters like head, discharge, and efficiency etc., determination of number of buckets. Reaction Turbines: Types of reaction turbines - inward and outward flow, radial mixed and axial; elements of the turbine, estimation of various parameters.	10
04	Similarity relations in turbines, definition of unit quantities and specific quantities, selection of turbines. Prediction of results of prototypes from the model test. Cavitations in turbines - causes, effects and remedies, Thoma's cavitations parameter G. Use of G v/s specific speed graphs. Determination of safe height of installation for the turbine. Characteristics of turbines, governing of turbines.	06

05	Gas Turbines Applications of gas turbine, Actual Brayton cycle, open and closed cycle gas turbine, methods to improve efficiency and specific output, open cycle with intercooling, reheat, and regeneration. Effect of operating variable on thermal efficiency and work ratio,	08
06	Jet Propulsion Engines Classification of jet propulsion engines, Thrust, Thrust power, Propulsive efficiency and thermal efficiency, Afterburner, Introduction to Turbojet, Turbofan, Ram jet, Turboprop and Rocket engine	06

List of Experiments

1. Study/Demonstration of Boilers
2. Study/Demonstration of Boiler mountings and accessories
3. Study of Steam Turbine
4. Trial on Impulse turbine
5. Trial on reaction turbine
6. Study of gas turbines
7. Study of Jet propulsion engines
8. Visit to Thermal Power Plant/Hydroelectric Power Plant/Gas Turbine Power Plant

Term Work

Term work shall consist of minimum 6 experiments from the list, 3 assignments containing numerical based on maximum contents of the syllabus and a visit report

The distribution of marks for term work shall be as follows:

- Laboratory work (Experiments) : **10 marks**
- Assignments : **05 marks**
- Visit report: **05 Marks**
- Attendance (Theory and Practical) : **05 marks**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

References

1. Practical Boiler Operation Engineering and Power Plant, A R Mallick, 3rd ed, PHI Learning
2. Thermal Engineering, Ballaney, Khanna Publishers, Reprint 1994
3. Thermal Engineering, Kothandraman, Domkundwar, Khajuria, Arora, Dhanpatrai & Sons.
4. Turbines, Compressors & Fans, S M Yahya, TMH
5. Thermal Engineering, R K. Rajput, Laxmi Publication
6. Steam and gas turbine, R Yadav
7. Fluid Mechanics and Hydraulic Machinery, Modi and Seth, Standard Book House
8. Hydraulic Machinery, Jagdish Lal
9. Hydraulic Machines, Vasandani
10. Fluid Mechanics and Machinery-B C S Rao, McGraw Hill
11. Fluid Mechanics and hydraulic Machines, Gupta, Pearson Education
12. Principles of Thermodynamics, H.A. Sorensen, Amerimal Publications, 1972.
13. Applied Thermodynamics for Engineers and Technologists, Eastop and Mcconky Longman, 1978
14. Hydraulic Turbines - Nechleba

Course Code	Course/Subject Name	Credits
MEC605	Mechatronics	4+1

Objectives

1. To present architecture of the mechatronics system
2. To study various actuators applicable to Mechatronics system
3. To study interfacing of the electromechanical devices.

Outcomes: Learner will be able to...

1. Identify the suitable sensor and actuator for a mechatronics system
2. Develop the skill required for interfacing the electromechanical system
3. Indigenously design and develop a mechatronic system

Modules	Details	Hrs.
01	1.1 Introduction to Mechatronics. Key element of mechatronics. mechatronics systems in factory, home and business applications. Basic Components of mechatronics systems. Mechatronics Design process, objectives, advantages of mechatronics	05
02	Actuators. 2.1 Electrical Actuating systems DC motors : Principles of operation of DC motor, Modelling of DC motor behavior, Heat dissipation in DC motor, Velocity Profile Optimization, Inertia matching, Servo Amplifier, DC motor service drive. Stepper Motors: Characteristics of a Stepper motor, Classification of a Stepper motor, Principle of Operation, Step Angle, Electrical model of energized coil, Drive method, Stepper motor performance, AC Induction motors: Three phase motor. 2.2 Voice coil actuator.	08
03	Actuators. 3.1 Pneumatic and Hydraulic actuating systems Components of pneumatic and hydraulic systems, pumps, compressor, filter, control valves, pressure regulation, relief valves, accumulator. 3.2 Harmonic drive, Comb drive. 3.3 Piezoelectric drives. 3.4 Selection of actuator	08
04	Development of circuits for industrial automation. 4.1 Electro-pneumatic systems, Electro-hydraulic system, hydro-pneumatic system, Development of circuits for Industrial automation. 4.2 Programmable Logic Controller (PLC) in automation: Basic structure, I/O processing. Ladder logic diagram, PLC for industrial process control, Selection of PLC.	08
05	5.1 System Interfacing and Data Acquisition: Data Acquisition systems (DAQs), data loggers, supervisory control and data acquisition, interfacing requirements, buffers, handshaking, polling and interrupt, digital communication, parallel communication, serial communication interface, universal asynchronous receiver and transmitter (UART), peripheral interface device (PIA), analog interfacing, Component interconnection and impedance matching, interfacing sensors and motor drives with microcomputer system.	10
06	6.1 Mechatronics case studies: Autonomous Mobile Robot, Wireless Surveillance Balloon, Fire Fighting robots, Cantilever beam vibration control using piezo sensors and actuators, Car engine management, pick and place robot, automatic camera, CNC machine	09

List of Experiments

1. Study of basic principles of sensing and actuation techniques used in Mechatronics systems
2. Study of Electro-pneumatic Logic Trainer kit, and experiments on Electro-pneumatic circuits
3. Study of Electro-hydraulic Logic Trainer kit, and experiments on Electro-hydraulic circuits
4. Experiments on Ladder programming for Mechatronics system (e.g. bottle filling plant)
5. Experiments on interfacing of mechanical system
6. Experiment based on waveform generation, interfacing and control of motors etc.
7. System Identification of any one of the actuator
8. Experimental Identification by frequency response approach of Mechanical, Electrical, Chemical system
9. Development of transfer function based on experimentally identified data, Stability analysis of predicted transfer function, and PID tuning and implementation on experimental setup
10. Experimental identification of mechanisms such as flexural based systems etc.

(Design based experiments shall be encouraged using standard National Instrument/ texas instrument/ dSPACEGmbh/ Arduino or any other platform)

Note: Error analysis is recommended.

Course Project

In course project students shall integrate and apply the knowledge gained during the course. The projects shall be developed by team of maximum four students. Further, course project shall demonstrate design, setup, and implementation of a simple mechatronics system.

Term Work

Term work shall consist of minimum 6 experiments from the list, one assignment on first three modules, one each on module 4 and module 5 respectively and a report on course project

The distribution of marks for term work shall be as follows:

- Laboratory work (Experiments) : **10 marks**
- Assignments : **05 marks**
- Course project: **05 marks**
- Attendance (Theory and Practical) : **05 marks**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

References

1. Mechatronics, Kenji Uchino and Jayne R. Giniewicz, publication: Marcel Dekker, Inc.
2. Applied Mechatronics- A. Smaili and F. Mrad, *OXFORD university press*.
3. Mechatronics System Design , Shetty and Kolk, *Cengage Learning, India Edition*
4. Introduction to Mechatronics and Measurement Systems, Alciatore and HistanTata *McGraw-Hill*
5. Mechatronics, Neculescu, *Pearson education*.
6. Mechatronics - Electromechanics and Control Mechanics , Mill *Springer-Verlag*
7. Mechatronics - Electronic Control Systems in Mechanical Engineering , Bolton *Pearson education*
8. Mechatronics - Electronics in products and processes , Bradley, et al. *Chapman and Hall*
9. Mechatronics - Mechanical System Interfacing , Auslander and Kempf, *Prentice Hall*
10. Introduction to Mechatronics, AppuKuttan K.K., *OXFORD Higher Education*
11. Pneumatic Circuits and Low Cost Automation: by Fawcett J.R.
12. The Art of Electronics, Horowitz and Hill Cambridge, *University Press*
13. Electromechanical Design Handbook , Walsh, *McGraw-Hill*
14. Electro-mechanical Engineering - An Integrated Approach , Fraser and Milne
15. Handbook of Electromechanical Product Design , Hurricks Longman, John Wiley, *Addison Wesley*
16. Principles and Applications of Electrical Engineering , Rizzoni, *Irwin Publishing*
17. Understanding Electro-Mechanical Engineering - An Introduction to Mechatronics , Kamm *IEEE*
18. Modeling and control of Dynamic Systems, Macia and Thaler, *Cengage Learning, India Edition*
19. Mechatronics, A. Smaili, F. Mrad, *OXFORD Higher Education*.
20. Pneumatic and Hydraulic Control Systems: Aizerman. M.A.
21. Industrial Hydraulics: Pippenger
22. Vickers Manual on Hydraulics
23. Computer Numerical Control of Machine Tools: Thyer. G.R.
24. Pneumatic Applications: Deppert Warner & Stoll Kurt
25. Mechanization by Pneumatic Control: Vol. 1 & 2 Deppert Warner & Stoll kurt
26. Hydraulics and Pneumatics for Production: Stewart
27. Hydraulic Valves and Controls: Pippenger
28. Fundamentals of pneumatics: Festo series
29. Automatic Control Engineering: Francis. H. Raven.
30. Mechatronics, NitaigourMahalik, *Tata McGraw-Hill*
31. Mechatronics, *HMT*
32. *System Identification: Theory for the User* (2nd Edition) , Lennart Ljung
33. Design with Microprocessors for Mechanical Engineers, Stiffler *McGraw-Hill*

Course Code	Course/Subject Name	Credits
MEC606	Finite Element Analysis &	3+1

Common with Mechanical Engineering

Objectives

1. To introduce the concepts of Mathematical Modeling of Engineering Problems.
2. To study the applicability of FEM to a range of Engineering Problems.
3. To acquaint with applications of numerical techniques for solving problems.

Outcomes: Learner will be able to...

1. Solve ordinary and partial differential equations using the Galerkin method.
2. Develop the finite element equations to model engineering problems governed by 2nd order partial differential equations.
3. Apply the basic finite element formulation techniques to solve engineering problems.
4. Use commercial FEA software, to solve problems related to mechanical engineering.

Module	Detailed Contents	Hrs.
01	<p>Introduction</p> <p>1.1 Introductory Concepts: Introduction to FEM, Historical Background, General FEM procedure. Applications of FEM in various fields. Advantages and disadvantages of FEM.</p> <p>1.2 Mathematical Modeling of field problems in Engineering, Governing Equations, Differential Equations in different fields.</p> <p>1.3 Approximate solution of differential equations-- Weighted residual techniques, Least squares, Galerkin methods, Boundary Value problems.</p>	06
02	<p>FEA Procedure</p> <p>2.1 Discrete and continuous models, Weighted Residual Methods – Ritz Technique – Basic concepts of the Finite Element Method.</p> <p>2.2 Definitions of various terms used in FEM like element, order of the element, internal and external node/s, degree of freedom, primary and secondary variables, boundary conditions.</p> <p>2.3 Minimization of a functional. Principle of minimum total potential. Piecewise Rayleigh-Ritz method. Formulation of “stiffness matrix”; transformation and assembly concepts.</p>	06
03	<p>One-Dimensional Problems</p> <p>3.1 One Dimensional Second Order Equations – Discretization – Element types- Linear and Higher order Elements – Derivation of Shape functions and Stiffness matrices and force vectors.</p> <p>3.2 Assembly of Matrices - solution of problems in one dimensional structural analysis, heat transfer and fluid flow (Stepped and Taper Bars, Fluid Network, Spring-Cart systems)</p> <p>3.3 Analysis of Plane Trusses, Analysis of Beams.</p> <p>3.4 Solution of one Dimensional structural and thermal problems using FE Software, Selection of suitable Element Type, Modeling, Meshing, Boundary Condition, Convergence of solution, Result analysis, Case studies.</p>	06

04	Two Dimensional Finite Element Formulations 4.1 Introduction, Three noded triangular element, four noded rectangular element, four noded quadrilateral element, eight noded quadrilateral element. 4.2 Natural coordinates and coordinates transformations: serendipity and Lagranges methods for deriving shape functions for triangular and quadrilateral element 4.3 Sub parametric, Isoperimetric, super parametric elements. Compatibility, Patch Test, Convergence criterion, Sources of errors.	06
05	Two Dimensional Vector Variable Problems 5.1 Equations of elasticity – Plane stress, plane strain and axisymmetric problems. 5.2 Jacobian matrix, stress analysis of CST and four node Quadratic element 5.3 Solution of 2-D Problems using FE Software (structural and Thermal), selection of element type, meshing and convergence of solution. (Can be covered during practical hours).	06
06	Finite Element Formulation of Dynamics and Numerical Techniques 6.1 Applications to free vibration problems of rod and beam. Lumped and consistent mass matrices. 6.2 Solutions Techniques to Dynamic problems, longitudinal vibration frequencies and mode shapes. Fourth Order Beam Equation, Transverse deflections and Natural frequencies of beams. 6.3 Finding frequencies of beam using FE Software (Can be covered during practical hours).	06

List of Assignment

Students should use the commercial software or programmes from the text-books or self-developed programs, to verify the results obtained by manual calculations. The input data and output results of the problem solved using the computer programs should be included in the Journal. The proposed list is as given below;

- 1 Any two problem using bar element
- 2 Any two problems using truss element
- 3 Any two problems using CST element
- 4 Any one problem using axisymmetric element
- 5 Any one problem of free vibration analysis using bar element
- 6 Any one problem on Steady State Heat conduction.

Course Project

A group of not more than four (04) students, shall do Finite Element Analysis of any mechanical engineering element/system, which involves element selection, assigning properties, meshing, assigning loads and boundary conditions, analysis and result interpretation.

Term Work

Term work shall consist of minimum **06** assignments and course project. The distribution of marks for term work shall be as follows:

- Laboratory work (experiments/assignments): 10 Marks.
- Course project: 10 Marks.
- Attendance: (Theory and Practicals): 05 Marks

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal Assessment

Assessment consists of two tests out of which; one should be compulsory class test (on minimum 40% of curriculum) and the other is either a class test (on minimum 70% of curriculum) or assignment on live problems or course project.

Practical/Oral examination

1. Practical examination duration is 2 hours.
2. Assignment for the examination shall be based on the list of assignment mentioned in the term work.
3. The distribution of marks for practical/oral examination shall be as follows:
 - i. Practical performance: 15 marks
 - ii. Oral: 10 marks
4. Evaluation of practical examination to be done based on the experiment performed and the output of the experiments during practical examination.
5. Students work along with evaluation report to be preserved till the next examination

Theory Examination

In question paper weightage of each module will be proportional to number of respective lecture hours as mention in the syllabus.

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Question number 1 will be compulsory and based on maximum contents of the syllabus
3. Remaining questions will be mixed in nature (for example, if Q.2 has part (a) from module 3 then part (b) will be from other than module 3)
4. Total four questions need to be solved.

References

1. Seshu. P. "Textbook of Finite Element Analysis" Prentice Hall of India, 2003.
2. J.N. Reddy, "Finite Element Method" Tata McGraw Hill, 2003.
3. Chandrupatla and Belegundu, "Introduction to Finite Elements in Engineering" PHI / Pearson Education, 2003.
4. Logan. D.L. "A first course in Finite Element Method", Thomson Asia Pvt. Ltd., 2002.
5. Cook R.D., Malkus. D.S. Plesha, ME., "Concepts and Applications of Finite Element Analysis", John – Wiley Sons 2003.
6. S.S. Rao, "The Finite Element Method in Engineering "Butter worth Heinemann, 2001.
7. M. Asghar Bhatti, " FUNDAMENTAL Finite Element Analysis and Applications with Mathematica and MATLAB Computations", Wiley India Pvt. Ltd.