

# UNIVERSITY OF MUMBAI



## **Bachelor of Engineering Mechanical Engineering**

**Third Year (Sem. V & VI) and Final Year (Sem. VII & VIII)**

**Revised Syllabus (REV- 2012) w. e. f. Academic Year 2014 -  
15 and 2015-2016 respectively**

**Under**

## **FACULTY OF TECHNOLOGY**

**(As per Semester Based Credit and Grading System)**

## **Deans Preamble**

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Technology of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty of Technology, University of Mumbai, in one of its meeting unanimously resolved that, each Board of Studies shall prepare some Program Educational Objectives (PEO's) and give freedom to affiliated Institutes to add few (PEO's) and course objectives and course outcomes to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. It was also resolved that, maximum senior faculty from colleges and experts from industry to be involved while revising the curriculum. I am happy to state that, each Board of studies has adhered to the resolutions passed by Faculty of Technology, and developed curriculum accordingly. In addition to outcome based education, semester based credit and grading system is also introduced to ensure quality of engineering education.

Semester based Credit and Grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. University of Mumbai has taken a lead in implementing the system through its affiliated Institutes and Faculty of Technology has devised a transparent credit assignment policy and adopted ten points scale to grade learner's performance. Credit and grading based system was implemented for First Year of Engineering from the academic year 2012-2013. Subsequently this system will be carried forward for Second Year Engineering in the academic year 2013-2014, for Third Year and Final Year Engineering in the academic years 2014-2015 and 2015-2016 respectively.

**Dr. S. K. Ukarande**  
**Dean,**  
**Faculty of Technology,**  
**Member - Management Council, Senate, Academic Council**  
**University of Mumbai, Mumbai**

## **Chairman Preamble**

Engineering education in India is expanding and is set to increase manifold. The major challenge in the current scenario is to ensure quality to the stakeholders along with expansion. To meet this challenge, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education and reflects the fact that in achieving recognition, the institution or program of study is committed and open to external review to meet certain minimum specified standards. The major emphasis of this accreditation process is to measure the outcomes of the program that is being accredited. Program outcomes are essentially a range of skills and knowledge that a student will have at the time of graduation from the program. In line with this Faculty of Technology of University of Mumbai has taken a lead in incorporating the philosophy of outcome based education in the process of curriculum development.

As the Chairman, Board of Studies in Mechanical Engineering of University of the Mumbai, I am happy to state here that, the Program Educational Objectives were finalized in a brain storming session, which was attended by more than 20 members from different affiliated Institutes of the University. They are either Heads of Departments or their senior representatives from the Department of Mechanical Engineering. The Program Educational Objectives finalized for the undergraduate program in Mechanical Engineering are listed below;

1. To prepare the Learner with a sound foundation in the mathematical, scientific and engineering fundamentals.
2. To prepare the Learner to use modern tools effectively in order to solve real life problems.
3. To prepare the Learner for a successful career in Indian and Multinational Organisations and to excel in their Postgraduate studies.
4. To encourage and motivate the Learner in the art of self-learning.
5. To inculcate a professional and ethical attitude, good leadership qualities and commitment to social responsibilities in the Learner's thought process.

In addition to the above, 2 to 3 more program educational objectives of their own may be added by affiliated Institutes.

In addition to Program Educational Objectives, for each course of undergraduate program, objectives and expected outcomes from the point of view of a learner are also included in the curriculum to support the philosophy of outcome based education. I strongly believe that even a small step taken in the right direction will definitely help in providing quality education to the major stake holders.

**Dr. S. M. Khot**

**Chairman, Board of Studies in Mechanical Engineering, University of Mumbai**

**Program Structure for B E Mechanical Engineering  
T. E. Mechanical -(Semester V)**

Subject Code	Subject Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract.	Theory	Pract.	Total
MEC501	I C Engines &	4	2	4	1	5
MEC502	Mechanical Measurements and Control	4	2	4	1	5
MEC503	Production Process-III &	4	2	4	1	5
MEC504	Theory of Machines- II&	4	2	4	1	5
MEC505	Heat Transfer &	4	2	4	1	5
MEL501	Business Communication and Ethics #	-	2 <sup>S</sup> +2	-	2	2
<b>Total</b>		<b>20</b>	<b>14</b>	<b>20</b>	<b>7</b>	<b>27</b>

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.					
MEC501	I C Engines &	20	20	20	80	03	25	25	150
MEC502	Mechanical Measurements and Control	20	20	20	80	03	25	25	150
MEC503	Production Process-III &	20	20	20	80	03	25	--	125
MEC504	Theory of Machines- II&	20	20	20	80	03	25	--	125
MEC505	Heat Transfer &	20	20	20	80	03	25	25*	150
MEL501	Business Communication and Ethics #	--	--	--	--	--	50	--	50
<b>Total</b>		<b>--</b>	<b>--</b>	<b>100</b>	<b>400</b>	<b>--</b>	<b>175</b>	<b>75</b>	<b>750</b>

\$ Theory for entire class to be conducted # common for all engineering programs

& Common with Automobile Engineering \* Only ORAL examination based on term work and syllabus

**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
<b>Total</b>		<b>22</b>	<b>12</b>	<b>22</b>	<b>6</b>	<b>28</b>

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
<b>Total</b>		<b>--</b>	<b>--</b>	<b>120</b>	<b>480</b>	<b>--</b>	<b>150</b>	<b>75</b>	<b>825</b>

& Common with Automobile Engineering \* Only ORAL examination based on term work and syllabus

Project –I and II: Students groups and load of faculty per week  
 Project Groups: Students can form groups with minimum 2 (Two) and not more than 4 (Four)  
 Faculty Load : In semester VII 1/2 hour per week per project group  
 In semester VIII 1 hour per week per project group  
 Each faculty is permitted to take (guide) maximum 4 (Four) project groups.

Course codes	Elective I	Course codes	Elective II
MEE7011	Product Life Cycle Management (PLM)	MEE8021	Micro Electro Mechanical Systems (MEMS)
MEE7012	Power Plant Engineering &	MEE8022	Renewable Energy Sources
MEE7013	Energy Management	MEE8023	Project Management &
MEE7014	Supply Chain Management &	MEE8024	Business Process Reengineering
MEE7015	Computational Fluid Dynamics &	MEE8025	Cryogenics
MEE7016	Advanced Turbo Machinery	MEE8026	Automobile Engineering
MEE7017	Piping Engineering	MEE8027	Process Equipment Design
MEE7018	Emission and Pollution Control	MEE8028	Alternative Fuels
MEE7019	Operations Research	MEE8029	Enterprise Resource Planning
MEE70110	Total Productive Maintenance (TPM)	MEE80210	World Class Manufacturing &
MEE70111	Robotics	MEE80211	Nanotechnology
MEE70112	Digital Prototyping for Product Design –I	MEE80212	Digital Prototyping for Product Design –II

& Common with Automobile Engineering

Course Code	Course/Subject Name	Credits
<b>MEC501</b>	<b>Internal Combustion Engines<sup>&amp;</sup></b>	<b>4+1</b>

<sup>&</sup>Common with Automobile Engineering

### Objectives

1. Study of air standard and actual engine cycles.
2. Study of SI and CI engine components and processes involved
3. Study and analysis of engine performance characteristics and engine emissions

**Outcomes:** Learner will be able to...

1. Differentiate SI and CI engines
2. Identify and explain working of engines components/systems
3. Plot and analyze engine performance characteristic
4. Perform exhaust gas analysis and comment on adverse implications on environment

Module	Detailed Contents	Hrs.
01	<b>Introduction</b> Heat engines; Internal and external combustion engines; Classification of I.C. Engines; Cycle of operations in four strokes and two-stroke IC engines and their comparative study; Scavenging and scavenging blowers, Air standard cycles and Fuel air cycles, Variable specific heat and its effects, Dissociation and other losses, Actual cycles, Deviation of actual engine cycle from ideal cycle	06
02	<b>Spark Ignition Engines</b> <b>A. Carburetors and fuel injection system in S I Engines :</b> Theory of carburetion, Simple carburetor, Essential parts of modern carburetor, Types of carburetors, Types of fuel injection systems in S I engines, Continuous injection system, Timed injection system, Electronic Fuel-Injection systems (EFIs), Advantages and disadvantages of SI engine fuel injection system <b>B. Ignition Systems :</b> Spark Plug and its requirements, Battery, Magneto, Electronic ignition systems <b>C. Combustion:</b> Combustion phenomenon in SI Engines, Ignition delay, Flame propagation, Pressure-Crank angle diagram, Abnormal combustion, Auto ignition, Detonation and Knocking, Factors affecting combustion and detonation, Types of combustion chambers	12
03	<b>Compression Ignition Engines</b> <b>A. Fuel Injection Systems :</b> Types i.e. Air injection systems, Airless/solid injection systems, Common rail, individual pump, distributor and unit injector etc, Injection pumps, Fuel injector, Types of nozzle, Electronically controlled unit fuel injection system, C I Engine Governors: necessity and characteristics <b>B. Combustion :</b> Combustion phenomenon in C I engines, Stages of combustion, Delay period, Knocking, Pressure-Crank angle diagram, Factors affecting combustion and knocking, Types of combustion chambers	12
04	<b>Engine lubrication :</b> Types of lubricants and their properties, SAE rating of lubricants, Types of lubrication systems <b>Engine Cooling :</b> Necessity of engine cooling, disadvantages of overcooling, Cooling systems and their comparison: Air cooling, Liquid cooling <b>Supercharging/Turbo-charging :</b> Objectives, Effects on power output and engine efficiency, Methods, Types, Limits	08

<b>05</b>	<p><b>Engine Testing and Performance:</b> Measurement of Break Horse Power, Indicated Power, Fuel Consumption, Air flow, BMEP, Performance characteristic of SI and CI Engines, Effect of load and Speed on mechanical, indicated thermal, break thermal and volumetric efficiencies, Heat balance sheet</p> <p><b>Exhaust Emissions:</b> Exhaust gas analysis and methods, necessity, constituents, Air pollution due to engine exhaust, Pollution control devices and EURO, BHARAT standards</p> <p><b>Fuels:</b> SI and CI engine fuels, Rating of fuels, Non conventional fuels: CNG, LPG, Bio-fuels, Hydrogen, Alcohol etc</p>	06
<b>06</b>	<p><b>Alternative Potential Engines:</b> Stratified charge engine, Wankel engine, Free-piston engine, Stirling engine, VCR engine, Dual fuel engines, Multi fuel engines</p> <p><b>Modern Trends in I C Engines</b></p>	04

## List of Experiments

### Part A: Study of physical systems in terms of constructional details and functions

- 1] 2 Stroke and 4 Stroke Engines
- 2] Carburetor.
- 3] Ignition system.
- 4] Fuel injection system.

### Part B: Students shall perform at least 5 experiments from the list

- 1] Morse Test on petrol engine.
- 2] Speed Test on petrol or/and diesel engine.
- 3] Load Test on diesel engine (engines).
- 4] Heat Balance test on diesel or petrol engines.
- 5] Experimental determination of Air fuel ratio and volumetric efficiency of the engine
- 6] Exhaust Gas/Smoke analysis of S.I./ C.I. engines
- 7] Effect of Supercharging on Performance Characteristics of an engine

## Term Work

Term work shall consist of minimum 6 experiments from the list out of which 4 must be actual trials on IC Engines and 1 case study/report (in group of not more than 3 students) on latest trends/developments in IC Engines

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

- Laboratory work (Experiments) : **15 marks**
- Case Study/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.

## Practical/Oral examination

1. Practical examination shall be conducted in a group of not more than 5 students. Examination shall be based on actual trials performed during the semester. Students are expected to actually take reading and plot the performance characteristics and comment.
2. Examiners are expected to evaluate results of each group and conduct oral based on the same
3. The distribution of marks for practical/oral examination shall be as follows:
  - i. Practical performance ..... 15 marks
  - ii. Oral ..... 10 marks
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. Internal Combustion Engines, Willard W. Pulkrabek, Pearson Education.
2. Internal Combustion Engines, Shyam Agrawal, New Age International
3. Internal Combustion Engine, Mathur and Sharma
4. Internal Combustion Engines, Mohanty, Standard Book House
5. Internal Combustion Engine, Gills and Smith
6. Internal Combustion Engines Fundamentals, John B. Heywood
7. Internal Combustion Engines, Gupta H N, 2<sup>nd</sup> ed, PHI
8. Internal Combustion Engine, V Ganesan - *TataMcGraw Hill*
9. Internal Combustion Engines, Richard Stone - *Palgrave Publication*
10. Internal Combustion Engine, S.L. Beohar
11. Internal Combustion Engine, P.M Heldt.
12. Internal Combustion Engines, V.L. Maleeve
13. Internal Combustion Engine, E.F. Oberi.
14. Internal Combustion Engine, Domkundwar



Course Code	Course/Subject Name	Credits
<b>MEC502</b>	<b>Mechanical Measurement and Control</b>	<b>4+1</b>

### Objectives

1. To impart knowledge of architecture of the measurement system
2. To deliver working principle of mechanical measurement system
3. To study concept of mathematical modelling of the control system
4. To Analyse control system under different time domain

**Outcomes:** Learner should be able to...

1. Identify and select proper measuring instrument for specific application
2. Illustrate working principle of measuring instruments
3. Explain calibration methodology and error analysis related to measuring instruments
4. Mathematically model and analyze system/process for standard input responses

Modules.	Details	Hrs.
<b>01</b>	1.1 Significance of Mechanical Measurements, Classification of measuring instruments, generalized measurement system, types of inputs: Desired, interfering and modifying inputs. 1.2 Static characteristics: Static calibration, Linearity, Static Sensitivity, Accuracy, Static error, Precision, Reproducibility, Threshold, Resolution, Hysteresis, Drift, Span & Range etc. 1.3 Errors in measurement: Types of errors, Effect of component errors, Probable errors.	08
<b>02</b>	<b>2.1 Displacement Measurement</b> : Transducers for displacement, displacement measurement, potentiometer, LVDT, Capacitance Types, Digital Transducers (optical encoder) , Nozzle Flapper Transducer <b>2.2 Strain Measurement</b> : Theory of Strain Gauges, gauge factor, temperature Compensation, Bridge circuit, orientation of strain gauges for force and torque, Strain gauge based load cells and torque sensors <b>2.3 Measurement of Angular Velocity:</b> Tachometers, Tachogenerators, Digital tachometers and Stroboscopic Methods. <b>2.4 Acceleration Measurement</b> , theory of accelerometer and vibrometers, practical accelerometers, strain gauge based and piezoelectric accelerometers.	08
<b>03</b>	<b>3.1 Pressure Measurement:</b> Elastic pressure transducers viz. Bourdon tubes, diaphragm, bellows and piezoelectric pressure sensors, High Pressure Measurements, Bridge man gauge. Vacuum measurement: Vacuum gauges viz. McLeod gauge, Ionization and Thermal Conductivity gauges. <b>3.2 Flow Measurement:</b> Bernoullis flowmeters, Ultrasonic Flowmeter, Magnetic flow meter, rotameter. <b>3.3 Temperature Measurement:</b> Electrical methods of temperature measurement Resistance thermometers, Thermistors and thermocouples, Pyrometers. <b>3.3 Sensitivity analysis of sensor-</b> influence of component variation, <b>Signal conditioning:</b> Amplifier, Conversion, Filtering, Impedance Buffering, Modulation / Demodulation, Linearization, Grounding and Isolation.	08

<b>04</b>	4.1 Introduction to control systems. Classification of control system. Open loop and closed loop systems. 4.2 Mathematical modelling of control systems, concept of transfer function, Block diagram algebra.	06
<b>05</b>	<b>5.1 Transient and steady state analysis of first and second order system.</b> Time Domain specifications. Step response of second order system. Steady-state error, error coefficients, steady state analysis of different type of systems using step, ramp and parabolic inputs.	06
<b>06</b>	<b>Stability analysis</b> 6.1 Introduction to concepts of stability. The Routh criteria for stability. 6.2 Experimental determination of frequency response, Stability analysis using Root locus, Bode plot and Nyquist Plots. 6.3 State space modeling. 6.4 Process control systems, ON-OFF control. P-I-D Control.	12

## List of Experiments

1. Calibration of Displacement sensors like LVDT, Potentiometers etc.
2. Calibration of Pressure Gauges
3. Calibration of Vacuum Gauges
4. Torque measurement using strain gauges
5. Calibration of tachometers
6. Vibration Measurement & Calibration of Accelerometers.
7. Experiments on feedback control systems and servomechanisms
8. System Identification of any one of the sensor
9. Experiment on frequency response system identification
10. Experiment on transient state response of a control system.
11. Experiment on design of PID controller for a system.

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

## Term Work

Term work shall consist of minimum **08** experiments (04 from the measurement group and 04 from the control group), assignments 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:
  - iii. Practical performance ..... 15 marks
  - iv. 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. Measurement Systems (Applications and Design) 5<sup>th</sup> ed.- E.O. Doebelin - *McGraw Hill*.
2. Mechanical Engineering Measurement - Thomas Beckwith, N.Lewis Buck, Roy Marangoni - *Narosa Publishing House, Bombay*.
3. Mechanical Engineering Measurements - A. K. Sawhney - *DhanpatRai& Sons, New Delhi*.
4. Instrumentation Devices & Systems - C.S. Rangan&G.R.Sarrna - *Tata McGraw Hill*.
5. Instrumentation & Mechanical Measurements - A.K. Thayal.
6. Control System Engineering: by Nagrath IJ. and Gopal .M., *Wiley EasternLtd*.
7. Modern Control engineering: by K.Ogata, *Prentice Hall*
8. Control systems: Dhanesh Manik, Cengage Learning
9. Automatic Control System, Benjamin Kuo, Prentice Hall
10. Control system theory with engineering applications, Lysherski, Sergey E, Springer
11. Instrumentation and Control System, W. Bolton, Elsevier
12. Experimental Methods for Engineers - J. P. Holman. - McGraw Hills Int. Edition.
13. Engineering Experimentation - E.O. Doebelin - McGraw Hills Int. Edition
14. Mechanical Measurements- S.P.Venkateshan, Ane books, India
15. Theory and Design for Mechanical Measurements, 3<sup>rd</sup> ed., Wiley
16. Control System Engineering: Norman Nise, John Wiley and Sons
17. Feedback Control System, Charles Phillips, R. D. Harbor

Course Code	Course/Subject Name	Credits
<b>MEC503</b>	<b>Production Process - III<sup>&amp;</sup></b>	<b>4+1</b>

<sup>&</sup> Common with Automobile Engineering

### Objectives

1. To study sheet metal forming as well as mechanical behavior of stress system in metal forming processes.
2. To develop capability to design jigs and fixtures.
3. To give exposure to Non-traditional machining operations.
4. To study concepts regarding modern manufacturing techniques like rapid prototyping, rapid tooling, agile manufacturing technologies etc.

**Outcome:** Learner will be able to..

1. Demonstrate understanding of sheet metal forming and various stress systems involved in metal forming operations.
2. Design jigs and fixtures for a given applications.
3. Get knowledge about non-conventional machining operations and its application areas.
4. Illustrate advanced concepts such as rapid prototyping and Agile manufacturing.

Module	Details	Hrs.
01	Introduction to High speed machines, special purpose machines, transfer line and other mass production machines. Types of automats and its tooling.	04
02	<b>Sheet Metal Forming :</b> Elementary treatment of press working, Operation on presses, Press devices Classification of presses, Constructional features of blanking, piercing, compound, combination, progressive, bending, forming and drawing dies, Load calculations, development of blanks, scrap strip layout, punches, selection of die sets, stock guides, strippers, pilots, stops etc. selection of presses, capacities and other details.	10
03	<b>Design of Jigs and Fixtures:</b> Need for jigs and fixtures, elements of Jigs and fixtures, principles of location, design of locating elements, locating pins support pins spring back, vee blocks, etc. principles of clamping simple hand operated clamps, like screw clamp, lever clamps and other types of clamps. Drill bushes-their types and applications indexing devices, auxiliary elements. Design of drill jigs like plate, leaf solid and box types for drilling combined with reaming, spot facing etc. design of milling fixtures such as plain, string, gang and indexing types. Design of turning fixtures.	12
04	<b>Non-traditional Machining</b> Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining, Electrochemical Machining (ECM), Chemical Machining (CHM) Electrical Discharge Machining (EDM), Plasma Arc Machining (PAM), Laser Beam Machining (LBM), Electron Beam Machining (EBM), Arc cutting processes and Oxy fuel cutting process.	08
05	<b>Plastics Injection Mold Design:</b> General arrangement of an injection mold, Basic systems of the mold – Feeding system, cooling system and ejection systems, Concepts of three plate molds and tooling for moulding articles with undercuts, Concepts of split molds, hot runner systems – Their advantages and limitation over conventional systems. Basic concepts of mold standardization and innovative mold components.	08

<b>06</b>	<b>Agile Manufacturing Technologies:</b> Introduction, Developing agile manufacturing, Integration of Product/Process Development, Application of IT/IS concepts, Agile supply chain management, Design of skill and knowledge and Computer control of Agile manufacturing. Flexible manufacturing systems.	<b>06</b>
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## Term Work

1. At least six assignments on concepts, Case studies and analysis based on the topics mentioned above.
2. Term work shall consist of minimum 6 assignments. The distribution of marks for term work shall be as follows

- Lab work (Case Studies): **10 marks**
- Assignments: **10 marks**
- Attendance: **05marks**

## 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. *Mechanical Metallurgy*, G E Dieter ,McGraw Hill.
2. *Jigs and Fixtures*, P H Joshi, Mc Graw Hill.
3. *Production Technology*, R C Patel & C G Gupte.
4. *Production Technology*, HMT, Tata Mc Graw Hill.
5. *Introduction to Jigs and Tool design*, HA Kempster, Butterworth Heinemann Ltd.
6. *Manufacturing Process*, R A Lindberg, PHI India.
7. *Agile Manufacturing- Forging Mew Frontiers*, Poul T Kidd,Amagow Co. UK.
8. *Agile Manufacturing*, AGunasekharan, the 21st Century Competitive strategy, Elsevier Press,India.
9. *Stereo Lithography and other RP & M Technologies*, Paul F.Jacobs: SME, NY 1996.
10. *Rapid Manufacturing*, Flham D.T &Dinjoy S.S Verlog London2001.
11. *Fundamentals of modern Manufacturing*, Fourth Edition, Mikell P Groover, John Wiley & Sons.
12. *Metals handbook* ,Forming and Forging, Vol. 14, ASM.

Course Code	Course/Subject Name	Credits
<b>MEC504</b>	<b>Theory of Machines-II<sup>&amp;</sup></b>	<b>4+1</b>

**& Common with Automobile Engineering**

### Objectives

1. To acquaint with working principles of clutches and its constructional details.
2. To study working and types of brakes and dynamometers.
3. To acquaint with working principles and applications of gyroscope and governors.
4. To demonstrate different types of gear trains and its applications.

**Outcomes:** Learner will be able to...

1. Apply the working principles of clutches and its constructional details.
2. Analyze working of brakes and dynamometers.
3. Demonstrate working mechanism of different types of governors.
4. Analyze and select gear trains.
5. Analyze gyroscopic effect on various applications

Module	Details	Hrs.
01	<b>1.1 Clutches:</b> Requirements of Clutches, Types of Clutches and Clutch materials, Positive clutches, friction clutches, Friction Clutches - Analysis of frictional torque, power transmission .Power loss in Friction in single plate, multiple plate clutch, and cone clutch, Centrifugal Clutches - construction, working	08
02	<b>2.1 Brakes:</b> Requirement of brake, Types of Brakes, Analysis of Block brakes - external and internal, Band brake-simple and differential, Band and block brake - simple and differential, Braking of vehicles - front wheels, rear wheels, all wheels on level and inclined roads, <b>2.2 Dynamometers</b> - Absorption and transmission dynamometers, Study and analysis of absorption type dynamometer - Proney brake, Rope brake, dynamometers, Study and analysis of transmission type dynamometers - Belt transmission, epicyclical, torsion dynamometers, Froude hydraulic dynamometer	08
03	<b>3.1 Governors:</b> Comparison between governors and flywheel, Types - centrifugal governors, inertia governors, <b>3.2 Force analysis of gravity loaded governors</b> - Watt, Porter, Proell, Force analysis of spring loaded governors - Hartnell, hartung, Wilson Hartnell, Force analysis of spring and gravity loaded governor, Performance characteristics of governors- stability, sensibility, isochronisms, Hunting, governor effort and governor power, coefficient of insensitiveness.	08
04	<b>4.1 Gyroscope:</b> Introduction - Gyroscopic couple and its effect on spinning bodies, Gyroscopic effect on naval ships during steering, pitching and rolling., Ship stabilization with gyroscopic effect <b>Two wheeler and four wheeler on curved path</b> - effect of gyroscopic and centrifugal couples, maximum permissible speeds on curve paths, Gyroscopic effect due to lateral misalignment of rigid disc mounted on shaft	08
05	<b>5.1 Gear Trains:</b> Kinematics and dynamic analysis of - simple gear trains, compound gear trains, reverted gear trains, epi-cyclic gear trains with spur or bevel gear combination. <b>5.2 Transmissions:</b> Necessity of gear box, Sliding mesh, Constant mesh, Synchromesh and epicyclic gear box,	08



<b>06</b>	<p><b>6.1 Static and Dynamic force analysis</b> in slider crank mechanism (neglecting mass of connecting rod and crank), Engine force analysis, Turning moment on crank shaft.</p> <p><b>6.2 Dynamically equivalent systems</b> to convert rigid body to two mass with and without correction couple.</p> <p><b>6.3 Flywheel and its applications</b>, Fluctuation in energy, function of flywheel, estimating inertia of flywheel for reciprocating prime movers and machines.</p>	<b>08</b>
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## List of Experiments

1. Study of Clutches
2. Study of Brakes
3. Experiments on Dynamometers - Rope Brake Dynamometer, Torsion Dynamometer
4. Experiments on Governors - Proell Governor, Hartnell Governor,
5. Experiments on Gyroscope
6. Study of power transmission system in automobile
7. Study of Cams & Followers.
8. Plotting of displacement-time, velocity-time, acceleration-time & jerk-time for uniform velocity, UARM, SHM & Cycloidal motion.
9. At least two numerical simulations using C++/MATLAB based on systems discussed in syllabus

## Term Work

Term work shall consist of minimum **eight** experiments, assignments consisting numerical based on above syllabus, at least 3 numerical from 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.

## 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. Theory of Machines - Thomas Bevan - C. B. S. Publishers
2. Theory of Machines - S. S. Ratan - Tata McGraw Hill
3. Theory of Machines - P. L. Ballaney, Khanna Publishers, Delhi
4. Dynamics of Machines – Norton, *McGraw Hill Publication*
5. Theory of Mechanisms and Machines - A. Ghosh and A. Malik - *Affiliated East – West Press Pvt. Ltd., New Delhi*
6. Theory of Machines - W. G. Green – *Bluckie & Sons Ltd.*
7. Mechanics & Dynamics of Machinery - J. Srinivas, *Scitech*
8. Kinematics, Dynamics and Design of Machinery, 2<sup>nd</sup> ed., Kenneth Waldron, Gary Kinzel, *Wiley India Edition*
9. Essential MATLAB for Engineers and Scientist - Brian D. Hanhn, Daniel Valentine,



Course Code	Course/Subject Name	Credits
<b>MEC505</b>	<b>Heat Transfer<sup>&amp;</sup></b>	<b>4+1</b>

**& Common with Automobile Engineering**

### Objectives

1. Study and analysis of basic heat transfer concepts applicable for steady state and transient conditions
2. Study mathematical modeling and designing concepts of heat exchangers

**Outcomes:** Learner should be able to...

1. Identify & explain the three modes of heat transfer (conduction, convection and radiation).
2. Develop mathematical model for each mode of heat transfer
3. Demonstrate and explain mechanism of boiling and condensation
4. Design and analyze different heat exchangers

Module	Detailed Contents	Hrs.
01	<b>Introduction</b> Typical heat transfer situations, Modes of heat transfer, heat transfer parameters, various thermo physical properties	02
02	<b>Conduction</b> Fourier's law of heat conduction, thermal conductivity, differential equation of heat conduction with heat generation in unsteady state in the Cartesian coordinate system, Boundary and initial conditions, Solution to three dimensional steady heat conduction problems, Steady heat conduction in plane walls, composite walls, Concept of thermal resistance and thermal resistance network, Heat conduction in cylinders and spheres, Differential equation of heat conduction in cylindrical coordinates, Conduction through Cylindrical and Spherical composite walls (Derivation NOT INCLUDED for Spherical walls), Critical thickness/radius of insulation and its importance.	10
03	<b>Extended Surfaces</b> Heat transfer from finned surfaces, Types of fins, Fin equation for rectangular fin and its solution, Fin efficiency, Fin effectiveness <b>Transient Heat Conduction</b> Lumped system analysis, One dimensional transient problems analytical solutions, One dimensional Heisler charts <b>Numerical Methods in Conduction</b> Importance of numerical methods, Finite difference formulation of one dimensional steady heat conduction equations	08
04	<b>Convection</b> Physical mechanism of convection, Natural and Forced convection, Velocity/hydrodynamic and Thermal boundary layer, Velocity and temperature profile, Differential equation of heat convection, Laminar flow heat transfer in circular pipe, constant heat flux and constant wall temperature, thermal entrance region, Turbulent flow heat transfer in circular pipes, Pipes of other cross sections, Heat transfer in laminar and turbulent flow over a flat plate, Heat pipe introduction and applications, Principles of dimensional analysis and its application in convective heat transfer, Empirical correlations for convection, Physical significance of various dimensionless numbers useful in natural and forced convection	10

<b>05</b>	<p><b>Radiation</b> Thermal radiation, Blackbody radiation, Radiation intensity, Radiative properties, Basic laws of radiation (Plank's law, Kirchoff's law, Stefan-Boltzman law, Wien's displacement law, Lambert's cosine law, Radiation exchange between black surfaces, Shape factor, Radiation exchange between gray surfaces, Radiosity-Irradiation method, Radiation shield and the radiation effect</p>	08
<b>06</b>	<p><b>Boiling and Condensation</b> Boiling heat transfer, Pool boiling, Flow boiling, Condensation heat transfer, Film condensation, Drop wise condensation</p> <p><b>Heat Exchangers</b> Types of heat exchangers, Overall heat transfer coefficient, Analysis of heat exchangers, LMTD method, Effectiveness-NTU method, Correction factor and effectiveness of heat exchangers</p>	10

### List of Experiments

1. Thermal conductivity of metal bar /composite wall / liquid /Insulating Material
2. Determination of contact resistance
3. Effect of area on Heat transfer
4. Radial heat conduction
5. Determination of fin efficiency and fin effectiveness
6. Unsteady state heat transfer
7. Heat pipe
8. Natural and Forced convection for flow over flat plate /through a circular pipe
9. Comparison of Overall heat transfer coefficient and effectiveness for double pipe/plate type /shell & tube heat exchanger
10. Determination of emissivity of a grey surface

### Term Work

Term work shall consist of minimum 7 experiments from the list, 3 assignments containing numerical based on modes of heat transfer and One Assignment based on live problem relevant to heat exchanger analysis

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

- Laboratory work (Experiments) : **10 marks**
- Numerical Assignments : **05 marks**
- Live problem assignment: **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.

## 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. Introduction to Thermodynamics and Heat Transfer, 2<sup>nd</sup> ed., Yunus A Cengel, McGraw Hill International.
2. Fundamentals of Heat and Mass Transfer, F. P. Incropera and D. P. DeWitt, Wiley India
3. Heat and Mass Transfer, 2<sup>nd</sup> ed., R Rudramoorthy and L Mayilsamy, PEARSON
4. Fundamentals of Engineering Heat and Mass Transfer, 4<sup>th</sup> ed., R C Sachdeva, New Age International
5. Heat Transfer, 2<sup>nd</sup> ed., A F Mills and V Ganesan, PEARSON
6. Heat Transfer, 9<sup>th</sup> ed., J P Holman, McGraw Hill
7. Engineering Heat and Mass Transfer, Mahesh M Rathore, Laxmi Publication
8. Principles of Heat Transfer, 6<sup>th</sup> ed., Frank Kreith, CENGAGE Learning
9. Heat and Mass transfer, 6<sup>th</sup> ed., D S Kumar, S K Kataria and Sons
10. Heat Transfer, S P Sukhatme, University Press
11. Heat and Mass Transfer, 2<sup>nd</sup> ed., P K Nag, Tata McGraw Hill
12. Fundamentals of Heat and Mass Transfer, Thirumaleshwar, Pearson Education
13. Engineering Heat Transfer, N V Suryanarayana, Penram Publication
14. Heat and Mass transfer, C P Arora, Dhanpatrai and Co.
15. Heat Transfer, Y V C Rao, University Press
16. Heat and Mass Transfer, R K Rajput, S.Chand and Company
17. Elements of Heat Transfer, Jakole and Hawkins
18. Heat Transfer, James Sueee, JAICO Publishing House
19. Heat Transfer, Donald Pitts & L E Sisson, Schaums Series, Mc Graw Hill International
20. Engineering Heat Transfer, Shao Ti Hsu
21. Heat Transfer, M Necati Ozisik, McGraw Hill International edition
22. Heat Transfer, Ghosdastidar, Oxford University Press

Course Code	Course/Subject Name	Credits
<b>MEL501</b>	<b>Business Communication &amp; Ethics<sup>&amp;</sup></b>	<b>2</b>

**& Common with All Engineering Programs**

**Pre-requisite**

- FEC206 Communication Skills

**Objectives**

1. To inculcate in students professional and ethical attitude, effective communication skills, teamwork, skills, multidisciplinary approach and an ability to understand engineer's social responsibilities.
2. To provide students with an academic environment where they will be aware of the excellence, leadership and lifelong learning needed for a successful professional career.
3. To inculcate professional ethics and codes of professional practice
4. To prepare students for successful careers that meets the global Industrial and Corporate requirement' provide an environment for students to work on Multidisciplinary projects as part of different teams to enhance their team building capabilities like leadership, motivation, teamwork etc.

**Outcomes:** A learner will be able to .....

1. communicate effectively in both verbal and written form and demonstrate knowledge of professional and ethical responsibilities
2. Participate and succeed in Campus placements and competitive examinations like GATE, CET.
3. Possess entrepreneurial approach and ability for life-long learning.
4. Have education necessary for understanding the impact of engineering solutions on Society and demonstrate awareness of contemporary issues.

Module	Unit No.	Topics	Hrs
<b>1.0</b>	<b>1.0</b>	<b>Report Writing</b>	<b>07</b>
	1.1	Objectives of report writing	
	1.2	Language and Style in a report	
	1.3	Types of reports	
	1.4	Formats of reports: Memo, letter, project and survey based	
<b>2.0</b>	<b>2.0</b>	<b>Technical Proposals</b>	<b>02</b>
	2.1	Objective of technical proposals	
	2.2	Parts of proposal	
<b>3.0</b>	<b>3.0</b>	<b>Introduction to Interpersonal Skills</b>	<b>07</b>
	3.1	Emotional Intelligence	
	3.2	Leadership	
	3.3	Team Buliding	
	3.4	Assertiveness	
	3.5	Conflict Resolution	
	3.6	Negotiation Skills	
	3.7	Motivation	
	3.8	Time Management	
<b>4.0</b>	<b>4.0</b>	<b>Meetings and Documentation</b>	<b>02</b>
	4.1	Strategies for conducting effective meetings	
	4.2	Notice	
	4.3	Agenda	
	4.4	Minutes of the meeting	

<b>5.0</b>	<b>5.0</b>	<b>Introduction to Corporate Ethics and etiquettes</b>	<b>02</b>
	5.1	Business Meeting etiquettes, Interview etiquettes, Professional and work etiquettes, Social skills	
	5.2	Greetings and Art of Conversation	
	5.3	Dressing and Grooming	
	5.4	Dinning etiquette	
	5.5	Ethical codes of conduct in business and corporate activities (Personal ethics, conflicting values, choosing a moral response, the process of making ethical decisions)	
<b>6.0</b>	<b>6.0</b>	<b>Employment Skills</b>	<b>06</b>
	6.1	Cover letter	
	6.2	Resume	
	6.3	Group Discussion	
	6.4	Presentation Skills	
	6.5	Interview Skills	
		<b>Total</b>	

### List of Assignments

1. Report Writing (Synopsis or the first draft of the Report)
2. Technical Proposal (Group activity, document of the proposal)
3. Interpersonal Skills (Group activity and Role play)
4. Interpersonal Skills ( Documentation in the form of soft copy or hard copy)
5. Meetings and Documentation ( Notice, Agenda, Minutes of Mock Meetings)
6. Corporate ethics and etiquettes (Case study, Role play)
7. Cover Letter and Resume
8. Printout of the PowerPoint presentation

### Term Work

Term work shall consist of all assignments from the list.

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

- Assignments : **20 marks**
- Project Report Presentation: **15 marks**
- Group Discussion: **10 marks**
- Attendance : **05 marks**

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

### References

1. Fred Luthans, "*Organizational Behavior*", Mc Graw Hill, edition
2. Lesiker and Petit, "*Report Writing for Business*", Mc Graw Hill, edition
3. Huckin and Olsen, "*Technical Writing and Professional Communication*", McGraw Hill
4. Wallace and Masters, "*Personal Development for Life and Work*", Thomson Learning, 12<sup>th</sup> edition
5. Heta Murphy, "*Effective Business Communication*", Mc Graw Hill, edition
6. R.C Sharma and Krishna Mohan, "*Business Correspondence and Report Writing*",
7. B N Ghosh, "*Managing Soft Skills for Personality Development*", Tata McGraw Hill. Lehman,
8. Dufrene, Sinha, "*BCOM*", Cengage Learning, 2<sup>nd</sup> edition
9. Bell . Smith, "*Management Communication*" Wiley India Edition, 3<sup>rd</sup> edition.
10. Dr. K. Alex ,"*Soft Skills*", S Chand and Company
11. Dr.KAlex,"*SoftSkills*",S Chand and Company
12. R.Subramaniam, "*Professional Ethics*" Oxford University Press 2013.

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

### 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.
<b>01</b>	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.	<b>04</b>
<b>02</b>	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.	<b>09</b>
<b>03</b>	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.	<b>09</b>
<b>04</b>	<b>Quality Control</b> 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.	<b>05</b>
<b>05</b>	<b>SQC and SQC tools</b> 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.	<b>06</b>
<b>06</b>	<b>Sampling Techniques</b> Sampling inspection and basic concepts, OC curves, consumer & producer risk, single & double sampling plans and use of sampling tables.	<b>03</b>

## 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
<b>MEC602</b>	<b>Machine Design-I<sup>&amp;</sup></b>	<b>4+1</b>

**& 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.
<b>01</b>	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.	<b>06</b>
<b>02</b>	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.	<b>06</b>
<b>03</b>	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	<b>12</b>
<b>04</b>	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	<b>06</b>
<b>05</b>	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	<b>11</b>
<b>06</b>	Design of Springs: Helical compression, tension springs under static and variable loads, Leaf springs.	<b>07</b>

## 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
<b>MEC603</b>	<b>Mechanical Vibration &amp;</b>	<b>4+1</b>

& 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><b>1.1 Basic Concepts of Vibration</b> 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><b>1.2 Free Undamped Single Degree of Freedom Vibration System</b> Longitudinal, transverse, torsional vibration system, Methods for formulation of differential equations by Newton, Energy, Lagrangian and Rayleigh's Method,.</p>	08
02	<p><b>2.1 Free Damped Single Degree of Freedom Vibration System</b> Viscous damped system – under damped, critically damped, over damped; Logarithmic decrement; Coulomb's damping; Combined viscous and coulomb's damping.</p> <p><b>2.2 Equivalent Single Degree of Freedom Vibration System</b> 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><b>3.1 Free Undamped Multi Degree of Freedom Vibration System</b> 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><b>4.1 Forced Single Degree of Freedom Vibratory System</b> Analysis of linear and torsional systems subjected to harmonic force excitation and harmonic motion excitation (excluding elastic damper)</p> <p><b>4.2 Vibration Isolation and Transmissibility</b> Force Transmissibility, Motion Transmissibility Typical isolators &amp; Mounts</p> <p><b>4.3 Rotor Dynamics:</b> Critical speed of single rotor, undamped and damped.</p>	09
05	<p><b>5.1 Vibration Measuring Instruments:</b> Principle of seismic instruments, vibrometer, accelerometer - undamped, damped</p> <p><b>5.2 Introduction to Conditioning Monitoring and Fault Diagnosis.:</b> At least two case studies in detail based on Conditioning Monitoring and Fault Diagnosis.</p>	06

<b>06</b>	<b>6.1 Balancing</b> Static and dynamic balancing of multi rotor system, Balancing of reciprocating masses In - line engines, V - engines (excluding radial engines)	<b>08</b>
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### 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. Srinivasan - *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
<b>MEC604</b>	<b>Thermal and Fluid Power Engineering<sup>&amp;</sup></b>	<b>4+1</b>

<sup>&</sup> 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	<b>Steam Generators</b> 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	<b>Steam Nozzle and Turbines</b> Flow through steam nozzle-velocity at exit and condition for maximum discharge, nozzle efficiency <b>Steam Turbine-</b> 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	<b>Impact of Jets and Water Turbines</b> 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. <b>Pelton Turbine:</b> 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. <b>Reaction Turbines:</b> 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

<b>05</b>	<b>Gas Turbines</b> 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
<b>06</b>	<b>Jet Propulsion Engines</b> 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, 3<sup>rd</sup> 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
<b>MEC605</b>	<b>Mechatronics</b>	<b>4+1</b>

### 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	<b>1.1 Introduction to Mechatronics.</b> 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	<b>Actuators.</b> <b>2.1 Electrical Actuating systems</b> 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. <b>2.2 Voice coil actuator.</b>	08
03	<b>Actuators.</b> <b>3.1 Pneumatic and Hydraulic actuating systems</b> Components of pneumatic and hydraulic systems, pumps, compressor, filter, control valves, pressure regulation, relief valves, accumulator. <b>3.2 Harmonic drive, Comb drive.</b> <b>3.3 Piezoelectric drives.</b> <b>3.4 Selection of actuator</b>	08
04	<b>Development of circuits for industrial automation.</b> 4.1 Electro-pneumatic systems, Electro-hydraulic system, hydro-pneumatic system, Development of circuits for Industrial automation. <b>4.2 Programmable Logic Controller (PLC) in automation:</b> Basic structure, I/O processing. Ladder logic diagram, PLC for industrial process control, Selection of PLC.	08
05	<b>5.1 System Interfacing and Data Acquisition:</b> 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	<b>6.1 Mechatronics case studies:</b> 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 Histand *Tata 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
<b>MEC606</b>	<b>Finite Element Analysis<sup>&amp;</sup></b>	<b>3+1</b>

**& 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 2<sup>nd</sup> 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.
<b>01</b>	<p><b>Introduction</b></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
<b>02</b>	<p><b>FEA Procedure</b></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
<b>03</b>	<p><b>One-Dimensional Problems</b></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
<b>04</b>	<p><b>Two Dimensional Finite Element Formulations</b></p> <p>4.1 Introduction, Three noded triangular element, four noded rectangular element, four noded quadrilateral element, eight noded quadrilateral element.</p> <p>4.2 Natural coordinates and coordinates transformations: serendipity and Lagranges methods for deriving shape functions for triangular and quadrilateral element</p> <p>4.3 Sub parametric, Isoperimetric, super parametric elements. Compatibility, Patch Test, Convergence criterion, Sources of errors.</p>	06

<b>05</b>	<p><b>Two Dimensional Vector Variable Problems</b></p> <p>5.1 Equations of elasticity – Plane stress, plane strain and axisymmetric problems.</p> <p>5.2 Jacobian matrix, stress analysis of CST and four node Quadratic element</p> <p>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).</p>	06
<b>06</b>	<p><b>Finite Element Formulation of Dynamics and Numerical Techniques</b></p> <p>6.1 Applications to free vibration problems of rod and beam. Lumped and consistent mass matrices.</p> <p>6.2 Solutions Techniques to Dynamic problems, longitudinal vibration frequencies and mode shapes. Fourth Order Beam Equation, Transverse deflections and Natural frequencies of beams.</p> <p>6.3 Finding frequencies of beam using FE Software (Can be covered during practical hours).</p>	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.