University of Mumbai

No. AAMS_UGS/ICC/2023-24/68

Sub: B.E. (Automation and Robotics) (Sem – V & VI).

CIRCULAR:-

Attention of the Principals of the Affiliated Colleges and Directors of the Recognized Institutions in Faculty of Science & Technology is invited to this office Circular No. AAMS_UGS/ICC/2023-24/09 dated 09th June, 2023 regarding Ordinance 3701 relating to introduction of new branch for B.E. (Automation and Robotics) (Sem. III & IV).

They are hereby informed that the recommendations made by the Board of Deans at its meeting held on 27th October, 2023 **vide** item No. 6.8 (N) have been accepted by the Academic Council at its meeting held on 01st November, 2023 **vide** item No. 6.8 (N) and that in accordance therewith, syllabus of **B.E. (Automation and Robotics) (Sem – V & VI) (CBCS)** is introduced and the same has been brought into force with effect from the academic year 2023-24.

(The said circular is available on the University's website www.mu.ac.in).

(Prof. Sunil Bhirud)
I/c. REGISTRAR

MUMBAI – 400 032
24th November, 2023

To,

The Principals of the Affiliated Colleges and Directors of the Recognized Institutions in Faculty of Science & Technology.

A.C/6.8(N) /01/11/2023

Copy forwarded with Compliments for information to:-

1) The Chairman, Board of Deans,
2) The Dean, Faculty of Science & Technology,
3) The Chairman, Board of Studies,
4) The Director, Board of Examinations and Evaluation,
5) The Director, Department of Students Development,
6) The Director, Department of Information & Communication Technology,
7) The Director, Institute of Distance and Open Learning (IDOL Admin), Vidyanagari,
8) The Co-ordinator, MKCL.

Copy for information and necessary action :-

1. **The Deputy Registrar, College Affiliations & Development Department (CAD),**
2. **College Teachers Approval Unit (CTA),**
3. **The Deputy Registrar, (Admissions, Enrolment, Eligibility and Migration Department (AEM),**
4. **The Deputy Registrar, Academic Appointments & Quality Assurance (AAQA)**
5. **The Deputy Registrar, Research Administration & Promotion Cell (RAPC),**
6. **The Deputy Registrar, Executive Authorities Section (EA)**
   He is requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to the above circular.
7. **The Deputy Registrar, PRO, Fort, (Publication Section),**
8. **The Deputy Registrar, Special Cell,**
9. **The Deputy Registrar, Fort Administration Department (FAD) Record Section,**
10. **The Deputy Registrar, Vidyanagari Administration Department (VAD),**

Copy for information :-

1. **The Director, Dept. of Information and Communication Technology (DICT), Vidyanagari,**
   He is requested to upload the Circular University Website
2. **The Director of Department of Student Development (DSD),**
3. **The Director, Institute of Distance and Open Learning (IDOL Admin), Vidyanagari,**
4. **All Deputy Registrar, Examination House,**
5. **The Deputy Registrars, Finance & Accounts Section,**
6. **The Assistant Registrar, Administrative sub-Campus Thane,**
7. **The Assistant Registrar, School of Engg. & Applied Sciences, Kalyan,**
8. **The Assistant Registrar, Ratnagiri sub-centre, Ratnagiri,**
9. **P.A to Hon'ble Vice-Chancellor,**
10. **P.A to Pro-Vice-Chancellor,**
11. **P.A to Registrar,**
12. **P.A to All Deans of all Faculties,**
13. **P.A to Finance & Account Officers, (F & A.O),**
14. **P.A to Director, Board of Examinations and Evaluation,**
15. **P.A to Director, Innovation, Incubation and Linkages,**
16. **P.A to Director, Department of Lifelong Learning and Extension (DLLE),**
17. **The Receptionist,**
18. **The Telephone Operator,**

Copy with compliments for information to :-

19. **The Secretary, MUASA**
20. **The Secretary, BUCTU.**

AC – 01/11/2023
Item No. – 6.8(N)

University of Mumbai

Syllabus for
B.E. (Automation and Robotics)

Semester - V & VI

Choice Based Credit System

(With effect from the academic year 2023-24)

University of Mumbai

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of Course	B.E. (Automation and Robotics)
2	Eligibility	Passing First Year Engineering as per the Ordinance O.6242
3	Passing Marks	40 %
4	Ordinance / Regulation	Ordinance O.6242
5	No. of years/Semesters	4 years / 8 semesters
6	Level	Under Graduation
7	Pattern	Semester
8	Status	New
9	To be implemented from Academic Year	With effect from Academic Year : 2023-24

Offg. Associate Dean
Faculty of Science and Technology

Offg. Dean
Faculty of Science and Technology

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 170, where in 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 Third Year of Engineering from the academic year 2023-24. Subsequently this will be carried forward for final year Engineering in the academic years 2024-25 respectively.

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 this particular syllabus wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. Efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current syllabus based on the recommendation of AICTE model curriculum overall credits are reduced to 170, 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.

Program Structure for Third Year Automation and Robotics Engineering
University of Mumbai (With Effect from 2023-2024)
Semester V

Course Code	Course Name	Theory	Pract	Theory	Pract	Total
ARC501	Power Electronics and Drives	3	--	3	--	3
ARC502	Industrial Processes	3		3		3
ARC503	Robot Kinematics & Dynamics	3	--	3	--	3
ARC504	Digital Signal Processing	3	--	3	--	3
ARDLO501X	**Departmental Level optional course -I**	3	--	3	--	3
ARL501	Power Electronics and Drives & Digital Signal Processing Lab	--	2	--	1	1
ARL502	Industrial Processes Lab	--	2	--	1	1
ARL503	Robot Kinematics and Dynamics Lab	--	2	--	1	1
ARSBL501	Professional Communication & Ethics Lab	--	2*+2	--	2	2
ARPBL501	Mini Project -III	--	4$	--	2	2
Total		**15**	14	**15**	**07**	**22**

Course Code	Course Name	Examination Scheme							
		Theory							
		Internal Assessment			End Sem. Exam	Exam. Duration (in Hrs)	Term Work	Pract/ Oral	Total
		Test 1	Test 2	Avg					
ARC501	Power Electronics and Drives	20	20	20	80	3		--	100
ARC502	Industrial Processes	20	20	20	80	3	--	--	100
ARC503	Robot Kinematics & Dynamics	20	20	20	80	3	--	--	100
ARC504	Digital Signal Processing	20	20	20	80	3	--	--	100
ARDLO501X	**Departmental Level optional course -I**	20	20	20	80	3	--	--	100
ARL501	Power Electronics and Drives & Digital Signal Processing Lab	--	--	--	--	--	25	25	50
ARL502	Industrial processes Lab	--	--	--	--	--	25	25	50
ARL503	Robot Kinematics and Dynamics Lab	--	--	--	--	--	25	25	50
ARSBL501	Professional Communication & Ethics Lab	--	--	--	--	--	25	25	50
ARPBL501	Mini Project -III	--	--	--	--	--	25	25	50
Total		--	--	**100**	**400**	--	**125**	**125**	**750**

$ indicates work load of Learner (Not Faculty), for Mini project
*** Out of 4 hours, 2-hour theory (entire class) and 2 hours practical (batches)**

SBL- Skill Based Laboratory

PBL- Project Based Laboratory

Departmental Level optional course -I

Course Code	Departmental Level optional course -I
ARDLO5011	Data Structures and Algorithms
ARDLO5012	Optimization Techniques
ARDLO5013	Advanced Sensors
ARDLO5014	Analytical Instrumentation

Semester VI

Course Code	Course Name	Theory	Pract.	Theory	Pract.	Total
ARC601	Robotic Control system (RCS)	3	--	3	--	3
ARC602	Process Instrumentation and Control (PIC)	3	--	3	--	3
ARC603	Manufacturing using Computer Aided Design	3	--	3	--	3
ARC604	Machine Learning (ML)	3	--	3	--	3
ARDLO602X	Departmental Level optional course - II	3	--	3	--	3
ARL601	Robotic Control system Lab	--	2	--	1	1
ARL602	Process Instrumentation and Control lab	--	2	--	1	1
ARL603	Machine Learning Lab	--	2	--	1	1
ARLSBL601	CAD Modelling and 3D printing lab	--	2*+2	--	2	2
ARPBL601	Mini Project-IV	--	4$	--	2	2
Total		**15**	**14**	**15**	**7**	**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.					
ARC601	Robotic Control system (RCS)	20	20	20	80	3	--	--	100
ARC602	Process Instrumentation and Control (PIC)	20	20	20	80	3	--	--	100
ARC603	Manufacturing using Computer Aided Design	20	20	20	80	3	--	--	100
ARC604	Machine Learning (ML)	20	20	20	80	3	--	--	100
ARDLO602X	Departmental Level optional course -II	20	20	20	80	3	--	--	100
ARL601	Robotic Control system Lab	--	--	--	--	--	25	25	50
ARL602	Process Instrumentation and Control lab	--	--	--	--	--	25	25	50
ARL603	Machine Learning Lab	--	--	--	--	--	25	25	50
ARLSBL601	CAD Modelling and 3D printing lab	--	--	--	--	--	25	25	50
ARPBL601	Mini Project-IV	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**125**	**125**	**750**

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

*** Out of 4 hours, 2-hour theory (entire class) and 2 hours practical batches)**

SBL- Skill Based Laboratory

PBL- Project Based Laboratory

Departmental Level optional course -II

Course Code	Departmental Level optional course -II
ARDLO6021	Database Management System (DBMS)
ARDLO6022	Industrial Robotics and Material handling systems
ARDLO6023	Metal Forming Technology
ARDLO6024	Biomedical Instrumentation

Course Code	Course Name	Credits
ARC501	Power Electronics and Drives	03

Course Objectives

1. To equip the students with the knowledge of semiconductor devices & their applications.
2. To learn the basic concepts and characteristics of Electrical motors and their respective drives.

Course Outcomes

Students will be able to:

1. Compare basic characteristics and ratings of various power electronic devices.
2. Use controlled rectifiers with different loads for various applications.
3. Implement Inverters & choppers with various techniques on different loads.
4. Explain working of electric drives, various motors and study their characteristics
5. Describe the working principle of DC drives.
6. Illustrate working of AC drives.

Module	Contents	Hours	CO mapping
	Prerequisite: Knowledge of Faraday's laws, Lenz's law. Semiconductor devices such as diodes and transistors and their characteristics.		
1.	**Power Electronic Devices:** Basic operation of silicon controlled rectifier, Static characteristics, two transistor analogy, Dynamic characteristics, Firing circuits (R,RC, Ramp triggering using UJT), Commutation circuits, Protection circuit of SCR. Other devices of Thyristor family: Basic operation and characteristics of DIAC, TRIAC, GTO, UJT, PUT, SUS, SBS, SCS, LASCR, Power diodes, power BJTs, power MOSFETs, IGBTs, Safe Operation Area (SOA) for each devices, Silicon Carbide (SiC) and GaN devices, Comparison of devices, selection of devices for various applications, Conduction and switching losses.	**07**	**CO1**
2.	**Controlled Rectifiers:** Basic working principle and applications Single phase half wave rectifiers, full wave rectifiers (mid-point and bridge configuration) for R and R-L load, freewheel diode, Rectification and inversion mode of single phase fully controlled rectifier, single phase dual converter, Three phase semi converter and full converter with R load, Applications, calculation of output voltage, single phase PWM rectifier, Selection of converter circuit.	**07**	**CO2**
3.	**Inverter:** Classification based on source and power level, Series and Parallel Inverter, CSI and VSI Inverter, Comparison of VSI and CSI, PWM techniques Converters: Introduction, switching mode regulators – Buck, Boost, Buck-Boost, Cycloconverter. Choppers: Introduction, Basic chopper operation and its classification, Step up and Step down Chopper, Jone's Chopper, Morgan's Chopper	**08**	**CO3**

4.	**Basics of Electric Drives** Introduction, Advantages of Electrical Drives, Parts of Electrical Drives, Introduction of drive system, structure of drive system, Necessity of drive system, different types of drive system. Electrical Actuation System: Solenoids, D.C. motors and its characteristics, A.C. motors and its characteristics, Stepper motors, Servomotors (AC and DC), stepper motors, BLDC and its characteristics, Permanent Magnet Synchronous Motor (PMSM)	**08**	**CO4**
5.	**DC Drives** DC Drive Operation: Introduction to Four quadrant operation – Motoring, Plugging, Dynamic and Regenerative Braking. Control of DC Drive by phase controlled converter: Speed control of DC drives, 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, Continuous current operation, Output voltage and current wave forms, Speed torque expressions, speed torque characteristics.	**06**	**CO5**
6.	**AC Drives:** Induction Motor Characteristics, Current Source Inverter fed Induction motor drive, Speed control methods: Stator voltage, Variable frequency, Rotor resistance, V/F control, PWM Control, Closed-loop control.	**03**	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

Theory Examination

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. P.S. Bhimbra, Power Electronics, Khanna publishers, 2004
2. M. H. Rashid, Handbook of Power Electronics, 2nd Edition, PHI, 2005.
3. M.D. Singh, Khanchandani, Power Electronics, Tata Mcgraw-Hill Education.
4. Nagrath I.J., Kothari D.P., Electrical Machines, second edition, Tata McGraw Hill, New Delhi.
5. B. L. Theraja, Fundamentals of Electrical & Electronics, S.Chand, Technical.
6. V.K. Mehta, Rohit Mehta, Principles of Electrical Engg. & Electronics, S.Chand
7. G. K. Dubey, Fundamentals of Electrical Drives,Narosa Publication.
8. S. K. Pillai, First Course on Electrical Drives, New Age International.

Reference Books:

1. Say M. G.,The performance & Design of Alternating Current Machines, 3rd edition, Oxford University
2. P.C. Sen, Power Electronics, Tata McGraw Hill, 2005
3. Mohan Undeland Robbins, Power Electronics- Converters application & Design, Wiley Eastern,1996
4. Dubey, Dorald, Thyristorised Power Controller, Wiley Eastern Ltd.1993

5. S.K. Bhattacharya, Industrial Electronics & Control, TATA McGraw Hill, 2007
6. Bose, Modern power Electronics & AC Drives Pearson Education Inc.2002
7. NPTEL Lectures.

Course Code	Course Name	Credits
ARC502	Industrial Processes	03

Objectives:

1. To make the students familiar with various Manufacturing Production Processes.
2. To make the students familiar with various industrial processes.
3. To give them an overview of hazardous materials, areas and their classification.

Outcomes: Learner will be able to…

1. Illustrate working principles and applications Manufacturing Processes and Identify Metal Working Processes.
2. Develop of various Machine Tools, Machining Processes.
3. Identify joining processes.
4. Explain heating process working of heat exchanger,evaporators and boilers
5. Elaborate heat and mass transfer process and working of distillation, dryers and reactors.
6. Classify hazardous areas in the industry.

Module	Detailed Contents	Hrs.	CO mapping
1.	**BASIC MANUFACTURING AND METALWORKING PROCESSES** Casting -Scope, Pattern, Pattern Allowances, Solidification, Gating and Risering, Sand Mould, Permanent Mould, Cold and Hot Chamber Die Casting, Shell Moulding, Investment Casting and Centrifugal Casting, Casting Defects and Remedies. Introduction to nondestructive testing. Fundamentals of Forming, Hot & Cold Working Processes, Rolling, Extension, Wire Drawing, Extrusion: Classification, Advantages, Limitations and applications Classification of Sheet metal operations, types of Presses used in sheet metal operations, types of dies.	**08**	**CO1**
2.	**MACHINE TOOLS, MACHINING PROCESSES** Lathe Machines, Milling Machines, Drilling Machines, and Grinding Machines and selection of grinding wheels(Dressing and Truing), Broaching machines, Lapping/Honing machines (Super Finishing Operations) and shaping/slotting/planning Machines. Nomenclature of single point cutting tool, Speed, feed, depth of cut, Taylor's tool life equation, Mechanics of orthogonal and oblique Cutting-Mechanics of chip Formation-Types of chips, theory of metal Cutting forces and power. Economical metal cutting, Cutting tools material & Cutting fluids.	**06**	**CO2**
3.	**JOINING PROCESSES** Classification of joining processes; Arc Welding – SMAW, GTAW, GMAW, FCAW, Submerged arc welding, etc. Resistance welding – theory, Spot, Seam, Projection welding processes etc., Gas welding. Thermit welding, Friction welding, Ultrasonic welding, Electron beam and Laser welding. Defects in welding, their cause and remedy, weldability, welding of dissimilar metals. NDT and other methods of testing welded joints. Soldering and Brazing applications.	**06**	**CO3**
4.	**Heat Transfer Processes and equipments** **Heat Exchangers:** process flow sheet symbols of heater, cooler, condenser, reboiler, classification as per fluid flow arrangement- concurrent and countercurrent and mixed type,and as per construction- double-pipe, shell and tube, plate type, finned type.	**07**	**CO4**

	Evaporator: evaporation process, terminologies:boiling point rise,economy, capacity, single and multi effect evaporators, types of evaporator: Horizontal-tube evaporators, Forced-circulation evaporators,short-tube and long vertical evaporators. **Boilers:** steam generation process, construction and types -water tube and fired tube boilers, safety interlocks, Shrink and swell effect and excess oxygen, boiler efficiency.		
5.	**Heat and Mass Transfer Processes and equipments:** **Distillation :** Basic principle, Distillation equipment and its accessories. Batch and continuous distillation, Binary product distillation, multi-product distillation, Vacuum distillation. **Dryer:** Process of drying, drying rate curve, types of dryer- Tray, fluidized bed, rotary and spray dryer, vacuum dryer **Reactor:** Reactor characteristics, runaway reaction and types of reactors- continuous and batch reactors.	**06**	**CO5**
6.	**Hazardous area classification** Area and material classification as per IEC and NEC standard, techniques used to reduce explosion hazards, intrinsic safety, and installation of intrinsically safe systems.	**06**	**CO6**

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). Duration of each test shall be one hour.

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. Question1 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.

Text Books:

1. Curtis D. Johnson, "Process Control Instrumentation Technology", PHI /Pearson Education 2002
2. George Stephanopoulos, "Chemical process control", PHI-1999
3. Fieldbus and Networking in Process Automation:- Sunit Kumar Sen
4. Lawrence M Thompson, Industrial Data Communication, 2nd edition , 1997.
5. D. A. Neamen, Micro Electronic Circuit Analysis and Design, McGraw-Hill, New Delhi, 2010
6. Elements of workshop technology. Vol. 1 & II by S K Hajra Choudhury
7. Manufacturing Science by Ghosh and Malik
8. Production Technology by P C Sharma.
9. Welding technology by O P Khanna

References:

1. Workshop technology Vol-. I, II & III by Chapman, Edward Arnold Education.
2. Manufacturing technology – Serope Kalpak Jian & Steven R. Schmid Pearson.
3. Production Technology – R. K. Jain Khanna publications.
4. Manufacturing technology – HMT.
5. Bela G. Liptak, "Instrument Engineer"s HandBook – Process Control", Chilton Company, 3rdEdition,1995.
6. Andrew S. Tanenbaum, Computer Networks, 4th edition, PHI/Pearson Education,2002.

7. Behrouz A. Forouzan, Data Communications and Networking, 2nd update edition, Tata McGraw

Links for online NPTEL / SWAYAM courses:

1. https://nptel.ac.in/courses/112107144

Course Code	Course Name	Credits
ARC503	Robot Kinematics and Dynamics	03

Objectives:

1. To introduce types of mechanisms for various robotic applications.
2. To get knowledge about basic Geometrical and Algebraic approach to solve forward kinematics of serial manipulator
3. To get knowledge about advanced forward kinematics of serial manipulators.
4. To get knowledge about inverse kinematics of various serial manipulators.
5. To get knowledge about design of robot manipulators based on dynamic analysis

Outcomes: Learner will be able to…

1. Select the type of mechanism for the robotic applications
2. Evaluate forward kinematic model for planar and spatial robot manipulator.
3. Evaluate forward kinematic model for multi-DOF robot manipulators.
4. Evaluate inverse kinematic model for multi-DOF robot manipulators.
5. Apply design procedure for mechanical grippers depending upon their types and mechanism.
6. Design of robot manipulators based on dynamic analysis

Module	Detailed Contents	Hrs.	CO mapping
1.	**Robot Mechanisms** kinematic Link, Types of links, Kinematics pair, Types of constrained motion, Classification of Kinematics pairs, Kinematics chain, Degrees of freedom of mechanisms, Inversion of mechanism, Analysis of mechanisms such as Gear trains, cams and followers, belt drives, four bar mechanism, slider crank mechanism etc.	06	CO1
2.	**FORWARD KINEMATICS - GEOMETRICAL AND ALGEBRAIC APPROACH** Need for forward and Inverse Kinematics Equation – Parameters in Design and Control – Methods of forward and inverse kinematics- Geometrical and Algebraic Approach in Forward Kinematics Solution, 1 DOF - 2 DOF Planar Robot (2P and 2R); 3DOF 2RP Spatial Robot.	06	CO2
3.	**FORWARD KINEMATIC MODELING – DENAVIT-HARTEBERG (DH) APPROACH** Unit Circle Trigonometry - Translation Matrix - Rotation matrix, Euler Angles - Quaternion Fundamental - Dot and Cross Products - Frames and Joint Coordinates - Homogeneous Transformation - D-H and Modified D-H Convention and Procedures – Forward kinematics Solution using D-H Convention: 3 DOF wrist, RR Planar, 3 DOF RRP, Cartesian, Cylindrical, Spherical, SCARA and Articulated 3 DOF robots - 3 DOF robot with wrist.	06	CO3
4.	**INVERSE KINEMATICS MODELING** Introduction to inverse kinematics -Issues in inverse kinematics - Inverse kinematics of 2 DOF Planar robot - 2 and 3 DOF planar and Spatial robot - Tool configuration - Inverse kinematics of 3 axis robot and 6 axis Robot - Inverse kinematics Computation- Closed loop solution	07	CO4

5.	**Robot end effectors:** Types of end effectors, mechanical grippers, vacuum grippers, magnetic grippers, adhesive grippers, tools. force analysis, the robot end effectors interface, considerations in gripper selection and design. **Robot Arm Dynamics** Robot dynamics – Rigid body dynamics, Newton-Euler formation, Lagrange-Euler, formation, generalized D'Alembert equations of motion.	**07**	**CO5**
6.	**Balancing and Vibrations** Static and Dynamic balancing, balancing of revolving and reciprocating masses, Balancing machines, free vibrations, Equations of motion, natural Frequency, Damped Vibration, bending critical speed of the simple shaft.	**07**	**CO6**

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). Duration of each test shall be one hour.

End Semester Examination: Weightage of each module in end semester examination will be proportional to number of respective lecture hours mentioned in the curriculum. Question paper will comprise of total six questions, each carrying 20 marks. Question 1 will be compulsory and should cover maximum contents of the curriculum. 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. Only Four questions need to be solved.

TEXT BOOKS:

1. Mikell P. Groover, "Industrial Robotics", McGraw Hill, 2nd edition, 2012.
2. John J. Craig, "Introduction to Robotics", 3rd Edition, Addison Wesley, ISE 2008.
3. Lynch, Kevin M., and Frank C. Park. Modern Robotics: Mechanics, Planning, and Control 1st ed. Cambridge University Press, 2017.

REFERENCES:

1. S K Saha, Introduction to Robotics, Tata McGraw-Hill, Second Edition, 2017.
2. Mikell P. Groover, "Industrial Robotics", McGraw Hill, 2nd edition, 2017.
3. Arthor Critchlow, "Introduction to Robotics", 1st edition, Macmillan, 2009.
4. Mohsen Shahinpoor, "A Robot Engineering Text Book", 1st edition, Harper and Row, 2004.
5. Deb S.R., "Robotics Technology and Flexible Automation", 2nd edition, Tata McGraw - Hill Publis Robotics: Control and Programming.
6. J. Srinivas, R. V. Dukkipati, K., "Robotics: Control and Programming", Narosa Publishing House, 2009.
7. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd., 2001 8. Bijay K. Ghosh, Ning Xi, T.J. Tarn, Control in Robotics and Automation Sensor - Based integration, Academic Press, 1999.
8. Hartenberg and Denavit, "Kinematics and Synthesis of Linkages", McGraw Hill Book Co.
9. J. E. Shigley and J.J.Uicker Jr., Theory of Machines and Mechanism, McGraw Hill [ISBN019515598X]
10. G K Grover', "Mechanical Vibration", Nemchand and brothers. [ISBN8185240752]
11. S. S. Ratan , Theory of Machines, Tata McGraw Hill [ISBN0070591202]
12. Yoram Koren, "Robotics for Engineers", McGraw Hill Book Co.
13. Groover M.P., Weiss M., Nagel R.N., Odrey N.G., "Industrial Robotics Technology-Programming and Applications", McGraw Hill Book Co

Course Code	Course Name	Credits
ARC504	**Digital Signal Processing**	**03**

Course Objectives:

1. To make conversant with the fundamentals of digital signal processing
2. To familiarise with the transforms used in Digital Signal Processing
3. To familiarise with the design techniques and performance analysis of digital filters
4. To introduce digital signal processors and applications

Course Outcomes: Learner will be able to:

1. Apply the concept of DT Signal and DT Systems.
2. Classify and analyse discrete time signals and systems.
3. Implement Digital Signal Transform techniques DTFT, DFT and FFT.
4. Design IIR digital filters to meet arbitrary specifications and Develop algorithms for implementation.
5. Design FIR digital filters to meet arbitrary specifications and Develop algorithms for implementation.
6. Use signal processing techniques and digital signal processors in various applications.

Module	Detailed Contents	Hrs.	CO mapping
1	**Discrete-Time Signal and Discrete-Time Systems** Introduction to Digital Signal Processing, Sampling and Reconstruction, Standard DT Signals, Concept of Digital Frequency, Representation of DT signal using Standard DT Signals, Signal Manipulations-shifting, reversal, scaling, addition, multiplication. Classification of Discrete-Time Signals, Classification of Discrete-Systems, LTI system, Impulse Response. Linear Convolution, Circular Convolution- Emphasis on graphical method, linear convolution using Circular Convolution. Software simulation - Impulse Response, Step Response, convolution, Correlation.	**08**	**CO1**
2	**Frequency Domain Analysis using DTFT and Z Transform** Introduction to DTFT. Properties of DTFT. Z transform - definition, properties of unilateral and bilateral Z Transform, Z transform of standard signals, ROC, poles and zeros of transfer function, Inverse Z transform. Analysis and characterization of LTI system using Z transform, impulse and step response, causality, stability, stability of causal system	**07**	**CO2**
3	**Discrete Fourier Transform and Fast Fourier Transform** DFT, Relation between DFT and DTFT, IDFT. Properties of DFT, circular convolution of sequences using DFT. Fast Fourier transforms (FFT), Radix-2 decimation in time and decimation in frequency FFT algorithms, inverse FFT.	**06**	**CO3**
4	**IIR Digital Filters** Comparison of IIR and FIR filters, Types of IIR Filters, Analog filter approximations: Butterworth, Chebyshev I and II.	**09**	**CO4**

	Mapping of S-plane to Z-plane, impulse invariance method, bilinear transformation method, Design of IIR digital filters from analog filters with examples, Software simulation – Design of IIR Filters. Analog and digital frequency transformations.		
5	**FIR Digital Filters** Characteristics of FIR digital filters, Minimum Phase, Maximum Phase, Mixed Phase and Linear Phase Filters Frequency response, location of the zero of linear phase FIR filters. Design of FIR filters using window techniques -Rectangular, Hamming, Hanning, Blackman, Bartlett, Software simulation – Design of FIR Filters.	**05**	**CO5**
6	**DSP Processors and Applications** General purpose digital signal processors, DSP processor architecture, Selecting digital signal processors, Special purpose DSP hardware. Applications of DSP: Radar Signal Processing and Speech Processing.	**04**	**CO6**

Assessment:

Internal Assessment for 20marks: 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 TestI). Duration of each test shall be one hour.

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 1will 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 module3)
4. Only Four questions need to be solved.

Text Books

1. Emmanuel C. Ifeachor, Barrie W. Jervis, “Digital Signal Processing”, A Practical Approach by, Pearson Education – Second edition
2. Tarun Kumar Rawat, “Digital Signal Processing”, Oxford University Press, 2015
3. S Salivahanan, A Vallavaraj, C Gnanapriya. “Digital Signal Processing” – TMH, 2007

References:

1. Proakis J., Manolakis D., "Digital Signal Processing", 4th Edition, Pearson Education
2. Sanjit K. Mitra, “Digital Signal Processing – A Computer Based Approach”, edition 4e McGraw Hill Education (India) Private Limited.

Course Code	Course Name	Credits
ARDLO5011	Data Structures and Algorithms	03

Course Objectives

1. To improve the logical ability
2. To teach efficient storage mechanisms of data for an easy access.
3. To design and implementation of various basic and advanced data structures and algorithm analysis.
4. To introduce various techniques for representation and analysis of the data in the real world.
5. To develop application using data structures and algorithm and analysis.
6. To teach the concept of protection and management of data.

Course Outcomes

Student will be able to:

1. Choose appropriate data structure as applied to specified problem definition and analyse the algorithm.
2. Handle operations like searching, insertion, deletion, traversing mechanism etc. on various data structures and algorithm analysis.
3. Apply concepts learned in various domains like DBMS, compiler construction etc.
4. Use linear and non-linear data structures like stacks, queues, linked list etc
5. Assess different sorting algorithms and select depending on application
6. Apply graph algorithms to solve real-world challenges

Module	Contents	Hrs.	CO mapping
1	**Introduction:** Introduction, Mathematics Review, Exponents, Logarithms, Series, Modular Arithmetic, The P Word, A Brief Introduction to Recursion, Recursion and Induction. Algorithm Analysis: Mathematical Background, Model, What to Analyse, Running Time Calculations, General Rules, Solutions for the Maximum Subsequence Sum Problem, Logarithms in the Running Time, Euclid's Algorithm, Exponentiation, Checking Your Analysis, A Grain of Salt.	6	CO1
2	**Stacks, Queues and List:** Stacks, Queues, Linked Lists, Double-ended Queues. Abstract Data Type (ADT), The List ADT, Simple Array Implementation of Lists, Linked Lists, Programming Details, Common Errors, Doubly Linked Lists, Circularly Linked Lists, Examples, Cursor Implementation of Linked Lists, The Stack ADT, Implementation of Stacks, Applications, The Queue ADT, Array Implementation of Queues, Applications of Queues.	9	CO2
3	**Trees and Search Trees:** Tree, Implementation of Trees, Tree Traversals with an Application, Binary Trees,Expression Trees, the Search Tree ADT-Binary Search Trees, AVL Trees, SingleRotation, Double Rotation, Red-Black Trees, External searching in B-Trees, Tree Traversals, B-Trees	9	CO3

4	**Priority queues:** The priority queues Abstract data Type, Implementing a Priority queues with a List, Heaps, Adaptable priority queues.	4	**CO4**
5	**Sorting Sets, and Selection:** Insertion Sort, Shellsort, Heapsort, Quicksort, Bucket Sort, Merge Sort and radix Sort, and A Lower Bound on comparison-based Sorting and radix Sort, the complexity of some sorting algorithms, comparison of Sorting Algorithms, The Set ADT and union / file Structures	4	**CO5**
6	**Graphs:** The graph Abstract Data Type, Data Structures for Graphs, Graph Traversals,Directed Graphs, Weighted Graphs, Shortest Paths, and Minimum spanning Trees. Applications of DFS and BSF, Shortest-Path Algorithms, Dijkstra's Algorithm,Graphs with Negative Edge Costs, Acyclic Graphs, Network Flow Problems,Minimum Spanning Tree	7	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on Minimum 02 Modules) and the other is either a class test or assignment on live problems or Course project.

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Mark Allien Weiss, “Data Structure and Algorithm Analysis in C”, Person.
2. Micheal Goodrict, Roberto Tamassia,” Data Structure and Algorithm in C++”, Wiley India
3. Data Structures A Psedocode Approach with C, Richard F. Gilberg & Behrouz A. Forouzan, second edition, CENGAGE Learning.
4. Data Structures Using C & C++, Rajesh K. Shukla, Wiley- India
5. Data Structures using C, Reema Thareja, Oxford University press.
6. Introduction to Data Structure and its Applications Jean-Paul Tremblay, P. G. Sorenson

Reference Books:

1. Ellis horowitz, Sarataj Sahni, S.Rajsekaran,” Fundamentals of computer algorithm”, University Press .
2. Mark Allen Weiss,”Data Structure & algorithm Analysis in C++”, 3rd Edition, Pearson Education
3. Data Structures Using C, ISRD Group, Second Edition, Tata McGraw-Hill
4. Data Structure Using C, Balagurusamy
5. C & Data Structures, Prof. P.S. Deshpande, Prof. O.G. Kakde, Dreamtech press.
6. Data Structures, Adapted by: GAV PAI, Schaum’s Outlines.

Course Code	Course Name	Credits
ARDLO5012	**Optimization Techniques**	**03**

Course Objectives

1. To Understand the need and origin of the optimization methods.
2. To understand various linear, nonlinear and other optimization techniques.
3. To understand various multi criterion and multi-objective decision making methods.
4. To understand recent tools in optimization

Course Outcomes

Students would be able ……

1. Identify the types of optimization problems and apply the calculus method to single variable problems.
2. Formulate the problem as Linear Programming problem and analyse the sensitivity of a decision variable.
3. Apply various linear and non-linear techniques for problem solving in various domain.
4. Apply multi-objective decision making methods for problem in manufacturing environment and other domain.
5. Apply multi criterion decision making methods for problem in manufacturing environment and other domain.
6. Apply Design of Experiments method for Optimization.

Module	Contents	Hrs.	CO mapping
1	Basic Concepts: Statement of the Optimization Problem, Basic Definitions, Optimality Criteria for Unconstrained Optimization, Optimality Criteria for Constrained Optimization, Engineering Application of Optimization, Classification of Optimization Problems. Classical Optimization Techniques: Single variable optimization.	**06**	**CO1**
2	Linear Programming Problem: Formulation, Simplex method, Big M Method, Two Phase, Primal to Dual, Dual Simplex method, Sensitivity Analysis and applications of LP Transportation and Assignment Models.	**08**	**CO2**
3	Integer Programming Model: Gomory's cutting plane method, Branch & Bound Technique. Non L.P. Model: Lagrangian method & Kuhn tucker Method, Newton's method. Discrete Event Simulation: Generation of Random Variable, Simulation Processes, Monte-Carlo Technique.	**08**	**CO3**
4	Multi Objective Decision making (MODM) Methods: Introduction to Multi objective optimization, Traditional Techniques such as, quadratic programming, geometric programming, Numerical on goal programming and dynamic programming. Introduction to Non-traditional optimization Techniques such as Genetic Algorithm, particle swarm, genetic algorithms, simulated annealing and Techniques based on Neural network & Fuzziness **(Only concepts)**	**08**	**CO4**
5	Multi Criterion Decision-making (MCDM) Methods: Introduction to multi criterion optimization, Simple Additive Weighting (SAW) Method Weighted Product Method (WPM), Analytic Network Process (ANP) Analytic Hierarchy Process (AHP) Method, TOPSIS Method PROMETHEE	**06**	**CO5**

6	Robust Design Methods: DOE and Taguchi techniques Full Factorial Design: The basics of "full factorials", ANOVA, Factorial effects and plots, and Model evaluation Fractional Factorial Design: The one-half fraction and one-quarter of the 2*k* design, The general 2*k-p* fractional factorial design Application of related software (Minitab, Design Expert or MATLAB)	**08**	**CO6**

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 content 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**.

Text/Reference Books:

1. S.S. Rao, "Engineering Optimization - Theory and Practice", John Wiley and Sons Inc.
2. Ranjan Ganguli, "Engineering Optimization - A Modern Approach" Universities Press
3. Pablo Pedregal, "Introduction to Optimization", Springer
4. L.C. Jhamb, "Quantitative Techniques Vol. 1 and 2", Everest Pub. House
5. Pierre D.A., "Optimization, Theory with Application", John Wiley & sons.
6. R V Rao, “Decision Making in the Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making” (Springer Publication).
7. Ritter, H., Martinetz, T., &Schulten, K., Addison,“Neural Computation and Self-Organizing Maps”-Wesley Publishing Company
8. Douglas C.Montgomery,“Design and analysis of experiments”(John Wiley & Sons Inc.)
9. Saravanan R,“Manufacturing Optimization through Intelligent Techniques”, Taylor & Francis (CRC Press)-2006.

Links for online NPTEL/SWAYAM courses:

https://nptel.ac.in/courses/112/101/112101298/ - Optimization from Fundamentals, IIT Bombay

Course Code	Course Name	Credits
ARDLO5013	Advanced Sensors	03

Course Objectives:

1. To expose the students to the concepts of smart sensors and micro sensors.
2. To provide sufficient knowledge about the sensor fabrication.
3. To create awareness about the various application fields of smart sensors.

Course Outcomes: The students will be able to -

1. Explain the various principles employed in transducers.
2. Examine the methods of fabricating a sensor.
3. Apply knowledge in designing smart sensors.
4. Discuss the techniques of fabrication and application of MEMS.
5. Describe the various applications of smart sensors.
6. Discuss advanced sensing technology.

Prerequisite: Fundamentals of transducers

Module	Content	Hrs	CO Mapping
1	**Review of Fundamental of Sensors:** Principle of physical and chemical transduction, sensor classification, characterization of mechanical, electrical, optical, thermal, magnetic, chemical and biological sensors, their calibration and determination of characteristics	**07**	**CO1**
2	**Sensor Fabrication**: Design considerations and selection criterion as per standards, Sensor fabrication techniques, process details and latest trends in sensor fabrication. Thick film sensing and system design.	**06**	**CO2**
3	**Smart Sensors:** Smart sensor basics, signal conditioning and A/D conversion for sensors, examples of available ICs (DHT, Smart analog IC 500, ADXL345) and their applications.	**07**	**CO3**
4	**Micro Sensors:** Introduction, Intrinsic characteristics of MEMS, common fabrication techniques, application of MEMS in sensing systems including pressure sensors, accelerometers, gyroscopes and strain gauges.	**06**	**CO4**
5	**Advanced Sensor Applications:** Temperature & Humidity measurement using DHT Sensor in environment monitoring, Acceleration measurement using ADXL345 for automotive industry, MEMS Temperature sensors for automotive applications, MEMS chemical sensors for survey meters, MEMS pressure sensors for medical applications	**07**	**CO5**

6	**Advanced Sensing Technology:** Sensors, instruments and measurement techniques for emerging application areas such as environmental measurement like DO (dissolves oxygen),BOD (biological oxygen demand), COD (chemical oxygen demand), TOC (total organic carbon), Cox (carbon dioxides), NOx (nitrogen oxide), for navigation and inertial measurements, for agricultural measurements such as soil moisture, wind speed, leaf wetness duration, sensors for food processing like smell or odour,taste.	**06**	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No.1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Chang Liu, Foundations of MEMS, Pearson Education Inc.,2012.
2. Stephen D Senturia, Microsystem Design, Springer Publication,2000.
3. Tai Ran Hsu, MEMS & Micro systems Design and Manufacture, Tata Mc Graw Hill, New Delhi,2002.
4. Jacob Fraden, Handbook of Modern Sensors, 5th Edition, Springer .
5. S. M. Sze, Semiconductor Sensors, Wiley
6. M J Usher, Sensors and Transducers, MacMillan,1985.

References:

1. Nadim Maluf, "An Introduction to Micro Electro Mechanical System Design", Artech House, 2000.
2. Mohamed Gad-el-Hak, editor, The MEMS Handbook, CRC press Baco Raton,2001.
3. Julian w. Gardner, Vijay K. Varadan, Osama O.Awadelkarim, Micro Sensors MEMS and Smart Devices, John Wiley & Son LTD,2002.
4. James J.Allen, Micro Electro Mechanical System Design, CRC Press Publisher,2005.
5. Thomas M. Adams and Richard A.Layton, Introduction to MEMS, Fabrication and Application, Springer,2010.

Course Code	Course Name	Credits
ARDLO5014	Analytical Instrumentation	03

Course objectives

. 1. Introduce the basic concept of qualitative and quantitative analysis of a given sample.
2. Study various spectroscopic techniques and its instrumentation.
3. Study the concept of separation science and its applications.
4. Study the concept of radiochemical analysis along with industrial analyzers.

Course Outcomes

The students will be able to:

1. Define and explain various fundamentals of spectroscopy, qualitative and quantitative analysis.
2. Discuss the terms, principle, instrumentation, operation and applications of Molecular spectroscopic techniques.
3. Differentiate between principle, instrumentation and operation of Atomic absorption and emission Spectroscopy.
4. Explain the various Separation techniques and its instrumentation.
5. Describe the principle and working of various Radiation detectors.
6. Discuss the principle and working of various Gas analyzers.

Details of Syllabus:

Prerequisite: Knowledge of sensors and analog electronic circuits.

Module	Content	Hrs	CO Mapping
1	**Introduction:** Introduction to analytical Instrumentation. Fundamentals of Spectroscopy: Nature of Electromagnetic Radiation, Electromagnetic spectrum, Beer Lambert's Law statement and derivation. Deviations from Beer's law. Numerical on EMR and laws of photometry. Interaction of radiation with matter. Instrumentation of spectroscopic analytical system – Radiation sources,Wavelength selectors, Detectors, signal processors and readout modules. Scintillation detector	9	CO1
2	**Molecular Spectroscopy:** Molecular Energy levels, correlation of energy levels with transitions. **Electronic transitions and Vibrational transitions –** Introduction to UV-VIS molecular spectroscopy – basics of single beam, double beam spectrophotometer and filter photometer, its instrumentation and applications. Basic principle,components and instrumentation of Fluorimeters, Phosphorimeters and Raman spectrometers.	9	CO2
3	**Molecular Spectroscopy – Nuclear/Rotational transitions** – Nuclear Magnetic Resonance (NMR) spectroscopy, basic principle and numerical problems based on NMR principle, instrumentation and constructional details of NMR Spectrometer. **Electron Spin Resonance (ESR) Spectroscopy** – Basic principle and construction of ESR spectrometer.	4	CO3

4	**Atomic Spectroscopy:** Atomic Energy levels, Atomic absorption spectrometers- components, working and absorption spectra. Atomic Emission spectrometers – components, working and emission spectra, comparison between AAS and AES.	**3**	**CO4**
5	**Separation Science:** **Chromatography:** Fundamentals of chromatographic Separations, Classification, Gas chromatographic system with components, factors affecting separation, applications. Analysis of Gas Chromatogram. HPLC – Its principle and instrumentation. **Mass Spectrometers:** Basic principle, components and types of mass spectrometers, sample handling techniques for liquids and solids, resolution and numerical problems based on resolution.	**9**	**CO5**
6	**Industrial Gas Analyzers:** Oxygen Analyzer, Combustion Gas Analyzers (COX, NOX, SOX, hydrocarbons), Gas density analyzer	**5**	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on minimum 02 Modules)

End Semester Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus where in sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective. Lecture hours as mentioned in the syllabus.

Text Books:

1. Willard, Merritt, Dean, Settle, Instrumental Methods of Analysis, CBS Publishers & Distributors, New Delhi, 7th Edition.
2. Khandpur R. S., Handbook of Analytical Instruments, Tata McGraw–Hill Publications, 3rd Edition.

Reference Books:

1. Skoog, Holler, Niemen, Thomson Principles of Instrumental Analysis, Books-Cole Publications, 5th Edition.
2. Ewing Galen W., Instrumental Methods of Chemical Analysis, McGraw-Hill Book Company, 5th Edition.
3. Braun Robert D., Introduction to Instrumental Analysis, McGraw-Hill Book Company.
4. Sherman R.E., Analytical Instrumentation, ISA Publication.
5. B. R. Bairi, Balvinder Singh, N.C.Rathod, P.V.Narurkar, Handbook nuclear medical Instruments, McGraw Hill Book Company.

Course Code	Course Name	Credits
ARL501	**Power Electronics and Drives & Digital Signal Processing Lab**	**01**

Course Objectives

1. To equip the students with the knowledge of semiconductor devices & their applications.
2. To learn the basic concept and characteristics of Electrical motors and their drives.
3. Study simulation software platform for digital signal processing and Plot different type of signals.
4. To understand the concept of linear, circular convolution, correlation and simulate it by computer software.
5. To understand Fourier transform and its algorithms such as FFT and IFFT and simulate it.
6. To design and implement filters both FIR and IIR using computer simulation..

Course Outcomes

Students will be able to:

1. Compare basic characteristics and ratings of power electronic devices.
2. Use controlled rectifiers, Inverters & choppers with different loads.
3. Illustrate working of AC & DC drives.
4. Demonstrate convolution and correlation concepts using simulation software.
5. Analyse frequency response of LTI systems using DTFT. Perform Discrete Fourier Transform of signals.
6. Design and implement FIR and IIR filters using computer simulation software platform.

List of Laboratory Experiments:

Sr. No	Detailed Contents	CO Mapping
01	Plot V-I characteristics of SCR.	**CO1**
02	Plot V-I characteristics of DIAC/TRIAC.	**CO1**
03	Plot V-I characteristics of IGBT	**CO1**
04	Half wave & full wave controlled rectifier.	**CO2**
05	SCR Based Inverter	**CO2**
06	Stepper Motor Control	**CO3**
07	BLDC Motor Control	**CO3**
08	DC Motor Control	**CO3**
09	Write a Program to implement Linear Convolution of the two given sequences.	**CO4**
10	Write a Program to obtain the auto-correlation and Cross-correlations of the given sequences.	**CO4**

11	Write a Program to obtain the circular convolution of the two given sequences.	**CO4**
12	Write a Program to obtain the linear convolution using circular convolution of two given sequences.	**CO4**
13	Write a Program to find the DFT of the given sequences. Plot its magnitude and phase plot. Also find its IDFT to obtain the original sequence.	**CO5**
14	Write a Program to obtain the DFT of the given sequences using DIT-FFT algorithm and plot its magnitude and phase spectrum.	**CO5**
15	Write a Program to design low-pass and high-pass FIR filters using window functions.	**CO6**
16	Write a Program to design a digital IIR low-pass filter using Butterworth/Chebyshev approximations.	**CO6**

Any other experiment based on syllabus which will help students to understand topic/concept.

Practical Oral Examination:

Oral examination will be based on entire syllabus.

Term Work:

Term work shall consist of minimum eight experiments and any two using software. The distribution of marks for term work shall be as follows:

Laboratory work (Experiments) : 10 Marks
Laboratory work (programs /journal) : 10 Marks
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.

Course Code	Course Name	Credits
ARL502	Industrial Processes Lab	01

Objectives:

1. To study the need Basic Manufacturing Processes.
2. To study various types cutting and joining operation
3. To make the students familiar with various industrial processes.
4. To give them an overview of hazardous materials, areas and their classification.
5. To study advanced Technologies in manufacturing processes

Outcomes: Learner will be able to…

1. Understand various safety instructions, measuring Instrutments and working instructions of Machine shop.
2. Illustrate working principles and applications Lathe Machine, Drilling Machine, Milling Machine Processes.
3. Explain the welding operation and use the various types Forging tools .
4. Explain heating process working of heat exchanger, evaporators and boilers.
5. Elaborate heat and mass transfer process and working of distillation, dryers and reactors.
6. Classify hazardous areas in the industry.

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List of Experiments:

Sr. No.	List of Experiments	CO Mapping
1.	Study of Safety & Working instruction in a Machine shop.	**CO1**
2.	Study of Measuring Instruments and cutting tools	**CO1**
3	Report on machining processes performed on lathe machines.	**CO2**
4.	One Job consisting of Plain and Taper Turning operations performed on mild steel, cylindrical components on lathe Machine.	**CO2**
5.	Report on machining processes performed on Drilling Machine	**CO2**
6	Fabrication of one simple job on Milling Machine	**CO2**
7.	Preparation of lap joint of GI sheet using Spot compressive Welding.	**CO3**
8.	Report on forging tools.	**CO3**
9.	Demonstrate the operation of Heat exchanger, evaporator, boilers.	**CO4**
10.	Assignments based on Heat transfer Processes and Equipments.	**CO4**
11.	Demonstrate the operation of distillation column, dryer, reactors.	**CO5**
12.	Assignments based on Heat and Mass transfer Processes and Equipments.	**CO5**
13.	Develop charts on hazardous area classification.	**CO6**
14.	Assignments based on Hazardous Area classification .	**CO6**

Any other experiment based on syllabus which will help students to understand the topic/concept. Chemical / Manufacturers Factory visit is advised to understand Equipment and controls as well as practical aspects of the subject.

Assessment:

Term work shall consist of minimum 04 experiments and 04 assignments.

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

Laboratory work (Experiments/assignments): 10 Marks

Laboratory work (journal): 10 Marks

Attendance : 05 Marks

End Semester Practical/Oral Examination:

Oral Examination will be based on experiments in the Laboratory as well as the theory syllabus.

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

Future Courses Mapping:

Mention other courses that can be taken after completion of this course

1. Advance Manufacturing and automation
2. Automation and Simulation
3. Composite & Nano Materials

Job Mapping:

What are the Job opportunities that one can get after learning this course?

1. Automation Engineer.
2. R & D Design & Development.

Course Code	Course Name	Credits
ARL503	Robot Kinematics and Dynamics Lab	01

Objectives:

1. To introduce types of mechanisms for various robotic applications.
2. To get knowledge about basic Geometrical and Algebraic approach to solve forward kinematics of serial manipulator
3. To get knowledge about advanced forward kinematics of serial manipulators.
4. To get knowledge about inverse kinematics of various serial manipulators.
5. To get knowledge about design of robot manipulators based on dynamic analysis

Outcomes: Learner will be able to…

1. Select the type of mechanism for the robotic applications
2. Explain and analyse the Coordinate frames, tranformations and Forward kinematics of robots
3. Explain & Analyse the Inverse kinematics of robots
4. Design of robot manipulators based on dynamic analysis
5. Measure the mass moment of inertia and balancing of masses of robotic links
6. Demonstrate understanding of fundamentals of industrial automation

List of Experiments: Minimum Eight experiments.

Sr. No.	List of Experiments	CO Mapping
1.	Computer program for analysis and synthesis of any mechanism and test it	**CO1**
2.	Determination of holding torque in epicyclic gear train.	**CO1**
3	Design of cams and followers	**CO1**
4.	Forward kinematics of robots using roboanalyzer	**CO2**
5.	Understanding coordinate frames and transformations using roboanalyzer	**CO2**
5.	Inverse kinematics of robots using roboanalyzer	**CO3**
6	Case Study: Kinematics of MTAB Mini Robot	**CO3**
7.	Inverse and Forward dynamics of robots using roboanalyzer	**CO4**
7.	Determination of mass moment of inertia and radius of gyration of robotic links.	**CO5**
8.	Experiment on balancing of mass	**CO5**
9.	Virtual Models of Industrial Robots using roboanalyzer	**C06**
10.	Industrial visit	**CO6**

Assessment:

Distribution of marks for term work

Laboratory work	20 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 15marks
b. Viva 10 marks

3. Evaluation of practical examination to be done based on the experiment performed and the output of the experiment during practical examination
4. Students work along with evaluation report to be preserved till the next examination

Virtual Labs

- http://ial-coep.vlabs.ac.in/ - Industrial Automation Laboratory, COEP.
- Visualization of DH (Denavit–Hartenberg) parameters in Roboanalyzer (*Roboanalyzer is free software developed by IIT Delhi, available on www.roboanalyzer.com).

Course code	Course Name	Credits
ARSBL501	Professional Communication and Ethics - II	02

Objectives:

Learners should be able to:

1. Discern and develop an effective style of writing important technical/business documents.
2. Investigate possible resources and plan a successful job campaign.
3. Understand the dynamics of professional communication in the form of group discussions, meetings, etc. required for career enhancement.
4. Develop creative and impactful presentation skills.
5. Analyse personal traits, interests, values, aptitudes and skills.
6. Understand the importance of integrity and develop a personal code of ethics.

Outcomes: Learners will be able to…

1. Plan and prepare effective business/ technical documents which will in turn provide solid foundation for their future managerial roles.
2. Strategize their personal and professional skills to build a professional image and meet the demands of the industry.
3. Emerge successful in group discussions, meetings and result-oriented agreeable solutions in group communication situations.
4. Deliver persuasive and professional presentations.
5. Develop creative thinking and interpersonal skills required for effective professional communication.
6. Apply codes of ethical conduct, personal integrity and norms of organizational behaviour.

MODULE	DETAILS	HOURS	CO Mapping
MODULE 1 - ADVANCED TECHNICAL WRITING: PROJECT/PROBLEM BASED LEARNING (PBL)			**CO1**
1.1. Purpose and Classification of Reports	**Classification on the basis of:** ● Subject Matter (Technology, Accounting, Finance, Marketing, etc.) ● Time Interval (Periodic, One-time, Special) ● Function (Informational, Analytical, etc.) ● Physical Factors (Memorandum, Letter, Short & Long)	06	
1.2. Parts of a Long Formal Report	● Prefatory Parts (Front Matter) ● Report Proper (Main Body) ● Appended Parts (Back Matter)		
1.3. Language and Style of	● Tense, Person & Voice of Reports ● Numbering Style of Chapters, Sections, Figures, Tables		

Reports	and Equations ● Referencing Styles in APA & MLA Format ● Proofreading through Plagiarism Checkers		
1.4. Definition, Purpose & Types of Proposal s	● Solicited (in conformance with RFP) & Unsolicited Proposals ● Types (Short and Long proposals)		
1.5. Parts of a Proposal	● Elements ● Scope and Limitations ● Conclusion		
1.6. Technical Paper Writing	● Parts of a Technical Paper (Abstract, Introduction, Research Methods, Findings and Analysis, Discussion, Limitations, Future Scope and References) ● Language and Formatting ● Referencing in IEEE Format		
MODULE 2 - EMPLOYMENT SKILLS			**CO2**
2.1. Cover Letter & Resume	● Parts and Content of a Cover Letter ● Difference between Bio-data, Resume & CV ● Essential Parts of a Resume ● Types of Resume (Chronological, Functional & Combination)	06	
2.2 Statement of Purpose	● Importance of SOP ● Tips for Writing an Effective SOP		
2.3 Verbal Aptitude Test	● Modelled on CAT, GRE, GMAT exams		
2.4. Group Discussions	● Purpose of a GD ● Parameters of Evaluating a GD ● Types of GDs (Normal, Case-based & Role Plays) ● GD Etiquettes		
2.5. Personal Interviews	● Planning and Preparation ● Types of Questions ● Types of Interviews (Structured, Stress, Behavioural, Problem Solving & Case-based) ● Modes of Interviews: Face-to-face (One-to one and Panel) Telephonic, Virtual		
MODULE 3 - BUSINESS MEETINGS			**CO3**
3.1. Conducting Business Meetings	● Types of Meetings ● Roles and Responsibilities of Chairperson, Secretary and Members ● Meeting Etiquette	02	
3.2. Documentation	● Notice ● Agenda ● Minutes		
MODULE 4 -TECHNICAL/ BUSINESS PRESENTATIONS			**CO4**

4.1. Effective Presentation Strategies	● Defining Purpose ● Analysing Audience, Location and Event ● Gathering, Selecting &Arranging Material ● Structuring a Presentation ● Making Effective Slides ● Types of Presentations Aids ● Closing a Presentation ● Platform Skills	02	
4.2 Group Presentations	● Sharing Responsibility in a Team ● Building the contents and visuals together ● Transition Phases		
MODULE 5 - INTERPERSONAL SKILLS			**CO5**
5.1. Interpersonal Skills	● Emotional Intelligence ● Leadership & Motivation ● Conflict Management & Negotiation ● Time Management ● Assertiveness ● Decision Making	08	
	●Financial Literacy ● Risk Assessment ● Data Analysis (e.g. Consumer Behaviour, Market Trends, etc.)		
MODULE 6 - CORPORATE ETHICS			**CO6**
6.1. Intellectual	● Copyrights ● Trademarks ● Patents ● Industrial Designs ● Geographical Indications ● Integrated Circuits ● Trade Secrets (Undisclosed Information)	02	
6.2. Case Studies	● Cases related to Business/ Corporate Ethics		

List of Assignments for Term work

(In the form of Short Notes, Questionnaire/ MCQ Test, Role Play, Case Study, Quiz, etc.)

1. Cover Letter and Resume
2. Short Proposal
3. Meeting Documentation
4. Writing a Technical Paper/ Analysing a Published Technical Paper
5. Writing a SOP
7. IPR
8. Interpersonal Skills
9. Aptitude test (Verbal Ability)

Note:

1. The Main Body of the project/book report should contain minimum 25 pages (excluding Front and Back matter).
2. The group size for the final report presentation should not be less than 5 students or exceed 7 students.
3. There will be an end–semester presentation based on the book report.

Guidelines for Internal Assessment

Term Work 25 Marks

Assignments 10 Marks
Attendance 05 Marks
Presentation slides 05 Marks
Book Report (hard copy) 05 Marks
Internal Oral - 25 Marks
Oral Examination will be based on a GD & the Project/Book Report presentation.
Group Discussion 10 Marks
Project presentation (Individual Presentation) 10 Marks
Group Dynamics 05 Marks

Suggested Reading

1. Arms, V. M. (2005). Humanities for the engineering curriculum: With selected chapters from Olsen/Huckin: Technical writing and professional communication, second edition. Boston, MA: McGraw-Hill.
2. Bovée, C. L., &Thill, J. V. (2021). Business communication today. Upper Saddle River, NJ: Pearson.
3. Butterfield, J. (2017). Verbal communication: Soft skills for a digital workplace. Boston, MA: Cengage Learning.
4. Masters, L. A., Wallace, H. R., & Harwood, L. (2011).Personal development for life and work. Mason: South-Western Cengage Learning.
5. Robbins, S. P., Judge, T. A., & Campbell, T. T. (2017). Organizational Behaviour. Harlow, England: Pearson.
6. Meenakshi Raman, Sangeeta Sharma (2004) Technical Communication, Principles and Practice. Oxford University Press
7. Archana Ram (2018) Place Mentor, Tests of Aptitude For Placement Readiness. Oxford University Press
8. Sanjay Kumar &PushpLata (2018). Communication Skills a workbook, New Delhi: Oxford University Press.

Virtual Labs

https://ve-iitg.vlabs.ac.in/- Virtual English and Communication Virtual Lab, IIT Guwahati
http://vlabs.iitb.ac.in/vlabs-dev/labs/communication/- Professional Communication Virtual Lab, IIT Bombay

Course code	Course Name	Credits
ARPBL501	Mini Project -III	02

Course 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.

Course Outcomes: 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. Analyze 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 lifelong learning.
9. Demonstrate project management principles during project work.

Guidelines for Mini Project

- Studentsshallformagroupof3to4students, 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.
- Student shall 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 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 & 2 in semester III and IV. Similarly, Mini Project 3 & 4 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 bead opted 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 logbook 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 finalization of problem
    - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of component's/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 finalization 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 skillsets
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 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 orresearchorganisationshavingexperienceofmorethanfiveyearsapproved 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 skillsets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

Course Code	Course Name	Credits
ARC601	Robotic Control system	03

Course Objectives

1. To make the students familiar with dynamic modeling of robots.
2. To make the students understand Nonlinear control of manipulators.
3. To make students understand Force control of manipulators.
4. To make the students understand Kinematic model of steered robot.
5. To make the students study Vision based control.
6. To make students understand PID control of single link manipulator and planar 2R manipulator.

Course Outcomes

On successful completion of the course, students will be able to -

1. Learn basic concepts in dynamic modeling of robots.
2. Understand and design Nonlinear control of manipulators.
3. Design Force control of manipulators
4. Analyse Kinematic model of steered robot and differentially driven mobile robot.
5. Understand Vision based control systems.
6. Design PID control of single link manipulator and planar 2R manipulator.

Module	Content	Hrs	CO Mapping
1	**Review of dynamic modelling of robots:** Introduction to robot control- Necessity of Controllers for Robots, typical block schematic closed loop and feed forward control. Linear control of manipulators - closed-loop control, second-order linear systems, control of second-order systems, control-law partitioning, trajectory-following control, Feedback control of single link manipulator, closed loop control of wall following robot- block schematic- sensor selection etc.	08	CO1
2	**Nonlinear Control of manipulators** PD Gravity Control, Computed Torque Control, adaptive control Task Space Control Schemes – resolved motion rate control and resolve motion acceleration control.	07	CO2
3	**Force control of manipulators** Introduction, application of industrial robots to assembly tasks, force control of a mass—spring system, the hybrid position/force control problem, the hybrid position/force control scheme.	06	CO3
4	**Kinematic model of steered robot and differentially driven mobile robot** Control of a mobile robot to move to a point, to follow a line, following a path, moving to a pose, Dynamic model of quad copter, Controller design to track any desired trajectory.	07	CO4
5	**Vision based Control** Configuration of a vision system, image segmentation, image interpretation, Pose estimation, Stereo vision, Camera Calibration, Position based visual servoing, Image based visual servoing, Hybrid visual servoing.	08	CO5
6	**Case study –**	03	CO6

	PID Control of single link manipulator and planar 2R manipulator, resolved motion rate control of 2R manipulator, force control of peg in whole assembly task, control of any industrial robot.		

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be a compulsory class test (on Minimum 02 Modules) and the other is either a class test or assignment on live problems or Course project.

Theory Examination:

1. Question paper will comprise 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on the entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question, paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Robotics and Control, R K Mittal, I J Nagrath
2. Nonlinear systems, Hassan K. Khalil, Pearson
3. Introduction to Robotics Mechanics and Control, John J. Craig, 3e, Pearson.
4. Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford
5. Robotics- Modelling planning and control- Bruno Siciliano , Lorenzo Sciavicco Luigi Villani, Giuseppe Oriolo, Springer-Verlag London.
6. Peter Corke, “Robotics, Vision and Control-Fundamental Algorithms in MATLAB”, Springer Tracts in Advanced Robotics, volume 73.
7. The Robotics Primer-Maja J Matari´c, The MIT Press

References:

1. Probabilistic Robotics: Sebastian Thrun, Wolfram Burgard, Dieter Fox, MIT Press
2. Modern Robotics Mechanics, Planning and Control, Kevin M. Lynch, Frank C. Park, Cambridge University Press, 2017.

Course Code	Course Name	Credits
ARC602	Process Instrumentation and control	03

Course Objectives

1. To make the students familiar with Process control Fundamentals.
2. To make the students understand control actions and controllers.
3. To make students understand various control schemes.
4. To make the students understand Heat transfer unit operations and control schemes.
5. To make the students understand Heat and Mass transfer unit operations and control schemes.
6. To make students understand Automation and control schemes in process industries.

Course Outcomes

On successful completion of the course, Students will be able to:

1. Learn basic concepts and fundamentals of Process control.
2. Analyse different process control actions and classify controllers like electronic, pneumatic and Hydraulic and their Tuning Techniques
3. Explain continuous and discrete control schemes
4. Describe control schemes of Heat transfer unit operations
5. Discuss control schemes of heat and mass transfer unit operations.
6. Explain Automation and control schemes in process industries.

Module	Contents	Hrs.	CO Mapping
1.	**Fundamentals of Process Control** Process Control Terminology, Development of Typical Process control loops like Pressure, Temperature, flow & Level. Process characteristics, control system parameters, Dynamic elements in a control loop, Dead time processes and smith predictor compensator.Inverse response behavior of processes and compensator. Dynamic Behavior of first and second order systems. Interacting and non-interacting systems.	**08**	**CO1**
2.	**Process control actions and Controllers** **Control actions** Types-Discontinuous,continuous (P, I, D) and composite control actions (PI, PD, and PID), Effects of control actions on control loop, selection criteria. **Controllers:** Need for controller, General features, specifications, classification working of Pneumatic and Electronic controllers. controller Tuning Methods-Process reaction curve, Ziegler-Nichols method.	**06**	**CO2**
3.	**Control schemes** Continuous process control : Feedback, Feed forward, cascade, Ratio, split range, selective control, inferential control, and selection Guidelines. **Discrete state process control** Need for Discrete state process control systems,Relay Logic symbols, Development of Relay ladder Logic diagram and case study examples.	**06**	**CO3**
4.	**Heat exchanger controls**: degrees of freedom, feedback, feed-forward, bypass control schemes. **Evaporator control**: steady state model, feedback, cascade, feed forward and selective control. **Boiler controls**- Drum level control- Single, two and three elements, and Combustion Control-Type 1, 2, 3 and 4, steam temperature control, boiler pressure control, furnace draft control.	**07**	**CO4**

5.	**Distillation column control strategies**- Top and bottom product composition controls-inferential and direct, Pressure controls, Vapors recompression, Feed controls- Column feed controls ,economizer. **Dryer control:** Process of drying, types and control strategies of dryer- Tray , fluidized bed, rotary and spray dryer. **Reactor control:** feedback, feed-forward, cascade schemes of temperature control of reactors.	**06**	**CO5**
6.	**Process Industries:** **Refinery Industry:** Process flow diagram, separation, conversion methods, sensors and control schemes. **Iron and steel Industry:** Process flow diagram, Sensors and Control schemes. Fertilizer Industry: Process flow diagram, sensors and control schemes. Overview of Effluent and sewage Treatment plant and its Automation.	**06**	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be a compulsory class test (on Minimum 02 Modules) and the other is either a class test or assignment on live problems or Course project.

Theory Examination:

1. Question paper will comprise 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on the entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question, paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Curtis D. Johnson, "Process Control Instrumentation Technology", PHI /Pearson Education 2002.
2. George Stephanopoulos, "Chemical process control", An introduction to theory and practice PHI-1999.

Reference Books:

1. Bela G. Liptak, "Instrument Engineer‟s HandBook – Process Control", Chilton Company, 3rdEdition,1995.
2. G. F. (Jerry) Gilman, "Boiler control system Engineering" Second Edition.

Course Code	Course Name	Credits
ARC603	Manufacturing using Computer Aided Design	03

Objectives:

1. To familiarize with basic concepts of computer graphics.
2. To acquaint with the process of using biomedical data for 3D modeling.
3. To study programming aspects of subtractive manufacturing process.
4. To familiarize with basic process of additive manufacturing in particularly 3D printing.

Outcomes: Learner will be able to…

1. Identify suitable computer graphics techniques for 3D modeling.
2. Transform, manipulate objects & store and manage data.
3. Develop 3D model using various types of available biomedical data.
4. Create the CAM Toolpath for specific given operations.
5. Build and create data for 3D printing of any given object using rapid prototyping and tooling processes.
6. Illustrate understanding of various cost-effective alternatives for manufacturing products.

Module	Detailed Contents	Hrs.	CO Mapping
1.	Computer Graphics 1.1 Introduction: Scope of CAD/CAM in product life cycle, CAD/CAM hardware and software, 2D and 3D computer graphics representation, Mapping of Geometric Models. 1.2 Parametric representation of curves and surfaces: Synthetic Curves - Bezier curves, Hermite Curves, B-spline curves. Surface representation. 1.3 Solid Modeling: Constructive solid geometry (CSG), Boundary Representation (BRep), Wire Frame Modeling, Solid Modeling, Surface Modeling, Parametric Modeling, Feature based modeling, Constraint Based Modeling.	**07**	**CO1**
2.	**Geometric Transformation** 2.1 Homogeneous Coordinate system, Matrix representation, Concatenations, 2D and 3D geometric transformation (Translation, Reflection, Scaling, Rotation)	**07**	**CO2**
3.	**Modeling based on Biomedical data** 3.1 Introduction to medical imaging: Computed tomography (CT), Cone beam CT (CBCT), Magnetic resonance (MR), Noncontact surface scanning, Medical scan data, Point cloud data 3.2 Working with medical scan data: Pixel data operations, Using CT data: a worked example, Point cloud data operations, Two-dimensional formats, Pseudo 3D formats, True 3D formats, File management and exchange	**06**	**CO3**
4.	**Subtractive Manufacturing** 4.1 Introduction: NC/CNC/DNC machines, Machining Centers, Coordinate system 4.2 CNC machining practices and programming: setup, and operation of two- and three axis. CNC machines programming using manual part programming method, Canned Cycles.	**07**	**CO4**

5.	**Additive Manufacturing** 5.1 Rapid Prototyping: Introduction, Classification of RP Processes, Advantages & disadvantages. RP Applications; in Design, Concept Models, Form & fit checking, Functional testing, CAD data verification, Rapid Tooling, and bio fabrication. 5.2 Working Principle, Application, Advantages & disadvantages: of Stereolithography Apparatus (SLA) Selective Laser Sintering (SLS), 3D Printing, Fused Deposition Modeling (FDM), and Laminated Object Manufacturing (LOM)	**07**	**CO5**
6.	**Virtual Manufacturing** 6.1 Virtual Manufacturing: Introduction, Scope, Socio-economic Aspects and Future Trends	**05**	**CO6**

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). Duration of each test shall be one hour.
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. CAD/ CAM, Theory & Practice, Ibrahim Zeid, R. Sivasubramanian, Tata McGraw Hill Publications
2. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications
3. CAD/CAM Computer Aided and Manufacturing, Mikell P. Groover and Emory W. Zimmers, Jr., Eastern Economy Edition
4. CNC Technology and Programming, Krar, S., and Gill, A., McGraw Hill Publishers.
5. 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.
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
8. Advanced Machining and Manufacturing Processes, Kaushik Kumar Divya Zindani, J. Paulo Davim, Springer International Publishing

Links for online NPTEL/SWAYAM courses:
1. https://nptel.ac.in/courses/112/102/112102101/
2. https://nptel.ac.in/courses/106/102/106102065/
3. https://nptel.ac.in/courses/106/102/106102065/
4. https://nptel.ac.in/courses/112/102/112102103/
5. https://nptel.ac.in/courses/112/105/112105211/
6. https://nptel.ac.in/courses/112/104/112104265/
7. https://www.youtube.com/watch?v=2cCMty9v3Tg
8. https://www.youtube.com/watch?v=2zPh26Q1BT8

Course Code	Course Name	Credits
ARC604	**Machine Learning**	**03**

Course Objectives

1. To familiarize student with basic concepts of Machine learning.
2. To provide understanding of the concepts of regression, classification, clustering and machine learning algorithms.
3. To introduce the students to various applications of Machine learning for industrial automation and robotics

Course Outcomes

On successful completion of the course, Students will be able to:

1. Introduce concepts of Artificial Intelligence and Machine learning
2. Explain statistical tools and development of model for ML.
3. Explain and analyze the various algorithms for Supervised learning
4. Explain and analyze the various algorithms for Unsupervised learning.
5. Explain and analyze the algorithms of Artificial NN.
6. Apply ML algorithms for industrial automation and robotics.

Module	Contents	Hrs.	CO Mapping
1.	**Introduction to Machine Learning:** Introduction to Artificial Intelligence, Machine learning and Deep learning, Types of machine learning – Supervised, Unsupervised and Reinforcement learning	**05**	**CO1**
2.	**Design of Machine Learning System:** Collection of data, Data statistics – mean, variance, covariance, standard deviation, random variable, probability distribution function, data pre-processing, data scaling, training of data, testing of data and its validation. Evaluation Metrics – Confusion matrix, precision, recall, F-score.	**08**	**CO2**
3.	**Supervised Learning:** Linear Regression, Multiple linear regression, Polynomial regression, Logistic Regression, Regularization techniques.	**06**	**CO3**
4.	**Unsupervised Learning and Classification:** K-means and Hierarchical Clustering, Decision trees, Naïve-Bayes, SVM for linearly separable data, Kernel SVM for non-linearly separable data Dimensionality Reduction: LDA, Principal Component Analysis (PCA)	**07**	**CO4**
5.	**Artificial Neural Networks:** The Neurons and the Brain, Neural Networks and Representation: Perceptron, Multilayer perceptron, Gradient Descent, back-propagation.	**07**	**CO5**
6.	**Application of ML algorithms in Industrial Automation and Robotics:** ML algorithms applied for Factory automation, autonomous cars, automated robotic arm, process control, Data screening, feature engineering, model design, limitations.	**06**	**CO6**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on Minimum 02 Modules) and the other is either a class test or assignment on live problems or Course project

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question, paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Harrington, Peter. Machine learning in action. Simon and Schuster, 2012.
2. Zheng, Alice, and Amanda Casari. Feature engineering for machine learning: principles and techniques for data scientists. " O'Reilly Media, Inc.", 2018.
3. Jiang, Hui. Machine Learning Fundamentals: A Concise Introduction. Cambridge University Press, 2021.
4. Huyen, C. "Designing Machine Learning Systems: An Iterative Process for Production-Ready Applications", O'Reilly Media, 2022.
5. Gupta, Itisha, and Garima Nagpal. Artificial Intelligence and Expert Systems. Stylus Publishing, LLC, 2020.

Reference Books:

1. Pandey, Yogendra Narayan, et al. Machine Learning in the Oil and Gas Industry. apress, Texas, 2020.
2. Bangert, Patrick, ed. Machine learning and data science in the oil and gas industry: Best practices, tools, and case studies. Gulf Professional Publishing, 2021.
3. Das, Santosh Kumar, et al., eds. Machine learning algorithms for industrial applications. Cham: Springer, 2021.

Course Code	Course Name	Credits
ARDLO6021	DataBase Management Systems	03

Course Objectives:

1. Learn and practice data modeling using the entity-relationship and developing database designs.
2. Understand the use of Structured Query Language (SQL) and learn SQL syntax.
3. Apply normalization techniques to normalize the database
4. Understand the needs of database processing and learn techniques for controlling the consequences of concurrent data access.

Course Outcomes:

The learner will be able:

1. To describe data models and schemas in DBMS.
2. Explain the features of database management systems and Relational database.
3. Use SQL- the standard language of relational databases.
4. Identify the functional dependencies and Design a database.
5. Describe the concept of Transactions Management and Concurrency.
6. Explain the concept of Query Processing and Optimization.

Module	Detailed content	Hours	CO Mapping
1	**Introduction Database Concepts:** Introduction, Characteristics of databases, File system V/s Database system, Users of Database system, Concerns when using an enterprise database, Data Independence, DBMS system architecture, Database Administrator **Entity–Relationship Data Model :** Introduction, Benefits of Data Modeling, Types of Models, Phases of Database Modeling, The Entity-Relationship (ER) Model, Generalization, Specialization and Aggregation, Extended Entity-Relationship (EER) Model.	**06**	**CO1**
2	**Relational Model and Algebra :** Introduction , Mapping the ER and EER Model to the Relational Model , Data Manipulation , Data Integrity ,Advantages of the Relational Model, Relational Algebra , Relational Algebra Queries, Relational Calculus.	**06**	**CO2**
3	**Structured Query Language (SQL) :** Overview of SQL , Data Definition Commands, Set operations , aggregate function , null values, , Data Manipulation commands, Data Control commands , Views in SQL, Nested and complex queries .	**07**	**CO3**
4	**Integrity and Security in Database:** Domain Constraints, Referential integrity, Assertions, Trigger, Security, and authorization in SQL **Relational–Database Design :** Design guidelines for relational schema, Function dependencies, Normal Forms- 1NF, 2 NF, 3NF, BCNF and 4NF	**08**	**CO4**
5	**Transactions Management and Concurrency:** Transaction concept, Transaction states, ACID properties, Implementation of atomicity and durability, Concurrent Executions, Serializability, Recoverability, Implementation of isolation, Concurrency Control: Lock-based , Timestamp-based , Validation-based protocols, Deadlock handling, Recovery System: Failure Classification, Storage structure, Recovery & atomicity, Log based recovery, Shadow paging.	**07**	**CO5**

6	**Query Processing and Optimization:** Overview ,Issues in Query Optimization ,Steps in Query Processing , System Catalog or Metadata, Query Parsing , Query Optimization, Access Paths , Query Code Generation , Query Execution, Algorithms for Computing Selection and Projection , Algorithms for Computing a Join , Computing Aggregation Functions , Cost Based Query Optimization .	**05**	**CO6**

Internal Assessment:
Internal Assessment consists of two tests out of which, (on Minimum 02 Modules) .

Termwork:
Term work should consist of at least 12 experiments.
Journal must include at least 2 assignments.

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books:
1. G. K. Gupta :"Database Management Systems", McGraw – Hill.
2. Korth, Slberchatz,Sudarshan, :"Database System Concepts", 6th Edition, McGraw – Hill
3. Elmasri and Navathe, " Fundamentals of Database Systems", 5thEdition, PEARSON Education.
4. Peter Rob and Carlos Coronel, " Database Systems Design, Implementation and Management", Thomson Learning, 5th Edition.

Reference Books :
1. Dr. P.S. Deshpande, SQL and PL/SQL for Oracle 10g,Black Book, Dreamtech Press Mark L. Gillenson, Paulraj Ponniah, " Introduction to Database Management",Wiley
2. Sharaman Shah ,"Oracle for Professional", SPD.
3. Raghu Ramkrishnan and Johannes Gehrke, " Database Management Systems",TMH
4. Debabrata Sahoo "Database Management Systems" Tata McGraw Hill, Schaum's Outline

Course Code	Course Name	Credits
ARDLO6022	Industrial Robotics and Material Handling System	03

Course Objectives:

1. To introduce the basic concepts, parts of robots and types of robots.
2. To make the student familiar with the various drive systems for robot, sensors and their applications in robots and programming of robots.
3. To discuss about the various applications of robots, justification and implementation of robot.
4. Concepts of material handling, principles and considerations in material handling systems design

Course Outcomes: Learner will be able to:

1. To introduce the basic concepts, parts of robots and types of robots.
2. To make the student familiar with the various drive systems for robot, sensors and their applications in robots and programming of robots.
3. To discuss about the various applications of robots, justification and implementation of robot.
4. Explain the gripper force analysis and design.
5. To introduce the basic concepts, principles and design considerations
6. Implement safety regulations in material handling systems.

Module	Detailed Contents	Hrs.	CO Mapping
01	Types of industrial robots, Load handling capacity, general considerations in Robotic material handling, material transfer, machine loading and unloading, CNC machine tool loading, Robot centered cell.	05	CO1
02	Robotic vision systems, image representation, object recognition and categorization, depth measurement, image data compression, visual inspection, software considerations.	07	CO2
03	Application of Robots in continuous arc welding, Spot welding, Spray painting, assembly operation, cleaning, robot for underwater applications.	07	CO3
04	Gripper force analysis and gripper design, design of multiple degrees of freedom, active and passive grippers. Selection of Robot: Factors influencing the choice of a robot, robot performance testing, economics of robotisation, Impact of robot on industry and society.	06	CO4
05	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	07	CO5

	and retrieval systems (ASRS), bar code technology, radio frequency identification technology.		
06	Factors affecting selection of material handling equipment, Material handling equation, Choices of Material Handling Equipment, General Procedure for Selection, Basic Analytical techniques, Selection of suitable types of material handling systems , Functions and Parameters, affecting service, packing and storage material, Selection of Material Handling Equipment in Green Sand Moulding Foundry, Sugar Manufacturing Industry.	**07**	**CO6**

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). Duration of each test shall be one hour.

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 1will 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 module3)
4. Only Four questions need to be solved.

Text Books

1. Richaerd D Klafter, Thomas Achmielewski and Mickael Negin, “Robotic Engineering – An integrated Approach” Prentice HallIndia, New Delhi, 2001.
2. Mikell P. Groover,”Automation, Production Systems, and Computer Integrated Manufacturing“, 2nd Edition, John Wiley & sons, Inc, 2007.
3. Industrial Automation and Robotics by Er. A. K. Gupta and S. K. Arora, University Science Press, Laxmi Publishing Pvt. Ltd.
4. mmer J. R., Material Handling, Tata McGraw Hill Publication.
5. James Apple, Material Handling System Design, John Wiley
6. Theodore H., Allegre Sr., Material Handling Principles and Practice, CBS Publishers and Distributors.

References:

1. James A Rehg, “Introduction to Robotics in CIM Systems”, Prentice Hall of India, 2002.
2. Deb S R, "Robotics Technology and Flexible Automation", Tata McGraw Hill, New Delhi, 1994.
3. Robotics and Control by R. K. Mittal and I. J. Nagrath, McGraw Hill Education (India) Private Limited.

Course Code	Course Name	Credits
ARDLO6023	**Metal Forming Technology**	03

Course Objectives

1. To conversant with the basic knowledge on fundamentals of metal forming processes
2. To study various metal forming processes
3. Understanding plastic deformation and technical analysis of forming processes

Course Outcomes

Students would be able

1. Understand the concept of different metal forming process.
2. Explain the concept of Rolling processes both analytically and numerically
3. Explain the concept of forging processes both analytically and numerically
4. Explain the concept of Extrusion processes both analytically and numerically
5. Explain the concept of Drawing processes both analytically and numerically.
6. Explain the Sheet Metal Forming principle, process parameters and their applications.

Module	Contents	Hrs.	CO Mapping
1	**Introduction to Metal Forming:** Metallurgical aspects of metal forming, slip, twinning mechanics of plastic deformation, effects of temperature, strain rate, microstructure and friction in metal forming-yield criteria and their significance, Classification of Metal Forming Processes, Advantages and Limitations, Stress strain relations in elastic and plastic deformation, concept of flow stresses, deformation mechanisms, Hot and Cold Working Processes and Its Effect on Mechanical Properties.	08	CO1
2	**Rolling:** Introduction and Classification, Types of Rolling Mills, Forces and Geometrical Relationships in Rolling, Calculation of Rolling Load, Roll Pass Design, and Defects in Rolled Products.	07	CO2
3	**Forging:** Introduction and Classification, operation and principle of Forging Processes and Equipment, Methods of forging, Open and Close Die Forging Processes, Defects, Structure and Properties of Forged Products. Force Analysis in forging.	07	CO3
4	**Extrusion:** Introduction and Classification, Extrusion Equipment, Forces in extrusion, Analysis of Extrusion Process, Extrusion of components including Seamless Pipes and Tubes. Extrusion of pipes by cold working.	06	CO4
5	**Drawing:** Introduction and Classification, Wire Drawing, Rod Drawing, Tube Drawing, Deep Drawing, Analysis of Wire Drawing Process and Load Calculations.	05	CO5

6	**Sheet Metal Forming:** Principle, process parameters, equipment and application of the following processes: spinning, stretch forming, plate, V and edge bending, Curling, Ironing, Roll Bending, Metal Spinning. Press brake forming, explosive forming, Hydro forming, electro hydraulic forming, and magnetic pulse forming. High Velocity forming of metals and High energy Rate forming	**06**	**CO6**

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.

Text/Reference Books: -

1. Lin D Balint M Pietrzyk, Microstructure Evolution in Metal Forming Processes 1st Edition
2. Amitabha Ghosh and Asok Kumar Mallick, Manufacturing Science, Affiliated East-West Press
3. Christian Brecher and Ozdemir , Advances in Production Technology, Springer Publications
4. P.C. Sharma , A Text Book on Production Engineering, S. Chand Publications
5. P. N. Rao, “Manufacturing Technology”, Tata McGraw Hill
6. Aviter, “Fundamental of Metal Working”, McGraw Hill Publisher
7. Dieter, “Mechanical Metallurgy”

Links for online NPTEL/SWAYAM courses:

https://nptel.ac.in/courses/112/107/112107250/ - Principles of Metal Forming Technology, IIT Roorkee
https://nptel.ac.in/courses/112/106/112106153/ - Forming, IIT Madras.

Course Code	Course Name	Credits
ARDLO6024	**Biomedical Instrumentation**	**03**

Course Objectives

1. To make students understand the Identification, classification, and working principle of various Biomedical Instruments used for Bio-potential measurement
2. To make students understand the application of the various biomedical instruments in diagnosis, therapeutic and imaging fields

Course Outcomes

The students will be able to:

1. Identify various Bio-potential with their specifications and perform their measurements.
2. Discuss various Physiological systems and to identify their parameters and related measurements.
3. Explain the principle and working of various cardiovascular parameters and their measurement techniques with applications.
4. Distinguish between the various medical imaging techniques based on the principles and concepts involved in them.
5. Relate between the different life support instruments and to describe their applications.
6. Describe the significance of electrical safety in biomedical measurement.

Prerequisite: Biology and human physiology.

Module	Contents	Hrs.	CO Mapping
1	**Bio-Potentials and their Measurement:** Structure of Cell, Origin of Bio-potential, electrical activity of cell and its characteristics and specifications. Measurement of RMP and AP. Electrode-Electrolyte interface and types of bio-potential electrodes.	**05**	**CO1**
2	**Physiological Systems and Related Measurement:** Respiratory system- Physiology of respiration and measurements of respiratory related parameters. Nervous system- Nerve cell, neural communication, nerve-muscle physiology, Generation of EEG and study of its characteristics. Normal and abnormal EEG, evoked potential and epilepsy. Muscular system- Generation of EMG signal and measurement. Cardiovascular system- Structure of Heart, Electrical and Mechanical activity of Heart, ECG measurements and Cardiac arrhythmias, Heart sound measurement. Design of ECG amplifier.	**08**	**CO2**
3	**Cardiovascular Measurement:** Blood Pressure measurement using Direct and Indirect techniques. Blood Flow meters- Electromagnetic and Ultrasonic types. Blood Volume measurement - Plethysmography. (Impedance) Cardiac Output measurement - Fick method, Dye-dilution and Thermo-dilution type	**08**	**CO3**

4	Imaging Techniques: * X-Ray tube construction, working and its application. CT Scan- CT Number, Block Diagram, scanning system and application. MRI – concept, working and its application Working principle of Ultrasound Imaging- Modes of scanning and their application.	**08**	**CO4**
5	Life support Instruments: Pacemaker- modes of pacing and its application. Defibrillator- AC and DC Defibrillators and their application. Heart Lung machine and its application during surgery. Hemodialysis system and the precautions to be taken during dialysis. Ventilator system and its important parameters for monitoring	**08**	**CO5**
6	Significance of Electrical Safety: Physiological effects of electrical current, Shock Hazards from electrical equipment and methods of accident prevention.	**02**	**CO6**

* **A Hospital Visit is recommended.**

Internal Assessment:

Internal Assessment consists of two tests out of which, one should be compulsory class test (on Minimum 02 Modules) and the other is either a class test or assignment on live problems or Course project.

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 Marks.
2. Total 4 questions need to be solved.
3. Question No. 1 will be compulsory and based on entire syllabus wherein sub questions of 4 to 5 marks will be asked.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Leslie Cromwell, ―Biomedical Instrumentation and Measurements‖, 2nd Edition, Pearson Education, 1980.
2. John G. Webster, ―Medical Instrumentation‖, John Wiley and Sons, 4th edition,2010.
3. R. S. Khandpur, ―Biomedical Instrumentation‖, TMH,2004

Reference Books:

1. Richard Aston, - Principles of Biomedical Instrumentation and Instruments‖, PH,1991.
2. Joseph J.Carrand JohnM.Brown,-Introduction to Biomedical Equipment Technology, PHI/Pearson Education, 4th edition,2001.
3. John E Hall, Gyton‘s- Medical Physiology, 12th edition,2011
4. L. E. Baker L. A. Geddes, -Principles of Applied Biomedical Instrumentation‖, John Wiley and Sons, 3rd Edition,1991.

Course Code	Course Name	Credits
ARL601	**Robotic Control System Lab**	**01**

Course Objectives

1. To make the students familiar with the dynamic modelling of robots.
2. To make the students understand Nonlinear Control of manipulators
3. To make students understand Force control of manipulators.
4. To make the students understand Kinematic model of steered robot.
5. To make the students understand Vision based Control.
6. To make students understand PID Control of single link manipulator and planar 2R manipulator.

Course Outcomes

On successful completion of the course, Students will be able to:

1. Learn basic concepts in dynamic modelling of robots.
2. Understand and design Nonlinear control of manipulators.
3. Design Force control of manipulators
4. Analyse Kinematic model of steered robot and differentially driven mobile robot.
5. Understand Vision based control systems.
6. Design PID control of single link manipulator and planar 2R manipulator.

List of Experiments: Minimum Eight experiments.

Sr. No.	List of Experiments	CO Mapping
1	Creating robot joint trajectories	**CO1**
2	Study Inverse and Forward dynamics of robots	**CO1**
3	Design stiffness control for 3-link planner manipulator.	**CO2**
4	Design trajectory following controller for a given system.	**CO3**
5	Design trajectory following controller for a linear system or using linearized model of the system.	**CO3**
6	Study of Forward Kinematics of a 5R Robot Manipulator	**CO3**
7	Study of Inverse Kinematics of a 5R Robot Manipulator	**CO3**
8	Design of controller for Multilink Manipulator	**CO3**
9	Design of Line follower robot control.	**CO4, CO5**
10	Design of Navigation control of mobile robot using Neural Network algorithm.	**CO4, CO5**
11	Design Control a virtual robot using a joystick	**CO6**
12	Study workspace Analysis of a 6-axis robot	**CO6**
13	Design PID Controller for single link manipulator	**CO6**

14	Case study on any Industrial Robot	**CO6**

Assessment:

Distribution of marks for term work

Laboratory work	20 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 15marks
   b. Viva 10 marks
3. Evaluation of practical examination to be done based on the experiment performed and the output of the experiment during practical examination
4. Students work along with evaluation report to be preserved till the next examination

Course Code	Course Name	Credits
ARL602	**Process Instrumentation and Control lab**	**01**

Course Objectives :

1. To make the students familiar with Process control Fundamentals.
2. To make the students understand control actions and controllers.
3. To make students understand various control schemes.
4. To make the students understand Heat transfer unit operations and control schemes.
5. To make the students understand Heat and Mass transfer unit operations and control schemes.
6. To make students understand Automation and control schemes in process industries.

Course Outcomes : On successful completion of the course, Students will be able to:

1. Learn basic concepts and fundamentals of Process control.
2. Analyze different process control actions and classify controllers like electronic, pneumatic and Hydraulic and their Tuning Techniques
3. Demonstrate continuous and discrete control schemes
4. Demonstrate control schemes of Heat transfer unit operations
5. Discuss control schemes of heat and mass transfer unit operations.
6. Describe Automation and control schemes in process industries.

Sr. No.	List of Experiments	CO Mapping
1	Study Self-Regulation and Non-self-Regulation system	**CO1**
2	Study Dynamic response of First order and second order systems.	**CO1**
3	Study Temperature control systems using ON OFF controllers.	**CO2**
4.	Study Level control systems using PID controllers.	**CO2,CO3**
5	Study and test Features and configuration of PID controllers.	**CO2,CO3**
6.	Study the Temperature control system using Heat Exchanger set up.	**CO4**
7	Assignments / Reports based on Evaporator / Boiler / DC / Dryer / Reactor	**CO5**
8	Assignments / Reports based on Process Industries.	**CO6**

Any other experiment based on syllabus which will help students to understand the topic/concept.

Oral Examination:

Oral Examination will be based on experiments in the Laboratory as well as the theory syllabus.

Chemical / Fertilizer Factory visit is advised to understand Equipment and controls as well as practical aspects of the subject.

Term Work:
Term work shall consist of minimum 06 experiments and 2 assignments.

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

Laboratory work (Experiments/assignments):	10 Marks
Laboratory work (journal):	10 Marks
Attendance (Theory plus Lab Practice):	05 Marks

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

Course Code	Course Name	Credits
ARL603	**Machine Learning Lab**	**01**

Course Objectives :

1. To familiarize student with basic concepts of Machine learning.
2. To provide understanding of the concepts of regression, classification, clustering and machine learning algorithms.
3. To introduce the students to various applications of Machine learning for industrial automation and robotics

Course Outcomes : On successful completion of the course, Students will be able to:

1. Develop programs to perform statistical analysis of data set.
2. Implement algorithms based on Supervised learning.
3. Implement algorithms based on Unsupervised learning.
4. Execute classification algorithms on given data set.
5. Develop programs based on Artificial NN.
6. Apply ML algorithms for industrial automation and robotics.

List of Experiments: Minimum ten experiments.

Sr. No.	List of Experiments	CO Mapping
1.	Write python program to determine mean, variance and standard deviation of given data set.	**CO1**
2.	Write python program to implement linear regression with one variable for given data set.	**CO1**
3.	Write python program to implement linear regression with two variables for given data set.	**CO1**
4.	Implement regularized regression techniques such as LASSO or Ridge for given dataset	**CO2**
5.	Write python programs to implement logistic regression for any given dataset.	**CO2**
6.	Write python programs to implement K-means clustering algorithm for image compression	**CO3**
7.	Write python programs to implement Hierarchical clustering for any application	**CO3**
8.	Implement SVM for any classification application	**CO4**
9.	Implement decision tree or random forest algorithm for data classification	**CO4**
10.	Implement ANN for hand-written digit recognition	**CO5**
11.	Write a program for application of ML algorithm for automation application	**CO6**
12.	Case study/ mini-project on applying ML algorithms for any robotic application	**CO6**

Assessment:

Distribution of marks for term work

Laboratory work	20 Marks
Attendance	05 Marks

End Semester Practical/Oral Examination:

1. Pair of Internal and External Examiner should conduct practical / viva based on contents
2. Evaluation of practical examination to be done based on the experiment performed and the output of the experiment during practical examination
3. Students work along with evaluation report to be preserved till the next examination

Course Code	Course Name	Credits
ARLSBL601	**CAD Modeling, CNC and 3-D Printing Lab**	**02**

Prerequisites: Engineering Drawing

Objectives:

1. To impart the 3D modeling skills for development of 3D models of basic engineering components.
2. To introduce Product data exchange among CAD systems.
3. To familiarize with production drawings with important features like GD &T, surface finish, heat treatments etc.
4. To familiarize with subtractive manufacturing process in particular CNC systems.
5. To acquaint with basic part programing process for specific operations.
6. To familiarize with additive manufacturing process in particularly 3D printing.

Outcomes: Learner will be able to…

1. Illustrate basic understanding of types of CAD model creation, visualize and prepare 2D modeling of a given object using modeling software.
2. Build solid model of a given object using 3D modeling software.
3. Generate assembly models of given objects using assembly tools of a modeling software and can perform product data exchange among CAD systems.
4. Develop and execute part programing for any given specific operation and can build any given object using various CNC operations.
5. Demonstrate CAM Tool path and prepare NC- G code.
6. Build any given real life object using 3D printing process.

Sr. No.	Exercises	Hrs.	CO Mapping
1.	**CAD Introduction** CAD models Creation, Types and uses of models from different perspectives. Parametric modeling.	**24**	**CO1**
2.	**2D Modeling** Geometric modeling of an Engineering component, demonstrating skills in sketching commands of creation (line, arc, circle etc.) modification (Trim, move, rotate etc.) and viewing using (Pan, Zoom, Rotate etc.)		**CO1**
3	**Solid Modeling** 3D Geometric modeling of an Engineering component, demonstrating modeling skills using commands like Extrude, Revolve, Sweep, Blend, Loft etc.		**CO2**
4.	**Assembly** Constraints, Exploded views, interference check. Drafting (Layouts, Standard & Sectional Views, Detailing & Plotting).		**CO3**

5.	**Data Exchange** CAD data exchange formats Like IGES, PDES, PARASOLID, DXF and STL along with their comparison and applicability.		**CO3**
6.	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)	**12**	**CO4**
7.	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)		**CO4**
8.	Tool-path generation by translation of part geometry from computer aided design (CAD) to computer aided manufacturing (CAM) systems.		**CO5**
9	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.		**CO5**
10	Development of physical 3D mechanical structure using any one of the rapid prototyping processes.	**12**	**CO6**
11	Check the constraints of any two RP systems for features like layer thickness, orientation of geometry, support generation, post processing etc.		**CO6**
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.		**CO6**

Assessment:

Term work

Part A

Using the above knowledge and skills acquired through starting five modules, students should complete Minimum five assignments/Experiments from the given sets of assignments **(one from each set)** using standard.

CAD modeler like PTC Creo/CATIA/ Solid work/UG /any other suitable software.

Set 1: Beginner Level:

3D modeling of basic Engineering components likes Nuts, Bolts, Keys, cotter, Screws, Springs etc.

Set 2: Intermediate Level: 3D modeling of basic Machine components like Clapper block, Single tool post, Lathe and Milling . Tail stock, Shaper tool head slide, jigs and fixtures Cotter, Knuckle joint, Couplings:

simple, muff, flanged Protected flange coupling, Oldham's coupling, Universal coupling,element of engine system and Miscellaneous parts.

Set 3: Advance Level:

1) Generation of any Assembly model (minimum three child parts) along with Production drawing for any of the system by creating 3D modeling with assembly constraints, Interference check, Exploded view, GD&T, Bill of material.
2) Reverse Engineering of a physical model: disassembling of any physical model having not less than five parts, measure the required dimensions of each component, sketch the minimum views required for each component, convert these sketches into 3-D model and create an assembly drawing with actual dimensions.

Part B

● **Any 2 exercises from 6 to 9 and 2 exercises from 10 to 12 of the above list**

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

1. Part A Exercises Printouts/Plots: 10 Marks
2. Part B Exercises: 10 Marks
3. Attendance: 05 Marks

End Semester Practical/Oral examination:

To be conducted by pair of Internal and External Examiner

1. Each student will be given a practical assignment on the basis of the above Exercises which will be completed within a given time and assessed by examiners during the oral examination.
2. The distribution of marks for oral-practical examination shall be as follows:

a. Practical Assignment: 15 marks

b. Oral: 10 marks

3. Evaluation of practical/oral examination to be done based on the performance of practical assignment.
4. Students work along with evaluation report to be preserved till the next examination

References:

1. Machine Drawing by N.D. Bhatt.
2. A textbook of Machine Drawing by Laxminarayan and M.L.Mathur, Jain brothers Delhi
3. Machine Drawing by Kamat and Rao
4. Machine Drawing by M.B.Shah
5. A text book of Machine Drawing by R.B.Gupta, Satyaprakashan, Tech. Publication
6. Machine Drawing by K.I. Narayana, P. Kannaiah, K.Venkata Reddy
7. Machine Drawing by Sidheshwar and Kanheya

8. Autodesk Inventor 2011 for Engineers and Designers by Sham Tickoo and Surinder Raina, Dreamtech Press
9. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications
10. CNC Technology and Programming, Krar, S., and Gill, A., McGraw Hill Publishers.
11. CNC Programming for Machining, Kaushik Kumar, Chikesh Ranjan, J. Paulo Davim, Springer Publication.
12. 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.
13. Biomaterials, artificial organs and tissue engineering, Edited by Larry L. Hench and Julian R. Jones, Woodhead Publishing and Maney Publishing, CRC Press 2005
14. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, I. Gibson l D. W. Rosen l B. Stucker, Springer Publication.
15. Rapid Prototyping and Manufacturing, P. F. Jacobs, Society of Manufacturing Engineers

Course code	Course Name	Credits
ARPBL601	Mini Project -IV	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.

Course Outcomes: 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. Analyze 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 lifelong learning.
9. Demonstrate project management principles during project work.

Guidelines for Mini Project

- Studentsshallformagroupof3to4students, 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.
- Student shall 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 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 & 2 in semester III and IV. Similarly, Mini Project 3 & 4 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 bead opted 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 logbook 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 finalization of problem
    - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of component's/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 finalization 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 skillsets
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 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 orresearchorganisationshavingexperienceofmorethanfiveyearsapproved 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 skillsets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication.