AC- 29/06/2021

Item No.: 6.9

UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Mechatronics Engineering

Third Year with Effect from AY 2021-22

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	**Third Year B.E. in Mechatronics Engineering**
2	Eligibility for Admission	**After Passing Second Year Engineering as per the Ordinance 0.6243**
3	Passing Marks	**40%**
4	Ordinances / Regulations (if any)	**Ordinance 0.6243**
5	No. of Years / Semesters	**8 semesters**
6	Level	~~P.G.~~ **/ U.G./** ~~Diploma / Certificate~~ (Strike out which is not applicable)
7	Pattern	~~Yearly~~ **/ Semester** (Strike out which is not applicable)
8	Status	~~New~~ **/ Revised** (Strike out which is not applicable)
9	To be implemented from Academic Year	**2021-2022**

Date

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

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 Science and Technology (in particular Engineering)of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty 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. 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. 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.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 171, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Second Year of Engineering from the academic year 2020-21. Subsequently this will be carried forward for Third Year and Final Year Engineering in the academic years 2021-22, 2022-23, respectively.

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Incorporation and implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of ‘C ‘ scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme ‘A' and ‘B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD’s/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Preface

Engineering education in India has to prepare budding minds for applying multidisciplinary knowledge for product and process innovation. Mechatronics is a new branch of engineering introduced in University of Mumbai from 2015, which synergistically applies the fundamentals of Mechanical, Electrical, Electronics and Information systems engineering to develop new products and processes. Thus Mechatronics focuses on development of products and processes that require combined application of multiple engineering domains.

Several changes in technological trends have happened since the introduction of last syllabus of Mechatronics in 2015. New avenues for synergistic application of fundamentals from multiple disciplines are opening up every day with technologies such as 3D Printing, Drones, IOT, Machine learning etc. are becoming popular. The curriculum is designed for preparing the students for a career in four major focus areas (a) Industrial Automation, (b) Embedded Systems (c) Digital Design and Manufacturing (d) Intelligent Control and Machine learning. There are upcoming career opportunities in all these domains. A conscious effort is made to include several technologies that are being promoted under the Industry 4.0 revolution.

The Updated Program Educational Objectives for this syllabus revision of the undergraduate program in Mechatronics Engineering are listed below;
1. To prepare the Learner in building technology systems through interdisciplinary approach.
2. To prepare the Learner to use modern tools embedding different disciplines of engineering in order to solve real life problems and prepare them for the fourth industrial revolution.
3. To prepare the Learner for career in Indian and Multinational Organisations and to excel in their Postgraduate studies; furthermore, to encourage and motivate the art of self-learning.
4. To inculcate a professional and ethical attitude, good leadership qualities in the Learner's thought process.

We trust this revised version of syllabus come up to the expectations of all stakeholders. We wish to place on record our sincere thanks and appreciations to the various contributors from the academia and industry for their most learned inputs in framing this syllabus.

Board of Studies in Mechanical Engineering

Dr. Vivek K. Sunnapwar : Chairman
Dr. S. M. Khot : Member
Dr. V. M. Phalle : Member
Dr. Siddappa Bhusnoor : Member
Dr. S.S. Pawar : Member
Dr. Sanjay U. Bokade : Member
Dr. Dhanraj Tambuskar : Member

Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
MTC601	Digital Manufacturing	3	--	--	3	--	--	3
MTC602	Power Electronics and Drives	3	--	--	3	--	--	3
MTC603	Instrumentation and Control	3	--	--	3	--	--	3
MTC604	Applied Hydraulics and Pneumatics	3	--	--	3	--	--	3
MTDO601	Department Optional Course – 2	3	--	--	3	--	--	3
MTL601	Python Programming Laboratory	--	2	--	--	1	--	1
MTL602	Instrumentation and Electric Drives Laboratory	--	2	--	--	1	--	1
MTL603	Applied Hydraulics and Pneumatics Laboratory	--	2	--	--	1	--	1
MTL604	CNC and 3-D Printing Laboratory	--	4	--	--	2	--	2
MTPBL605	Mini Project – 2 B	--	4[$]	--	--	2	--	2
					15	**07**		**22**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract /Oral	Total
		Internal Assessment			End Sem. Exam	Exam. Duration (in Hrs)			
		Test1	Test2	Avg.					
MTC601	Digital Manufacturing	20	20	20	80	3	--	--	100
MTC602	Power Electronics and Drives	20	20	20	80	3	--	--	100
MTC603	Instrumentation and Control	20	20	20	80	3	--	--	100
MTC604	Applied Hydraulics and Pneumatics	20	20	20	80	3	--	--	100
MTDO601	Department Optional Course – 2	20	20	20	80	3	--	--	100
MTL601	Python Programming Laboratory	--	--	--	--	--	25	25	50
MTL602	Instrumentation and Electric Drives Laboratory	--	--	--	--	--	25	25	50
MTL603	Applied Hydraulics and Pneumatics Laboratory	--	--	--	--	--	25	25	50
MTL604	CNC and 3-D Printing Laboratory	--	--	--	--	--	50	--	50

MTPBL601	Mini Project – 2 B	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	--	**150**	**100**	**750**

$ indicates work load of Learner (Not Faculty), for Mini Project

Students group and load of faculty per week.

Mini Project 2A and 2B :

Students can form groups with minimum 2 (Two) and not more than 4 (Four)

Faculty Load :1 hour per week per four groups

Department Optional Course – 2

1) Microfabrication Processes
2) Machine Interface Design
3) Fundamentals of Multi Body Dynamics

Course Code	Course Name	Credits
MTC601	**Digital Manufacturing**	**03**

Prerequisites: MTSBL301 CAD – Modeling Laboratory, MTL405 Machine Shop Practice, MTC502 Sensors and Actuators

Objectives

1. Introduce digitization / computerization in Manufacturing
2. Develop competency in additive and subtractive manufacturing processes
3. Introduce Industry 4.0 and related technologies.

Outcomes: Learner will be able to...

1. Analyze impact of digitalization on manufacturing
2. Demonstrate understanding of NC and CNC technology for subtractive manufacturing
3. Implement manual part programming for CNC Machines
4. Understand and apply computer aided part programming
5. Analyze and compare various technologies used in additive manufacturing
6. Explain industrial revolutions and technologies important for Industry 4.0

Module	Details	Hrs.
01	**Introduction to Digital Manufacturing** Types of manufacturing processes : Subtractive, Additive , Formative and Hybrid. Digital Manufacturing Concepts: Digitalization and the Networked Economy, Model Based Definition, Product Life Cycle, Concept of Digital Thread, Digital Twin.	4
02	**CNC Technology** **Numerical Control of Machines** Introduction-NC Machine, CNC Machines, DNC, Classification Advantages and Disadvantages of CNC Machines, Applications of CNC, **Tooling for CNC machines** Introduction, Cutting tools materials, types of cutting tools, tool selection, ISO specifications, clamping systems in tool holders. Tool probing and presetting, Automatic Pallet Changer (APC) and Automatic Turret Changer (ATC), Study of various probes and special tools. **CNC Control System** CNC motion controller, Linear, circular, parabolic, cubic, helical interpolator, Positioning and contouring control loops, MCU ,Adaptive control – ACO and ACC systems, Maintenance of CNC Machines.	8
03	**CNC Manual Part Programming** – NC Words, Writing Part Program for Turning Machine and Milling Machine **Part Programming using Subroutines, Do Loops and Canned Cycle** – Introduction, Subroutines, Do Loops, Canned Cycles for CNC Turning Machine and Milling Machine. Introduction to Parametric Programming	7
04	**CNC Computer-aided Part Programming** – Introduction, Computer-aided Part Programming Languages, APT, MACROS, Milling Machine Programs. **CAD/CAM Integration:** Tool path Generation from CAD models, Computer Aided Process Planning,	5
05	**Additive Manufacturing** The generic AM process, AM technology components, AM Classification. Working Principle, Application, Advantages & disadvantages: of Stereo lithography Apparatus (SLA), Scanning and Projection type SLA, Digital Light Processing(DLP), Selective Laser Sintering (SLS), Multi Jet Fusion(MJF) , 3D Printing, Fused Deposition Modeling (FDM), and Laminated Object Manufacturing	7

	(LOM) Rapid Prototyping : Benefits and Applications Rapid Tooling / Rapid Manufacturing: Injection Molding, Investment Casting ,Direct Digital Manufacturing.	
06	**Industry 4.0** The Various Industrial Revolutions, Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0, Mass Customization and agile manufacturing. **Digital Twin Concepts** : Need for digital twin, Monitoring and Data Management , Data Analytics , Cyber physical systems in Machine tools. Twin Control Approach , Virtual Machine Tool and Machining Process Model. Case study of Digital Twin in Automotive Manufacturing **Industrial Robots:** Manipulator and Mobile Robots Application in Industry. Robotic workcell simulation. Cobots introduction. **Internet of Things (IoT) enabled manufacturing** Overview of IOT Enabled Manufacturing Systems, Cyber Physical systems	8
Self-study Topic	**CNC Transducers** Positional transducers, optical gratings, encoders, Inductosyns, Magnescales.	**--**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

6. Question paper will comprise of total 06 questions, each carrying 20marks.
7. Total 04 questions need to be solved.
8. Question No: 01 will be compulsory and based on entire syllabus wherein sub- questions of 2 to 5 marks will be asked.
9. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
10. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text/Reference Books:

1. Xun Xu "Integrating Advanced Computer-Aided Design, Manufacturing, and Numerical Control: Principles and Implementations" Hershey New York
2. John Stark "Product Lifecycle Management Volume 1: 21st Century Paradigm for Product Realization" Springer
3. G. E. Thyer “Computer Numerical Control of Machine Tools”, Industrial Press Inc., New York
4. Steve Krar, Arthur Gill, “CNC Technology and Programming”,MC Graw Hill
5. Kundra, Rao and Tewari, “Numerical Control and Computer Aided Manufacturing” Tata McGraw-Hill, New Delhi.
6. Mikell P. Groover, “Automation Production Systems, and CIM, Pearson Education

7. Ian Gibson,David Rosen,Brent Stucker "Additive Manufacturing Technologies 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing" Springer
8. Rapid Prototyping and Manufacturing, P. F. Jacobs, Society of Manufacturing Engineers
9. Advanced Machining and Manufacturing Processes, Kaushik Kumar DivyaZindani, J. Paulo Davim, Springer International Publishing
10. Mikel Armendia, Mani Ghassempouri, Erdem Ozturk, Flavien Peysson "Twin-Control A Digital Twin Approach to Improve Machine Tools Lifecycle" Springer
11. Victor Singh and Karen E. Willcox." Engineering Design with Digital Thread" American Institute of Aeronautics and Astronautics
12. Zude Zhou , Shane (Shengquan) Xie Dejun Chen "Fundamentals of Digital Manufacturing Science" Springer
13. Rapid Manufacturing –An Industrial revolution for the digital age by N.Hopkinson, R.J.M.Hauge, P M, Dickens, Wiley
14. Rapid Manufacturing by Pham D T and Dimov, Springer Verlag
15. Industry 4.0: The Industrial Internet of Things by Alasdair Gilchrist, 2016, Apress.
16. Cyber-Physical Systems: From Theory to Practice by Danda B. Rawat, Joel Rodrigues, Ivan Stojmenovic, 2015, C.R.C. Press.
17. Optimization of Manufacturing Systems using Internet of Things by Yingfeng Zhang, Fei Tao, 2017, Academic Press (AP), Elsevier.

Links for online NPTEL/SWAYAM courses:

https://nptel.ac.in/courses/110/106/110106146/

https://nptel.ac.in/courses/112/105/112105211/

https://nptel.ac.in/noc/courses/noc16/SEM2/noc16-me21/

https://onlinecourses.nptel.ac.in/noc19_me46/preview

https://onlinecourses.nptel.ac.in/noc20_cs69/preview

Course Code	Course Name	Credits
MTC602	**Power Electronics and Drives**	**03**

Prerequisite: MTC305 Applied Electrical and Electronics Engineering, MTC502 Sensors and Actuators

Objectives:

1. To teach power semiconductor switches and power converters.
2. To teach different controlling methods for industrial drives.

Outcomes: Learner will be able to...

1. Discuss tradeoffs involved in power semiconductor switches
2. Analyze different types of power converters.
3. Analyze issues involved in controlling of AC and DC drives.
4. Realize drive considerations for different industrial applications.

Module	Details	Hrs.
Pre Requisite	**Basic Electrical Engineering** **Electrical Circuit and Machines** **Basic Electronics and Digital Circuit Design**	
1	**Power Semiconductor Switches** **1.1 SCR:** Principle of operation, static and dynamic characteristics, gate characteristics, turn-on and turn-off methods, protection. **1.2 Principle of operation and characteristics of:** TRIAC, power BJT, power MOSFET, IGBT.	**06**
2	**DC Converters** **2.1 AC-DC Converters** Phase Controlled Converters: Working and waveforms of: Single phase semi, full converters with R, R-L load. **2.2 DC-DC converters:** Basic principle of step up and step down choppers. Buck, Boost, Buck-Boost, Cuk regulators	**06**
3	**AC Converters** **3.1 Inverters (DC-AC):** Single phase half / full bridge voltage source inverters with R load **3.2 AC-AC Converters** **AC voltage Controllers:** Single phase AC voltage controller – on – off control and phase control. **Cycloconverters:** principle of operation of single phase step-up and stepdown cycloconverters.	**07**
4	**Electrical Drives** **4.1 Introduction** Definition and difference between mechanical & electrical drive, Block Diagram, Classification, Choice Of Electrical Drives **4.2 Dynamic Characteristics of Electrical Motor** Fundamental torque equations, Multi quadrant operation	**05**

5	**DC and AC Motor Drives** **5.1 DC Drive** **Operation**:Motoring, Plugging, Dynamic and Regenerative Braking. **Control of DC Drive by phase controlled converter:** Single phase, semi/ full converter drive for separately excited dc motor. **Control of DC Drive by Chopper regulators:** Single quadrant, Two – quadrant and four quadrant chopper fed dc separately excited motors **5.4 AC Drives:** Current Source Inverter fed Induction motor drive, Closed-loop induction motor drive with constant volts/Hz control, PWM inverter fed induction motor drive	**09**
6	**Applications of Electric Drives** 6.1 Introduction to Solar and battery powered Drives; 6.2 Servo motor drive requirement – control and implementation 6.3 Electrical Vehicles Drives	**06**
Self Study	**Stepper Motor Drive** **Reluctance motor Drive** **BLDC Motor Drive**	

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein sub-questions of 2 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
5. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text/Reference Books:

1. Reshid, M.H., "Power Electronics – Circuits Devices and Application" Prentice Hall International, New Delhi.

2. J Mohan Undeland and Robbins, "Power Electronics", John Wilry and Sons, New York.

3. P. C. Sen, "Power Electronics", Tata McGraw-Hill, New Delhi.

4. Singh, M.D., Khanchandani, K.B., "Power Electronics", Tata McGraw-Hill Education Pvt. Ltd, New Delhi. 5. S. K. Mandal, "Power Electronics", McGraw-Hill Education (I) Pvt. Ltd, New Delhi.

6. Vedam Subramanyam, "Thyristor Control of Electric drives", Tata McGraw Hill Publilcations

7. P.S. Bimbhra, Power Electronics, Khanna Publications.

8. Vedam Subramanyam, "Electric Drives: Concepts & Applications", 2nd edition, Tata McGraw Hill Education, New Delhi.

Links for online NPTEL/SWAYAM courses:
https://nptel.ac.in/courses/108/105/108105066/
https://nptel.ac.in/courses/108/101/108101126/
https://nptel.ac.in/courses/108/108/108108077/
https://nptel.ac.in/courses/108/104/108104140/

Course Code	Course Name	Credits
MTC603	**Instrumentation and Control**	**03**

Prerequisites: MTC305 Applied Electrical and Electronics Engineering, MTC405 Application of Integrated Circuits, MTC502 Sensors and Actuators, MTC503 Mechatronic Systems Modelling and Control

Objectives:

1. To teach fundamental Process controller and its design
2. To educate students the criteria for selection of suitable transmitters (Sensor/Actuators)
3. To help students in enhancing their knowledge about different controllers

Outcomes: Learner will be able to...

1. Identify process control loop components
2. Select proper transmitter for different parameters
3. Use suitable actuators for different situations
4. Design controller for different processes and applications
5. Tune PID Controllers
6. Write the ladder diagram programs for discrete process control industrial applications.

Module	Details	Hrs.
1. 0	**Fundamentals of process and control** 1.1 Elements of process control loop, Concept of Process variables, set point, controlled variable, manipulated variable, load variable. Representation of Process loop components using standard symbols (basics with reference to control loop), and Examples of process loops like temperature, flow, level, pressure etc. Current to pneumatic converter & Pressure to Current converter. 1.2 Process Characteristics: Process load, Process lag, Self Regulation, Distance/velocity lag (dead time), Capacity. Control System Parameters Error, Variable Range, Control Lag, Cycling, Direct/Reverse Action.	06
2.0	**Transmitters:** 2.1 Need of transmitter (concept of field area & control room area), Need for standardization of signals, Current, voltage, and pneumatic signal standards, Concept of live & dead zero 2.2 Types of transmitters: Two and four wire transmitters, Electronic and Pneumatic transmitters Electronic Differential Pressure Transmitter	04
3.0	**Actuators** 3.1 **Control valve :**Necessity, comparison with other final control elements, Control valve Characteristics (Inherent & Installed) , Control valve terminology: Range ability, Turndown, valve capacity, viscosity index, AO, AC (Fail Safe Action) etc. Construction, Advantages, Disadvantages & applications of Globe: Single, double, 3way, angle, Gate, Needle, Diaphragm, Rotary valves, Ball, Butterfly. Classification of control valve based on: valve body. Construction, type of actuation, application etc. 3.2 **Types of actuators:** Electric: Solenoid, Motors, Hydraulic, Pneumatic: Spring Diaphragm , & Smart actuators. 3.3 **Control valve accessories:** Positioners: Applications/Need, Types, Effect on performance of Control valves. Volume boosters, Pressure boosters, Reversing relay, Solenoid valves, Air lock.	08

4.0	**Controller** 4.1 **Discontinuous:** ON/OFF, Multi-position Control, Floating Control. 4.2 **Continuous:** Proportional (offset), Integral (Reset windup), Derivative, Proportional- Integral, Proportional- Derivative, Proportional- Integral-derivative, Types of PID combination (Non Interacting, Interacting and Parallel), Setpoint Weighting, Error Squared, Anti-windup, Back Calculation and Tracking , Concept of Bump less transfers in PID controller, Effect of process characteristics on PID combination, Selection & application of controller actions.	08
5.0	**Tuning of controller:** 5.1 **Different Criteria**: Quarter Amplitude Decay Ratio, Loop disturbance, Optimum Control, Measure of Quality, Stability Criteria Tuning Methods: Process Reaction Curve (open loop), Ziegler Nichols (closed loop), λ Tuning, & Frequency Response Method. 5.2 **Digital PID controllers :** : Velocity & Position algorithm, Block Schematic, Faceplate of Digital controller, Direct Digital Control. Introduction to Adaptive control and self tuning of digital PID controllers.	07
6.0	**Discrete Process Control** : **6.1** Continuous versus Discrete Process Control, Relay based ladder diagram using standard symbols, Limitations of relay based system. **Programmable Logic Controller (PLC)** 6.2 Architecture of PLC, Types of Input & Output modules (AI, DI, DO, AO), Wiring diagram, 6.3 PLC Basic instructions, Timers & Counters, PLC ladder diagram, FBD and IL, PLC programming for process applications,	06

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein sub-questions of 2 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
5. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text Books:

1. Process control and Instrument technology, C.D.Johnson, TMH

References:

1. PID Controllers: Theory, Design, and Tuning Karl J. Åström , Tore Hägglund, ISA
2. Instrumentation for Process measurement and control , N.A. Anderson, CRC Press
3. Introduction to Programmable Logic Controller, Gary Dunning, DELMAR Cengage Learning.
4. Programmable Logic Controller, Webb, PHI Reference Books
5. Tuning of Industrial control systems, ISA
6. Control valve Handbook, ISA

7. Process Instruments and Controls Handbook, Douglas M. Considine, McGraw-Hill.
8. Process Control, Instrument Engineering Hand book, B.G. Liptak, Butterworth-Heinemann Ltd
9. Programmable Logic Controller, NIIT
10. Fundamentals of Process Control Theory, Paul Murrill, ISA
11. Lessons in Industrial Instrumentation, By Tony R. Kuphaldt, Version 0.4 – Released Jan 11, 2009.

Links for online NPTEL/SWAYAM courses:
https://nptel.ac.in/courses/108/105/108105063/
https://nptel.ac.in/courses/108/105/108105064/

Course Code	Course Name	Credits
MTC604	**Applied Hydraulics and Pneumatics**	**03**

Prerequisite: MTC503 Sensors and Actuators, MTC403 Thermal and Fluid Engineering

Objectives:

1. To study fundamentals of fluid power system.
2. To study pneumatics & hydraulic system and its components.
3. To study system and its applications.

Outcomes: Learner will be able to...

1. Analyze fluid power system
2. Describe construction and working of hydraulic components
3. Design hydraulic system.
4. Describe construction and working of pneumatic components
5. Design pneumatic system.
6. Design of electrical control for various fluid power applications.

Module	Details	Hrs.
01	**Fluid Power Systems and Fundamentals** Introduction to fluid power, Advantages of fluid power, Application of fluid power system. Types of fluid power systems, Properties of hydraulic fluids, General types of fluids, Fluid power symbols. Basics of Hydraulics, Applications of Pascals Law, Laminar and Turbulent flow, Reynold's number, Darcy's equation, Losses in pipe, valves and fittings.	06
02	**Hydraulic Systems & Components** **Sources of Hydraulic Power:** Pumping theory, Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps, pump performance, Variable displacement pumps. **Fluid Power Actuators:** Linear hydraulic actuators, Types of hydraulic cylinders – Single acting, Double acting, Cushioning mechanism, Construction of double acting cylinder. **Construction of Control Components:** Directional control valves, Shuttle valve, check valve, pressure control valve, pressure reducing valve, counter balance valve, unloading valves, sequence valve, Flow control valve – Fixed and adjustable, Pressure compensated valves, Servo valves(Mechanical and Electrohydraulic) , Proportional control valves. **Accumulators and Intensifiers:** Types of accumulators, intensifier	09
03	**Design and Analysis of Hydraulic Circuits** Single acting and double acting cylinder circuits, regenerative circuit, sequence circuit, Automatic cylinder reciprocating system, Cylinder synchronizing circuit (Parallel and Series), Fail safe circuits(Prevent cylinder extension, Overload protection, Two handed safety) Meter in and meter out circuit. Accumulators circuits, – Applications of Intensifier – Intensifier circuit,	06
04	**Pneumatic Systems and Components** **Pneumatic Components:** Properties of air, Compressors, Filter, Regulator, Lubricator Unit, classification of pneumatic actuators, Air control valves, Quick exhaust valves, directional control valves, non-return valves, logic valves, time delay valves, pressure sequence valve,	05
05	**Design of Pneumatic Circuits** Pneumatic logic circuits for various applications. Displacement step diagram, Speed control circuits, hydro-pneumatic circuit, sequential circuit design for various applications using cascade and shift register method.	07
06	**Electrical controls for fluid power** electrical control push button, limit switch, pressure switch, solenoid valves, Relays, Electro-pneumatic systems, Dominant OFF and Dominant ON circuit, Two	06

	cylinder sequencing, Counting and timing, Electro-hydraulic system, hydro-pneumatic system,	

Assessment:

Internal Assessment Test:

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End Semester Theory Examination:

2. Question paper will comprise of total 06 questions, each carrying 20marks.
3. Total 04 questions need to be solved.
4. Question No: 01 will be compulsory and based on entire syllabus wherein sub- questions of 2 to 5 marks will be asked.
5. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
6. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text Books:

1. Fluid Power with Applications by Anthony Esposito - Pearson Education 2000.
2. Pneumatic Controls by Joji P, Wiley India Pvt.Ltd

References:

1. A text book on Fluid mechanics and Hydraulic machines: Sukumar Pati, 2012 Tata McGraw Hill.
2. Power Hydraulics by Michael J, Prinches and Ashby J. G, - Prentice Hall, 1989
3. Industrial Hydraulics: Pippenger
4. Vickers Manual on Hydraulics
5. Fluid Mechanics and Fluid Power Engineering by Dr.D S Kumar , Kataria Publishers 2014
6. Fluid Mechanics and Hydraulic machines by Modi & Seth, Standard Publishers Distributors
7. Pneumatic Circuits and Low Cos by Fawcett J.R.
8. Fundamentals of pneumatics: Festo series
9. Fundamentals of hydraulics: Festo series

Links for online NPTEL/SWAYAM courses:

https://nptel.ac.in/courses/112/106/112106175/

https://nptel.ac.in/courses/112/105/112105047/

Course Code	Course Name	Credits
MTL601	**Python Programming Laboratory**	**01**

Prerequisites: MTL301 Data Structures and Algorithms Laboratory

Objectives:

1. To introduce basic concepts of Python programming language as well as common packages and libraries.
2. To generate an ability to design, analyze and perform experiments on real life problems in mechatronics engineering using python.

Outcomes: Upon successful completion of this course, the learner will be able to

1. Understand basic concepts in python.
2. Independently write code in Python, to be able to find python packages, install and utilize them
3. Understand how real world engineering problems can be solved and understood using Python
4. Draft and prepare case studies and report

Module	Details	Hours
1.	Introduction to python and its applications. Installation of Python and setting up a programming environment such as Anaconda and Spyder Python Basics: Variable and variable types, Booleans, Numbers (integers, floats, fractions, complex numbers), strings, lists, tuples, sets, dictionaries. bytes and byte arrays, Manipulating variables, indexing, slicing, basic operators (arithmetic, relational, logical, membership, identity). String methods, list methods, list slicing, set methods, in built python functions, input and output functions.	4
2.	Basic Coding in Python: If, else, elif statements, for loops, range function, while loops, List comprehensions, functions in python. Introduction to OOP, Classes, Objects, Reading and writing files.	2
3.	Python libraries: Installing of different libraries, packages or modules. Basic concepts of the following libraries: NumPy, Matplotlib, Pandas, SciPy Optional libraries based on case studies in Module 4: Pillow, Scikit, OpenCV, Python in Raspberry Pi	4
4.	Case Studies using Python (Select any 3): 1. Solving a linear differential equation using SciKit and plotting the result in matplotlib. Students can use differential equations from any previous topic studied in the programme such as mechanics, kinematics of machines, Mechatronic Systems Modelling and Control etc. 2. Image processing and manipulation and auto detection of any object. Applications in self-driving cars may be discussed. 3. Python programming of a Raspberry PI: Students can sense using a sensor, process the reading and then control some physical output (like motor or LED) 4. Project involving basic machine learning (Students should understand the basic concepts of machine learning and apply to specific situation) 5. Any other case study that uses Python to solve Mechanical Engineering problems. 6. Customizing applications by writing API programs using python like to create joints, get physical properties, get circle and arc data from edge.	6

Note: In module 4: Advanced learners may opt to do multiple case studies beyond minimum required. Student with laptops or personal computers should be encourages to install Python on it and independently work on these projects.

Students should prepare a short report for each case study and submit their findings. They should also give a presentation on their case study as well as a live demonstration of their projects.

Suggested Text Books and Resources

1. Core Python Programming, Dr. R. NageswaraRao, Dreamtech Press
2. Programming through Python, M.T.Savaliya and R.K.Maurya, StarEdu Solutions
3. Beginning Python: Using Python 2.6 and Python 3.1. James Payne, Wrox publication2.
4. Any digital resources and online guides for python or its packages. Such as "The Python Tutorial", http://docs.python.org/release/3.0.1/tutorial/

Assessment:

Internal:

Laboratory Work: 5 Marks
Case Study Reports and Presentation: 5 marks each: Total 15 marks
Attendance: 5 Marks

External Practical/Oral:

1. Practical examination of 2 hours duration followed by Oral to be conducted by Pair of Internal and External Examiner based on contents
2. Evaluation of practical examination to be done by examiner based on the printout of students work
3. Distribution of marks
    a. Practical examination: 20 marks
    b. Oral based on practical examination: 05 marks

Note: Students work along with evaluation report to be preserved till the next examination

Course Code	Course Name	Credits
MTL602	**Instrumentation and Electric Drives Laboratory**	**01**

Pre-requisite: MTL502 Mechatronic Systems Modelling and Control MTL501 Sensors and Actuators Laboratory, MTL404 Technical Computing Laboratory

Objectives:

1. To study the basic of instrumentation
2. To study control strategies
3. To study power electronic circuits
4. To study AC and DC Drive implementation

Outcomes: Learner will be able to...

1. Characterization of Instruments used in process control
2. Implementation of PID controller and its variations
3. Implement PLC programming for process
4. Implementation of DC Motor Drives
5. Implement of AC Motor Drives

List of Practical's:

Part A

1) Demonstration of I(Current)/P(Pressure) and P(Pressure)/I(Pressure) converter using integrated Circuits
2) P, PI, PD and PID Controller its performance and tuning
3) Implementation of Digital PID Controller.
4) PLC programming(Ladder diagram, Instruction list and Functional Block Diagram)
5) Determination of Control Valve Characteristics
6) Tuning of industrial PID controller for process control application

Part B

1) Study of different triggering circuits for SCR.(R, RC and UJT Triggering)
2) Study of thyristors controlled DC Drive.
3) Study of Chopper fed DC Drive.
4) Study of AC Single phase motor-speed control .
5) PWM Inverter fed 3 phase Induction Motor control using PSPICE / MATLAB / PSIM / SCILAB Software OR hardware
6) VSI / CSI fed Induction motor Drive analysis using MATLAB / SPICE / PSIM/ SCILAB Software OR hardware.

Term Work:

Term work shall consist of 5 experiments from Part A and 5 experiments from Part B and 3 assignments on I&C and 3 Assignments on PED.

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

1. Laboratory work (Experiments) **:** **10 marks**
2. Assignments : **10 marks**
3. Attendance **05 marks**

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

Practical and Oral Examination:

Practical examination of 2 hours duration based on experiments mentioned in the list.

Marks distribution: 25 Marks = Practical examination (15 Marks) + Oral examination (10 Marks). Practical and Oral examination is to be conducted by pair of internal and external examiners

Course Code	Course Name	Credits
MTL603	**Applied Hydraulics and Pneumatics Laboratory**	**01**

Pre-requisite: MTL501 Sensors and Actuators Laboratory,

Objectives:

1. To study fundamentals of fluid power system.
2. To study pneumatics & hydraulic system and its components.
3. To design pneumatic and hydraulic circuits for industrial application

Outcomes: Learner will be able to...

1. Design pneumatic and electro-pneumatic system for industrial application.
2. Design hydraulic and electro-hydraulic system for industrial application.
3. Characterization of Hydraulic system components
4. Selection of Hydraulic and Pneumatic System components

Suggested List of laboratory experiments (Minimum Eight):

Sr. No.	Experiment List
01	Study of Hydraulic System Components
02	Characteristics of reciprocating pumps, gear pump etc.
03	Design and Development of Hydraulic circuit for single cylinder / hydraulic motor manual operation with meter in and meter out speed control (Simulation and Hardware Implementation)
04	Design and Development of Electro-Hydraulic circuit for single cylinder reciprocation (Simulation and Hardware Implementation)
05	Study of Pneumatic System Components
06	Design and Development of Pneumatic circuit for cylinder actuation based on logic operation (Simulation and Hardware Implementation)
07	Design and implementation of pneumatic circuit for Two cylinder sequencing (Simulation and Hardware Implementation)
08	Design and implementation of electro-pneumatic circuit for Two cylinder sequencing (Simulation and Hardware Implementation)
09	Design and implementation of electro-pneumatic circuit for single cylinder reciprocation with counter (Simulation and Hardware Implementation)
10	Design and implementation of electro-pneumatic circuit for two cylinder sequencing with timer (Simulation and Hardware Implementation)
11	Design and implementation of hydraulic circuit based on Proportional / Servo Valves (Simulation and Hardware Implementation)
12	Implementation and Characterization of Pneumatic Muscle with Electronic Pressure Regulator

Term Work:

Term work consists of performing minimum 8 practical mentioned as above. Final certification and acceptance of the term work ensures satisfactory performance of laboratory work.
The distribution of marks for term work shall be as follows:

- Laboratory work (Experiment/journal) : 20 marks.
- Attendance (Theory and Practical) : 05Marks

End Semester Examination:

Pair of Internal and External Examiner should conduct Practical and Oral. Practical exam (15 marks) will be on any one of the experiments from the list and oral exam (10 marks) will be based on the entire syllabus of the laboratory.

Course Code	Course Name	Credits
MTL604	**CNC and 3-D Printing Laboratory**	**02**

Prerequisites: MTSBL301 CAD – Modeling Laboratory
Objectives:

1. To distinguish the model development with respect to subtractive and additive manufacturing systems.
2. To develop learners' understanding of the practical applications of a Computer-aided Manufacture & Rapid Prototyping System**.**

Outcomes: Learner will be able to...

1. Demonstrate CAM Tool path and prepare NC- G code.
2. Apply rapid prototyping and tooling concepts for any real life applicationsn
3. Convert 2D images into 3D model

Sr. No.	List of Exercises	CO
1	Part programming and part fabrication on CNC Turning trainer (Involving processes like Step turning, facing, Taper turning, threading, etc.) (One job in a group of 4-5 students)	**01**
2	Part programming and part fabrication on CNC Milling trainer (Involving processes like contouring, drilling, facing, pocketing etc.) (One job in a group of 4-5 students)	**01**
3	Part Programming Simulation for any Unconventional Machining Process (Electric Discharge Machining, laser cutting Machining, Plasma Cutting Machining etc.)	**01**
4	Tool-path generation by translation of part geometry from computer aided design (CAD) to computer aided manufacturing (CAM) systems.	**01**
5	Post processing of Code generated via CAM system	**01**
6	Case Study: Report on a visit conducted to any Commercial CNC Machining Centre explaining the Design features, pre processing in CAM software and its capabilities.	**01**
7	Development of physical 3D mechanical structure using any one of the rapid prototyping processes.	**02**
8	Check the constraints of any two RP systems for features like layer thickness, orientation of geometry, support generation, post processing etc.	**02**
9	Design an object with free form surface & printing it using any RP process.	**02**

10	Segmentation in Slicer's Segment Editor module for the purpose of 3D printing (3D Slicer open source) (Application: Any Bone part as per available Dicom files)	**02 & 03**
11	Creation of 3D model from 2D images using any image processing software and printing it. (3D Slicer open source) (Application: Any body organ like Heart, Gallbladder etc.. as per available Dicom files)	**02 & 03**
12	Case Study: Usability of rapid tooling integrated investment casting process, with their advantages and limitations in any one of emerging areas of dentistry, jewelry, surgical implants, turbine blades, etc.	**02**

Term work shall consist of

- Any **4 exercises from 1 to 6 and 3 exercises from 7 to 11 of the above list**
- Exercise 12 is mandatory.

Text/Reference Books:

1. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications
2. CNC Technology and Programming, Krar, S., and Gill, A., McGraw Hill Publishers.
3. CNC Programming for Machining, Kaushik Kumar, ChikeshRanjan, J. Paulo Davim, Springer Publication.
4. Medical Modelling The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead Publishing Series in Biomaterials: Number 91, Elsevier Ltd.
5. Biomaterials, artificial organs and tissue engineering, Edited by Larry L. Hench and Julian R. Jones, Woodhead Publishing and Maney Publishing, CRC Press 2005
6. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, I. Gibson l D. W. Rosen l B. Stucker, Springer Publication.
7. Rapid Prototyping and Manufacturing, P. F. Jacobs, Society of Manufacturing Engineers.

Course Code	Course Name	Credits
MTDO601	**Microfabrication Processes**	**03**

Prerequisite: MTC303 Engineering Materials and Metallurgy, MTC501 CAD & CAE

Objectives:

1. To gain an understanding of standard microfabrication techniques (fundamental principles) and the issues surrounding them.
2. To know the major classes, components, and applications of microfabrication.
3. To understand the essentials and constraints of microfabrication processes.

Outcome: Learner will be able to ..

1. Identify appropriate microfabrication process for development of functional microsystem.
2. Apply knowledge of microfabrication techniques to the design and develop a microsystem.
3. Understand the working principle of different microfabrication processes

Module	Details	Hrs.
01	Introduction to microfabrication processes, Additive and subtractive type microfabrication processes. Advantages and disadvantages of additive and subtractive microfabrication. Applications and scope, Microfabrication process and its CAD compatibility.	6
02	Diffusion, Ion Implantation, Chemical–Mechanical Polishing (CMP). Bonding. Glass Micro processing. Surface Micromachining, dimensional uncertainties, sealing processes in surface micromachining, IC compatibility, poly-Si surface micromachining, hinged polysilicon, thick polysilicon, CVD silicon dioxides.	7
03	Photolithography overview, masks, spinning resist and soft baking, , exposure and post exposure treatment, development, post baking, resist, wafer priming, resist stripping, critical dimensions, line width, overall resolution, resist profile, overview of profile type, lift-off technique, Extreme UV lithography, Pattern Generation, Micro stereo lithography (types: scanning, projection, Integral Hardening, (IH), multi-resist, constraint surface), bulk lithography	8
04	Working Principles of Electro-discharge Machining (EDM), Reverse Micro- EDM, Wire cut EDM, laser micromachining, Electro-chemical machining.	6
05	Dry Etching, Sputtering or Ion Etching, Plasma etching, reaction mechanism, Ion energy vs Pressure relationship in a plasma. Chemical Etching, Energy driven anisotropy, Dopant driven anisotropy, Deep Reactive Ion Etching, Comparing dry and wet etching, combining dry and wet etching.	6
06	LIGA and Micromolding: Synchrotron orbital Radiation (SOR), X-ray masks, resist requirement, exposure, development, metal deposition, molding, demolding, sacrificial layers	6

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein sub- questions of 2 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
5. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text/Reference Books:

1. Sami Franssila, "Introduction to Micro fabrication", Wiley 2nd Edition.
2. Marc J Madou, Fundamentals of Microfabrication, The Science of minituarization, second edition, CRC press.
3. Yi Qin, Micromanufacturing Engineering and Technology, Micro and Nanotechnology series, Elsevier.
4. Nadim Mulaf and Kirt Williams, "An Introduction to Microelectromechanical systems Engineering", Artech House.
5. Stanley Wolf and Richard Tauber, "Silicon Processing for the VLSI era Volume -1 Technology", Lattice press.
6. Vijay K. Varadan, K.J.Vinoy and S. Gopalkrishnan, "Smart Material Systems and MEMS: Design and Development Methodologies", John Wiley and sons Ltd.

Links for online NPTEL/SWAYAM courses:

https://onlinecourses.nptel.ac.in/noc19_bt29/preview

https://onlinecourses.nptel.ac.in/noc20_ee56/preview

Course Code	Course Name	Credits
MTDO601	**Machine Interface Design**	**03**

Prerequisites: MTC603 Instrumentation and Control
Objectives:

1. To stress the importance of a good interface design.
2. To understand the importance of human psychology in designing good interfaces.
3. To motivate students to apply HMI in industrial application.
4. To bring out the creativity in each student – build innovative applications that are user friendly.
5. To encourage students to indulge into research in Machine Interface Design.

Outcomes: Learner will be able to..

1. Explain the psychopathology of user interface design
2. Design innovative and user friendly interfaces for industrial application.
3. Criticize existing interface designs, and improve them.
4. Design application for social and technical task with safety concern.

Module	Details	Hrs.
01	**1.1 Introduction:** Introduction to Human Machine Interface, Hardware, software and operating environment to use HMI in various fields. 1.2 The psychopathology of everyday things – complexity of modern devices; human-centered design; fundamental principles of interaction; 1.3 Psychology of everyday actions- how people do things; the seven stages of action and three levels of processing; human error;	7
02	**2.1 GUI** – benefits of a good UI; popularity of graphics; concept of direct manipulation; advantages and disadvantages; characteristics of GUI; characteristics of Web UI; General design principles. **2.2 User Interface Design Process:** Steps in UI design	7
03	3.1 Graphical screen design: graphical design concepts, components of visible language, graphical design by grids 3.2 Beyond screen design: characteristics of good representations, information visualization, Tufte's guidelines, visual variables, metaphors, direct Manipulation, Haptic Interfaces,	6
04	**4.1 Interaction styles and communication** – menus; windows; device based controls, screen based controls, feedback and guidance, icons, colors. **4.2 Societal and Individual Impact of User Interfaces:** Future Interfaces, Ten Plagues of the Information Age, Overcoming the Obstacle of Animism	6
05	5.1 Design principles and usability heuristics: design principles, principles to support usability, golden rules and heuristics, Human Computer Inetraction (HCI) patterns 5.2 HCI design standards: process-oriented standards, product-oriented standards, strengths and limitations of HCI Standards	6
06	**Case studies:** Designing and evaluating Human-Machine Interface (HMI) for 1. Process control application. 2. Flight control system	7

	3. Robotics Welding 4. Air-conditioning system 5. Smart phones 6. Medical Devices 7. Augmented Reality Based Machine Maintenance	

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

11. Question paper will comprise of total 06 questions, each carrying 20marks.
12. Total 04 questions need to be solved.
13. Question No: 01 will be compulsory and based on entire syllabus wherein sub- questions of 2 to 5 marks will be asked.
14. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
15. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text/Reference Books:

1. Donald A. Normann, "Design of everyday things", Basic Books; Reprint edition 2002.
2. Wilbert O. Galitz, "The Essential Guide to User Interface Design", Wiley publication.
3. Ben Shneiderman and Catherine Plaisant,: Desinging the user Interface:,Pearson,Addison Wesley.
4. Alan Cooper, Robert Reimann, David Cronin, "About Face3: Essentials of Interaction design", Wiley publication.
5. Jeff Johnson, "Designing with the mind in mind", Morgan Kaufmann Publication.
6. "Human-Machine Interface Design for Process Control Applications", Jean-Yves Fiset, ISA,2009
7. Dix A. et al., Human-Computer Interaction. Harlow, England: Prentice Hall, 2004, ISBN-10: 0130461091
8. Yvonne Rogers, Helen Sharp, Jenny Preece, Interaction Design: Beyond Human Computer Interaction, 3rd Edition, Wiley, 2011, ISBN-10: 0470665769
9. Guy A. Boy "The Handbook of Human Machine Interaction", Ashgate publishing Ltd.
10. "Human Haptic Perception Basics and Applications" Birkhaeuser Verlag AG, Boston Basel Berlin
11. Changzhi KeBo KangDongyi ChenXinyu Li "An Augmented Reality-Based Application for Equipment Maintenance" ACII 2005 Springer

Links for online NPTEL/SWAYAM courses:

https://nptel.ac.in/courses/106/106/106106177/
https://nptel.ac.in/courses/106/103/106103115/
https://onlinecourses.nptel.ac.in/noc21_cs50/preview

Course Code	Course Name	Credits
MTDO601	**Fundamentals of Multibody Dynamics**	**03**

Perquisites: MTC402 Kinematics of Machinery, MTC501 CAD and CAE

Objectives

1. Study motion of mechanical system caused by external forces using computational approach.
2. Study multibody dynamics modelling for designing complex products.
3. Introduce multibody vibration analysis

Outcomes: Learner will be able to...

1. Explain rigid body kinematics of multibody systems
2. Model forces on multibody Mechanical systems
3. Define and solve equations of motion of Multibody systems
4. Define constraints in multibody systems
5. Analyse vibrations in multibody systems

Module	Details	Hrs.
01	Introduction and applications of Multibody Dynamics **Rigid-Body Kinematics** Introduction, Vectors Differentiation, Generalized Coordinates(Cartesian Coordinates Euler angles and Direction Cosines), Euler and Rodriguez Formula, Angular Velocity, Angular Acceleration. **Kinematics for General Multibody Systems** Introduction, Configuration Graphs for Treelike Multibody Systems, Generalized Coordinates Partitioning, Transformation Matrices and Their Derivatives for *N*-Interconnected Rigid Bodies, Angular Velocities and Accelerations	6
02	**Modeling of Forces in Multibody Systems** Introduction, Forces, Moments and Equivalence Force Systems, Generalized Active Force, Modeling of Springs and Dampers at the Joints. Contact Forces, Gravitational Forces, Generalized Inertia Forces, Inertia Properties, Second Moment, Inertia Dyadic.	6
03	**Equations of Motion of Multibody Systems** Introduction, Equations of Motion, Derivation of Kane's Equations Through the Principle of Virtual Work, Matrix Representation of the Equations of Motion.	6
04	**Lagrange Equations** Introduction, Energy Equations, Lagrange's Equations, Application of Lagrange Equations to Multibody Systems, Relationship Between Kane's and Lagrange Equations.	5
05	**Handling of Constraints in Multibody Systems Dynamics** Introduction, Holonomic and Nonholonomic Constraints , Constrained Multibody Systems, The Augmented Method, Coordinate Reduction, Evaluation of the Constraint Forces	8
06	**Linearization and Vibration Analysis of Multibody Systems** Introduction, Linearization of the Equations of Motion, Free Vibration of Continuous Beams: Natural Mode Shapes and Frequencies Transverse Vibration,	8

	Longitudinal Vibration, Torsional Vibration. The Eigenvalue Problem, Rayleigh–Ritz Method, Forced System Response and Selection of Mode Shapes. Case study on application of Multibody dynamic simulation for motion analysis of (a) Vehicle Suspension and (b) Washing Machine.	
Self-study Topic	**Particle Dynamics**	**--**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test is to be conducted when approx. 40% syllabus is completed and second class test when additional 35% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein sub- questions of 2 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.(e.g. Suppose Q.2 has part (a) from module3 then part (b) will be from any module other than module 3)
5. In question paper weightage of each module will be proportional to number of respective lecture hrs as mentioned in the syllabus.

Text Books:

1. "Fundamentals of Multibody Dynamics Theory and Applications" Farid Amirouche

References:

1. Shabana, A.A., 2005, Dynamics of Multibody Systems, Cambridge Press
2. Chaudhary, H., and Saha, S.K., 2013, Dynamics and Balancing of Multibody Systems, Springer (India)
3. Shah, S., Saha, S.K., and Dutt, J.K., 2014, Dynamics of Tree-type Robotic Systems, Springer
4. Banerjee, Arun K., 2016, Flexible Multibody Dynamics—Efficient Formulations and Applications, Wiley
5. Edara, R. and Shih, S., "Effective Use of Multibody Dynamics Simulation in Vehicle Suspension System Development," SAE Technical Paper 2004-01-1547, 2004, https://doi.org/10.4271/2004-01-1547.
6. Nygårds, T., Berbyuk, V. Multibody modeling and vibration dynamics analysis of washing machines. Multibody Syst Dyn 27, 197–238 (2012). https://doi.org/10.1007/s11044-011-9292-5

Links for online NPTEL/SWAYAM courses:

https://www.mooc-list.com/course/modeling-and-simulation-multibody-systems-edx

Course Code	Course Name	Credits
MTPBL301	**Mini Project-2B**	**02**

Objectives:

1. To acquaint with the process of identifying the needs and converting it into the problem.
2. To familiarize the process of solving the problem in a group.
3. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems.
4. To inculcate the process of self-learning and research.

Outcome: Learner will be able to…

1. Identify problems based on societal /research needs.
2. Apply Knowledge and skill to solve societal problems in a group.
3. Develop interpersonal skills to work as member of a group or leader.
4. Draw the proper inferences from available results through theoretical/ experimental/simulations.
5. Analyse the impact of solutions in societal and environmental context for sustainable development.
6. Use standard norms of engineering practices
7. Excel in written and oral communication.
8. Demonstrate capabilities of self-learning in a group, which leads to life long learning.
9. Demonstrate project management principles during project work.

Guidelines for Mini Project

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problem statement for mini project in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students hall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert the best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.
- With the focus on the self-learning, innovation, addressing societal problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality to be carried out in two semesters by all the groups of the

students. i.e. Mini Project 1 in semester III and IV. Similarly, Mini Project 2 in semesters V and VI.

- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on case by case basis.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
    - Marks awarded by guide/supervisor based on log book : 10
    - Marks awarded by review committee : 10
    - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

One-year project:

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
    - First shall be for finalisation of problem
    - Second shall be on finalisation of proposed solution of problem.
- In second semester expected work shall be procurement of components/systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
    - First review is based on readiness of building working prototype to be conducted.
    - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

Half-year project:

- In this case in one semester students' group shall complete project in all aspects including,
    - Identification of need/problem
    - Proposed final solution
    - Procurement of components/systems
    - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
    - First shall be for finalisation of problem and proposed solution
    - Second shall be for implementation and testing of solution.

Assessment criteria of Mini Project.

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In **one year, project**, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.
- In case of **half year project** all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Practical/Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organisations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Mini Project shall be assessed based on following points;

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication