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UNIVERSITY OF MUMBAI

Revised syllabus (Rev- 2016) from Academic Year 2016 -17
Under

FACULTY OF TECHNOLOGY

Mechanical Engineering

Second Year with Effect from AY 2017-18
Third Year with Effect from AY 2018-19
Final Year with Effect from AY 2019-20

As per **Choice Based Credit and Grading System**
with effect from the AY 2016–17

Co-ordinator, Faculty of Technology's 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). It is also resolved that course objectives and course outcomes are 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.

Choice 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 assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 12-13 weeks and remaining 2-3 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

Choice based Credit and grading system is implemented from the academic year 2016-17 through optional courses at department and institute level. This will be effective for SE, TE and BE from academic year 2017-18, 2018-19 and 2019-20 respectively.

Dr. S. K. Ukarande
Co-ordinator,
Faculty of Technology,
Member - Academic Council
University of Mumbai, Mumbai

Chairman's Preamble:

Engineering education in India is expanding and is set to increase manifold. Themajor 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 the University of Mumbai, I am happy to state here that, the Program Educational Objectives for Undergraduate Program were finalized in a brain storming session, which was attended by more than 40 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 motivate the Learner in the art of self-learning and to use modern tools for solving real life problems
3. To inculcate a professional and ethical attitude, good leadership qualities and commitment to social responsibilities in the Learner's thought process
4. To prepare the Learner for a successful career in Indian and Multinational Organisations

In addition to Program Educational Objectives, for each course of the program, objectives and expected outcomes from a learner's point of view 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 stakeholders.

Dr. S. M. Khot

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

Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract	Theory	Pract	Total
MEC601	Metrology and Quality engineering	04	--	04	--	04
MEC602	Machine Design I	04	--	04	--	04
MEC603	Finite Element analysis	04	--	04	--	04
MEC604	Refrigeration and Air Conditioning	04	--	04	--	04
MEDLO 602X	Department Level Optional Course II	04	--	04	--	04
MEL601	Metrology and Quality Engineering	--	02	--	01	01
MEL602	Machine Design I	--	02	--	01	01
MEL603	Finite Element Analysis	--	02	--	01	01
MEL604	Refrigeration and Air Conditioning	--	02	--	01	01
MEL605	Mechatronics Lab	--	02	--	01	01
Total		**20**	**10**	**20**	**05**	**25**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem Exam	Exam Duration (Hrs)			
		Test1	Test 2	Avg					
MEC601	Metrology and Quality engineering	20	20	20	80	03	--	--	100
MEC602	Machine Design I	20	20	20	80	03	--	--	100
MEC603	Finite Element Analysis	20	20	20	80	03	--	--	100
MEC604	Refrigeration and Air Conditioning	20	20	20	80	03	--	--	100
MEDLO 602X	Department Level Optional Course II	20	20	20	80	03	--	--	100
MEL601	Metrology and Quality engineering	--	--	--	--	--	25	25	50
MEL602	Machine Design I	--	--	--	--	--	25	--	25
MEL603	Finite Element analysis	--	--	--	--	--	25	25	50
MEL604	Refrigeration and Air Conditioning	--	--	--	--	--	25	25	50
MEL605	Mechatronics Lab	--	--	--	--	--	25	25	50
Total				**100**	**400**		**125**	**100**	**725**

Course Code	Department Level Optional Course II
MEDLO6021	Mechatronics
MEDLO6022	Robotics
MEDLO6023	Industrial Automation

Course Code	Course/Subject Name	Credits
MEC 601	**Metrology and Quality Engineering**	**4**

Objectives:

1. To acquaint with measuring equipment used for linear and angular measurements.
2. To familiarize with different classes of measuring instruments and scope of measurement in industry and research
3. To acquaint with operations of precision measurement, instrument/equipment for measurement
4. To inculcate the fundamentals of quality concepts and statistics in metrology

Outcomes: Learner will be able to…

1. Demonstrate inspection methods and different gauges
2. Illustrate working principle of measuring instruments and calibration methodology
3. Illustrate basic concepts and statistical methods in quality control
4. Demonstrate characteristics of screw threads, gear profile, and tool profile
5. Illustrate the different sampling techniques in quality control
6. Illustrate different nondestructive techniques used for quality evaluation

Module	Details	Hours
1	1.1 **Introduction to Metrology:** Fundamental Definitions, Types of Standards, Precision and Accuracy, Measurement Errors, linear measurements by Vernier calliper, micrometer, slip gauges, Angular Measurement: Universal bevel protractor, clinometers, sine bar, angle gaugescase studies on Industrial and Research Applications and Scope 1.2 **Introduction to Nano-Metrology**	06
2	1.3 **Design of Gauges :** Limits, Fits, Tolerances, Types of Gauges, Taylor's Principle of Limit Gauges, IS 919 for design of gauges 1.4 **Comparators :** Definition, Classification, Working principle of Mechanical, Opto-mechanical, Pneumatic and Electrical/Electronic comparators with advantages, limitations and uses 1.5 **Surface Texture measurement:** Surface roughness, Waviness, Roughness Parameter Ra, Rz, RMS etc., working of Tomlinson surface meter, Taly-surf surface roughness tester, Surface roughness symbols 1.6 **Flatness Test measurement by Interference principle:** Concept of Flatness, Interferometer principle for measurement, Optical Flats – study of Surface textures under monochromatic light source, fingertip test technique	14
3	3.1 **Screw Thread Measurement :** Screw threads Terminology, screw thread errors, Effective diameter measurement of screw thread by Floating Carriage micrometer 3.2 **Gear Measurement :** Gear Terminology, Gear errors, Measurement by Parkinson Gear tester and Gear tooth Vernier Calliper 3.3 **Special Measuring Instruments :** Measurement by Tool Maker's Microscope, Optical Profile Projector, CMM and Autocollimator	12

4	4.1 **Quality Engineering** Introduction to Quality, Classification of Quality Tools, Quality of Design, Quality of Conformance, Compromise between Quality and Cost, Introduction to Six Sigma 4.2 **SQC & SQC tools** Statistics in Quality control, Variables and Attributes data, Process Capability, Control charts for variables and for attribute data($\bar{X}$and R-Chart, p-chart np-chart, c-chart, U-chart), Applications of SQC in engineering – case studies	08
5	5.1 **Sampling Techniques** Advantages of Sampling Inspection, operating characteristic (OC) curve. Choosing OC curve for appropriate sampling plan, acceptance sampling 5.2 **Role of computers in metrology**	04
6	6.1 **Non-destructive Testing** Visual, Dye Penetrant, Magnetic Particle, X ray Radiography, Ultrasonic Testing, Eddy Current testing methods.	04

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

References

1. Engineering Metrology,K.J. Hume, Kalyani Publications
2. Mechanical Measurements and Metrology by RKJain, Khanna Publishers
3. A text book of Engineering Metrology by IC Gupta, DhanpatRai Publications
4. Metrology and Measurement by Anand,Bewoor and VinayKulkarni, McGraw Hill
5. Engineering Metrology and Measurement by N V Raghavendra and Krishnamurthy, Oxford University Press
6. Engineering Metrology and Measurements, Bentley, Pearson Education
7. Statistical Quality Control by AL Grant, McGraw Hill, New York
8. Statistical Quality Control by R C Gupta, Khanna Publishers
9. Juran on Planning for Quality,Juran J M,TheFree Press, 1988.
10. Statistical Quality Control by M Mahajan, Dhanpat Rai and Sons

Course Code	Course Name	Credits
MEC602	**MACHINE DESIGN – I***	**4**

Objective:

1. To study basic principles of machine design
2. To acquaint with the concepts of design based on strength & rigidity
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. Illustrate basic principles of machine design
3. Design machine elements for static as well as dynamic loading
4. Design machine elements on the basis of strength/ rigidity concepts
5. Use design data books in designing various components
6. Acquire skill in preparing production drawings pertaining to various designs

Modules	Details	Hrs.
1	Mechanical Engineering Design, Design methods, Aesthetic and Ergonomics consideration in design, Material properties and their uses in design, Manufacturing consideration in design, Design consideration of casting and forging, Basic principle of Machine Design, Modes of failures, Factor of safety, Design stresses, Theories of failures (Selection in the process of designing), Standards, I.S. Codes, Preferred Series and Numbers	**06**
2	**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**
3	**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**
4	**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**
5	**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 Flange couplings, Bush pin type flexible couplings	**11**
6	**Design of Springs:** Helical compression, Tension Springs under Static and Variable loads, Leaf springs	**07**

<u>Assessment</u>:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

References:

1. Design of Machine Elements - V.B. Banadari, Tata McGraw Hill Publication
2. Design of Machine Elements - Sharma, Purohil. Prentice Hall India Publication
3. Machine Design -An Integrated Approach - Robert L. Norton, Pearson Education
4. Machine Design by Pandya & Shah, Charotar Publishing
5. Mechanical Engineering Design by J.E.Shigley, McGraw Hill
6. Recommended Data Books - PSG
7. Machine Design by Reshetov, Mir Publication
8. Machine Design by Black Adams, McGraw Hill
9. Fundamentals of Machine Elements by Hawrock, Jacobson McGraw Hill
10. Machine Design by R.C.Patel, Pandya, Sikh, Vol-I & II C. Jamnadas & Co
11. Design of Machine Elements by V.M.Faires
12. Design of Machine Elements by Spotts

Course Code	Course Name	Credits
MEC603	**Finite Element Analysis**	**4**

Objectives:

1. To familiarise with concepts of FEM
2. To study the applicability of FEM to engineering problems
3. To acquaint with application of numerical techniques for solving problems

Outcomes: Learner will be able to…

1. Solve differential equations using weighted residual methods
2. Develop the finite element equations to model engineering problems governed by second order differential equations
3. Apply the basic finite element formulation techniques to solve engineering problems by using one dimensional elements
4. Apply the basic finite element formulation techniques to solve engineering problems by using two dimensional elements
5. Apply the basic finite element formulation techniques to find natural frequency of single degree of vibration system
6. Use commercial FEA software, to solve problems related to mechanical engineering

Module	Details	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 Modelling of field problems in engineering, Governing equations, Differential equations in different fields 1.3 Approximate solution of differential equations, Weighted residual techniques, Boundary value problems	**08**
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	**08**
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, modelling, meshing, boundary condition, convergence of solution, result analysis, case studies	**10**
04	**Two Dimensional Finite Element Formulations:** 4.1 Introduction, three node triangular element, four node rectangular element, four node quadrilateral element, eight node quadrilateral element 4.2 Natural coordinates and coordinates transformations: serendipity and Lagrange's methods for deriving shape functions for triangular and quadrilateral element 4.3 Sub parametric, Isoparametric, super parametric elements, Compatibility, Patch test, Convergence criterion, sources of errors	**08**

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	**08**
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	**06**

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

References:

1. Text book of Finite Element Analysis by Seshu P, Prentice Hall of India
2. Finite Element Method by JNReddy, TMH
3. 'Introduction to Finite Elements in Engineering, Chandrupatla and Belegundu,Pearson Education
4. Finite Element Methods by R Dhanraj and K Prabhakaran Nair, Oxford University Press
5. A first course in Finite Element Method by Logan D L, Thomson Asia PvtLtd
6. 'Concepts and Applications of Finite Element Analysis by Cook R D, Malkus D S, Plesha ME, John-Wiley Sons
7. The Finite Element Method in Engineering by SSRao, Butter WorthHeinemann
8. Fundamental Finite Element Analysis and Application with Mathematica and MATLAB Computations by M. Asghar Bhatti, Wiley India Pvt. Ltd.

Course Code	Course/Subject Name	Credits
MEC604	**Refrigeration and Air Conditioning**	**4**

Objectives

1. To study working and operating principles of Air Refrigeration, Vapour Compression and Vapour Absorption system
2. To study components of refrigeration and air conditioning systems
3. To study controls and applications of refrigeration and air conditioning

Outcomes: Learner will be able to…

1. Demonstrate fundamental principles of refrigeration and air conditioning
2. Identify and locate various important components of the refrigeration and air conditioning system
3. Illustrate various refrigeration and air conditioning processes using psychometric chart
4. Design Air Conditioning system using cooling load calculations.
5. Estimate air conditioning system parameters
6. Demonstrate understanding of duct design concepts

Module	Detailed Contents	Hrs.
01	**Introduction to Refrigeration:** Methods of refrigeration, First and Second Law applied to refrigerating machines, Carnot refrigerator, Carnot heat pump, unit of refrigeration, Co- efficient of Performance, Energy Efficiency Ratio (EER), and BEE star rating Air refrigeration systems: Bell Coleman cycle, applications Aircraft air refrigeration systems: Need for aircraft refrigeration, Simple, Bootstrap including evaporative cooling, Reduced ambient, Regenerative air cooling system, Comparison of these systems based on DART rating.	08
02	**Vapour Compression Refrigeration System**: Simple vapour compression cycle, Effect of liquid sub cooling& superheating, effect of evaporator and condenser pressures, methods of subcooling, use of P-h charts, Actual VCR cycle, Use of P-h Charts, Comparison between air-cooled and water-cooled condenser based air conditioning systems, Types of condensers, evaporators, expansion devices and Compressors **Cooling tower:** Types of cooling towers, tower approach, tower range, tower efficiency, tower losses, tower maintenance **Refrigerants**: Desirable properties of refrigerants, ASHRAE numbering system for refrigerants. Thermodynamic, Chemical and Physical properties, Secondary refrigerants, ODP and GWP, Montreal protocol and India's commitment, Recent substitutes for refrigerants	12
03	**Other Refrigeration Systems**: Vapour Absorption Refrigeration, Importance of VAR system, COP of ideal VAR system, Ammonia-water VAR system, Lithium Bromide – Water VAR system, Single and double effect, Electrolux refrigeration system, **Non-Conventional Refrigeration Systems:** Thermoelectric Refrigeration, Thermo-acoustic Refrigeration, Vortex Tube Refrigeration	06
04	**Psychrometry:** Need for air conditioning, Principle of psychromerty, Psychrometric properties, chart and processes, air washers, requirements of comfort air conditioning, summer and Winter Air conditioning	05
05	**Design of Air Conditioning Systems**: Different Heat sources,- Adiabatic mixing of two air streams, Bypass factor, sensible heat factor, RSHF, GSHF, ERSHF, Room apparatus dew point and coil apparatus dew point, Ventilation and infiltration, Inside and Outside Design condition, Cooling Load estimation , Introduction to Unitary Products viz. Room/Split and Packaged Air Conditioners, Introduction to recent developments viz. Variable Refrigerant Flow systems, VAV control systems, Inverter Units. Human Comfort, Thermal exchange of body with environment, Effective temperature, Comfort chart, Comfort zone, Indoor Air Quality, Green Buildings	12

	Duct Design Friction chart for circular ducts, Equivalent diameter of a circular duct for rectangular ducts, Static pressure regain and equal pressure drop methods of duct design, Factors considered in air distribution system, Air distribution systems for cooling and heating	
06	**Controls and Applications**: Controls – LP/HP cutoff, Thermostats, Humidistats, Interlocking control, Electronic Controllers Applications Refrigeration & A/C Ice plant – food storage plants – diary and food processing plants, Food preservation ,Freeze Drying, A/c in textile ,printing pharmaceutical industry and Hospitals , Liquefaction of LNG, Liquefaction of gases (cryogenics), Deep sea water air-conditioning	05

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

References

1 Refrigeration and air-conditioning – C P Arora, TMH
2 Principles of refrigeration – R J Dossat, Willey Eastern Publication
3 Refrigeration and air-conditioning – W F Stoeker and J W Jones, TMH
4 Modern Air-conditioning practice – C P Arora, TMH
5 Refrigeration and air-conditioning- Manohar Prasad, New Age Int (P) Ltd
6 Basic Refrigeration and air-conditioning- P.Ananthanarayana, TMH
7 ASHRAE Handbook of Fundamentals
8 ASHRAE Handbook of Systems
9 ASHRAE Handbook of Equipment
10 ISHRAE Air Conditioning Handbook
11 ISHRAE Refrigeration Handbook

Course Code	Course Name	Credits
MEDLO6021	**Mechatronics**	**4**

Objectives

1. To study key elements of Mechatronics system and its integration
2. To familiarise concepts of sensors characterization and its interfacing with microcontrollers
3. To acquaint with concepts of actuators and its interfacing with microcontrollers
4. To study continuous control logics i.e. P, PI, PD and PID
5. To study discrete control logics in PLC systems and its industrial applications

Outcomes: Learner will be able to…

1. Identify the suitable sensor and actuator for a mechatronics system
2. Select suitable logic controls
3. Analyse continuous control logics for standard input conditions
4. Develop ladder logic programming
5. Design hydraulic/pneumatic circuits
6. Design a mechatronic system

Module	Detailed Contents	Hrs.
1	**Introduction of Mechatronics and its block diagram representation** Key elements of mechatronics, Applications of Mechatronics domestic, industrial etc. Representation of mechatronic system in block diagram and concept of transfer function for each element of mechatronic system, Reduction methods and its numerical treatment for represented block diagram	08
2	**Selection of Sensors & Actuators** Sensors: Criteria for selection of sensors based on requirements, principle of measurement, sensing method, performance chart etc. (Displacement, temperature, acceleration, force/pressure) based on static and dynamic characteristics. Actuators: Selection of actuators based on principle of operation, performance characteristics, maximum loading conditions, safety etc. Principle and selection of mechano-electrical actuators (1) DC motors (2) Stepper Motors (3) Solenoid Actuators (4) Servo Motors (5) BLDC	08
3	**Data Acquisition, Signal Conditioning & Microcontroller System Theory:** Concept of Bit accuracy/width and Sampling speed, sampling theorem, aliasing, Nyquist criteria, ADC (Analog to Digital Convertor) Successive approximation method and sample and hold circuitry, DAC (Digital to Analog Convertor) R-2R circuit and DAC resolution Signal Filters: Low pass, High Pass and Band Pass with circuit diagrams for simple cases	08
4	**Pneumatics and hydraulics:** Hydraulic and pneumatic devices: Different types of valves, Actuators and auxiliary elements in Pneumatics and hydraulics, their applications and use of their ISO symbols, Synthesis and design of circuits (up to 2 cylinders)–pneumatic, electro- pneumatics and hydraulics, electro-hydraulics	08
5	**Control System** Control system design and analysis by Root Locus Method, Control system Design by Frequency response method, stability margin, Nyquist diagram, Bode diagram P, I and D control actions, P, PI, PD and PID control systems, Transient response:- Percentage overshoot, Rise time, Delay time, Steady state error, PID tuning (manual), Zigler Method	08
6	**Discrete Control System PLC (Programming Logic Control)Theory:** Introduction to PLC, Architecture, Ladder Logic programming for different types of logic gates, Latching, Timers, Counter, Practical Examples of Ladder Programming	08

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **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 HistandTata McGraw-Hill
5. Mechatronics, Necsulescu, Pearson education
6. Mechatronics - Electromechanics and Control Mechanics , Mill Springer-Verlag
7. Mechatronics - Electronic Control Systems in Mechanical Engineering , Bolton Pearson eduaction
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 JR
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 , KammIEEE
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, StifflerMcGraw-Hill

Course Code	Course/Subject Name	Credits
MEDLO6022	**Robotics**	**04**

Objectives:

1. To study the basics of robotics and its control
2. To study various design principles of robotics through kinematic analysis, workspace analysis, and trajectory planning
3. To study applications of robots in industrial inspection and material handling
4. To study the role of a robot as a humanoid

Outcomes: Learner will be able to…

1. Demonstrate the basic functioning of a robot
2. Identify various components of robots
3. Carryout kinematic analysis, workspace analysis, and trajectory planning for a robot
4. Identify suitable sensors/actuators for robot
5. Select an appropriate robot for given industrial inspection and material handling systems.
6. Illustrate various aspects of a robot as a humanoid

Module	Details	Hrs.
01	**Introduction** Definition of robot, Evolution of robots, Laws of robots, International Robotic Standards, Types of robots, Selection of robots, Robot Classifications, Degrees of freedom, Robot configuration, Accuracy and repeatability, Specification of a robot, Robot feedback controls: Point to point control and Continuous path control, Control system for robot joint, Adaptive control, Actuators and sensors, Drives and transmission systems, End effectors, Applications of robots	08
02	**Kinematics of Robots** **Direct:** Link coordinates D-H Representation, The ARM equation, Direct kinematic analysis for Four axis, SCARA Robot and three, five, and six axis Articulated Robots. **Inverse:** The inverse kinematics problem, General properties of solutions, Tool configuration, Inverse kinematics of four axis SCARA robot and three and five axis Articulated robot. **Mobile Robot Kinematics** Introduction, Kinematic models and constraints, Representing robot position, Forward kinematic models, Wheel kinematic constraints, Robot kinematic constraints, Mobile robot maneuverability, Degree of mobility, Degree of steerability, Mobile robot workspace, Degree of freedom, Holonomic robots, Path and trajectory considerations, Motion control, Open loop control, Feedback control.	10
03	**Workspace Analysis and Trajectory Planning** Workspace Analysis, work envelope of a Four axis SCARA robot and five axis articulated robot workspace fixtures, the pick and place operations, Joint space technique - Continuous path motion, Interpolated motion, Straight line motion and Cartesian space technique in trajectory planning.	10
04	**Sensors & Actuators** Sensors: Selection of sensors (Displacement, temperature, acceleration ,force/pressure) based on static and dynamic charecterstics, Interfacing: Concept of interfacing, bit accuracy and sampling speed, amplifying electronics, and microcontroller Actuators: Principle and selection of mechano-electrical actuators (1) DC motors (2) Stepper Motors (3) Solenoid Actuators (4) Servo Motors (5) BLDC	08

05	**Robots for Inspection and Material Handling** Robotic vision systems, Image representation, Object recognition and categorization, Depth measurement, Image data compression, Visual inspection, Software considerations Concepts of material handling, Principles and considerations in material handling systems design, Conventional material handling systems - Industrial trucks, Monorails, Rail guided vehicles, Conveyor systems, Cranes and Hoists, Advanced material handling systems, Automated guided vehicle systems, Automated storage and retrieval systems, Bar code technology, Radio frequency identification technology	08
06	**Humanoids** Wheeled and legged, Legged locomotion and balance, Arm movement, Gaze and auditory orientation control, Facial expression, Hands and manipulation, Sound and speech generation, Motion capture/Learning from demonstration, Human activity recognition using vision, touch, and sound, Vision, Tactile Sensing, Models of emotion and motivation, Performance, Interaction, Safety and robustness, Applications, Case studies	08

Assessment:

Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**
First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:
Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

References

1. Yoram Korean, “Robotics for engineers”, McGrew Hill Co.
2. M.P. Groover, M. Weiss, R.N. Nagel, and N.G. Odrey, “Industrial Robotics Technology programming and Applications”, McGraw-Hill,
3. Robotics: Fundamental Concepts and Analysis by Ashitava Ghosal, Oxford University Press
4. R.K. Mittal and I.J. Nagrath, “Robotics and Control”, TMH Publications
5. Robert J. Schilling, “Fundamentals of Robotics Analysis and Control”, PHI Learning
6. Bijay K. Ghosh, Ning Xi, T.J. Tarn, Control in Robtics and Automation Sensor – Based integration, Academic Press
7. K.S.Fu, R.C.Gonzalex, and C.S.G.Lee, “Robotics Control Sensing, Vision and Intelligence”, McGrew hill Book co.
8. Hartenberg and Denavit, “Kinematics and Synthesis of linkages”, McGrew Hill Book Co.
9. A.S. Hall, “Kinematics and Linkage Design”, Prentice Hall
10. J.Hirchhorn, “Kinematics and Dynamics of Machinery”, McGrew Hill Book Company

11. P.A. Janaki Raman, “Robotics and Image Processing An Introduction”, Tata McGraw Hill Publishing company Ltd.
12. Richard D Klafter, Thomas A Chmielewski, and Michael Negin, “Robotics Engineering – An Integrated Approach”, Eastern Economy Edition, Prentice Hall of India P Ltd.
13. Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, “Introduction to Autonomous Mobile Robots”, Bradford Company Scituate, USA
14. Alonzo Kelly, Karl Iagnemma, and Andrew Howard, “Field and Service Robotics”, Springer
15. Riadh Siaer, “The future of Humanoid Robots- Research and applications”, Intech Publications

Course Code	Course Name	Credits
MEDLO6023	**Industrial Automation**	**4**

Objectives:

1. To study the need for the automation, its advantages and limitations
2. To study the basic functional elements of automation
3. To familiarise with the levels of automation and strategies of automation
4. To acquaint with control of mechanical operations involving pneumatic, electric, hydraulic and electronic systems

Outcomes: Learner will be able to…

1. Demonstrate basics of industrial automation
2. Identify various types of automation
3. Demonstrate use of automated controls using pneumatic and hydraulic systems.
4. Illustrate the control systems in automated system.
5. Demonstrate applicability of PLC in process industry
6. Design elecrto-pneumatic circuits

Module	Detailed Contents	Hrs.
01	**Introduction to Automation**: Definition and fundamentals of automation, reasons for Automating, basic elements of an automated system: Power, Program and control system **Advanced automation functions:** safety, maintenance & repair diagnosis, error detection and recovery **Levels of automation** **Automation principles and strategies:** USA principle, ten strategies of automation and production system, automation migration strategy	06
02	**Mechanization and Automation:** Mechanization and automation, product cycle, hard Vs flexible automation, Capital- intensive Vs low cost automation Types of systems-mechanical, electrical, hydraulic, pneumatic and hybrid systems Automation using CAMS, Geneva mechanisms, gears etc. Assembly line Automation: automated assembly systems, transfer systems, vibratory bowl feeders, non-vibratory feeders, part orienting, feed track, part placing & part escapement systems Introduction to Material storage/ handling and transport systems, and its automation using AS/RS, AGVS and conveyors etc.	08
03	**Pneumatics and hydraulics:**Hydraulic and pneumatic devices-Different types of valves , Actuators and auxiliary elements in Pneumatics & hydraulics , their applications and use of their ISO symbols Synthesis and design of circuits (up to 3 cylinders)–pneumatic, electro pneumatics and hydraulics Design of Electro-Pneumatic Circuits using single solenoid and double solenoid valves; with and without grouping	14
04	Sensors & Actuators Sensors: Selection of sensors (Displacement, temperature, acceleration, force /pressure) based on static and dynamic characteristics Interfacing: Concept of interfacing, bit accuracy and sampling speed, amplifying electronics, and microcontroller Actuators: Principle and selection of mechano-electrical actuators (1) DC motors (2) Stepper Motors (3) Solenoid Actuators (4) Servo Motors (5) BLDC	06

05	**Industrial control systems:** Process industries versus discrete manufacturing industries, Continuous verses discrete control, Computer process control, Forms of computer process control Discrete control using PLC- discrete process control, Programmable logic controller, its architecture,ladder digs, Ladder Logic Programming for different types of logic gates, Latching, Timers, Counter, Practical Examples of Ladder Programming	10
06	**Robots and their applications:** Introduction to robots, Types, Classifications, Selection of robots, Robot Degrees of freedom, Robot configuration, Accuracy and repeatability, Specification of a robot, Robot feedback controls: Point to point control and Continuous path control, Control system for robot joint, Adaptive control, Drives and transmission systems, End effectors, Industrial robot applications of robots	08

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum**
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 any module other than module 3)
4. Only **Four questions need to be solved**

Reference Books:

1. M.P.Groover “Automation, Production Systems and Computer Integrated Manufacturing”, Pearson Education,New Delhi
2. Joffrey Boothroyd, Peter Dewhurst and Winston A. Knight, “Product Design for manufacture and Assembly”, CRC Press
3. M.P. Groover, M. Weiss, R.N. Nagel, and N.G. Odrey, “Industrial Robotics Technology programming and Applications”, McGraw-Hill,
4. Yoram Korean, “Robotics for engineers”, McGrew Hill Co
5. John W Webb and Reis, Ronald A., "Programmable Logic Controllers: Principles & Applications”, Prentice Hall.
6. Frank Petruzella," Programmable Logic Controllers", McGraw-Hill Education; 4 edition
7. Industrial Hydraulics: Pippenger
8. Mechatronics - Mechanical System Interfacing , Auslander and Kempf, Prentice Hall
9. Pneumatic Circuits and Low Cost Automation: by Fawcett J.R.
10. Fundamentals of pneumatics: Festo series

Course Code	Course/Subject Name	Credits
MEL601	**Metrology and Quality Engineering**	**1**

Objectives:

1. To familiarise with working of gauges
2. To acquaint with gear parameter measurement
3. To acquaint with operations of precision measurement, instrument/equipment for measurement
4. To inculcate the fundamentals of quality concepts and statistics in metrology

Outcomes: Learner will be able to…

1. Measure linear and angular dimensions
2. Measure surface roughness
3. Measure various parameters of gear tooth profile
4. Use optical profile projector for measurement
5. Use various instruments for measurement of screw threads
6. Measure flatness by Autocollimator / Interferometry method

Six Experiments need to be performed on the below mentioned topics:

Sr. No.	**Topic**
1	Vernier Calliper, Micrometer and Bevel Protractor for linear and angular measurement
2	Surface measurement by Surface roughness tester
3	Gear measurement – Gear tooth Vernier calliper / Parkinson gear tester
4	Screw Thread Measurement – screw thread Micrometer, Floating carriage micrometer /bench micrometer
5	Optical profile projector for miniature linear / angular measurements of screw / gear or components
6	Tool maker's microscope for linear / angular measurement of single point tools
7	Comparator – Mechanical / Pneumatic type
8	Flatness measurement by Autocollimator / Interferometry method
9	QC charts for 50 sample readings of OD / ID of specimen and printouts

Term-Work

Consists of minimum six experiments from the above list and presented with Aim, Apparatus/equipment's, and Introduction, Working principle, Diagram, method, observation table, Analysis, Results and conclusion/inferences.

Also, minimum 5 assignments to help smooth conducting of laboratory exercises and one case study relevant to contents

Project Based Learning may be incorporated by judiciously reducing number of assignments

Distribution of marks for term work shall be as follows:

Laboratory work**:**	**15 marks**
Assignments:	**05 marks**
Attendance**:**	**05 marks**

End Semester Practical/Oral examination

1. Pair of Internal and External Examiner should conduct practical/viva based on contents
2. Distribution of marks for practical/viva examination shall be as follows:
   a) Practical performance ……**15** marks
   b) 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

Course Code	Course Name	Credits
MEL602	**Machine Design –I ***	**1**

Objectives:

1. To study the basic design principles
2. To familiarize with use of design data books & various codes of practice
3. To make conversant with preparation of working drawings based on designs

Outcomes: Learner will be able to…

1. Design shaft under various conditions
2. Design Knuckle Joint / cotter joint
3. Design Screw Jack/C-clamp along with frame
4. Design Flexible flange couplings/ Leaf spring
5. Convert design dimensions into working/manufacturing drawing
6. Use design data book/standard codes to standardise the designed dimensions

Term Work: (Comprises a & b)

a) Term work - Shall consist of (minimum 3) design exercises from the list which may include computer aided drawing on **A3 size sheets**.

1) Knuckle Joint / cotter joint
2) Screw Jack
3) Flexible flange couplings
4) Leaf springs
5) C-clamps along with the Frame

b) Assignment: Design exercises in the form of design calculations with sketches and/ or drawings on following machine elements.

1) Bolted and welded joints
2) Combined stresses problem using theory of failure.
3) Shaft design (solid and hollow shaft)
4) Design against fluctuating loads (finite and infinite life)

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

- Part - a : 15 marks.
- Part--b : 05 marks.
- Attendance: 05 Marks.

Course Code	Course Name	Credits
MEL603	**Finite Element Analysis**	**1**

Objectives:

1. To familiarise FEA concept for practical implementation
2. To acquaint with FEA application software

Outcomes: Learner will be able to…

1. Select appropriate element for given problem
2. Select suitable meshing and perform convergence test
3. Select appropriate solver for given problem
4. Interpret the result
5. Apply basic aspects of FEA to solve engineering problems
6. Validate FEA solution

Term Work: (Comprises a and b)

a) List of Experiments: Students should use the commercial software or programmes form 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 given below:

1. Any two problems using bar element
2. Any two problems using truss element
3. Any two problems using CST element
4. Any two problem using axisymmetric element
5. Any one problem of free vibration analysis using bar element
6. Any one problem on steady state heat conduction

While performing the analysis the students should understand the concepts of selection of element type, meshing and convergence of solution.

b) Course Project:

A group of not more than four 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.

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

Part a:	15 marks.
Part b:	05 marks.
Attendance:	05 Marks.

End Semester Practical/Oral examination

1. Pair of Internal and External Examiner should conduct practical/viva based on contents
2. Duration of practical examination is 2 hour
3. Distribution of marks for practical/viva examination shall be as follows:
   a) Practical performance ……**15** marks
   b) 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

Course Code	Course/Subject Name	Credits
MEL604	**Refrigeration and Air Conditioning TW/Practical**	**1**

Objectives

1. To study operating principles of Vapour Compression system
2. To study components of refrigeration and air conditioning systems
3. To study controls and applications of refrigeration and air conditioning

Outcomes: Learner will be able to…

1. Demonstrate fundamental principles of refrigeration and air conditioning
2. Identify and locate various important components of the refrigeration and air conditioning system
3. Represent various refrigeration and air conditioning processes using psychometric chart
4. Operate and maintain refrigeration system
5. Operate and maintain air conditioning system
6. Simulate VCRS

Part A: List of Experiments

Trial on window air conditioner or Air Conditioning Test Rig
Trial on water cooler/Refrigeration Test Rig
Trial on Ice Plant
Trial on cooling tower

Part B: Demonstrations/Reports/Assignments/Simulations

Demonstration of domestic refrigerator along with wiring diagram
Demonstration of leak detection, evacuation and charging of refrigerant
Report on different protocols to regulate global warming
Visit report of Refrigeration establishment like Cold storage plant or ice plant or air-conditioning plant
Assignment on humidification and dehumidification, heating and cooling, mixing of two air streams
Steady state Simulation of VCR system with developed code or any analytical software

Term work

Term work shall consists of minimum Three Laboratory Experiments, at least one demonstration exercise, Industrial Visit Report, at least one assignment consisting of numerical based on Refrigeration and Air Conditioning and one simulation exercise on VCR

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

Part a:	15 marks.
Part b:	05 marks.
Attendance:	05 Marks.

End Semester Practical/Oral examination:

1. Pair of Internal and External Examiner should conduct practical/viva based on contents
2. Practical examination (in a group of not more than 5 students) duration is 2 hours
3. Distribution of marks for practical/viva examination shall be as follows:
    a. Practical performance ……**15** marks
    b. 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

Subject Code	Subject Name	Credits
MEL 605	**Mechatronics Lab**	**01**

Objectives

1. To study sensors and actuators
2. To study control systems
3. To study automation

Outcomes: Learner will be able to…

1. Demonstrate implementation of interfacing sensors and actuators using microcontrollers
2. Demonstrate of interfacing various utilities with microcontrollers
3. Demonstrate discrete control system using PLC microcontroller
4. Design and develop a control system for specific use
5. Implement program to PLC system and demonstrate its application
6. Develop pneumatic circuits for a specific system

The laboratory experiments should be based on the following

Group 1: Sensors & Actuators

1. Theoretical & Experimental Implementation of Interfacing of Sensors using microcontroller and determination of sensor characteristics such as Static Characteristics (Sensitivity, Accuracy, Range, Resolution etc.), Dynamic Characteristics (Transient Response and Frequency Response)
2. Measurement and Calibration of Load / Force (*It is suggested to determine all characteristics of sensor mentioned in previous experiments)*
3. Measurement, Calibration and Comparison of Temperature Sensors (Thermocouple, RTD and Thermistor) *(It is suggested to determine all characteristics of sensor mentioned in previous experiments)*
4. Interfacing of Stepper Motor with microcontroller and its programming for Rotational or XY table *(It is suggested to program to vary the position of rotary or XY table and compare the positioning accuracy using standard calibrated angular or linear sensor)*
5. Interfacing of DC Motor with microcontroller and its programming for characterization of DC motor setup *(It is suggested to program to vary the speed of DC motor and determine its load-speed characteristics)*
6. Interfacing of Water Heater with microcontroller and its programming for determination of its transient and steady state characteristics *(It is suggested to program to vary the input current to heater and determine its transient and steady state characteristics)*

Group 2: Control Systems

1. Experimental demonstration of Discrete control system using PLC microcontroller using standard PLC demo setup (Bottle filling Machine, Traffic Light Signal, Water heater and its stirring System etc.). *(here it is suggested to carry out ladder programing and demonstrate its operation)*
2. System Identification of Spring Mass Damper System for step input & harmonic input and determination of poles and zeros of system. *(Spring Mass Damper setup with all required position sensors mounted is to be characterized for step input, it is suggested to determine transfer function (i.e. input output relation) of the setup and plotting its transient and frequency response (Bode plot))*
3. Design & Experimental Implementation of PID control strategy for Spring Mass Damper Setup to control precisely position of mass. (*it is suggested to conduct experimental study on effect of variation of controller parameters on its transient characteristics also to study the changes in poles and zeros of system*).
4. Design & Experimental Implementation of PID control strategy for DC motor speed control under varying loading conditions and effect of variation of load is to be studied.
5. Design & Experimental implementation of PID control strategy for Real Time Temperature Control of furnace *(it is suggested to conduct experimental study on effect of variation of controller parameters on its transient characteristics also to study the changes in poles and zeros of system)*.
6. Modeling and design of control system for quarter car suspension model using any suitable modeling and analysis software.

Group 3: Automation

1. Real time Logic implementation for traffic Control demo setup and it is necessary to carry out ladder programming and implement program to PLC system and demonstrate its operations
2. IOT: Real time interfacing of sensors (temperature, humidity, position, level etc.) and actuator (stepper motor, dc motor, servo motor etc.) with microcontroller and Ethernet shield and controlling the actuator and monitoring of sensor output remotely using internet.
3. Robotics: Real Time demonstration of line following robot using standard robotic kit
4. Demonstration and study of functions of components of robotics arm.
5. Visualization of DH parameters in Roboanalyzer.(*Roboanalyzer is free software developed by IIT Delhi, available on www.roboanalyzer.com)
6. Designing sequential operation for two cylinders using electro-hydraulic circuits
7. Designing sequential operation for two cylinders using electro- pneumatic circuits
8. Development of pneumatic circuits to understand pneumatic components and their working

Term work

Term work shall consists of minimum Nine Experiments, Three from each group mentioned above

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

Laboratory Work:	20 marks.
Attendance:	05 Marks.

End Semester Practical/Oral examination:

1. Pair of Internal and External Examiner should conduct practical/oral based on contents
2. Practical examination (in a group of not more than 4 students) duration is 2 hours
3. Distribution of marks for practical/Oral examination shall be as follows:
    a. Practical performance ……**15** marks
    b. 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