UNIVERSITY OF MUMBAI

Bachelor of Engineering

Automobile 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. Automobile-
(Semester VI)

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract.	Theory	Pract.	Total
AEC601	Automotive System	3	2	3	1	4
AEC602	Machine Design I[&]	4	2	4	1	5
AEC603	Mechanical Vibrations[&]	4	2	4	1	5
AEC604	Thermal and Fluid Power Engineering[&]	4	2	4	1	5
AEC605	Operations Research	3	2	3	1	4
AEC606	Finite Element Analysis[&]	3	2	3	1	4
Total		**21**	**12**	**21**	**6**	**27**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract./ oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test1	Test 2	Avg.					
AEC601	Automotive System	20	20	20	80	03	25	25	150
AEC602	Machine Design I[&]	20	20	20	80	03	25	--	125
AEC603	Mechanical Vibrations [&]	20	20	20	80	03	25	25*	150
AEC604	Thermal and Fluid Power Engineering[&]	20	20	20	80	03	25	--	125
AEC605	Operations Research	20	20	20	80	03	25	--	125
AEC606	Finite Element Analysis[&]	20	20	20	80	03	25	25	150
Total		**--**	**--**	**120**	**480**	**--**	**150**	**75**	**825**

[&] Common with Mechanical Engineering *** Only ORAL examination based on term work and syllabus**

Course Code	Course/Subject	Credits
AEC601	**Automotive Systems**	**3+1**

Objectives

1. To study basic and advance automotive systems.
2. To study working of different automotive systems and subsystems.
3. To study different vehicle layouts.
4. To have basic idea about how automotive systems are developed.

Outcomes: Learner will be able to……

1. Practically identify different automotive systems and subsystems.
2. Practically identify different automotive components.
3. Illustrate working and functions of various automotive components

Module	Details	Hrs.
1	**1. CLUTCHES** 1.1 Function requirements 1.2 Types of single plate clutch 1.3 Clutch control systems 1.4 Clutch center plate construction 1.5 Direct release clutch 1.6 Centrifugally operated clutches 1.7 Multiplate clutches 1.8 Angle spring clutch 1.9 Wet clutch	05
2	**2. TRANSMISSION** 2.1 Purpose and element of gear box 2.2 Constant mesh gear box 2.3 Sliding mesh gear box 2.4 Synchromesh gear box 2.5 Gear selector mechanism 2.6 Heavy vehicle gear boxes 2.7 Fluid coupling and torque convertors 2.7.1 Fluid coupling 2.7.2 Torque converters 2.8 Epicyclic gear box operation 2.9 Semi – Automatic and Automatic transmission 2.9.1 Hydraulic control systems 2.9.2 Electro hydraulic control systems 2.9.3 Automatic layshaft gear boxes 2.9.4 Dual mode transmission with sequential gear change 2.9.5 Direct shift gear boxes 2.9.6 Over drive gears 2.9.7 Continuously variable transmissions 2.10 Electric drives 2.10.1 General arrangement and description of electric transmissions 2.10.2 Working principle and control 2.10.3 Advantages and limitations of electric drives	08

3	**3. DRIVE LINES** 3.1 Drive Lines 3.1.1 Universal joints 3.1.2 Constant velocity joints 3.1.3 Propeller shaft construction 3.1.4 Drive line arrangement 3.1.5 Rear-wheel drive and front-wheel drive layouts 3.1.6 Front-wheel drive shafts 3.1.7 Tandem axle drive for heavy vehicles 3.1.8 Drive lines for public service vehicles	05
4	**4. FINAL DRIVE AND REAR AXLES** 4.1 Final drive gears and bearings 4.2 Differential gears 4.3 Differential- All types 4.4 Rear axle construction 4.5 Heavy vehicle rear axle 4.6 Four wheel drive systems 4.6.1 Basic consideration of four wheel drive 4.6.2 Part time four wheel drive 4.6.3 Full time four wheel drive	05
5	**5. BRAKING AND SUSPENSION SYSTEMS** 5.1 Braking System 5.1.1 Hydraulic brake systems 5.1.2 Air brake systems 5.1.3 Endurance brake systems 5.2 Suspension System 5.2.1 Basic ride considerations 5.2.2 Types of suspension systems 5.2.3 Types of suspension spring 5.2.4 Tandem axle suspension 5.2.5 Shock dampers 5.2.6 Adaptive suspension systems 5.2.7 Active roll control systems	07
6	**6. STEERING , TYRES, ROAD WHEELS AND HUBS** 6.1 Steering systems 6.1.1 Steering principles and layout 6.1.2 Front end geometry and wheel alignment 6.1.3 Steering and suspension ball joints 6.1.4 Manual steering gears 6.1.5 Steering axles for heavy vehicles 6.1.6 Hydraulic power-assisted steering 6.1.7 Speed-sensitive hydraulic power-assisted steering 6.1.8 Electro-hydraulic power-assisted steering 6.1.9 Electrical power-assisted steering 6.1.10 Types of four-wheel steering 6.2 Tyres, Road wheels and Hubs 6.2.1 Introduction to Tyre characteristics 6.2.2 Tyre construction 6.2.3 Road wheels and hubs	06

List of Assignments/Practical's

Study of cut section models covering all the modules is desirable.

1. Dismantling and reassembling of Clutch.
2. Dismantling and reassembling of Gear box.
3. Dismantling and reassembling of Propeller Shaft.
4. Dismantling and reassembling of Differential.
5. Dismantling and reassembling of Steering gear linkages and steering gear box.
6. Dismantling and reassembling of all types of braking systems.

Case Studies

Assign case studies for each student on any one of the following topics:

1. **Four wheelers**: Light and Heavy vehicles (Passenger and Commercial)
2. **Three wheelers**: Case study of Indian models. Front mounted engine and rear mounted engine types. Auto rickshaws, Pick up van, Delivery van and Trailer, Bijili electric vehicle.
3. **Two wheelers**: Case study of major Indian models of major motor cycles, scooters and mopeds.
4. **Off Road Vehicles:** Case study regarding working principle and construction of each- Earth Moving Machines, Scrappers, Graders, Shovels and Ditchers, Farm Equipment's, Military and Combat Vehicles.

Term Work

Term work shall consist of

A. Assignments/ Practical's as per list
B. Case Studies as above

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

- Part A **: 10 marks**
- Part B : **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.

Practical/Oral examination

1. Practical examination shall be conducted in a group of not more than 4 students. Examination shall be based on dismantling and reassembling performed during the semester.
2. Examiners are expected to evaluate each group and conduct oral based on the same
3. The distribution of marks for practical/oral examination shall be as follows:
   iii. Practical performance …… 15 marks
   iv. Oral …… ……. .10 marks
4. Students work along with dismantling and reassembling evaluation report to be preserved till the next examination

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. Light and Heavy Vehicle Technology, M.J. Nunney, Elsevier, Fourth Edition.
2. Automotive Technology, Jack Erjavec, Cengage Learning, Fifth Edition.
3. Automotive Braking, Thomas W. Birch, Cengage Learning, Third Edition.
4. Motor Automotive technology, Anthony E. Schwaller, Delmar, Third Edition.
5. Automotive suspension and steering systems, Thomas W. Birch, Delmar Cengage Learning, Third Edition.

Course Code	Course/Subject Name	Credits
AEC602	**Machine Design-I[&]**	**4+1**

[&] Common with Mechanical Engineering

Objectives

1. To study basic principles of machine design
2. To acquaint with the concepts of strength design related to various components.

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

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 Lame'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**

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,Purohit. Prentice Hall India Pub.
3. Machine Design - An Integrated Approach -- Robert L. Norton – Pearson Education.
4. Machine Design - Pandya & Shah- Charotar PI/blishing.
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. Jamnadas & Co. Educational & Law Publishers
11. Design of Machine Elements - V.M. Faires
12. Design of Machine Elements - Spotts

Course Code	Course/Subject Name	Credits
AEC603	**Mechanical Vibration[&]**	**4+1**

[&] Common with Mechanical 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	**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. **1.2 Free Undamped Single Degree of Freedom Vibration System** Longitudinal, transverse, torsinal vibration system, Methods for formulation of differential equations by Newton, Energy, Lagrangian and Rayleigh's Method,.	**08**
02	**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. **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	**08**
03	**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	**09**
04	**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) **4.2 Vibration Isolation and Transmissibility:** Force Transmissibility, Motion Transmissibility Typical isolators& Mounts **4.3 Rotor Dynamics:** Critical speed of single rotor, undamped and damped.	**09**
05	**5.1 Vibration Measuring Instruments:** Principle of seismic instruments, vibrometer, accelerometer - undamped, damped **5.2** Introduction to Conditioning Monitoring and Fault Diagnosis.: Atleast 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 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
AEC604	**Thermal and Fluid Power Engineering[&]**	**4+1**

[&] Common with Mechanical 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, JagdishLal
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	Credits
AEC605	**Operations Research**	**3+1**

Objectives

1. To understand, different resources used in industries and optimize them.
2. To understand different quantitative methods of optimization.
3. To understand fundamentals of optimization technique that will help in higher study.
4. To have basic idea about quantitative techniques to be used in automobile industries.

Outcomes: Learner will be able to…..

1. Develop fundamental knowledge of optimization technique.
2. Formulate the industrial problem for optimization of resources.
3. Minimize idle time, manufacturing cost and maximize profit, sales etc.

Modules	Details	Hrs.
01	**Linear Programming** Problem Formulation, Graphical Method, Simplex Method – Artificial Variable Techniques - Big M- Method, Two Phase Method – Duality – Dual Simplex Method.	06
02	**Transportation Problem** Formulation – Solution by North West corner rule, Row Minima Method, Matrix Minima Method, Vogel's Approximation Method – Optimality by MODI Method – Unbalanced Transportation Method – Degeneracy. **Assignment** Formulation – Optimality by Hungarian Method, Travelling Salesman Problem.	06
03	**Queuing Models** Introduction, Poisson Arrivals – Exponential Service – Single Channel with Finite and Infinite Population. **Game Theory** Introduction, Maximin & Minimax Principle, Graphical Method (2 x m & n x 2) matrix – Method of Dominance – Method of Marices.	06
04	**Project Management** Phases of Project Management, Network construction, Critical Path Method, Project Evaluation & Review Technique – Resource Analysis-Resource Leveling.	06
05	**Inventory Control** Introduction – Deterministic Model – Instantaneous demand with & without shortage- Models with one and Multiple price break. **Simulation** Definition, Types of Simulation Models – Monte Carlo Technique – Practical Problems – Applications in Inventory & Queuing problems.	06
06	**Decision Theory** Introduction – Decision Making Environment – Decision Under Uncertainty, Criterion of Pessimism, Criterion of Optimism, Laplace Criterion, Hurwitz Criterion, Criterion of Regret – Decision Making Under Risk, Expected Monetary Value (EMV) Criterion, Expected Opportunity Loss (EOL) Criterion – Decision Tree.	06

Term Work

Term work shall consist of minimum 06 assignments, at least one from each module. Introduction of software is desirable.

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

- Assignments : **20 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. R. Pannerselvam, Operations Research: PHI Publications.
2. N.D. Vohra, Quantitative Technique in Management: Tata McGraw Hill Education Pvt. Ltd.
3. S.S. Rao, Optimization: Theory and Applications, New Age International Pvt. Ltd.
4. Introduction to Operations Research, Taha, Pearson Education

Course Code	Course/Subject Name	Credits
AEC606	**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	**Introduction** 1.1 Introductory Concepts: Introduction to FEM, Historical Background, General FEM procedure. Applications of FEM in various fields. Advantages and disadvantages of FEM. 1.2 Mathematical Modeling of field problems in Engineering, Governing Equations, Differential Equations in different fields. 1.3 Approximate solution of differential equations-- Weighted residual techniques, Least squares, Galerkin methods, Boundary Value problems.	06
02	**FEA Procedure** 2.1 Discrete and continuous models, Weighted Residual Methods – Ritz Technique – Basic concepts of the Finite Element Method. 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. 2.3 Minimization of a functional. Principle of minimum total potential. Piecewise Rayleigh-Ritz method. Formulation of "stiffness matrix"; transformation and assembly concepts.	06
03	**One-Dimensional Problems** 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. 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) 3.3 Analysis of Plane Trusses, Analysis of Beams. 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.	06

04	**Two Dimensional Finite Element Formulations** 4.1 Introduction, Three nodded triangular element, four nodded rectangular element, four nodded quadrilateral element, eight nodded 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" 4th Ed Pearson Education, 2012.
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.