Model Curriculum for UG Degree Course in

Robotics and Artificial Intelligence Engineering

(Engineering & Technology)

2023

ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

Nelson Mandela Marg, Vasant Kunj, New Delhi 110070

www.aicte-india.org

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MESSAGE

The quality of technical education depends on many factors but largely on- outcome based socially and industrially relevant curriculum, good quality motivated faculty, teaching learning process, effective industry internship and evaluation of students based on desired outcomes. Therefore, it was imperative that a Model Curriculum be prepared by best experts from academia and industry, keeping in view the latest industry trends and market requirements and be made available to all universities / board of technical education and engineering institutions in the country. AICTE constituted team of experts to prepare the model curriculum of UG Degree Course in Robotics and Artificial Intelligence Engineering. Similar exercise is done for other UG, Diploma and PG level in engineering, MBA, PGDM, Architecture, etc.

It comprises of basic science and engineering courses, having focus on fundamentals, significant discipline level courses and ample electives both from the disciplines and cross disciplines including emerging areas all within a cumulative structure of 165 credits. Summer Internships have been embedded to make the student understand the industry requirements and have hands on experience. Virtual Labs has been introduced for few experiments. Also, most courses have been mapped to its equivalent SWAYAM/NPTEL Course to offer an alternative for learning that course online from SWAYAM. These features will allow students to develop a problem-solving approach to face the challenges in the future and develop outcome based learning approach.

As a major initiative by AICTE, a three-week mandatory induction program for students has also been designed and has to be given at the beginning of the course. The idea behind this is to make the students feel comfortable in their new environment, open them up, set a healthy daily routine, develop awareness, sensitivity and understanding of the self, people around them, society at large, and nature.

AICTE places on record, special thanks to Dr. Bharat Kumar B Ahuja, Dr Shantipal S Ohol, Dr. Arockia Selvakumar Arockia Doss, Dr. Rajesh Kumar, Dr. Sukhdeep Singh Dhami, Dr Hargovind Bansal and other committee members. We are sure that this Model Curriculum will help to enhance not just the employability skills but will also enable youngsters to become job creators.

We strongly urge the institutions / universities / boards of technical education in India to adopt this Model Curriculum at the earliest. This is a suggestive curriculum and the concerned university / institution / board should build on and exercise flexibility in readjustment of courses within the overall 160 credits.

(Prof. T. G. Sitharam)
Chairman
All India Council for Technical Education

PREFACE

Taking cognizance of growing concern about quality of technical education in India, AICTE in its 49th council meeting held on 14.03.2017 approved a package of measures for improving quality of technical education - Revision of Curriculum, Mandatory Internship, and Student Induction Program were amongst the few.

AICTE constituted committee of academia industry experts to prepare model curriculum of UG Course in Robotics and Artificial Intelligence Engineering. During the development of curriculum, the employability and employment opportunities for graduates, future ready workforce who will be skilled enough to handle the rapid growth in the field of Robotics and Artificial Intelligence Engineering were kept in mind.

AICTE has introduced mandatory internship in the new curriculum which will equip the students with practical understanding and training about industry practices in a suitable industry or organization. In the course of development of model curriculum, the committee took feedback of industry experts on the draft curriculum and accordingly modified the draft before finalization. This exercise has ensured that essential emphasis on industry requirements and market trends, employability and problem solving approach is given.

After due deliberations, the scheme and syllabus have been formulated. Salient features of this model curriculum are enumerated as under:

- Reduced number of credits.
- Introduction of Student Induction Program.
- Well defined learning objectives & outcomes for each course.
- Inclusion of courses on socially relevant topics.
- Built-in flexibility to the students in terms of professional elective and open elective courses.
- Mandatory internship to equip the students with practical knowledge and provide them exposure to real time industrial environments.
- Virtual Labs.
- Mapping of Courses to its equivalent NPTEL/SWAYAM Course.
- Course on 'Entrepreneurship and Startups' to encourage entrepreneurial mindset.
- Introduction of Design Thinking and Universal Human Value course.

I gratefully acknowledge the time and efforts of the members of the working group Dr. Bharat Kumar B Ahuja, Dr Shantipal S Ohol, Dr. Arockia Selvakumar Arockia Doss, Dr. Rajesh Kumar, Dr. Sukhdeep Singh Dhami, Dr Hargovind Bansal and other committee members.

Special thanks to Prof. Prof. T. G. Sitharam, Chairman; Dr. Abhay Jere, Vice-Chairman; and Prof. Rajive Kumar, Member Secretary, AICTE who all have been instrumental and encouraging throughout the process of development of this model curriculum.

I appreciate the dedication put by the Dr. Naveen Arora, Assistant Director (P&AP); Dr. Anil Sharma, Assistant Director (P&AP), Mr. Rakesh Kumar Pandit, Young Professional (P&AP); Ms. Nishtha Sehgal, IT Consultant and other office staff of AICTE.

(Dr. Ramesh Unnikrishnan)
Advisor – II (P&AP)

Committee for Model Curriculum

S.No	Name	Designation & Organization
1	Dr Bharat Kumar B Ahuja (Chairman)	Professor & Director, Department of Production Engineering & Industrial Management, College of Engineering, Pune
2	Dr Shantipal S Ohol	Associate Professor in Mechanical Engineering, College of Engineering, Pune
3	Dr. Arockia Selvakumar Arockia Doss	Senior Associate Professor, School Of Mechanical And Building Sciences, VIT University, Chennai, India
4	Dr. Rajesh Kumar	Professor, Dept. of Electrical Engineering, MNIT Jaipur
5	Dr. Sukhdeep Singh Dhami	Professor, Dept. of Mechanical Engineering, NITTTR Chandigarh
6	Dr Hargovind Bansal	Senior Lead Engineer, Qualcomm India Pvt Limited

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GENERAL COURSE STRUCTURE & CREDIT DISTRIBUTION

GENERAL COURSE STRUCTURE & THEME

A. Definition of Credit:

1 Hr. Lecture (L) per week	1 Credit
1 Hr. Tutorial (T) per week	1 Credit
1 Hr. Practical (P) per week	0.5 Credit
2 Hours Practical (P) per week	1 Credit

B. Range of Credits: In the light of the fact that a typical Model Four-year Under Graduate degree program in Engineering has about 160 credits, the total number of credits proposed for the four-year B. Tech/B.E. in Robotics and Artificial Intelligence Engineering (Engineering & Technology) is kept as 160.

C. Structure of UG Program in Robotics and Artificial Intelligence: The structure of UG program in Robotics and Artificial Intelligence Engineering shall have essentially the following categories of courses with the breakup of credits as given:

S.No.	Category	**Credit Breakup for R&AI**
1	Humanities and Social Sciences including Management courses	11*
2	Basic Science courses	26*
3	Engineering Science courses including workshop, drawing, basics of electrical/mechanical/computer etc.	21*
4	Professional core courses	62*
5	Professional Elective courses relevant to chosen specialization/branch	4*
6	Open subjects – Electives from other technical and /or emerging subjects	4*
7	Project work, seminar and internship in industry or elsewhere	14*
8	Laboratory Courses	18*
9	Mandatory Courses [Environmental Sciences, Induction Program, Indian Constitution, Essence of Indian Knowledge Tradition]	(non-credit)
	Total	**160***

**Minor variation is allowed as per need of the respective disciplines.*

Professional Elective Courses (PEC): Total 2 to be taken, one from each Elective Course Type, based on individual interest and project.

Open Elective Courses (OEC): Total 2 to be taken, one from each Elective Course Type, based on individual interest and project.

TOTAL = **160 credits**

D. Course code and definition:

Course code	Definitions
L	Lectures
T	Tutorials
P	Practicals
C	Credits
BSC	Basic Science Courses
ESC	Engineering Science Courses
HSMC	Humanities and Social Sciences including Management courses
PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective Courses
LC	Laboratory Courses
MC	Mandatory Courses

- **Course level coding scheme:** Three-digit number (odd numbers are for the odd semester courses and even numbers are for even semester courses) used as suffix with the Course Code for identifying the level of the course. Digit at hundred's place signifies the year in which course is offered. e.g.

  101, 102 … etc. for first year.

  201, 202 …. Etc. for second year.

  301, 302 … for third year.

- **Category-wise Courses**

HUMANITIES & SOCIAL SCIENCES COURSES [HS] & MANAGEMENT COURSES

(i) Number of Humanities & Social Science Courses: 6
(ii) Credits: 11

Sl. No	Category	Course Code	Course Title	Semester	Hours per week			Credits
					L	T	P	
1	HSMC	HSMC-101	English for Technical Writing	I	2	0	2	3
2	HSMC	HSMC-102	Universal Human Values – 2: Understanding Harmony And Ethical Human Conduct	II	3	0	0	3
3	HSMC	HSMC-103	Design Thinking	I	0	0	2	1
4	HSMC	HSMC-401	Innovation and Creativity	IV	1	0	0	1
5	HSMC	HSMC-601	Entrepreneurship	VI	1	0	0	1
6	HSMC	HSMC-701	Intellectual Property Rights	VII	2	0	0	2
Total Credits					9	0	4	**11**

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BASIC SCIENCE COURSES [BSC] (Total 7)

S.No	Category	Course Code	Course Title	Semester	Hours per week			Credits
					L	T	P	
1	BSC	BSC-101	Physics- I	I	3	1	2	5
2	BSC	BSC-102	Maths-I (Linear Algebra and Univariate calculus)	I	3	1	0	4
3	BSC	BSC-103	Chemistry-I	II	3	1	0	4
4	BSC	BSC-104	Maths–II (Ordinary Differential Equations and Multivariate Calculus)	II	3	1	0	4
5	BSC	BSC-301	Vector Calculus and Partial Differential Equations	III	2	1	0	3
6	BSC	BSC-401	Probability & Statistics	IV	2	1	0	3
7	BSC	BSC-402	Biology for Engineers & Biomimetics	IV	2	1	0	3
Total Credits					18	7	2	**26**

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ENGINEERING SCIENCE COURSES [ESC] (Total 7)

S.No	Category	Course Code	Course Title	Semester	Hours per week			Credits
					L	T	P	
1	ESC	ESC-101	Basic Electrical Engineering	I	2	1	2	4
2	ESC	ESC-102	Engineering Graphics and Design	I	1	0	4	3
3	ESC	ESC-103	Programming for Problem Solving	II	3	0	4	5
4	ESC	ESC-104	Workshop: Manufacturing Practice	II	0	0	3	2
5	ESC	ESC-105	Workshop: Electronics and Computer	II	0	0	4	2
6	ESC	ESC-301	Fundamentals of Mechanical Engineering	III	2	0	0	2
7	ESC	ESC-302	Electrical Machines & Drives	III	2	0	2	3
Total Credits					11	1	18	**21**

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PROFESSIONAL CORE COURSES [PCC] (Total 26)

S. No	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	PCC	PCC RAI-301	Analog & Digital Electronics	3	0	0	3
2	PCC	PCC RAI-302	Fundamentals of Materials Science & Smart Materials	2	0	0	2
3	PCC	PCC RAI-303	Fundamentals of Robotics & AI	3	0	0	3
4	PCC	PCC RAI-304	Wireless Networks	1	0	0	1
5	PCC	PCC RAI-401	Machine Learning	1	0	2	2
6	PCC	PCC RAI-402	Sensors and Actuators for Robotics	2	0	0	2
7	PCC	PCC RAI-403	Microcontrollers and its Applications	2	0	0	2
8	PCC	PCC RAI-404	Signals and Systems	2	0	0	2
9	PCC	PCC RAI-405	Robot Safety and Maintenance	2	0	0	2
10	PCC	PCC RAI-501	Data Structures, Files and Algorithms	2	1	0	3
11	PCC	PCC RAI-502	Theory of Machines & Machine Design	3	0	0	3
12	PCC	PCC RAI-503	Industrial Electronics and Power Convertors	3	0	0	3
13	PCC	PCC RAI-504	Advances in Robotics and Artificial Intelligence	2	1	0	3
14	PCC	PCC RAI-505	Control Systems	2	0	0	2
15	PCC	PCC RAI-506	Hydraulic & Pneumatic Drives for Robots	2	0	2	3
16	PCC	PCC RAI-601	Kinematics of Robotics	3	0	0	3
17	PCC	PCC RAI-602	Embedded Systems Design	3	0	0	3
18	PCC	PCC RAI-603	Data Science	2	1	0	3
19	PCC	PCC RAI-604	Dynamics and Trajectory Planning	2	0	0	2
20	PCC	PCC RAI-605	Robot Operating Systems	1	0	2	2
21	PCC	PCC RAI-606	Knowledge Engineering and Expert System	2	0	0	2
22	PCC	PCC RAI-701	Smart Manufacturing	2	0	0	2
23	PCC	PCC RAI-702	Internet of Robotic Things (RIoT)	2	0	0	2
24	PCC	PCC RAI-703	Data Modeling and Visualization	2	0	0	2
25	PCC	PCC RAI-704	Image Processing & Computer Vision	2	0	2	3
26	PCC	PCC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping)	2	0	0	2
Total Credits				55	3	8	**62**

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PROFESSIONAL ELECTIVE COURSES [PEC]

(Total 2 to be taken, one from each Elective Course Type)

S. No	Category	Code	Course Title	Hours per week			Credits
				L	T	P	
1	PEC	PEC RAI-601	Elective Course-I Mobile and Micro-robotics (Tract: Robotics)	2	0	0	2
2	PEC	PEC RAI-602	Elective Course-I Data Analytics (Tract: AI)	2	0	0	2
3	PEC	PEC RAI-603	Elective Course-I Intelligent Manufacturing (Tract: Mechatronics)	2	0	0	2
4	PEC	PEC RAI-604	Elective Course-I Microcontrollers Architecture and Programming (Tract: Control Systems)	2	0	0	2
5	PEC	PEC RAI-801	Elective Course-III Advanced Robotics Programming (Tract: Robotics)	2	0	0	2
6	PEC	PEC RAI-802	Elective Course-III Advanced Artificial Intelligence (Tract: AI)	2	0	0	2
7	PEC	PEC RAI-803	Elective Course-III Micro Electro Mechanical Systems (Tract: Mechatronics)	2	0	0	2
8	PEC	PEC RAI-804	Elective Course-III Advanced Control Systems (Tract: Control Systems)	2	0	0	2
Total Credits				4	0	0	**4**

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OPEN ELECTIVE COURSES [OEC]

(Total 2 to be taken, one from each Elective Course Type)

S. No	Category	Code	Course Title	Hours per week			Credits
				L	T	P	
1	OEC	OEC RAI-701	Elective Course-II Autonomous Robotics and Telecherics (Tract: Robotics)	2	0	0	2
2	OEC	OEC RAI-702	Elective Course-II Deep Learning (Tract: AI)	2	0	0	2
3	OEC	OEC RAI-703	Elective Course-II Mechatronics System Design (Tract: Mechatronics)	2	0	0	2

4	OEC	OEC RAI-704	Elective Course-II Control of Robotic Systems (Tract: Control Systems)	2	0	0	2
5	OEC	OEC RAI-801	Elective Course-IV Biomedical Robotics (Tract: Robotics)	2	0	0	2
6	OEC	OEC RAI-802	Elective Course-IV Augmented Reality and Virtual Reality (Tract: AI)	2	0	0	2
7	OEC	OEC RAI-803	Elective Course-IV Advanced Mechatronics (Tract: Mechatronics)	2	0	0	2
8	OEC	OEC RAI-804	Elective Course-IV Robot Dynamics and Control (Tract: Control Systems)	2	0	0	2
Total Credits				4	0	0	**4**

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ENGINEERING PROJECT (4 Stages)

Sl. No	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	PROJ	PROJ RAI-401	Mini Project	0	0	4	2
2	PROJ	PROJ RAI-601	Mini Project	0	0	4	2
3	PROJ	PROJ RAI-701	Project Stage – I	0	0	4	2
4	PROJ	PROJ RAI-801	Project Stage – II	0	0	16	8
Total Credits				0	0	28	**14**

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LABORATORY COURSES [LC] (Total 18)

Sl. No.	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	LC	LC RAI-301	Materials Science Laboratory	0	0	2	1
2	LC	LC RAI-302	Analog & Digital Electronics Laboratory	0	0	2	1
3	LC	LC RAI-303	Robot Programming Laboratory	0	0	2	1
4	LC	LC RAI-401	Sensors and Actuators Laboratory	0	0	2	1
5	LC	LC RAI-402	Microcontrollers & its Applications Laboratory	0	0	2	1
6	LC	LC RAI-403	Signals and Systems Laboratory	0	0	2	1
7	LC	LC RAI-501	Control Systems Laboratory	0	0	2	1
8	LC	LC RAI-502	Industrial Electronics Laboratory	0	0	2	1

9	LC	LC RAI-503	Artificial Intelligence Laboratory	0	0	2	1
10	LC	LC RAI-504	Hydraulic & Pneumatic Drives Laboratory	0	0	2	1
11	LC	LC RAI-505	Theory of Machines & Mechanism Laboratory	0	0	2	1
12	LC	LC RAI-601	Robotic Simulation Laboratory	0	0	2	1
13	LC	LC RAI-602	Embedded Systems Laboratory	0	0	2	1
14	LC	LC RAI-701	Smart Manufacturing Laboratory	0	0	2	1
15	LC	LC RAI-702	Robotics and AI case studies with RIoT	0	0	2	1
16	LC	LC RAI-703	Data Modeling and Visualization Laboratory	0	0	2	1
17	LC	LC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping) Laboratory	0	0	2	1
18	LC	LC RAI-802	Seminar	0	1	0	1
Total Credits				0	1	34	**18**

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AUDIT COURSES [AU] (Total 4)

Sl. No.	**Category**	**Course Code**	**Course Title**	**Hours per week**			**Credits**
				L	**T**	**P**	
1	AU	AU-102	Sports & Yoga or NSS/NCC (Audit Course)	2	0	0	0
2	MLC	MLC RAI-701	Intellectual Property Rights (Audit Course)	1	0	0	0
3	LLC	LLC RAI-701	Liberal Learning Course (Audit Course)	1	0	0	0
4	LCC	LLC RAI-801	Liberal Learning Course (Audit Course)	1	0	0	0
Total credits				5	0	0	**0**

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TOTAL = 160 credits | BSC = 18%, ESC = 13%, PCC = 39%, PEC+HSMC+OEC = 11%, PROJ = 9% || LC = 11%

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INDUCTION PROGRAM

The Essence and Details of Induction program can also be understood from the 'Detailed Guide on Student Induction program', as available on AICTE Portal, (Link:https://www.aicteindia.org/sites/default/files/Detailed%20Guide%20on%20Student%20Induction%20program.pdf). For more, Refer **Appendix III.**

Induction program (mandatory)	**Three-week duration**
Induction program for students to be offered right at the start of the first year.	• Physical activity • Creative Arts • Universal Human Values • Literary • Proficiency Modules • Lectures by Eminent People • Visits to local Areas • Familiarization to Dept./Branch & Innovations

E. Mandatory Visits/ Workshop/Expert Lectures:

a. It is mandatory to arrange one industrial visit every semester for the students of each branch.

b. It is mandatory to conduct a One-week workshop during the winter break after fifth semester on professional/ industry/ entrepreneurial orientation.

c. It is mandatory to organize at least one expert lecture per semester for each branch by inviting resource persons from domain specific industry.

F. Evaluation Scheme (Suggestive only):

a. **For Theory Courses:**
(The weightage of Internal assessment is 40% and for End Semester Exam is 60%)
The student has to obtain at least 40% marks individually both in internal assessment and end semester exams to pass.

b. **For Practical Courses:**
(The weightage of Internal assessment is 60% and for End Semester Exam is 40%)
The student has to obtain at least 40% marks individually both in internal assessment and end semester exams to pass.

c. For Summer Internship / Projects / Seminar etc.
Evaluation is based on work done, quality of report, performance in viva-voce, presentation etc.

Note: The internal assessment is based on the student's performance in mid semester tests (two best out of three), quizzes, assignments, class performance, attendance, viva-voce in practical, lab record etc.

G. Mapping of Marks to Grades

Each course (Theory/Practical) is to be assigned 100 marks, irrespective of the number of credits, and the mapping of marks to grades may be done as per the following table:

Range of Marks	**Assigned Grade**
91-100	AA/A^+
81-90	AB/A
71-80	BB/B^+
61-70	BC/B
51-60	CC/C^+
46-50	CD/C
40-45	DD/D
< 40	FF/F (Fail due to less marks)
-	F^R (Fail due to shortage of attendance and therefore, to repeat the course)

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Semester wise Structure and Curriculum for

UG Course

in

Robotics and Artificial Intelligence Engineering

(Engineering & Technology)

SEMESTER- I

Sl. No.	Category	Course Code	Course Title	Hours per week			Credits
3 WEEKS COMPULSORY INDUCTION PROGRAM (UHV-I)							
				L	**T**	**P**	
1	BSC	BSC-101	Physics-I	3	1	2	5
2	BSC	BSC-102	Mathematics-I (Linear Algebra and Univariate calculus)	3	1	0	4
3	ESC	ESC-101	Basic Electrical Engineering	2	1	2	4
4	ESC	ESC-102	Engineering Graphics and Design	1	0	4	3
5	HSMC	HSMC-103	Design Thinking	0	0	2	1
6	HSMC	HSMC-101	English for Technical Writing	2	0	2	3
7	AU	AU-101	IDEA Lab Workshop	2	0	4	0
			Total credits	13	3	16	**20**

SEMESTER- II

Sl. No	Category	Course Code	Course Title	Hours per week			Credits
				L	**T**	**P**	
1	BSC	BSC-103	Chemistry-I	3	0	2	4
2	BSC	BSC-104	Mathematics –II (Ordinary Differential Equations and Multivariate Calculus)	3	1	0	4
3	ESC	ESC-103	Programming for Problem Solving	3	0	4	5
4	ESC	ESC-104	Workshop : Manufacturing Practice	0	0	4	2
5	ESC	ESC-105	Workshop : Electronics and Computer	0	0	4	2
6	HSMC	HSMC-102	Universal Human Values – 2: Understanding Harmony And Ethical Human Conduct	3	0	0	3
7	AU	AU-102	Sports and Yoga or NSS/NCC	2	0	0	0
			Total credits	14	1	14	**20**

SEMESTER-III

Sl. No	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	BSC	BSC-301	Vector Calculus and Partial Differential Equations	2	1	0	3
2	ESC	ESC-301	Fundamentals of Mechanical Engineering	2	0	0	2
3	ESC	ESC-302	Electrical Machines & Drives	2	0	2	3
4	PCC	PCC RAI-301	Analog & Digital Electronics	3	0	0	3
5	PCC	PCC RAI-302	Fundamentals of Materials Science & Smart Materials	2	0	0	2
6	PCC	PCC RAI-303	Fundamentals of Robotics & AI	3	0	0	3
7	PCC	PCC RAI-304	Wireless Networks	1	0	0	1
8	LC	LC RAI-301	Materials Science Laboratory	0	0	2	1
9	LC	LC RAI-302	Analog & Digital Electronics Laboratory	0	0	2	1
10	LC	LC RAI-303	Robot Programming Laboratory	0	0	2	1
Total Credits				15	1	8	**20**

SEMESTER-IV

Sl. No	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	BSC	BSC-401	Probability & Statistics	2	1	0	3
2	BSC	BSC-402	Biology for Engineers & Biomimetics	2	1	0	3
3	PCC	PCC RAI-401	Machine Learning	1	0	2	2
4	PCC	PCC RAI-402	Sensors and Actuators for Robotics	2	0	0	2
5	PCC	PCC RAI-403	Microcontrollers and its Applications	2	0	0	2
6	PCC	PCC RAI-404	Signals and Systems	2	0	0	2
7	PCC	PCC RAI-405	Robot Safety and Maintenance	2	0	0	2
8	LC	LC RAI-401	Sensors and Actuators Laboratory	0	0	2	1
9	LC	LC RAI-402	Microcontrollers & its Applications Laboratory	0	0	2	1
10	LC	LC RAI-403	Signals and Systems Laboratory	0	0	2	1
11	PROJ	PROJ RAI-401	Mini Project	0	0	4	2
12	HSMC	HSMC-401	Innovation and Creativity	1	0	0	1
Total Credits				14	2	12	**22**

SEMESTER-V

Sl. No.	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	PCC	PCC RAI-501	Data Structures, Files and Algorithms	2	1	0	3
2	PCC	PCC RAI-502	Theory of Machines & Machine Design	3	0	0	3
3	PCC	PCC RAI-503	Industrial Electronics and Power Convertors	3	0	0	3
4	PCC	PCC RAI-504	Advances in Robotics and Artificial Intelligence	2	1	0	3
5	PCC	PCC RAI-505	Control Systems	2	0	0	2
6	PCC	PCC RAI-506	Hydraulic & Pneumatic Drives for Robots	2	0	2	3
7	LC	LC RAI-501	Control Systems Laboratory	0	0	2	1
8	LC	LC RAI-502	Industrial Electronics Laboratory	0	0	2	1
9	LC	LC RAI-503	Artificial Intelligence Laboratory	0	0	2	1
10	LC	LC RAI-504	Hydraulic & Pneumatic Drives Laboratory	0	0	2	1
11	LC	LC RAI-505	Theory of Machines & Mechanism Laboratory	0	0	2	1
Total Credits				14	2	12	**22**

SEMESTER-VI

Sl. No.	Category	Course Code	Course Title	Hours per week			Credits
				L	T	P	
1	PCC	PCC RAI-601	Kinematics of Robotics	3	0	0	3
2	PCC	PCC RAI-602	Embedded Systems Design	3	0	0	3
3	PCC	PCC RAI-603	Data Science	2	1	0	3
4	PCC	PCC RAI-604	Dynamics and Trajectory Planning	2	0	0	2
5	PCC	PCC RAI-605	Robot Operating Systems	1	0	2	2
6	PCC	PCC RAI-606	Knowledge Engineering and Expert System	2	0	0	2
7	PEC	PEC	Elective-I	2	0	0	2
8	LC	LC RAI-601	Robotic Simulation Laboratory	0	0	2	1
9	LC	LC RAI-602	Embedded Systems Laboratory	0	0	2	1
10	PROJ	PROJ RAI-601	Mini Project	0	0	4	2
11	HSMC	HSMC-601	Entrepreneurship	1	0	0	1
Total Credits				16	1	10	**22**

Sr. No.	Course Code	Course Specialization / Track	Elective Course -I
1	PEC RAI-601	Robotics	Mobile and Micro Robotics
2	PEC RAI-602	AI	Data Analytics
3	PEC RAI-603	Mechatronics	Intelligent Manufacturing
4	PEC RAI-604	Control Systems	Microcontrollers Architecture and Programming

SEMESTER-VII

Sl. No	Category	Code	Course Title	Hours per week			Credits
				L	T	P	
1	PCC	PCC RAI-701	Smart Manufacturing	2	0	0	2
2	PCC	PCC RAI-702	Internet of Robotic Things (RIoT)	2	0	0	2
3	PCC	PCC RAI-703	Data Modeling and Visualization	2	0	0	2
4	PCC	PCC RAI-704	Image Processing & Computer Vision	2	0	2	3
5	OEC	OEC	Elective - II	2	0	0	2
6	LC	LC RAI-701	Smart Manufacturing Laboratory	0	0	2	1
7	LC	LC RAI-702	Robotics and AI case studies with RIoT	0	0	2	1
8	LC	LC RAI-703	Data Modeling and Visualization Laboratory	0	0	2	1
9	PROJ	PROJ RAI-701	Internship/ Project Stage – I	0	0	4	2
10	HSMC	HSMC RAI-701	Intellectual Property Rights (Audit Course)	2	0	0	2
11	LLC	LLC RAI-701	Liberal Learning Course (Audit Course)	1	0	0	0
Total Credits				13	0	12	**18**

Sr. No.	Course Code	Course Specialization/Track	Elective Course -II
1	OEC RAI-701	Robotics	Autonomous Robotics and Telecherics
2	OEC RAI-702	AI	Deep Learning
3	OEC RAI-703	Mechatronics	Mechatronics System Design
4	OEC RAI-704	Control Systems	Control of Robotic Systems

SEMESTER-VIII

Sl. No	Category	Code	Course Title	Hours per week			Credits
				L	T	P	
1	PCC	PCC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping)	2	0	0	2
2	PEC	PEC	Elective -III	2	0	0	2
3	OEC	OEC	Elective - IV	2	0	0	2
4	LC	LC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping) Laboratory	0	0	2	1
5	PROJ	PROJ RAI-801	Project Stage – II	0	0	16	8
6	LC	LC RAI-802	Seminar	0	1	0	1
7	LCC	LLC RAI-801	Liberal Learning Course (Audit Course)	1	0	0	0
			Total credits	**7**	**1**	**18**	**16**

Sr. No.	Course Code	Course Specialization/Track	Elective Course -III
1	PEC RAI-801	Robotics	Advanced Robotics Programming
2	PEC RAI-802	AI	Advanced Artificial Intelligence
3	PEC RAI-803	Mechatronics	Micro Electro Mechanical Systems
4	PEC RAI-804	Control Systems	Advanced Control System

Sr. No.	Course Code	Course Specialization/Track	Elective Course IV
1	OEC RAI-801	Robotics	Biomedical Robotics
2	OEC RAI-802	AI	Augmented Reality and Virtual Reality
3	OEC RAI-803	Mechatronics	Advanced Mechatronics
4	OEC RAI-804	Control Systems	Robot Dynamics and Control

- **Total = 160 Credits**

SEMESTER – I

SEMESTER I

BSC-101	Physics-I	3L:1T:2P	5 Credits

Course Objective:

To enhance the fundamental knowledge in Physics and its applications relevant to various streams of Engineering and Technology.

1. Introduction to Electromagnetic Theory
Pre-requisites (if any): Mathematics course with vector calculus

Module I: Electrostatics in vacuum

Calculation of electric field and electrostatic potential for a charge distribution; Divergence and curl of electrostatic field; Laplace's and Poisson's equations for electrostatic potential and uniqueness of their solution and connection with steady state diffusion and thermal conduction; Practical examples like Faraday's cage and coffee-ring effect; Boundary conditions of electric field and electrostatic potential; method of images; energy of a charge distribution and its expression in terms of electric field.

Module II: Electrostatics in a linear dielectric medium

Electrostatic field and potential of a dipole. Bound charges due to electric polarization; Electric displacement; boundary conditions on displacement; Solving simple electrostatics problems in presence of dielectrics – Point charge at the center of a dielectric sphere, charge in front of a dielectric slab, dielectric slab and dielectric sphere in uniform electric field.

Module III: Magneto statics

Bio-Savart law, Divergence and curl of static magnetic field; vector potential and calculating it for a given magnetic field using Stokes' theorem; the equation for the vector potential and its solution for given current densities.

Module IV: Magneto statics in a linear magnetic medium

Magnetization and associated bound currents; auxiliary magnetic field H; Boundary conditions on B and H. Solving for magnetic field due to simple magnets like a bar magnet; magnetic susceptibility and ferromagnetic, paramagnetic and diamagnetic materials; Qualitative discussion of magnetic field in presence of magnetic materials.

Module V: Faraday's law

Faraday's law in terms of EMF produced by changing magnetic flux; equivalence of Faraday's law and motional EMF; Lenz's law; Electromagnetic breaking and its applications; Differential form of Faraday's law expressing curl of electric field in terms of time-derivative of magnetic field and calculating electric field due to changing magnetic fields in quasi-static approximation; energy stored in a magnetic field.

Module VI: Displacement current, Magnetic field due to time-dependent electric field and Maxwell's equations

Continuity equation for current densities; Modifying equation for the curl of magnetic field to satisfy continuity equation; displace current and magnetic field arising from time dependent electric field; calculating magnetic field due to changing electric fields in quasistatic approximation. Maxwell's equation in vacuum and non-conducting medium; Energy in an electromagnetic field; Flow of energy and Pointing vector with examples. Qualitative discussion of momentum in electromagnetic fields.

Module VII: Electromagnetic waves

The wave equation; Plane electromagnetic waves in vacuum, their transverse nature and polarization; relation between electric and magnetic fields of an electromagnetic wave; energy carried by electromagnetic waves and examples. Momentum carried by electromagnetic waves and resultant pressure. Reflection and transmission of electromagnetic waves from a non-conducting medium-vacuum interface for normal incidence.

Laboratory/ Practicals:

Choice of experiments from the following:

1. Experiments on electromagnetic induction and electromagnetic braking;
2. LC circuit and LCR circuit;
3. Resonance phenomena in LCR circuits;
4. Magnetic field from Helmholtz coil;
5. Measurement of Lorentz force in a vacuum tube.

Text Books/Suggested References:

1. David Griffiths, Introduction to Electrodynamics
2. Halliday and Resnick, Physics
3. W. Saslow, Electricity, magnetism and light

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	INTRODUCTION TO ELECTROMAGNETIC THEORY	PROF. MANOJ HARBOLA	IIT KANPUR

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	LC circuit and LCR circuit;	1. http://vlab.amrita.edu/?sub=1&brch=75&sim=326&cnt=1 2. http://vlab.amrita.edu/?sub=1&brch=75&sim=330&cnt=1 3. http://vlab.amrita.edu/?sub=1&brch=75&sim=318&cnt=1 4. http://vlab.amrita.edu/?sub=1&brch=75&sim=325&cnt=1 5. http://vlabs.iitkgp.ernet.in/asnm/exp12/index.htm
2	Resonance phenomena in LCR circuits	http://vlab.amrita.edu/?sub=1&brch=75&sim=325&cnt=1

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2. Introduction to Mechanics
Pre-requisites (if any): High School Education

Module I

Transformation of scalars and vectors under Rotation transformation; Forces in Nature; Newton's laws and its completeness in describing particle motion; Form invariance of Newton's Second Law; Solving Newton's equations of motion in polar coordinates; Problems including constraints and friction; Extension to cylindrical and spherical coordinates.

Module II

Potential energy function; F = - Grad V, equipotential surfaces and meaning of gradient; Conservative and non-conservative forces, curl of a force field; Central forces; Conservation of Angular Momentum; Energy equation and energy diagrams; Elliptical, parabolic and hyperbolic orbits; Kepler problem; Application: Satellite manoeuvres;

Module III

Non-inertial frames of reference; Rotating coordinate system: Five-term acceleration formula. Centripetal and Coriolis accelerations; Applications: Weather systems, Foucault pendulum;

Module IV

Harmonic oscillator; Damped harmonic motion – over-damped, critically damped and lightly-damped oscillators; Forced oscillations and resonance.

Module V

Definition and motion of a rigid body in the plane; Rotation in the plane; Kinematics in a coordinate system rotating and translating in the plane; Angular momentum about a point of a rigid body in planar motion; Euler's laws of motion, their independence from Newton's laws, and their necessity in describing rigid body motion; Examples.

Module VI

Introduction to three-dimensional rigid body motion — only need to highlight the distinction from two-dimensional motion in terms of (a) Angular velocity vector, and its rate of change and (b) Moment of inertia tensor; Three-dimensional motion of a rigid body wherein all points move in a coplanar manner: e.g. Rod executing conical motion with center of mass fixed — only need to show that this motion looks two-dimensional but is three-dimensional, and two-dimensional formulation fails.

Laboratory - Introduction to Mechanics

Suggested list of experiments from the following:

1. Coupled oscillators;
2. Experiments on an air-track;
3. Experiment on moment of inertia measurement,
4. Experiments with gyroscope;
5. Resonance phenomena in mechanical oscillators.

TEXTBOOKS/REFERENCES:

1. Engineering Mechanics, 2nd edition — MK Harbola
2. Introduction to Mechanics — MK Verma
3. An Introduction to Mechanics — D Kleppner & R Kolenkow
4. Principles of Mechanics — JL Synge & BA Griffiths
5. Mechanics — JP Den Hartog
6. Engineering Mechanics - Dynamics, 7th ed. - JL Meriam
7. Mechanical Vibrations — JP Den Hartog
8. Theory of Vibrations with Applications — WT Thomson

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	ENGINEERING MECHANICS	PROF. MANOJ HARBOLA	IIT KANPUR

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	Experiment on moment of inertia measurement.	https://vlab.amrita.edu/?sub=1&brch=74&sim=571&cnt=1

3. Quantum Mechanics for Engineers
Pre-requisites (if any): Mathematics Course on Differential equations & linear algebra

Module I: Wave nature of particles and the Schrodinger equation

Introduction to Quantum mechanics, Wave nature of Particles, Time-dependent and time independent Schrodinger equation for wave function, born interpretation, probability current, Expectation values, Free-particle wave function and wave-packets, Uncertainty principle.

Module II: Mathematical Preliminaries for quantum mechanics

Complex numbers, Linear vector spaces, inner product, operators, eigenvalue problems, Hermitian operators, Hermite polynomials, Legendre's equation, spherical harmonics.

Module III: Applying the Schrodinger equation

Solution of stationary-state Schrodinger equation for one dimensional problems– particle in a box, particle in attractive delta-function potential, square-well potential, linear harmonic oscillator. Numerical solution of stationary-state Schrodinger equation for one dimensional problems for different potentials Scattering from a potential barrier and tunneling; related examples like alpha-decay, field ionization and scanning tunneling microscope Three-dimensional problems: particle in three dimensional box and related examples, Angular momentum operator, Rigid Rotor, Hydrogen atom ground-state, orbitals, interaction with magnetic field, spin, Numerical solution stationary-state radial Schrodinger equation for spherically symmetric potentials.

Module IV: Introduction to molecular bonding

Particle in double delta-function potential, Molecules (hydrogen molecule, valence bond and molecular orbitals picture), singlet/triplet states, chemical bonding, hybridization.

Module V: Introduction to solids

Free electron theory of metals, Fermi level, density of states, Application to white dwarfs and neutron stars, Bloch's theorem for particles in a periodic potential, Kronig-Penney model and origin of energy bands Numerical solution for energy in one-dimensional periodic lattice by mixing plane waves.

Laboratory - Quantum Mechanics for Engineers

Suggested list of experiments: Frank-Hertz experiment; photoelectric effect experiment; recording hydrogen atom spectrum.

TEXTBOOKS/REFERENCES:

1. Eisberg and Resnick, Introduction to Quantum Physics
2. D. J. Griffiths, Quantum mechanics
3. Richard Robinett, Quantum Mechanics
4. Daniel McQuarrie, Quantum Chemistry

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	INTRODUCTION TO ELECTROMAGNETIC THEORY	PROF. MANOJ HARBOLA	IIT KANPUR
2	QUANTUM MECHANICS I	PROF. P. RAMADEVI	IIT BOMBAY

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	Photoelectric effect experiment.	http://mpv-au.vlabs.ac.in/modern-physics/Photo_Electric_Effect/

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4. Oscillations, waves and optics
Pre-requisites (if any): Mathematics Course on Differential equations

Module I: Simple harmonic motion, damped and forced simple harmonic oscillator
Mechanical and electrical simple harmonic oscillators, complex number notation and phasor representation of simple harmonic motion, damped harmonic oscillator – heavy, critical and light damping, energy decay in a damped harmonic oscillator, quality factor, forced mechanical and electrical oscillators, electrical and mechanical impedance, steady state motion of forced damped harmonic oscillator, power absorbed by oscillator.

Module II: Non-dispersive transverse and longitudinal waves in one dimension and introduction to dispersion
Transverse wave on a string, the wave equation on a string, Harmonic waves, reflection and transmission of waves at a boundary, impedance matching, standing waves and their Eigen frequencies, longitudinal waves and the wave equation for them, acoustics waves and speed of sound, standing sound waves. Waves with dispersion, water waves, superposition of waves and Fourier method, wave groups and group velocity.

Module III: The propagation of light and geometric optics
Fermat's principle of stationary time and its applications e.g. in explaining mirage effect, laws of reflection and refraction, Light as an electromagnetic wave and Fresnel equations, reflectance and transmittance, Brewster's angle, total internal reflection, and evanescent wave. Mirrors and lenses and optical instruments based on them, transfer formula and the matrix method.

Module IV: Wave optics
Huygens' principle, superposition of waves and interference of light by wave front splitting and amplitude splitting; Young's double slit experiment, Newton's rings, Michelson interferometer, Mach-Zehnder interferometer.
Farunhofer diffraction from a single slit and a circular aperture, the Rayleigh criterion for limit of resolution and its application to vision; Diffraction gratings and their resolving power.

Module V: Lasers
Einstein's theory of matter radiation interaction and A and B coefficients; amplification of light by population inversion, different types of lasers: gas lasers (He-Ne, CO2), solid-state lasers (ruby, Neodymium), dye lasers; Properties of laser beams: mono-chromaticity, coherence, directionality and brightness, laser speckles, applications of lasers in science, engineering and medicine.

Laboratory - Oscillations, waves and optics
Suggested list of experiments from the following:

- Diffraction and interference experiments (from ordinary light or laser pointers); measurement of speed of light on a table top using modulation; minimum deviation from a prism.

TEXTBOOKS/REFERENCES:

1. Ian G. Main, Oscillations and waves in physics
2. H.J. Pain, The physics of vibrations and waves
3. E. Hecht, Optics
4. A. Ghatak, Optics
5. O. Svelto, Principles of Lasers

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	WAVES AND OSCILLATIONS	PROF. M. S. SANTHANAM	IISER PUNE

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	Diffraction and interference experiments (from ordinary light or laser pointers).	http://ov-au.vlabs.ac.in/optics/Diffraction_Grating/
2	Minimum deviation from a prism.	http://ov-au.vlabs.ac.in/optics/Spectrometer_i_d_Curve/

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BSC-102	Maths-I (Linear Algebra & Univariate Calculus)	3L:1T:0P	4 Credits

Course Content:

Module I: Matrices and linear equations:
Basic properties of matrices, row operations and Gauss elimination, Determinants and their basic properties. Basic concepts in linear algebra: vector spaces, subspaces, linear independence and dependence of vectors, bases, dimensions. Row and Column spaces, rank, Applications to systems of linear equations.

Module II: Eigenvalues and Eigenvectors:
Linear mappings, representation by matrices, rank-nullity theorem, Eigenvalues, Eigen vectors and their basic properties, diagonalization.

Module III: Calculus Theorems:
Review of limits, continuity and differentiability, Mean value theorems, Taylor's theorem, local extrema, increasing and decreasing functions, concavity, points of inflection.

Module IV: Calculus Theorems:
Integrals as limits of Riemann sums, fundamental theorem of calculus, surface area, integrals by special techniques: reduction formulae, arc length, solids of revolution, improper integrals, tests for convergence, Gamma and Beta functions.

Suggested Text Books:

(i) Thomas' Calculus (12^{th} edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.
(ii) Advanced Engineering Mathematics (10^{th} edition) by Erwin Kreyszig, Wiley eastern Ltd.

Suggested Reference Books:

(i) Serge Lang, "Introduction to Linear Algebra (2^{nd} edition)", Springer, 2005.
(ii) Howard Anton and Chris Rorres, "Elementary Linear Algebra (10^{th} edition)", John Wiley and sons, 2010.
(iii) K.D Joshi, "Calculus for Scientists and Engineers", CRC Press, 2002.
(iv) Sudhir Ghorpade and Balmohan Limaye, "A Course in Calculus and Real Analysis (1^{st} edition)", Springer-Verlag, New York.
(v) C.R. Wylie, "Advanced Engineering Mathematics", McGraw Hill Publications, New Delhi, 2017.
(vi) Peter V. O' Neil, "Advanced Engineering Mathematics (7^{th} edition)", Thomson. Brooks / Cole, Singapore, 1991.
(vii) Shanti Narayan, "Differential Calculus", S. Chand and company, New Delhi.
(viii) P.N. Wartikar and J.N. Wartikar, "Applied Mathematics Vol. I", Pune Vidyarthi Griha Prakashan Pune, 2014.

Course Outcomes:
After completion of this course, the students will be able to:

- Understand and apply basic concepts. (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- Apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages.)
- Give reasoning. (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- Analyse the problem and apply the appropriate concept. (To measure this outcome, questions will be based on applications of core concepts.

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ESC-101	Basic Electrical Engineering	2L:1T:2P	4 Credits

Course Objective:

The objective of this Course is to provide the students with an introductory and broad treatment of the field of Electrical Engineering.

Course Contents:

Module I: D. C. Circuits covering, Ohm's Law and Kirchhoff's Laws; Analysis of series, parallel and series-parallel circuits excited by independent voltage sources; Power and energy; Electromagnetism covering, Faradays Laws, Lenz's Law, Fleming's Rules, Statically and dynamically induced EMF; Concepts of self-inductance, mutual inductance and coefficient of coupling; Energy stored in magnetic fields;

Module II: Single Phase A.C. Circuits covering, Generation of sinusoidal voltage- definition of average value, root mean square value, form factor and peak factor of sinusoidal voltage and current and phasor representation of alternating quantities; Analysis with phasor diagrams of R, L, C, RL, RC and RLC circuits; Real power, reactive power, apparent power and power factor, series, parallel and series- parallel circuits; Three Phase A.C. Circuits covering, Necessity and Advantages of three phase systems, Generation of three phase power, definition of Phase sequence, balanced supply and balanced load; Relationship between line and phase values of balanced star and delta connections; Power in balanced three phase circuits, measurement of power by two wattmeter method;

Module III: Transformers covering, Principle of operation and construction of single phase transformers (core and shell types). EMF equation, losses, efficiency and voltage regulation; Synchronous Generators covering, Principle of operation; Types and constructional features; EMF equation;

Module IV: DC Machines covering, working principle of DC machine as a generator and a motor; Types and constructional features; EMF equation of generator, relation between EMF induced and terminal voltage enumerating the brush drop and drop due to armature reaction; DC motor working principle; Back EMF and its significance, torque equation; Types of D.C. motors, characteristics and applications; Necessity of a starter for DC motor;

Module V: Three Phase Induction Motors covering; Concept of rotating magnetic field; Principle of operation, types and constructional features; Slip and its significance; Applications of squirrel cage and slip ring motors; Necessity of a starter, star-delta starter.

Module VI: Sources of Electrical Power covering, Introduction to Wind, Solar, Fuel cell, Tidal, Geo-thermal, Hydroelectric, Thermal-steam, diesel, gas, nuclear power plants; Concept of cogeneration, and distributed generation;

TEXT/REFERENCS BOOKS:

1. Nagrath I.J. and D. P. Kothari (2001), Basic Electrical Engineering, Tata McGraw Hill.
2. Hayt and Kimberly, Engineering Circuit Analysis, Tata McGraw Hill.
3. Kulshreshtha D.C. (2009), Basic Electrical Engineering, Tata McGraw Hill.

4. Rajendra Prasad (2009), Fundamentals of Electrical Engineering, Prentice Hall, India Hughes, E. 2005)

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	BASIC ELECTRIC CIRCUITS	PROF. ANKUSH SHARMA	IIT KANPUR
2	BASIC ELECTRICAL CIRCUITS	PROF. NAGENDRA KRISHNAPURA	IITM
3	FUNDAMENTALS OF ELECTRICAL ENGINEERING	PROF. DEBAPRIYA DAS	IIT KGP

COURSE OUTCOMES:

The students will learn:

1. To explain strong basics of Electrical Engineering and practical implementation of Electrical fundamentals.
2. To identify different applications of commonly used electrical machinery.

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ESC-102	Engineering Graphics & Design	1L:0T:4P	3 Credits

COURSE OBJECTIVE(S):

The objective of this Course is to provide the basic knowledge about Engineering Drawing. Detailed concepts are given in projections, technical drawing, dimensioning and specifications, so useful for a student in preparing for an engineering career.

COURSE CONTENTS:

Traditional Engineering Graphics: Principles of Engineering Graphics; Orthographic Projection; Descriptive Geometry; Drawing Principles; Isometric Projection; Surface Development; Perspective; Reading a Drawing; Sectional Views; Dimensioning & Tolerances; True Length, Angle; intersection, Shortest Distance.

Computer Graphics: Engineering Graphics Software; -Spatial Transformations; Orthographic Projections; Model Viewing; Co-ordinate Systems; Multi-view Projection; Exploded Assembly; Model Viewing; Animation; Spatial Manipulation; Surface Modelling; Solid Modelling; Introduction to Building Information Modelling (BIM).

(Except the basic essential concepts, most of the teaching part can happen concurrently in the laboratory)

Module I: Introduction to Engineering Drawing

Principles of Engineering Graphics and their significance, usage of Drawing instruments, lettering, Conic sections including the Rectangular Hyperbola (General method only); Cycloid, Epicycloid, Hypocycloid and Involute; Scales – Plain, Diagonal and Vernier Scales;

Module II: Orthographic Projections

Principles of Orthographic Projections-Conventions - Projections of Points and lines inclined to both planes; Projections of planes inclined Planes - Auxiliary Planes;

Module III: Projections of Regular Solids

Covering those inclined to both the Planes- Auxiliary Views; Draw simple annotation, dimensioning and scale. Floor plans that include: windows, doors, and fixtures such as WC, bath, sink, shower, etc.

Module IV: Sections and Sectional Views of Right Angular Solids

Prism, Cylinder, Pyramid, Cone – Auxiliary Views; Development of surfaces of Right Regular Solids - Prism, Pyramid, Cylinder and Cone; Draw the sectional orthographic views of geometrical solids, objects from industry and dwellings (foundation to slab only).

Module V: Isometric Projections

Principles of Isometric projection – Isometric Scale, Isometric Views, Conventions; Isometric Views of lines, Planes, Simple and compound Solids; Conversion of Isometric Views to Orthographic Views and Vice-versa, Conventions;

Module VI: Overview of Computer Graphics

Listing the computer technologies that impact on graphical communication, Demonstrating knowledge of the theory of CAD software [such as: The Menu System, Toolbars (Standard, Object Properties, Draw, Modify and Dimension), Drawing Area (Background, Crosshairs, Coordinate System), Dialog boxes and windows, Shortcut menus (Button Bars), The Command Line (where applicable), The Status Bar, Different methods of zoom as used in CAD, Select and erase objects.; Isometric Views of lines, Planes, Simple and compound Solids];

Module VII: Customisation & CAD Drawing

Consisting of set up of the drawing page and the printer, including scale settings, setting up of Modules and drawing limits; ISO and ANSI standards for coordinate dimensioning and tolerancing; Orthographic constraints, Snap to objects manually and automatically; Producing drawings by using various coordinate input entry methods to draw straight lines, Applying various ways of drawing circles;

Module VIII: Annotations, layering & other functions

Covering applying dimensions to objects, applying annotations to drawings; Setting up and use of Layers, layers to create drawings, Create, edit and use customized layers; Changing line lengths through modifying existing lines (extend/lengthen); Printing documents to paper using the print command; orthographic projection techniques; Drawing sectional views of composite right regular geometric solids and project the true shape of the sectioned surface; Drawing annotation, Computer-aided design (CAD) software modeling of parts and assemblies. Parametric and non-parametric solid, surface, and wireframe models. Part editing and two-dimensional documentation of models. Planar projection theory, including sketching of perspective, isometric, multiview, auxiliary, and section views. Spatial visualization exercises. Dimensioning guidelines, tolerancing techniques; dimensioning and scale multi views of dwelling;

Module IX: Demonstration of a simple team design project that illustrates

Geometry and topology of engineered components: creation of engineering models and their presentation in standard 2D blueprint form and as 3D wire-frame and shaded solids; meshed topologies for engineering analysis and tool-path generation for component manufacture; geometric dimensioning and tolerancing; Use of solid-modeling software for creating associative models at the component and assembly levels; floor plans that include: windows, doors, and fixtures such as WC, bath, sink, shower, etc. Applying colour coding according to building drawing practice; Drawing sectional elevation showing foundation to ceiling; Introduction to Building Information Modelling (BIM).

Text/Reference Books:

1. Bhatt N.D., Panchal V.M. & Ingle P.R., (2014), Engineering Drawing, Charotar Publishing House.
2. Shah, M.B. & Rana B.C. (2008), Engineering Drawing and Computer Graphics, Pearson Education.
3. Agrawal B. & Agrawal C. M. (2012), Engineering Graphics, TMH Publication
4. Narayana, K.L. & P Kannaiah (2008), Text book on Engineering Drawing, Scitech Publishers.
5. (Corresponding set of) CAD Software Theory and User Manuals.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	PROF. RAJARAM LAKKARAJU	IIT KHARAGPUR	ENGINEERING DRAWING AND COMPUTER GRAPHICS
2	PROF. NIHAR RANJAN PATRA	IIT KANPUR	ENGINEERING GRAPHICS

Course Outcomes:

All phases of manufacturing or construction require the conversion of new ideas and design concepts into the basic line language of graphics. Therefore, there are many areas (civil, mechanical, electrical, architectural and industrial) in which the skills of the CAD technicians play major roles in the design and development of new products or construction. Students prepare for actual work situations through practical training in a new state-of-the-art computer designed CAD laboratory using engineering software. This course is designed to address:

- to prepare you to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- to prepare you to communicate effectively
- to prepare you to use the techniques, skills, and modern engineering tools necessary for engineering practice

The students will learn:

- To describe engineering design and its place in society.
- To discuss the visual aspects of engineering design.
- To use engineering graphics standards.
- To illustrate solid modelling.
- To use computer-aided geometric design.
- To design creating working drawings.
- To inspect engineering communication.

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HSMC-103	Design Thinking	0L:0T:2P	1 Credit

Detailed Content:

Module 1: An Insight to Learning:

Understanding the Learning Process, Kolb's Learning Styles, Assessing and Interpreting, Remembering Memory, Understanding the Memory process, Problems in retention, Memory enhancement techniques, Experience & Expression Understanding Emotions: Experience & Expression, Assessing Empathy, Application with Peers.

Module 2: Basics of Design Thinking:

Definition of Design Thinking, need for Design Thinking, Objective of Design Thinking, Concepts & Brainstorming, Stages of Design Thinking Process (explain with examples) – *Being Ingenious & Fixing Problem:* Empathize, Define, Ideate, Prototype, Test, Understanding Creative thinking process, Understanding Problem Solving, Testing Creative Problem Solving.

Module 3: Process of Product Design:

Process of Engineering Product Design, Design Thinking Approach, Stages of Product Design, Examples of best product designs and functions, Assignment – Engineering Product Design. *Prototyping & Testing:* Prototype and its need, Rapid Prototype Development process, Testing, Sample Example, Test Group Marketing.

Module 4: Celebrating the Difference Understanding:

Individual differences & Uniqueness Group Discussion and Activities to encourage the understanding, acceptance and appreciation of Individual differences.

Module 5: Design Thinking & Customer Centricity:

Practical Examples of Customer Challenges, Use of Design Thinking to Enhance Customer Experience, Parameters of Product experience, Alignment of Customer Expectations with Product Design.

Module 6: Feedback, Re-Design & Re-Create:

Feedback loop, Focus on User Experience, Address "ergonomic challenges, User focused design, rapid prototyping & testing, final product, Final Presentation – "Solving Practical Engineering Problem through Innovative Product Design & Creative Solution".

Suggested Text Books:

(i) Den Dekker Teun, "Design Thinking", Wolters-Noordhoff B.V., Dec, 2020.

(ii) Pavan Soni , "Design Your Thinking: The Mindsets, Toolsets and Skill Sets for Creative Problem-solving" , Penguin Random House India Private Limited, 23 December 2020.

Suggested Reference Books:

(i) Prof. Karl Ulrich, U. Penn, "Design: Creation of Artifacts in Society by Change", Oct, 2012.

(ii) Tim Brown, "Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation", Kindle edition, 2009.

Course Outcomes:

At the end of this course, the students will be able to:

- Compare and classify the various learning styles and memory techniques and Apply them in their engineering education.
- Develop new ways of creative thinking and Learn the innovation cycle of Design Thinking process for developing innovative products.
- Propose real-time innovative engineering product designs and Choose appropriate frameworks, strategies, techniques during prototype development.
- Perceive individual differences and its impact on everyday decisions and further Create a better customer experience.
- Analyze emotional experience and Inspect emotional expressions to better understand users while designing innovative products.

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HSMC-101	English	2L:0T:2P	3 Credits

Course Objective:

- To provide learning environment to practice listening, speaking, reading and writing skills.
- To assist the students to carry on the tasks and activities through guided instructions and materials.
- To effectively integrate English language learning with employability skills and training.
- To provide hands-on experience through case-studies, mini-projects, group and individual presentations.

Course Content:

Module I: Vocabulary Building

1.1. The concept of Word Formation
1.2. Root words from foreign languages and their use in English
1.3. Acquaintance with prefixes and suffixes from foreign languages in English to form derivatives.
1.4. Synonyms, antonyms, and standard abbreviations.

Module II: Basic Writing Skills

1.1. Sentence Structures
1.2. Use of phrases and clauses in sentences
1.3. Importance of proper punctuation
1.4. Creating coherence
1.5. Organizing principles of paragraphs in documents
1.6. Techniques for writing precisely

Module III: Identifying Common Errors in Writing

1.1. Subject-verb agreement
1.2. Noun-pronoun agreement
1.3. Misplaced modifiers
1.4. Articles
1.5. Prepositions
1.6. Redundancies
1.7. Clichés

Module IV: Nature and Style of sensible Writing

1.1. Describing
1.2. Defining
1.3. Classifying
1.4. Providing examples or evidence
1.5. Writing introduction and conclusion

Module V: Writing Practices

1.1. Comprehension

1.2. Précis Writing
1.3. Essay Writing

Module VI: Oral Communication

(This Module involves interactive practice sessions in Language Lab)

- Listening Comprehension
- Pronunciation, Intonation, Stress and Rhythm
- Common Everyday Situations: Conversations and Dialogues
- Communication at Workplace
- Interviews
- Formal Presentations

Text/Reference Books:

1. Practical English Usage. Michael Swan. OUP. 1995.
2. Remedial English Grammar. F.T. Wood. Macmillan.2007
3. On Writing Well. William Zinsser. Harper Resource Book. 2001
4. Study Writing. Liz Hamp-Lyons and Ben Heasly. Cambridge University Press. 2006.
5. Communication Skills. Sanjay Kumar and PushpLata. Oxford University Press. 2011.
6. Exercises in Spoken English. Parts. I-III. CIEFL, Hyderabad. Oxford University Press.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	ENGLISH LANGUAGE FOR COMPETITIVE EXAMS	PROF. AYSHA IQBAL	IIT MADRAS
2.	TECHNICAL ENGLISH FOR ENGINEERS	PROF. AYSHA IQBAL	IIT MADRAS

Course Outcomes: The student will acquire basic proficiency in English including reading and listening comprehension, writing and speaking skills.

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AU-101	IDEA Lab Workshop	2L:0T:4P	0 Credit

Course Objectives:

1. To learn all the skills associated with the tools and inventory associated with the IDEA Lab.
2. Learn useful mechanical and electronic fabrication processes.
3. Learn necessary skills to build useful and standalone system/ project with enclosures.
4. Learn necessary skills to create print and electronic documentation for the system/project

Course Contents:

Unit #	Topics	
1.	Electronic component familiarization, Understanding electronic system design flow. Schematic design and PCB layout and Gerber creation using EagleCAD. Documentation using Doxygen, Google Docs, Overleaf. Version control tools - GIT and GitHub. Basic 2D and 3D designing using CAD tools such as FreeCAD, Sketchup, Prusa Slicer, FlatCAM, Inkspace, OpenBSP and VeriCUT.	Introduction to basic hand tools - Tape measure, combination square, Vernier caliper, hammers, fasteners, wrenches, pliers, saws, tube cutter, chisels, vice and clamps, tapping and threading. Adhesives Introduction to Power tools: Power saws, band saw, jigsaw, angle grinder, belt sander, bench grinder, rotary tools. Various types of drill bits,
2.	Familiarization and use of basic measurement instruments - DSO including various triggering modes, DSO probes, DMM, LCR bridge, Signal and function generator. Logic analyzer and MSO. Bench power supply (with 4-wire output) Circuit prototyping using (a) breadboard, (b) Zero PCB (c) 'Manhattan' style and (d) custom PCB. Single, double and multilayer PCBs. Single and double-sided PCB prototype fabrication in the lab. Soldering using soldering iron/station. Soldering using a temperature controlled reflow oven. Automated circuit assembly and soldering using pick and place machines.	Mechanical cutting processes - 3-axis CNC routing, basic turning, milling, drilling and grinding operations, Laser cutting, Laser engraving etc. Basic welding and brazing and other joining techniques for assembly. Concept of Lab aboard a Box.

3.	Electronic circuit building blocks including common sensors. Arduino and Raspberry Pi programming and use. Digital Input and output. Measuring time and events. PWM. Serial communication. Analog input. Interrupts programming. Power Supply design (Linear and Switching types), Wireless power supply, USB PD, Solar panels, Battery types and charging	3D printing and prototyping technology – 3D printing using FDM, SLS and SLA. Basics of 3D scanning, point cloud data generation for reverse engineering. Prototyping using subtractive cutting processes. 2D and 3D Structures for prototype building using Laser cutter and CNC routers. Basics of IPR and patents; Accessing and utilizing patent information in IDEA Lab
4.	Discussion and implementation of a mini project.	
5.	Documentation of the mini project (Report and video).	

Laboratory Activities:

S. No.	List of Lab activities and experiments
1.	Schematic and PCB layout design of a suitable circuit, fabrication and testing of the circuit.
2.	Machining of 3D geometry on soft material such as soft wood or modelling wax.
3.	3D scanning of computer mouse geometry surface. 3D printing of scanned geometry using FDM or SLA printer.
4.	2D profile cutting of press fit box/casing in acrylic (3 or 6 mm thickness)/cardboard, MDF (2 mm) board using laser cutter & engraver.
5.	2D profile cutting on plywood /MDF (6-12 mm) for press fit designs.
6.	Familiarity and use of welding equipment.
7.	Familiarity and use of normal and wood lathe.
8.	Embedded programming using Arduino and/or Raspberry Pi.
9.	Design and implementation of a capstone project involving embedded hardware, software and machined or 3D printed enclosure.

Reference Books:

S. No.	Title
1.	The Big Book of Maker Skills: Tools & Techniques for Building Great Tech Projects. Chris Hackett. Weldon Owen; 2018. ISBN-13: 978-1681884325.

2.	The Total Inventors Manual (Popular Science): Transform Your Idea into a Top-Selling Product. Sean Michael Ragan (Author). Weldon Owen; 2017. ISBN-13: 978-1681881584.
3.	Make: Tools: How They Work and How to Use Them. Platt, Charles. Shroff/Maker Media. 2018. ISBN-13: 978-9352137374
4.	The Art of Electronics. 3rd edition. Paul Horowitz and Winfield Hill. Cambridge University Press. ISBN: 9780521809269
5.	Practical Electronics for Inventors. 4th edition. Paul Sherz and Simon Monk. McGraw Hill. ISBN-13: 978-1259587542
6.	Encyclopedia of Electronic Components (Volume 1, 2 and 3). Charles Platt. Shroff Publishers. ISBN-13: 978-9352131945, 978-9352131952, 978-9352133703
7.	Building Scientific Apparatus. 4th edition. John H. Moore, Christopher C. Davis, Michael A. Coplan and Sandra C. Greer. Cambridge University Press. ISBN-13: 978-0521878586
8.	Programming Arduino: Getting Started with Sketches. 2nd edition. Simon Monk. McGraw Hill. ISBN-13: 978-1259641633
9.	Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards. Simon Monk and Duncan Amos. McGraw Hill Education. ISBN-13 : 978-1260019193.
10.	Pro GIT. 2nd edition. Scott Chacon and Ben Straub. A press. ISBN-13 : 978-1484200773
11.	Venuvinod, PK., MA. W., Rapid Prototyping – Laser Based and Other Technologies, Kluwer, 2004.
12.	Ian Gibson, David W Rosen, Brent Stucker., “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, Springer, 2010
13.	Chapman W.A.J, “Workshop Technology”, Volume I, II, III, CBS Publishers and distributors, 5th Edition,2002.

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SEMESTER – II

SEMESTER II

BSC-103	Chemistry- I	3L:0T:2P	5 Credits

Course Objective:

The objective of the Chemistry-I is to acquaint the students with the basic phenomenon/concepts of chemistry, the student faces during course of their study in the industry and Engineering field. The student with the knowledge of the basic chemistry, will understand and explain scientifically the various chemistry related problems in the industry/engineering field. The student will able to understand the new developments and breakthroughs efficiently in engineering and technology. The introduction of the latest (R&D oriented) topics will make the engineering student upgraded with the new technologies.

Course Content:

Module I: Atomic and Molecular Structure

Schrodinger equation. Particle in a box solutions and their applications for conjugated molecules and nanoparticles. Forms of the hydrogen atom wave functions and the plots of these functions to explore their spatial variations. Molecular orbitals of diatomic molecules and plots of the multicenter orbitals. Equations for atomic and molecular orbitals. Energy level diagrams of diatomic. Pi-molecular orbitals of butadiene and benzene and aromaticity. Crystal field theory and the energy level diagrams for transition metal ions and their magnetic properties. Band structure of solids and the role of doping on band structures.

Module II: Spectroscopic techniques and applications

Principles of spectroscopy and selection rules. Electronic spectroscopy. Fluorescence and its applications in medicine. Vibrational and rotational spectroscopy of diatomic molecules. Applications. Nuclear magnetic resonance and magnetic resonance imaging, surface characterization techniques. Diffraction and scattering.

Module III: Intermolecular forces and potential energy surfaces

Ionic, dipolar and van Der Waals interactions. Equations of state of real gases and critical phenomena. Potential energy surfaces of H3, H2F and HCN and trajectories on these surfaces.

Module IV: Use of free energy in chemical equilibria

Thermodynamic functions: energy, entropy and free energy. Estimations of entropy and free energies. Free energy and EMF. Cell potentials, the Nernst equation and applications. Acid base, oxidation reduction and solubility equilibria. Water chemistry. Corrosion. Use of free energy considerations in metallurgy through Ellingham diagrams.

Module V: Periodic properties

Effective nuclear charge, penetration of orbitals, variations of s, p, d and f orbital energies of atoms in the periodic table, electronic configurations, atomic and ionic sizes, ionization energies, electron

affinity and electronegativity, polarizability, oxidation states, coordination numbers and geometries, hard soft acids and bases, molecular geometries.

Module VI: Stereochemistry

Representations of 3 dimensional structures, structural isomers and stereoisomers, configurations and symmetry and chirality, enantiomers, diastereomers, optical activity, absolute configurations and conformational analysis. Isomerism in transitional metal compounds.

Module VII: Organic reactions and synthesis of a drug molecule

Introduction to reactions involving substitution, addition, elimination, oxidation, reduction, cyclization and ring openings. Synthesis of a commonly used drug molecule.

LABORATORY

Choice of 10-12 experiments from the following:

1. Determination of surface tension and viscosity.
2. Thin layer chromatography.
3. Ion exchange column for removal of hardness of water.
4. Determination of chloride content of water.
5. Colligative properties using freezing point depression.
6. Determination of the rate constant of a reaction.
7. Determination of cell constant and conductance of solutions.
8. Potentiometry - determination of redox potentials and EMFs.
9. Synthesis of a polymer/drug.
10. Saponification/acid value of an oil.
11. Chemical analysis of a salt.
12. Lattice structures and packing of spheres.
13. Models of potential energy surfaces.
14. Chemical oscillations- Iodine clock reaction.
15. Determination of the partition coefficient of a substance between two immiscible liquids.
16. Adsorption of acetic acid by charcoal.
17. Use of the capillary viscosimeters to the demonstrate of the isoelectric point as the pH of minimum viscosity for gelatin sols and/or coagulation of the white part of egg.

Text/Reference Books:

1. University chemistry, by B. H. Mahan
2. Chemistry: Principles and Applications, by M. J. Sienko and R. A. Plane
3. Fundamentals of Molecular Spectroscopy, by C. N. Banwell
4. Engineering Chemistry (NPTEL Web-book), by B. L. Tembe, Kamaluddin and M. S. Krishnan
5. Physical Chemistry, by P. W. Atkins
6. Organic Chemistry: Structure and Function by K. P. C. Volhardt and N. E. Schore, 5th Edition http://bcs.whfreeman.com/vollhardtschore5e/default.asp

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	CHEMISTRY - I	PROF. MANGALA SUNDER KRISHNAN	IITM

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	Determination of surface tension and viscosity.	http://pcv-au.vlabs.ac.in/physical-chemistry/Determination_of_Viscosity_of_Organic_Solvents/
2	Ion exchange column for removal of hardness of water.	http://icv-au.vlabs.ac.in/inorganic-chemistry/Water_Analysis_Determination_of_Chemical_Parameters/
3	Determination of chloride content of water.	http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk_labs/Environmental_Engineering_1/experiments/determination-of-chloride-nitk/simulation.html
4	Colligative properties using freezing point depression.	http://pcv-au.vlabs.ac.in/physical-chemistry/Cryoscopy/
5	Determination of the rate constant of a reaction.	http://pcv-au.vlabs.ac.in/physical-chemistry/EMF_Measurement/
6	Determination of cell constant and conductance of solutions.	http://icv-au.vlabs.ac.in/inorganic-chemistry/Water_Analysis_Determination_of_Physical_Parameters/
7	Potentiometry - determination of redox potentials and EMFs.	http://pcv-au.vlabs.ac.in/physical-chemistry/EMF_Measurement/
8	Saponification/acid value of an oil.	http://biotech01.vlabs.ac.in/bio-chemistry/Estimation_of_Saponification_Value_of_Fats_or_Oils/
9	Lattice structures and packing of spheres.	https://vlab.amrita.edu/?sub=1&brch=282&sim=370&cnt=1

Course Outcomes: The concepts developed in this course will aid in quantification of several concepts in chemistry that have been introduced at the 10+2 levels in schools. Technology is being increasingly based on the electronic, atomic and molecular level modifications. Quantum theory is more than 100 years old and to understand phenomena at nanometer levels, one has to base the description of all chemical processes at molecular levels. The course will enable the students:

- To analyse microscopic chemistry in terms of atomic and molecular orbitals and intermolecular forces.
- To rationalise bulk properties and processes using thermodynamic considerations.
- To distinguish the ranges of the electromagnetic spectrum used for exciting different molecular energy levels in various spectroscopic techniques
- To rationalise periodic properties such as ionization potential, electronegativity, oxidation states and electronegativity.
- To list major chemical reactions that are used in the synthesis of molecules.

Laboratory Outcomes: The chemistry laboratory course will consist of experiments illustrating the principles of chemistry relevant to the study of science and engineering. The students will learn:

- To estimate rate constants of reactions from concentration of reactants/products as a function of time.
- To measure molecular/system properties such as surface tension, viscosity, conductance of solutions, redox potentials, chloride content of water, etc.
- To synthesize a small drug molecule and analyze a salt sample.

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BSC-104	Maths–II (Ordinary Differential Equations and Multivariate Calculus)	3L:1T:0P	4 Credits

Detailed Content:

Module 1:
Review of first order differential equations, Reduction of order, linear differential equations, homogeneous higher order linear differential equations, non-homogeneous higher order linear differential equations with constant coefficients and reducible to differential equations with constant coefficients (method of undetermined coefficients and method of variation of parameters), systems of differential equations, applications to orthogonal trajectories, mass spring systems and electrical circuits.

Module 2:
Functions of several variables, level curves and level surfaces, partial and directional derivatives, differentiability, chain rule, local extreme values and saddle points, constrained optimization.

Module 3:
Double integrals in Cartesian and polar coordinates, iterated integrals, change of variables, triple integrals in Cartesian, spherical and cylindrical coordinates, and substitutions in multiple integrals, Applications to Area, Volume, Moments and Center of Mass.

Suggested Text Books:

(i) Thomas' Calculus (12th edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.
(ii) Advanced Engineering Mathematics (10th edition) by Erwin Kreyszig, Wiley eastern Ltd.

Suggested Reference Books:

(i) K.D Joshi, "Calculus for Scientists and Engineers", CRC Press, 2002.
(ii) Sudhir Ghorpade and Balmohan Limaye, "A Course in Multivariate Calculus and Analysis", Springer Science and Business Media.
(iii) George Simmons, "Differential Equations with Applications and Historical notes", Tata McGraw Hill publishing company Ltd, New Delhi, 2006.
(iv) C.R. Wylie, "Advanced Engineering Mathematics", McGraw Hill Publications, New Delhi, 2017.
(v) Peter V. O' Neil, "Advanced Engineering Mathematics", (7^{th} edition), Thomson. Brooks / Cole, Singapore, 1991.
(vi) Michael D. Greenberg, "Advanced Engineering Mathematics", (2^{nd} edition), Pearson Education, 1998.

Course Outcomes:

After completion of this course, the students will be able to:

- Understand basic concepts (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.).
- Illustrate any example.
- Analyze the problem and apply the appropriate concept (To measure this outcome, questions will be based on applications of core concepts).
- Know and recall core knowledge of the syllabus (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.).

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ESC-103	Programming for Problem Solving	3L:0T:4P	5 Credits

Course Objectives:

1. To learn the fundamentals of computers.
2. To understand the various steps in program development.
3. To learn the syntax and semantics of C programming language.
4. To learn the usage of structured programming approach in solving problems.
5. To understated and formulate algorithm for programming script
6. To analyze the output based on the given input variables

Course Contents:

Module I: Introduction to Programming**;** Introduction to components of a computer system (disks, memory, processor, where a program is stored and executed, operating system, compilers etc.)

Idea of Algorithm: steps to solve logical and numerical problems. Representation of Algorithm: Flowchart/Pseudocode with examples.

From algorithms to programs; source code, variables (with data types) variables and memory locations, Syntax and Logical Errors in compilation, object and executable code.

Module II: Arithmetic expressions and precedence.

Module III: Conditional Branching and Loops. Writing and evaluation of conditionals and consequent branching. Iteration and loops.

Module IV: Arrays, Arrays (1-D, 2-D), Character arrays and Strings

Module V: Basic Algorithms, Searching, Basic Sorting Algorithms (Bubble, Insertion and Selection), Finding roots of equations, notion of order of complexity through example programs (no formal definition required)

Module VI: Function, Functions (including using built in libraries), Parameter passing in functions, call by value, Passing arrays to functions: idea of call by reference

Module VII: Recursion, Recursion as a different way of solving problems. Example programs, such as Finding Factorial, Fibonacci series, Ackerman function etc. Quick sort or Merge sort.

Module VIII: Structures, Defining structures and Array of Structures

Module IX: Pointers, Idea of pointers, Defining pointers, Use of Pointers in self-referential structures, notion of linked list (no implementation)

Module X: File handling (only if time is available, otherwise should be done as part of the lab).

PRACTICALS:

1. Familiarization with programming environment
2. Simple computational problems using arithmetic expressions
3. Problems involving if-then-else structures
4. Iterative problems e.g., sum of series
5. 1D Array manipulation
6. Matrix problems, String operations
7. Simple functions
8. Programming for solving Numerical methods problems
9. Recursive functions
10. Pointers and structures
11. File operations

TEXT/REFERENCE BOOKS:

1. Byron Gottfried, Schaum's Outline of Programming with C, McGraw-Hill.
2. E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill.
3. Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice Hall of India.

Alternative NPTEL/SWAYAM Course:

S. No.	NPTEL Course Name	Instructor	Host Institute
1	INTRODUCTION TO PROGRAMMING IN C	PROF. SATYADEV NANDAKUMAR	IIT KANPUR
2	PROBLEM SOLVING THROUGH PROGRAMMING IN C	PROF. ANUPAM BASU	IIT KHARAGPUR

EXPERIMENTS THAT MAY BE PERFORMED THROUGH VIRTUAL LABS:

S. No.	Experiment Name	Experiment Link(s)
1	Simple computational problems using arithmetic expressions.	http://ps-iiith.vlabs.ac.in/exp7/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab
2	Iterative problems e.g., sum of series.	http://ps-iiith.vlabs.ac.in/exp4/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab
3	1D Array manipulation.	http://cse02-iiith.vlabs.ac.in/exp4/index.html

4	Matrix problems, String operations.	http://ps-iiith.vlabs.ac.in/exp5/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab
5	Simple functions.	http://cse02-iiith.vlabs.ac.in/exp2/index.html
6	Programming for solving Numerical methods problems.	http://ps-iiith.vlabs.ac.in/exp1/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab
7	Recursive functions.	http://ps-iiith.vlabs.ac.in/exp6/Introduction.html?domain=Computer%20Science&lab=Problem%20Solving%20Lab

COURSE OUTCOMES: The student will learn following through lectures:

- To formulate simple algorithms for arithmetic and logical problems.
- To translate the algorithms to programs (in C language).
- To test and execute the programs and correct syntax and logical errors.
- To implement conditional branching, iteration and recursion.
- To decompose a problem into functions and synthesize a complete program using divide and conquer approach.
- To use arrays, pointers and structures to formulate algorithms and programs.
- To apply programming to solve matrix addition and multiplication problems and searching and sorting problems.
- To apply programming to solve simple numerical method problems, namely rot finding of function, differentiation of function and simple integration.

The student will learn following through Practicals:

- To formulate the algorithms for simple problems.
- To translate given algorithms to a working and correct program.
- To be able to correct syntax errors as reported by the compilers.
- To be able to identify and correct logical errors encountered at run time.
- To be able to write iterative as well as recursive programs.
- To be able to represent data in arrays, strings and structures and manipulate them through a program.
- To be able to declare pointers of different types and use them in defining self-referential structures.
- To be able to create, read and write to and from simple text files.

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ESC-104	Workshop: Manufacturing Practice	0L:0T:3P	1.5 Credits

Course Content:

- Manufacturing Methods- casting, forming, machining, joining, advanced manufacturing methods **(3 lectures).**
- CNC machining, Additive manufacturing **(1 lecture).**
- Fitting operations & power tools **(1 lecture).**
- Electrical & Electronics **(1 lecture).**
- Carpentry **(1 lecture).**
- Plastic molding, glass cutting **(1 lecture).**
- Metal casting **(1 lecture).**
- Welding (arc welding & gas welding), brazing **(1 lecture).**

Suggested Text Books:

(i) Hajra Choudhury S.K., Hajra Choudhury A.K. and Nirjhar Roy S.K., "Elements of Workshop Technology", Media promoters and publishers private limited, Mumbai,Vol. I 2008 and Vol. II 2010.
(ii) Kalpakjian S. And Steven S. Schmid, "Manufacturing Engineering and Technology", 4th edition, Pearson Education India Edition, 2002.

Suggested Reference Books:

(i) Gowri P. Hariharan and A. Suresh Babu, "Manufacturing Technology – I" Pearson Education, 2008.
(ii) Roy A. Lindberg, "Processes and Materials of Manufacture", 4th edition, Prentice Hall India, 1998.
(iii) Rao P.N., "Manufacturing Technology", Vol. I and Vol. II, Tata McGraw Hill House, 2017.

Course Outcomes:

After completion of this course, the students will be able to:

- Acquire knowledge of the different manufacturing processes which are commonly employed in the industry, to fabricate components using different materials.
- Understand the difference between traditional manufacturing and advanced manufacturing processes.

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AU-102	Sports and Yoga (Audit Course)	2L:0T:0P	0 Credit

Course Objective(s):

- To make the students understand the importance of sound health and fitness principles as they relate to better health.
- To expose the students to a variety of physical and yogic activities aimed at stimulating their continued inquiry about Yoga, physical education, health and fitness.
- To create a safe, progressive, methodical and efficient activity based plan to enhance improvement and minimize risk of injury.
- To develop among students an appreciation of physical activity as a lifetime pursuit and a means to better health.

Course Contents:

Module I: Introduction to Physical Education

- Meaning & definition of Physical Education
- Aims & Objectives of Physical Education
- Changing trends in Physical Education

Module II: Olympic Movement

- Ancient & Modern Olympics (Summer & Winter)
- Olympic Symbols, Ideals, Objectives & Values
- Awards and Honours in the field of Sports in India (Dronacharya Award, Arjuna Award, Dhayanchand Award, Rajiv Gandhi Khel Ratna Award etc.)

Module III: Physical Fitness, Wellness & Lifestyle

- Meaning & Importance of Physical Fitness & Wellness
- Components of Physical fitness
- Components of Health related fitness
- Components of wellness
- Preventing Health Threats through Lifestyle Change
- Concept of Positive Lifestyle

Module IV: Fundamentals of Anatomy & Physiology in Physical Education, Sports and Yoga

- Define Anatomy, Physiology & Its Importance
- Effect of exercise on the functioning of Various Body Systems. (Circulatory System, Respiratory System, Neuro-Muscular System etc.)

Module V: Kinesiology, Biomechanics & Sports

- Meaning & Importance of Kinesiology & Biomechanics in Physical Edu. & Sports
- Newton's Law of Motion & its application in sports.
- Friction and its effects in Sports.

Module VI: Postures

- Meaning and Concept of Postures.
- Causes of Bad Posture.
- Advantages & disadvantages of weight training.
- Concept & advantages of Correct Posture.
- Common Postural Deformities – Knock Knee; Flat Foot; Round Shoulders; Lordosis, Kyphosis, Bow Legs and Scoliosis.
- Corrective Measures for Postural Deformities

Module VII: Yoga

- Meaning & Importance of Yoga
- Elements of Yoga
- Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas
- Yoga for concentration & related Asanas (Sukhasana; Tadasana; Padmasana & Shashankasana)
- Relaxation Techniques for improving concentration - Yog-nidra

Module VIII: Yoga & Lifestyle

- Asanas as preventive measures.
- Hypertension: Tadasana, Vajrasana, Pavan Muktasana, Ardha Chakrasana, Bhujangasana, Sharasana.
- Obesity: Procedure, Benefits & contraindications for Vajrasana, Hastasana, Trikonasana, Ardh Matsyendrasana.
- Back Pain: Tadasana, Ardh Matsyendrasana, Vakrasana, Shalabhasana, Bhujangasana.
- Diabetes: Procedure, Benefits & contraindications for Bhujangasana, Paschimottasana, Pavan Muktasana, Ardh Matsyendrasana.
- Asthema: Procedure, Benefits & contraindications for Sukhasana, Chakrasana, Gomukhasana, Parvatasana, Bhujangasana, Paschimottasana, Matsyasana.

Module IX: Training and Planning in Sports

- Meaning of Training
- Warming up and limbering down
- Skill, Technique & Style
- Meaning and Objectives of Planning.
- Tournament – Knock-Out, League/Round Robin & Combination.

Module X: Psychology & Sports

- Definition & Importance of Psychology in Physical Edu. & Sports
- Define & Differentiate Between Growth & Development
- Adolescent Problems & Their Management
- Emotion: Concept, Type & Controlling of emotions
- Meaning, Concept & Types of Aggressions in Sports.
- Psychological benefits of exercise.
- Anxiety & Fear and its effects on Sports Performance.
- Motivation, its type & techniques.
- Understanding Stress & Coping Strategies.

Module XI: Doping

- Meaning and Concept of Doping
- Prohibited Substances & Methods
- Side Effects of Prohibited Substances

Module XII: Sports Medicine

- First Aid – Definition, Aims & Objectives.
- Sports injuries: Classification, Causes & Prevention.
- Management of Injuries: Soft Tissue Injuries and Bone & Joint Injuries

Module XIII: Sports / Games

Following subtopics related to any one Game/Sport of choice of student out of:

Athletics, Badminton, Basketball, Chess, Cricket, Kabaddi, Lawn Tennis, Swimming, Table Tennis, Volleyball, Yoga etc.

- History of the Game/Sport.
- Latest General Rules of the Game/Sport.
- Specifications of Play Fields and Related Sports Equipment.
- Important Tournaments and Venues.
- Sports Personalities.
- Proper Sports Gear and its Importance.

Text Books/References:

1. Modern Trends and Physical Education by Prof. Ajmer Singh.
2. Light On Yoga by B.K.S. Iyengar.
3. Health and Physical Education – NCERT (11th and 12th Classes)

Course Outcomes:

On successful completion of the course the students will be able:

1. To practice Physical activities and Hatha Yoga focusing on yoga for strength, flexibility, and relaxation.
2. To learn techniques for increasing concentration and decreasing anxiety which leads to stronger academic performance.
3. To learn breathing exercises and healthy fitness activities
4. To understand basic skills associated with yoga and physical activities including strength and flexibility, balance and coordination.
5. To perform yoga movements in various combination and forms.
6. To assess current personal fitness levels.
7. To identify opportModuleies for participation in yoga and sports activities.
8. To develop understanding of health-related fitness components: cardiorespiratory endurance, flexibility and body composition etc.
9. To improve personal fitness through participation in sports and yogic activities.
10. To develop understanding of psychological problems associated with the age and lifestyle.
11. To demonstrate an understanding of sound nutritional practices as related to health and physical performance.
12. To assess yoga activities in terms of fitness value.
13. To identify and apply injury prevention principles related to yoga and physical fitness activities.
1. To understand and correctly apply biomechanical and physiological principles elated to exercise and training.

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ESC-105	Workshop: Electronics and Computer	0L:0T:4P	2 Credits

Detailed Content:

The following content should be covered in the Workshop practice:

Electronics:

Role of various Engineering disciplines in Mechatronics, Mechatronics Design elements, Scope and Applications of Mechatronics, Analog electronic components and devices, Oscillators as signal generators, Power supplies and voltage regulators, Power Electronics- Devices, Industrial electronic circuits, Digital Electronics- Arithmetic circuits, Multiplexers/Demultiplexers, Registers, Counters, Memories, Few examples of transducers, Signal conditioning Circuits using Operational amplifiers, Noise Problems, Grounding and shielding, Data acquisition systems,-Single channel and multichannel, Data loggers, Control Systems Components, Classification of Control Systems, Transfer functions, Time and Frequency response Analysis tools.

Computer:

What is Computer, Basic Applications of Computer; Components of Computer System, Central Processing Unit (CPU), VDU, Keyboard and Mouse, Other input/output Devices, Computer Memory, Concepts of Hardware and Software; Concept of Computing, Data and Information; Applications of IECT; Connecting keyboard, mouse, monitor and printer to CPU and checking power supply. What is an Operating System; Basics of Popular Operating Systems; The User Interface, Using Mouse; Using right Button of the Mouse and Moving Icons on the screen, Use of Common Icons, Status Bar, Using Menu and Menu-selection, running an Application, Viewing of File, Folders and Directories, Creating and Renaming of files and folders, Opening and closing of different Windows; Using help; Creating Shortcuts, Basics of O.S Setup; Common utilities.

Suggested Text Books:

(i) D.P. Kothari, I J. Nagrath, "Basic Electrical and Electronics Engineering", 2nd edition, McGraw Hill, 2020.

(ii) Sinha, P. K, "Computer Fundamentals: Concepts, Systems & Applications", 3rd edition, BPB, 2004.

Course Outcomes:

After the completion of this course, the students will be able to:

- Identify different electronic components.
- Understand the working principle of different electronic devices.
- Understand the use and working of each component in computer system.
- Differentiate the use of operating system in programming languages.

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HSMC-102	Universal Human Values-II: Understanding Harmony And Ethical Human Conduct	3L:0T:0P	3 Credits

Pre-requisites: None. Universal Human Values 1 (Desirable)

1-COURSES ON HUMAN VALUES

During the Induction Program, students would get an initial exposure to human values through Universal Human Values-I. This exposure is to be augmented by this compulsory full semester foundation course.

Objectives of UHV-II Course

This introductory course input is intended:

1. To help the students appreciate the essential complementarily between 'VALUES' and 'SKILLS' to ensure sustained happiness and prosperity which are the core aspirations of all human beings.
2. To facilitate the development of a Holistic perspective among students towards life and profession as well as towards happiness and prosperity based on a correct understanding of the Human reality and the rest of existence. Such a holistic perspective forms the basis of Universal Human Values and movement towards value-based living in a natural way.
3. To highlight plausible implications of such a Holistic understanding in terms of ethical human conduct, trustful and mutually fulfilling human behavior and mutually enriching interaction with Nature.

Thus, this course is intended to provide a much-needed orientational input in value education to the young enquiring minds.

Salient Features of the Course

The salient features of this course are:

1. It presents a universal approach to value education by developing the right understanding of reality (i.e. a worldview of the reality “as it is”) through the process of self-exploration.
2. The whole course is presented in the form of a dialogue whereby a set of proposals about various aspects of the reality are presented and the students are encouraged to self-explore the proposals by verifying them on the basis of their natural acceptance within oneself and validate experientially in living.
3. The prime focus throughout the course is toward affecting a qualitative transformation in the life of the student rather than just a transfer of information.
4. While introducing the holistic worldview and its implications, a critical appraisal of the prevailing notions is also made to enable the students discern the difference on their own right.

Course Methodology

1. The methodology of this course is explorational and thus universally adaptable. It involves a systematic and rational study of the human being vis-à-vis the rest of existence.
2. The course is in the form of 28 lectures (discussions) and 14 practice sessions.
3. It is free from any dogma or value prescriptions.
4. It is a process of self-investigation and self-exploration, and not of giving sermons. Whatever is found as truth or reality is stated as a proposal and the students are facilitated to verify it in their own right, based on their Natural Acceptance and subsequent Experiential Validation – the whole existence is the lab and every activity is a source of reflection.
5. This process of self-exploration takes the form of a dialogue between the teacher and the students to begin with, and then to continue within the student in every activity, leading to continuous self-evolution.
6. This self-exploration also enables them to critically evaluate their pre-conditionings and present beliefs.

2-COURSE TOPICS

The course has 28 lectures and 14 tutorials in 5 modules. The lectures and tutorials are of 01-hour duration. Tutorial sessions are to be used to explore and practice what has been proposed during the lecture sessions.

The Teacher's Manual provides the outline for lectures as well as practice sessions. The teacher is expected to present the issues to be discussed as propositions and encourage the students to have a dialogue.

The syllabus for the lectures and practice sessions is given below:

Module 1 – Introduction to Value Education (6 lectures and 3 tutorials for practice session)

Lecture 1: Right Understanding, Relationship and Physical Facility (Holistic Development and the Role of Education)
Lecture 2: Understanding Value Education
Tutorial 1: **Practice Session PS1** Sharing about Oneself
Lecture 3: Self-exploration as the Process for Value Education
Lecture 4: Continuous Happiness and Prosperity – the Basic Human Aspirations
Tutorial 2: Practice Session PS2 Exploring Human Consciousness
Lecture 5: Happiness and Prosperity – Current Scenario
Lecture 6: Method to Fulfill the Basic Human Aspirations
Tutorial 3: Practice Session PS3 Exploring Natural Acceptance

Expected outcome:

The students start exploring themselves: get comfortable with each other and with the teacher; they start appreciating the need and relevance for the course.

The students start finding that technical education without study of human values can generate more problems than solutions. They also start feeling that lack of understanding of human values is the

root cause of most of the present-day problems; and a sustained solution could emerge only through understanding of value-based living. Any solution brought out through fear, temptation of dogma will not be sustainable.

The students are able to see that verification on the basic of natural acceptance and experiential validation through living is the only way to verify right or wrong, and referring to any external source like text or instrument or any other person cannot enable them to verify with authenticity; it will only develop assumptions.

The students are able to see that their practice in living is not in harmony with their natural acceptance most of the time, and all they need to do is to refer to their natural acceptance to overcome this disharmony.

The students are able to see that lack of right understanding leading to lack of relationship is the major cause of problems in their family and not the lack of physical facility in most of the cases, while they have given higher priority to earning of physical facility in their life giving less value to or even ignoring relationships and not being aware that right understanding is the most important requirement for any human being.

Module 2 – Harmony in the Human Being (6 lectures and 3 tutorials for practice session)

Lecture 7: Understanding Human being as the Co-existence of the Self and the Body
Lecture 8: Distinguishing between the Needs of the Self and the Body
Tutorial 4: Practice Session PS4 Exploring the difference of Needs of Self and Body
Lecture 9: The Body as an Instrument of the Self
Lecture 10: Understanding Harmony in the Self
Tutorial 5: Practice Session PS5 Exploring Sources of Imagination in the Self
Lecture 11: Harmony of the Self with the Body
Lecture 12: Programme to ensure self-regulation and Health
Tutorial 6: Practice Session PS6 Exploring Harmony of Self with the Body

Expected outcome:

The students are able to see that they can enlist their desires and the desires are not vague. Also they are able to relate their desires to 'I' and 'Body' distinctly. If any desire appears related to both, they are able to see that the feeling is related to I while the physical facility is related to the body. They are also able to see that 'I' and Body are two realities, and most of their desires are related to 'I' and not body, while their efforts are mostly centered on the fulfilment of the needs of the body assuming that it will meet the needs of 'I' too.

The students are able to see that all physical facility they are required for a limited time in a limited quantity. Also, they are able to see that in case of feelings, they want continuity of the naturally acceptable feelings and they do not want feelings which are not naturally acceptable even for a single moment.

The students are able to see that activities like understanding, desire, though and selection are the activities of 'I' only the activities like breathing, palpitation of different parts of the body are fully the activities of the body with the acceptance of 'I' while the activities they do with their sense organs like hearing through ears, seeing through eyes, sensing through touch, tasting through tongue and

smelling through nose or the activities they do with their work organs like hands, legs etc. are such activities that require the participation of both 'I' and body.

The students become aware of their activities of 'I' and start finding their focus of attention at different moments. Also they are able to see that most of their desires are coming from outside (through preconditioning or sensation) and are not based on their natural acceptance

The students are able to list down activities related to proper upkeep of the body and practice them in their daily routine. They are also able to appreciate the plants wildly growing in and around the campus which can be beneficial in curing different diseases.

Module 3 – Harmony in the Family and Society (6 lectures and 3 tutorials for practice session)

Lecture 13: Harmony in the Family – the Basic Unit of Human Interaction
Lecture 14: 'Trust' – the Foundational Value in Relationship
Tutorial 7: Practice Session PS7 Exploring the Feeling of Trust
Lecture 15: 'Respect' – as the Right Evaluation
Tutorial 8: Practice Session PS8 Exploring the Feeling of Respect
Lecture 16: Other Feelings, Justice in Human-to-Human Relationship
Lecture 17: Understanding Harmony in the Society
Lecture 18: Vision for the Universal Human Order
Tutorial 9: Practice Session PS9 Exploring Systems to fulfil Human Goal

Expected outcome:

The students are able to note that the natural acceptance (intention) is always for living in harmony, only competence is lacking! We generally evaluate ourselves on the basis of our intention and others on the basis of their competence! We seldom look at our competence and others' intention as a result we conclude that I am a good person and other is a bad person.

The students are able to see that respect is right evaluation, and only right evaluation leads to fulfilment in relationship. Many present problems in the society are an outcome of differentiation (lack of understanding of respect), like gender biasness, generation gap, caste conflicts, class struggle, dominations through power play, communal violence, clash of isms and so on so forth. All these problems can be solved by realizing that the other is like me as he has the same natural acceptance, potential and program to ensure a happy and prosperous life for them and for others through he may have different body, physical facility or beliefs.

The students are able to use their creativity for education children. The students are able to see that they can play a role in providing value education for children. They are able to put in simple words the issues that are essential to understand for children and comprehensible to them. The students are able to develop an outline of holistic model for social science and compare it with the existing model.

Module 4 – Harmony in the Nature/Existence (4 lectures and 2 tutorials for practice session)

Lecture 19: Understanding Harmony in the Nature

Lecture 20: Interconnectedness, self-regulation and Mutual Fulfilment among the Four Orders of Nature
Tutorial 10: Practice Session PS10 Exploring the Four Orders of Nature
Lecture 21: Realizing Existence as Co-existence at All Levels
Lecture 22: The Holistic Perception of Harmony in Existence
Tutorial 11: Practice Session PS11 Exploring Co-existence in Existence

Expected outcome:

The students are able to differentiate between the characteristics and activities of different orders and study the mutual fulfilment among them. They are also able to see that human being s are not fulfilling to other orders today and need to take appropriate steps to ensure right participation (in terms of nurturing, protection and right utilization) in the nature.

The students feel confident that they can understand the whole existence; nothing is a mystery in this existence. They are also able to see the interconnectedness in the nature, and point out how different courses of study relate to the different units and levels. Also, they are able to make out how these courses can be made appropriate and holistic.

Module 5 – Implications of the Holistic Understanding – a Look at Professional Ethics (6 lectures and 3 tutorials for practice session)

Lecture 23: Natural Acceptance of Human Values
Lecture 24: Definitiveness of (Ethical) Human Conduct
Tutorial 12: Practice Session PS12 Exploring Ethical Human Conduct
Lecture 25: A Basis for Humanistic Education, Humanistic Constitution and Universal Human Order
Lecture 26: Competence in Professional Ethics
Tutorial 13: Practice Session PS13 Exploring Humanistic Models in Education
Lecture 27: Holistic Technologies, Production Systems and Management Models-Typical Case Studies
Lecture 28: Strategies for Transition towards Value-based Life and Profession
Tutorial 14: Practice Session PS14 Exploring Steps of Transition towards Universal Human Order

Expected outcome:

The students are able to present sustainable solutions to the problems in society and nature. They are also able to see that these solutions are practicable and draw roadmaps to achieve them.

The students are able to grasp the right utilization of their knowledge in their streams of Technology/Engineering/Management/any other area of study to ensure mutual fulfilment. E.g. mutually enriching production system with rest of nature.

The students are able to sincerely evaluate the course and share with their friends. They are also able to suggest measures to make the course more effective and relevant. They are also able to make use of their understanding in the course for the happy and prosperous family and society.

Guidelines and Content for Practice Sessions (Tutorials)

In order to connect the content of the proposals with practice (living), 14 practice sessions have been designed. The full set of practice sessions is available in the Teacher's Manual as well as the website.

Practice Sessions for Module 1 – Introduction to Value Education

PS1 Sharing about Oneself

PS2 Exploring Human Consciousness

PS3 Exploring Natural Acceptance

Practice Sessions for Module 2 – Harmony in the Human Being

PS4 Exploring the difference of Needs of Self and Body

PS5 Exploring Sources of Imagination in the Self

PS6 Exploring Harmony of Self with the Body

Practice Sessions for Module 3 – Harmony in the Family and Society

PS7 Exploring the Feeling of Trust

PS8 Exploring the Feeling of Respect

PS9 Exploring Systems to fulfil Human Goal

Practice Sessions for Module 4 – Harmony in the Nature (Existence)

PS10 Exploring the Four Orders of Nature

PS11 Exploring Co-existence in Existence

Practice Sessions for Module 5 – Implications of the Holistic Understanding – a Look at Professional Ethics

PS12 Exploring Ethical Human Conduct

PS13 Exploring Humanistic Models in Education

PS14 Exploring Steps of Transition towards Universal Human Order

As an example, PS7 is a practice session in module 3 regarding trust. It is explained below:

PS7: Form small groups in the class and in that group initiate dialogue and ask the eight questions related to trust. The eight questions are:

1a. Do I want to make myself happy?	1b. Am I able to make myself always happy?
2a. Do I want to make the other happy?	2b. Am I able to make the other always happy?
3a. Does the other want to make him happy?	3b. Is the other able to make him always happy?
4a. Does the other want to make me happy?	4b. Is the other able to make me always happy?
Intention (Natural Acceptance)	Competence
What is the answer?	What is the answer?

Let each student answer the questions for himself/herself and everyone else. Discuss the difference between intention and competence. Observe whether you evaluate your intention and competence as well as the others' intention and competence.

Expected outcome of PS7: The students are able to see that the first four questions are related to our Natural Acceptance i.e. intention and the next four to our Competence. They are able to note that the intention is always correct, only competence is lacking! We generally evaluate ourselves on the basis of our intention and others on the basis of their competence! We seldom look at our competence and others' intention, as a result we conclude that I am a good person and other is a bad person.

3-READINGS:

3-1-Text Book and Teachers Manual

a. The Textbook

A Foundation Course in Human Values and Professional Ethics, R R Gaur, R Asthana, G P Bagaria, 2nd Revised Edition, Excel Books, New Delhi, 2019. ISBN 978-93-87034-47-1

b. The Teacher's Manual

Teachers' Manual for A Foundation Course in Human Values and Professional Ethics, RR Gaur, R Asthana, G P Bagaria, 2nd Revised Edition, Excel Books, New Delhi, 2019. ISBN 978-93-87034-53-

3-2-Reference Books

1. JeevanVidya: EkParichaya, A Nagaraj, JeevanVidyaPrakashan, Amarkantak, 1999.

2. Human Values, A.N. Tripathi, New Age Intl. Publishers, New Delhi, 2004.

3. The Story of Stuff (Book).
4. The Story of My Experiments with Truth - by Mohandas Karamchand Gandhi
5. Small is Beautiful - E. F Schumacher.
6. Slow is Beautiful - Cecile Andrews
7. Economy of Permanence - J C Kumarappa
8. Bharat Mein Angreji Raj – Pandit Sunderlal
9. Rediscovering India - by Dharampal
10. Hind Swaraj or Indian Home Rule - by Mohandas K. Gandhi
11. India Wins Freedom - Maulana Abdul Kalam Azad
12. Vivekananda - Romain Rolland (English)
13. Gandhi - Romain Rolland (English)

4-MODE OF CONDUCT (L-T-P-C 2-1-0-3)

Lecture hours are to be used for interactive discussion, placing the proposals about the topics at hand and motivating students to reflect, explore and verify them.

Tutorial hours are to be used for practice sessions.

While analysing and discussing the topic, the faculty mentor's role is in pointing to essential elements to help in sorting them out from the surface elements. In other words, help the students explore the important or critical elements.

In the discussions, particularly during practice sessions (tutorials), the mentor encourages the student to connect with one's own self and do self-observation, self-reflection and self-exploration.

Scenarios may be used to initiate discussion. The student is encouraged to take up" ordinary" situations rather than" extra-ordinary" situations. Such observations and their analyses are shared and discussed with other students and faculty mentor, in a group sitting.

Tutorials (experiments or practical) are important for the course. The difference is that the laboratory is everyday life, and practical are how you behave and work in real life. Depending on the nature of topics, worksheets, home assignment and/or activity are included. The practice sessions (tutorials) would also provide support to a student in performing actions commensurate to his/her beliefs. It is intended that this would lead to development of commitment, namely behaving and working based on basic human values.

It is recommended that this content be placed before the student as it is, in the form of a basic foundation course, without including anything else or excluding any part of this content. Additional content may be offered in separate, higher courses.

This course is to be taught by faculty from every teaching department.

Teacher preparation with a minimum exposure to at least one 8-day Faculty Development Program on Universal Human Values is deemed essential.

5-SUGGESTED ASSESSMENT:

This is a compulsory credit course. The assessment is to provide a fair state of development of the student, so participation in classroom discussions, self-assessment, peer assessment etc. will be used in evaluation.

Example:

Assessment by faculty mentor: 10 marks

Self-assessment: 10 marks

Assessment by peers: 10 marks

Socially relevant project/Group Activities/Assignments: 20 marks

Semester End Examination: 50 marks

The overall pass percentage is 40%. In case the student fails, he/she must repeat the course.

6-OUTCOME OF THE COURSE:

By the end of the course, students are expected to become more aware of themselves, and their surroundings (family, society, nature); they would become more responsible in life, and in handling problems with sustainable solutions, while keeping human relationships and human nature in mind.

They would have better critical ability. They would also become sensitive to their commitment towards what they have understood (human values, human relationship and human society). It is hoped that they would be able to apply what they have learnt to their own self in different day-to-day settings in real life, at least a beginning would be made in this direction.

Therefore, the course and further follow up is expected to positively impact common graduate attributes like:

1. Holistic vision of life
2. Socially responsible behaviour
3. Environmentally responsible work
4. Ethical human conduct
5. Having Competence and Capabilities for Maintaining Health and Hygiene
6. Appreciation and aspiration for excellence (merit) and gratitude for all

This is only an introductory foundational input. It would be desirable to follow it up by

a) Faculty-student or mentor-mentee programs throughout their time with the institution

b) Higher level courses on human values in every aspect of living.

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SEMESTER – III

SEMESTER III

BSC-301	**Vector Calculus and Partial Differential Equations**	**2L:1T:0P**	**3 Credits**

Detailed Content:

Module 1:

Vector differentiation, gradient, divergence and curl, line and surface integrals, path independence, statements and illustrations of theorems of Green, Stokes and Gauss, arc length parameterization, applications.

Module 2:

Partial differential equations with separation of variables, boundary value problems: vibrations of a string, heat equation, potential equation, vibrations of circular membranes.

Module 3:

Laplace Transforms, its properties, Unit step function, Dirac delta functions, Convolution Theorem, periodic functions, solving differential equations using Laplace transform.

Suggested Text Books:

(i) Maurice D. Weir, Joel Hass, Frank R. Giordano, "Thomas' Calculus", Pearson Education, 12th Edition, 2002.

(ii) Erwin Kreyszig, "Advanced Engineering Mathematics", Wiley eastern Ltd., 10th Edition, 2011.

Suggested Reference Books:

(i) C.R. Wylie, "Advanced Engineering Mathematics", McGraw Hill Publications, New Delhi.

(ii) Peter V. O' Neil, "Advanced Engineering Mathematics", Thomson Brooks / Cole, Singapore, 7th edition, 2011.

(iii) Fritz John, "Partial Differential Equations" (4th edition), Springer, 1991.

(iv) Michael D. Greenberg, "Advanced Engineering Mathematics (2nd edition)", Pearson Education, 1998.

Course Outcomes:

After the completion of this course, the students will be able to:

- Know and recall core knowledge of the syllabus (To measure this outcome, questions may be of the type- define, identify, state, match, list, name etc.).

- Apply Partial differential concept to wherever necessary in Engineering Problems.
- Apply and Perform Laplace Transformation.
- Apply core concepts to new situations. (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen passages).
- Understand basic concepts (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.).
- Analyze the problem and apply the appropriate concept (To measure this outcome, questions will be based on applications of core concepts).

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ESC-301	Fundamentals of Mechanical Engineering	2L:0T:0P	2 Credits

Pre-requisites (if any)	Basic mathematics.

Detailed Content:

Module 1: Introduction to Thermodynamics:

Work, Heat, Equilibrium, Enthalpy, Entropy, Internal Energy, Laws of thermodynamics, Heat cycles – Carnot, Otto and Diesel, Properties of Steam.

Module 2: Elementary Ideas of Energy Conversion Devices:

Boilers, Steam and Gas Turbines, SI and CI Engines, Refrigeration and Air Conditioning.

Module 3: Fluid Mechanics and Machinery:

Fluid Properties and Fluid Statics, Types of Fluid Flow, Work and Energy of Moving Fluids, Hydraulic Pumps, Hydraulic Turbines.

Module 4: Mechanics of Material:

Materials and Mechanical Properties, Stress and Strain Concepts, Stress-Strain Diagrams for Ductile and Hard Materials, Principal Stresses and Strains, Shear Force and Bending Moments, Flexural and Torsional Loading.

Module 5: Power Transmission Devices:

Power Transmission Elements, Shaft and Axle, Rope, Belt and Chain Drives, Gear Drives, Dynamometers.

Module 6: Manufacturing Processes:

Types of Manufacturing Processes, Machining Operations, Turning, Drilling, Milling and Grinding, Forming and Forging Operations, Joining Processes, Soldering, Brazing and Welding.

Suggested Text Books:

(i) D. S. Kumar., "Fundamentals of Mechanical Engineering and Mechatronics", S.K. Kataria & Sons, 2021.

(ii) R. K. Bansal, "A Textbook of Fluid Mechanics and Hydraulic Machines", Laxmi Publications, 2019.

Suggested Reference Books:

(i) Sadhu Singh, "Principles of Mechanical Engineering", S. Chand, 2010.

(ii) P. K. Nag, "Engineering Thermodynamics", McGraw Hill Education, 2017.

(iii) S. S. Rattan, "Theory of Machines", McGraw Hill Education, 2019.

(iv) S. S. Rattan, "Strength of Materials", McGraw Hill Education, 2017.

Course Outcomes:

After the completion of this course, the students will be able to:

- Understanding of the fundamentals essential for designing robot structure.
- Understanding of the fundamentals for selecting robot material according to its working environment.
- Knowledge of various mechanical elements used in mechanisms.
- Knowledge of various manufacturing processes.
- Knowledge of basic thermodynamic and Fluid mechanics concepts.

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ESC-302	Electrical Machines & Drives	2L:0T:2P	3 Credits

Detailed Content:

Module 1: Introduction to D.C. Motors:

Principles of working, Significance of back EMF, Torque Equation, Types, Characteristics and Selection of DC Motors, Starting of DC Motors, Speed Control, Losses and Efficiency, Condition for Maximum Efficiency, Braking of DC Motors, Effect of saturation and armature reaction on losses; Applications, Permanent Magnet DC Motors, Type and Routine tests.

Module 2: Introduction to Three Phase Induction (Asynchronous) Motor:

Types of induction motor, flux and MMF waves, development of circuit model, power across air gap, torque and power output, starting methods, speed control, induction generator, induction machine dynamics, high efficiency induction motors, Single phase IM, Modeling of induction machine.

Module 3: Introduction to Synchronous Machines:

Construction, types, armature reaction, circuit model of synchronous machine, determination of synchronous reactance, phasor diagram, power angle characteristics, parallel operation of synchronous generators, synchronizing to infinite bus bars, two axis theory, synchronous motor operation, dynamics, modeling of synchronous machine, PM synchronous machines.

Module 4: Electric Drives, Dynamics and Control:

Definition, Advantages of electrical drives, Components of Electric drive system, Selection Factors, speed control and drive classifications, Motor-Load Dynamics, Speed Torque conventions and multi quadrant operation, Equivalent values of drive parameters. Load Torque Components, Nature and classification of Load Torques, Constant Torque and Constant Power operation of a Drive, Steady state stability, Load epilation and selection motors. .

Module 5: Introduction to DC Motor Drives:

Dc motors and their performance starting, transient analysis, speed control, ward Leonard drives, Controlled rectifier fed drives, full controlled 3 phase rectifier control of dc separately excited motor], multi-quadrant operation, Chopper controlled drives Closed loop speed control of DC motor.

Module 6: Induction and Synchronous Motor Drives:

Induction motor analysis, starting and speed control methods- voltage and frequency control, current control, closed loop control of induction motor drives, rotor resistance control, Slip power recovery – Static Kramer and Scherbius Drive, Single phase induction motor starting, braking and speed control. Synchronous motor operation with fixed frequency, variable speed drives, PMAC and BLDC motor drives, Stepper motor drives, switched reluctance motor drives.

Suggested Text Books:

(i) D. P. Kothari, I. J. Nagrath, “Electric Machines “, Tata McGraw Hill Publication, Fourth edition, reprint 2012.

(ii) A.E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans, "Electric Machinery", Tata McGraw Hill Publication, sixth edition, 2002.

Suggested Text Books:

(i) M. G. Say," Alternating current machines", fifth edition, E.L.B.S. Publication, 1987.
(ii) A. F. Puchstein, T.C. Lloyd, A.G. Conrad, "Alternating current machines", John Wiley and Sons, New York 1954.
(iii) P. C. Sen, "Principles of Electric Machines and Power Electronics ", John Wiley and Sons Publication, second edition 1997.
(iv) M. H. Rashid, "Power Electronics -Circuits, devices and Applications", 3rd Edition, PHI Pub. 2004.
(v) B. K. Bose, "Modern Power Electronics and AC Drives", Pearson Education, Asia, 2003.
(vi) G. K. Dubey, "Fundamentals of Electrical Drives", Second edition (sixth reprint), Narosa Publishing house, 2001.

Course outcomes:

At the end of this course, the students will demonstrate the ability to:

- Analyze DC drive, Induction and Synchronous Motors Drives.
- Evaluate the steady state behavior and basic operating characteristics of A.C Machine.
- Understand the basics of electric drives and fundamentals of drive dynamics.
- Demonstrate analytical skills to assess machine performance in steady state.

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PCC RAI-301	Analog & Digital Electronics	3L:0T:0P	3 Credits

Course Content:

Module 1: Physics of Bipolar Junction Transistors:

Structure of NPN and PNP Transistors, Energy-Band Diagram, Operation of BJT, I/V characteristics, Large Signal model, Small signal model, Concept of trans conductance, Early Effect. Bipolar amplifier: CE, CC & CB Physics of MOS Transistors: Structure of N and P MOSFET, Energy-Band Diagram, Operation of MOSFET, Channel Length Modulation, CMOS Technology, Comparison of Bipolar & MOS Devices.

Module 2: Fundamentals of Op-Amp:

Op-Amp Parameters Circuits with resistive feedback: Concept of feedback & their types, Inverting & non-inverting configurations, current to voltage converters, voltage to current converters, summing amplifier, difference amplifier, instrumentation amplifier.

Module 3: Non-linear circuits:

Schmitt trigger, Voltage comparators, comparator applications, precision rectifiers, analog switches, peak detectors, sample & hold circuits, Integrators & differentiators, Clippers and Clampers Feedback & Oscillator Circuit: Effect of positive and negative feedback, Analysis of practical feedback amplifiers, Sinusoidal Oscillators (RC, LC and Crystal), Multi-vibrators using 555 timers.

Module 4: Logic Simplification and Combinational Logic Design:

Review of Boolean Algebra and De Morgan's Theorem, SOP & POS forms, Canonical forms, Karnaugh maps up to 6 variables, Binary codes, Code Conversion. MSI devices like Multiplexers, Encoder, Decoder, Comparators, Half and Full Adders, Subtractors, BCD Adder, Barrel shifter and ALU.

Module 5: Sequential Logic Design:

Building blocks like S-R, JK and D latch, Master-Slave JK FF, Edge triggered FF, Ripple and Synchronous counters, Shift registers, Finite state machines, Design of synchronous FSM.

Module 6: Logic Families and Semiconductor Memories:

TTL NAND gate, Specifications, Noise margin, Propagation delay, fan-in, fan-out, Tristate TTL, ECL, CMOS families and their interfacing, Memory elements, Concept of PLDs like PAL, PLA, CPLDs, FPGA etc. Logic implementation using Programmable Devices (ROM, PLA).

Suggested Text Books:

(i) Behzad Razavi, "Fundamentals of Microelectronics", Second Edition; Wiley, 2016.

(ii) Ramakant A Gaikwad, "Op-Amps and Linear Integrated Circuits", PHI, 4th edition, 2016.

Suggested Reference Books:

(i) Thomas L Floyd, "Electronic Devices", 10th edition, Pearson, 2017.

(ii) G.B. Clayton, "Operational Amplifiers", International Edition, 2nd Edition,1979.

(iii) A. Anand Kumar, "Fundamentals of Digital circuits", PHI, Fourth edition, 2016.

(iv) R.P. Jain, "Modern digital Electronics", Tata McGraw Hill, fourth edition, 2010.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Design and Analyze Analog sub-circuits using BJT and FET.
- Design & analyze modular combinational circuits with MSI devices like MUX/DEMUX, Decoder, Encoder, etc.
- Design the linear and non-linear applications of Op-Amp.
- Design & analyze synchronous sequential logic circuits with FFs and combinatorial circuits.
- Design & analyze modular combinational circuits with MSI devices like MUX/DEMUX, Decoder, Encoder, etc.

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PCC RAI-302	Fundamentals of Materials Science & Smart Materials	2L:0T:0P	2 Credits

Course Content:

- **Material Science:**

Module 1: Introduction to engineering materials & their properties:

Crystalline versus non crystalline solids, Unit cell, Crystal systems, Bravais lattice, Fundamental reasons behind classification of lattice, Miller indices for directions & planes, Close-packed planes & directions, packing efficiency, Interstitial voids, Role of X-ray diffraction in determining crystal structures. Deformation of metals, understanding of some material-properties independent of interatomic bonding forces/energies, Stiffness versus modulus, Theoretical/ideal strength versus actual strength of metals, Crystal defects, Role of dislocations in deformation, Strengthening Mechanisms, Role of Cottrell atmosphere.

Module 2: Phase Diagrams:

Objectives & classification, System, Phases & structural constituent of phase diagram. Temperature–Pressure phase diagram of iron & Clausius –Clapeyron equation for boundary between phase regions of temperature-versus-pressure phase diagrams, Gibbs phase rule, Lever rule, Solid solutions, Hume-Rothery rules, Isomorphous, Eutectic, Peritectic & Eutectoid system, Equilibrium diagrams for non-ferrous alloys.

Module 3: Heat Treatment:

Definition, Purpose & classification of heat treatment processes for various types of steels, Bainite & Martensite formation, Introduction & applications of various case hardening & surface hardening treatments, Precipitation Hardening, Heat treatment defects.

- **Smart materials:**

Module 4: Concept of Smart Materials:

Retrospective review, main notion, energy aspects of external influence, systematization and methods of smart materials description: methods of materials taxonomy, smart material model, classification of smart materials and engineering systems, Materials for electrical engineering and electronics: conductors, semiconductors, dielectrics, magnetic materials, optically active materials, materials for thermoelectric devices, smart battery materials, radio wave absorbing materials, sealing materials, heat-insulating and sound absorbing materials.

Module 5: Structural material:

self-healing materials, heat and cold resistant materials, radiation resistant materials, corrosion-resistant materials and anti-corrosive coatings, lubricants, frictional materials,

materials for operation at abnormal temperatures. Materials for biological and biomedical systems materials for implants, targeted drug delivery and tissue growth, antimicrobial materials, filters for water cleaning, biodegradable packages, active and bio-selective packages.

Module 6: Mechanics of smart materials:

Object and subject of smart materials mechanics, structural and functional analysis smart materials in terms of mechanics, the materials with negative characteristics as source of smart effects in structures: Auxetics, statements and solutions of some smart materials based mechanics problems – e.g. self-healing of cracks, self-reinforcing of multimodular materials, porous materials-auxetic materials reversible transformations, self- assembling porous materials etc. Smart materials and energy problem: Global energy problem, energy consumption for production of materials, technical and economical efficiency of smart materials and technical systems.

Suggested Text Books:

(i) Raghvan, Materials Science and Engineering, Prentice Hall of India Publishing 5th Edition, 2006.

(ii) W.D. Callister, Materials Science and Engineering 8th Edition, 2006.

Suggested Reference Books:

(i) Encyclopedia of Smart Materials (Volume 1 and 2) by Mel Schwartz, John Wiley and Sons, 1st Edition, 2002.

(ii) Design, Fabrication Properties and Applications of Smart and Advanced Materials, Edited by Xu Hou, CRC Press, 1st Edition, 2016.

(iii) Smart Materials: Integrated Design, Engineering Approaches and Potential Applications, Edited by Anca Filimon, Apple Academic Press and CRC Press, 1st Edition, 2019.

(iv) Smart Materials Taxonomy by Victor Goldade, Serge Shil'ko, Alexander Neverov, CRC Press, 1st Edition, 2016.

(v) Askland & Phule, Material Science & Engineering of materials 4th Edition, 2002.

(vi) Reed Hill, Physical Metallurgy 4th Edition, 2009.

(vii) S.H. Avner, Introduction to Physical Metallurgy 2nd Edition, 1974.

(viii) D.A. Porter & K.E. Easterling, Phase Transformations in Metals & Alloys 3rd Edition, 1992.

Course Outcomes:

At the end of the course, the students will be able to:

- Analyze the properties of smart materials and structures in the broader external conditions for the utilization in selected technologies.
- Understand the basic properties that characterize the behavior of materials and classify the materials with their types of loadings/environment that materials should withstand.
- Acquire the knowledge of various smart materials, their fabrication and their multidisciplinary applications.
- Know the concept of "Smart" materials and systems.

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PCC RAI-303	Fundamentals of Robotics & AI	3L:0T:0P	3 Credits

Detailed Content:

Module 1: Introduction:

Introduction to Robotics-classification with respect to geometrical configuration (Anatomy), Industrial robots specifications. Selection based on the Application. Controlled system & chain type: Serial manipulator & Parallel Manipulator. Components of Industrial robotics-precession of movement-resolution, accuracy & Repeatability-Dynamic characteristics- speed of motion, load carrying capacity & speed of response.

Module 2: Sensors, Drives and Grippers:

Characteristics of sensing devices, Criterion for selections of sensors, Classification, & applications of sensors. Internal sensors: Position sensors, & Velocity sensors, External sensors: Proximity sensors, Tactile Sensors, & Force or Torque sensors.

Drives – Basic types of drives. Advantages and Disadvantages of each type. Selection / suitability of drives for Robotic application. Controllers, Types of Controller and introduction to close loop controller Grippers, Mechanical Gripper-Grasping force, mechanisms for actuation, Magnetic gripper vacuum cup gripper-considerations in gripper selection & design.

Module 3: Kinematics of Manipulators:

Kinematics-Manipulators Kinematics, Rotation Matrix, Homogeneous Transformation Matrix, D-H transformation matrix, D-H method of assignment of frames. Direct and Inverse Kinematics for industrial robots. Differential Kinematics for planar serial robots

Robot Applications: Material transfer and machine loading/unloading, processing operations assembly and inspection. Programming and Languages: Methods of robot programming, Introduction to various languages such as RAIL and VAL II …etc., Features of each type and development of languages for recent robot systems.

Module 4: Introduction to Artificial Intelligence:

Overview: foundations, scope, problems, and approaches of AI. Intelligent agents: reactive, deliberative, goal-driven, utility-driven, and learning agents, Artificial Intelligence programming techniques.

Module 5: Problem-solving through Search:

forward and backward, state-space, blind, heuristic, problem reduction, alpha-beta pruning, minimax, constraint propagation, neural, stochastic, and evolutionary search algorithms, sample applications.

Module 6: Knowledge Representation and Reasoning:

Ontologies, foundations of knowledge representation and reasoning, representing and reasoning about objects, relations, events, actions, time, and space; predicate logic, situation calculus, description logics, reasoning with defaults, reasoning about knowledge, sample applications. Planning: planning as search, partial order planning, construction and use of planning graphs. Representing and Reasoning with Uncertain Applications of AI (vision/robotics etc.).

Suggested Text Books:

(i) John J. Craig, Introduction to Robotics, Pearson Education Inc., Asia, 3rd Edition, 2005.

(ii) Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press, 2006.

(iii) Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, 2019.

Suggested Reference Books:

(i) S. K. Saha, Introduction to Robotics, TATA McGraw Hills Education, 2014.

(ii) S. B. Nikku, Introduction to Robotics – Analysis, Control, Applications, 3rd edition, John Wiley & Sons Ltd., 2020.

(iii) Mikell Groover, Mitchell Weiss, Roger N. Nagel, Nicholas Odrey, Ashish Dutta, Industrial Robotics 2nd edition, SIE, McGraw Hill Education (India) Pvt. Ltd., 2012.

(iv) R. D. Klafter, Thomas A. Chmielewski, and Michael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc., 2009.

(v) Russell, Stuart and Norvig, Peter, Artificial Intelligence: A Modern Approach" Prentice Hall, 2003.

(vi) Aleksander, Igor and Burnett, Piers, Thinking Machines Oxford, 1987.

(vii) Bench-Capon, T. J. M., Knowledge Representation: An approach to artificial intelligence Academic Press, 1990.

(viii) Genesereth, Michael R. and Nilsson, Nils J, Logical Foundations of Artificial Intelligence Morgan Kaufmann, 1987.

(ix) Michael Negnevitsky, Artificial Intelligence: A Guide to Intelligent Systems (3rd Edition), 2011.

(x) Vinod Chandra S.S., Anand Hareendran S, "Artificial Intelligence and Machine Learning", 2014.

(xi) Luger " Artificial Intelligence", Edition 5, Pearson, 2008.

Course Outcomes:

At the end of the course, the students will be able to:

- Differentiate types of robots and robot grippers.
- Apply basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation and learning.
- Understand AI, its current scope and limitations, and societal implications.
- Analyze forces in links and joints of a robot.
- Demonstrate awareness and a fundamental understanding of AI techniques in intelligent agents, artificial neural networks.
- Model forward and inverse kinematics of robot manipulator.

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PCC RAI-304	Wireless Networks	1L:0T:0P	1 Credit

Course Content:

Module 1: Wireless Networks:

Wireless network topologies, infrastructure and ad-hoc networks, different generations of wireless networks; The cellular concept and design fundamentals, coverage and user capacity.

Module 2: Wireless Fading Channels:

Large scale path loss modeling and shadow fading, indoor and outdoor propagation models; Multipath and Doppler, types of small-scale fading, simulation techniques.

Module 3: Multiple Access Techniques:
Performance in fading and multipath channels. Fixed assignment and random access; Capacity and performance of FDMA, TDMA, DS/CDMA and FH/CDMA; WCDMA and OFDMA; Access techniques for WLAN, Bluetooth and mobile data networks.

Module 4: Ad Hoc Wireless Sensor Networks:

Overview, Communication Coverage, Sensing Coverage, Localization, Routing.

Module 5: Wireless Local Area Networks:

Introduction**,** WLAN Topologies, WLAN Technologies, IEEE 802.11 WLAN, Other WLAN Standards- HIPERLAN.

Module 6: Quality-of-Service (QoS) in Wireless Networks:

QoS issues in Wireless Networks, a case study of broadband service regulations for maintaining QoS by telecom regulatory bodies such as TRAI.

Suggested Text Books:

(i) Larry L. Peterson and Bruce S. Davie," Wireless Networking Complete", Morgan Kaufmann, 2010.
(ii) Pahalvan, K. and Krishnamurthy, P., "Principles of Wireless Networks: A Unified Approach", Pearson Education, 2017.

Suggested Reference Books:

(i) Prasad, R. and Munoz, L., "WLANs and WPANs: Towards 4G Wireless", Artech House, 2003.

(ii) Haykin, S. and Moher, M., "Modern Wireless Communication", Pearson Education, 2021.

(iii) Pandya, R., "Mobile and Personal Communication Systems and Services", Prentice-Hall of India, 1999.

(iv) Rappaport, T.S., "Wireless Communications: Principles and Practice", 2nd Ed., Pearson Education, 1996.

(v) Stallings, W., "Wireless Communications and Networking", Pearson Education, 2016.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Explain concepts and issues involved in the design of wireless networks.
- Understand cellular (mobile) communication systems.
- Analyze mechanisms to improve Quality of service in Networking.
- Elaborate the concept of multiple access in Communication Networking.
- State key features and operating principles of Wi-Fi (Bluetooth) and WLAN.

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LC RAI-301	Material Science Laboratory	0L:0T:2P	1 Credit

Course Content:

- Hardness testing (Study of Hardness conversion number).
- Rockwell/Vickers hardness test.
- Brinell and Poldi hardness Test.
- Impact Test for Steel, Aluminum, Brass and Copper (Charpy/Izod).
- Non Destructive testing - Dye Penetrant Test/ Magnetic Particle test/ Ultrasonic Test.
- Specimen Preparation procedure for microscopic examination & Demonstration of Optical Metallurgical microscope.
- Observation and Drawing of Microstructure of Steels, Cast Iron of various compositions, Non Ferrous Metals of various compositions.
- Testing of materials used in robotics technology (Hardness, Strength etc.).
- Aluminium casting and Aluminum alloys.
- Carbon Fiber plates, tubes and channels.
- FRP sheets and Channels.

Suggested Text Books:

(i) Raghvan, Materials Science and Engineering, Prentice Hall of India Publishing 5th Edition, 2006.

(ii) W.D. Callister, Materials Science and Engineering 8th Edition, 2006.

Suggested Reference Books:

(i) Encyclopedia of Smart Materials (Volume 1 and 2) by Mel Schwartz, John Wiley and Sons, 1st Edition, 2002.

(ii) Design, Fabrication Properties and Applications of Smart and Advanced Materials, Edited by Xu Hou, CRC Press, 1st Edition, 2016.

(iii) Smart Materials: Integrated Design, Engineering Approaches and Potential Applications, Edited by Anca Filimon, Apple Academic Press and CRC Press, 1st Edition, 2019.

(iv) Smart Materials Taxonomy by Victor Goldade, Serge Shil'ko, Alexander Neverov, CRC Press, 1st Edition, 2016.

(v) Askland & Phule, Material Science & Engineering of materials 4th Edition, 2002.

(vi) Reed Hill, Physical Metallurgy 4th Edition, 2009.

(vii) S.H. Avner, Introduction to Physical Metallurgy 2nd Edition, 1974.

(viii) D.A. Porter & K.E. Easterling, Phase Transformations in Metals & Alloys 3rd Edition, 1992.

Course Outcomes:

At the end of the course, the students will be able to:

- Determine mechanical properties using destructive and nondestructive testing of materials.
- Study of different parameters of the system viz., phases, variables, components, grains, grain boundary, and degree of freedom. etc.
- Understand the use of non-conventional materials such as CNT, FRP, Al alloys etc.
- Select appropriate materials for Robotic applications.

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LC RAI-302	Analog & Digital Electronics Laboratory	0L:0T:2P	1 Credit

Detailed Content:

- Input and Output Characteristics of BJT in CE configuration.
- Transfer and Drain Characteristics of MOSFET.
- Design and simulate LC and RC oscillators.
- Build and test LC or RC oscillator.
- Op-amp Applications-I: Integrator, Differentiators, Comparator, Schmitt trigger.
- Design different types of multivibrators using IC 555.
- Simplification and implementation of a Boolean function using k -map technique e.g. code converter.
- Use of Multiplexers, Encoders, Demultiplexer and decoders for implementing logic.
- Design and implementation of ripple and synchronous counters using JK and D FF and additional gates.
- Design of MOD counter using ICs like 7490/93 (ripple) and 74192/193(synchronous).

Suggested Text Books:

(i) Behzad Razavi, "Fundamentals of Microelectronics", Second Edition; Wiley, 2016.

(ii) Ramakant A Gaikwad, "Op-Amps and Linear Integrated Circuits", PHI, 4th edition,2016

Suggested Reference Books:

(i) Thomas L Floyd, "Electronic Devices", 10th edition, Pearson, 2017.

(ii) G.B. Clayton, "Operational Amplifiers", International Edition, 2nd Edition,1979.

(iii) A. Anand Kumar, "Fundamentals of Digital circuits", PHI, Fourth edition, 2016.

(iv) R.P. Jain, "Modern digital Electronics", Tata McGraw Hill, fourth edition, 2010.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Analyze and design various applications of Op-Amp.
- Identify and characterize basic devices such as BJT and FET from their package information by referring to manufacturers' data sheets.
- Design, simulate, built and debug complex sequential circuits based on an abstract functional specification.
- Design, simulate, built and debug complex combinational circuits based on an abstract functional specification.

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LC RAI-303	Robot Programming Laboratory	0L:0T:2P	1 Credit

Detailed Content:

- Robot Programming using Flex Pendant- Lead through programming including Coordinate systems of Robot.
- Wrist Mechanism-Interpolation-Interlock commands.
- VAL language commands motion control, hand control, program control, pick and place applications.
- Palletizing applications using VAL.
- Object detection and Sorting.
- Robot welding application using VAL program.
- RAPID Language and AML.
- Programming using Robot studio software.

Suggested Text Books:

(i) Hughes Cameron, "Robot Programming", Pearson Publishers, 2016.

(ii) J. Srinivas, "Robotics: Control and Programming", Narosa Publication, 2009.

Suggested Reference Books:

(i) Lentin Joseph, "Learning Robotics Using Python", Second Edition Design, simulate, program, and prototype an autonomous mobile robot using ROS, OpenCV, PCL, and Python, Packt Publishing Paperback – 1 January 2018.

(ii) Staple Danny, "Learn Robotics Programming", Packt Publishing Limited, Feb 2021.

(iii) Kailashi Chandra Mahajan, Prashant Kumar Patnnaik, Raghvendra Kumar, "Robotics for Engineers", Vikas Publishing House, 2016.

Course Outcomes:

At the end of this course, the students will be able to:

- Use fundamental and technical knowledge of robot Programming.
- Learn Robot Programming using teach Pendant for various applications.
- Use RAPID Language and AML.
- Program a Robot for Industrial applications.
- Program using Robot studio software.

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SEMESTER – IV

SEMESTER IV

BSC-401	Probability & Statistics	2L:1T:0P	3 credits

Detailed Content:

Module 1: Descriptive statistics:
Measures of location and variation. Visualization of data: Frequency tables, bar diagrams, histograms, heat maps, other visualization tools. Review on introduction to combinatorics and probability theory.

Module 2: Some of the basic probability distributions:
Binomial, Poisson, Exponential, and Normal. Central limit theorem.

Module 3: Introduction to 'R':
Introductory R language fundamentals and basic syntax, major R data structures, Using R to perform data analysis, creating visualizations using R.

Module 4: Basic statistical inference and hypothesis testing:
Estimation, basic tests such as t- test, z-test, F-test, $\chi 2$ –test; Non parametric tests: Sign test, Wilcoxon signed rank test.

Module 5: Regression methods:
Simple linear regression and multiple regression.

Module 6: Engineering applications of statistics:
Engineering applications of statistics (Branch Specific (any 2)): Discussion on reliability and quality control. Introduction to random processes, stochastic processes, Markov chains. Machine learning and data science.

Suggested Text Books:

(i) Ronald E, Walpole, Sharon L. Myers, Keying Ye, Probability and Statistics for Engineers and Scientists (8th Edition), Pearson Prentice Hall, 2007.
(ii) Tilman M. Davies, the book of R: A first course in Programming and Statistics (1st Edition), No Starch Press, USA, 2016.

Suggested Reference Books:

(i) Ross S.M., Introduction to probability and statistics for Engineers and Scientists (8th Edition), Elsevier Academic press, 2014.
(ii) S. P. Gupta, Statistical Methods, S. Chand & Sons, 37th revised edition, 2008.
(iii) Kishor S. Trivedi, Probability and Statistics with Reliability, Queuing and Computer Science Applications (2nd Edition), Wiley Student edition, 2008.
(iv) Stephens L.J., Schaum's outline of statistics for Engineers, Latest edition, 2019.
(v) The practice of Business Statistics by Manish Sharma and Amit Gupta, Khanna Publishing Company Private Limited, New Delhi, 2014.
(vi) Norman Matloff, The Art of R Programming - A Tour of Statistical Software Design, (1st Edition), No Starch Press, USA, 2011.

(vii) Sudha Purohit, Sharad Gore, Shailaja Deshmukh, Statistics using R (2nd Edition), Narosa Publications, 2019.
(viii) Randall Pruim, Foundations and Applications of Statistics - An introduction using R (2nd Edition), American Mathematical Society, 2018.
(ix) Hadley Wickham and Garrett Grolemund, R for Data Science: Import, Tidy, transform, Visualize and Model Data, (1st Edition), O'Reilly Publications, 2017.

Course Outcomes:

At the end of this course, the students will be able to:

- Make use of concepts of random variables and associated probability distributions to solve problems, illustrate the central limit theorem.
- Demonstrate a number of methods of summarizing and visualizing data sets, evaluating probabilities of events.
- Evaluate for basic statistical inference (t-test, z-test, F-test, χ^2 –test, confidence interval, non-parametric tests).
- Explain basic principles of regression analysis and perform the same.
- Demonstrate use of R software for all the above.

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BSC-402	Biology for Engineers & Biomimetics	2L:1T:0P	3 credits

Course Content:

Module 1: Biomolecules and biopolymers:
Structure and Function, Organic and inorganic molecules; Unique Properties of water, Vitamins and Minerals, Carbohydrates, Lipids, Amino Acids and proteins, Nucleic Acids (DNA and RNA), Cell as a basic unit of life, prokaryotic and eukaryotic cells, microbes, plant and animal cells; Cell organelles, structure and function; Cell membrane, Levels of organization: cells, tissues, organs, systems & organisms.

Module 2: Transport Phenomena in Biological Systems:
Membrane channels and ion channels; Fluid flow and mass transfer (nutrients & ions); In plants: Xylem and Phloem; In animals: Blood and Lymph Transport of gases: Oxygen and Carbon dioxide. Heat Transport - Body temperature regulation. Communication: Cell junctions, Cell-cell communications, cell signaling, Hormones, Pheromones and cell behavior, Defense mechanisms: In plants: Herbivore, secondary metabolites, In animals: Innate and Adaptive immune systems.

Module 3: Engineering perspectives of biological sciences:
Biology and engineering, crosstalk – At cell level: Hybridoma, technology, At tissue level: Plant Tissue Culture, Animal Tissue. Culture; Tissue Engineering: Principles, methods and applications, Nano biotechnology.

Module 4: Introduction to Biomimetics:
Introduction to Biomimetics and Biomimicry, Biomimetic Principles, steps in biomimetic method, Biomimetic Material and working principle.

Module 5: Biomimetic sensors:
Sensor Classification, Acoustic Sensors, Chemical Sensors, Electric Sensors, Optical Sensors, Magnetic Sensors, Mechanical Sensors, Thermal Sensors, Radiation sensors, Biomimetic Sensor Design, Biomimetic tactile Sensors based on Nanomaterials, Recent Advances in biomimetic sensing technology, Ionic Polymer and Metal composites as biomimetic Sensors and Actuators, Applications of Sensors.

Module 6: Biomimetic actuators:
EAP (Electroactive polymers), Artificial Muscles, Biomimetic applications of electrochemical actuators, Materials used for Actuators, Hydrogel actuators and Sensors for Biomedical soft robots, 3D printing Magnetic actuators, Biomimetic Actuation device and System, Control of Biomimetic System, Non Muscular Biomimetic Actuator based on electrodynamic swelling.

Suggested Text Books:

(i) Palsson B.O. and Bhatia S.N, “Tissue Engineering”, Pearson, 2009.
(ii) Rao CNR, et.al. “Chemistry of Nanomaterials: Synthesis, Properties and Applications”, 2004.

Suggested Reference Books:

(i) Yoseph Bar-Cohen, “Biomimetics- Biologically Inspired Technologies”, 2005.

(ii) Eggins B.R. "Biosensors: An Introduction", John Wiley & Sons Publishers, 2006.
(iii) Lehninger, A. L., Nelson, D. L., & Cox, M. M. Lehninger principles of biochemistry, New York: Worth Publishers, 2000.
(iv) Lodish H, Berk A, Zipursky SL, et al. "Molecular Cell Biology", W. H. Freeman, 2000.
(v) Joseph D. Bronzino, John Enderle, Susan M. Blanchard "Introduction to Biomedical Engineering", 1999.
(vi) Routledge Taylor and Francis group, "Introduction to Biomedical Engineering technologies", 2012.
(vii) Fraden, J., "Handbook of modern sensors: physics, designs, and applications", Springer, New York, 2004.
(viii) Toko, K., "Biomimetic sensor technology", Cambridge University Press, Cambridge, 2000.
(ix) Purves W.K., Sadava, D., Orians, G.H., Heller, H.C., "Life, The Science of Biology", 6th edition, 2001.

Course Outcomes:

At the end of this course, the students will be able to:

- Understand basic biological principles and organizational structure of living systems at molecular level.
- Know Energy transformations and information processing in biological systems.
- Appreciate biological processes with an engineering perspective.
- Know about Different Biomimetic sensors.
- Impart knowledge about the common corridors of biology and engineering and biologically inspired technologies.
- Comprehend basic biological principles and organizational structure of living systems at cellular level.

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PCC RAI-401	Machine Learning	1L:0T:2P	2 credits

Detailed Content:

Module 1: Introduction to Machine Learning:
Introduction to Machine Learning, Learning Paradigms, PAC learning, Basics of Probability, Version Spaces.

Module 2: Supervised Learning:
Linear and Nonlinear examples, Multi-Class & Multi-Label classification, Linear Regression, Multilinear Regression, Naïve Bayes Classifier, Decision Trees, ID3, CART, Error bounds.

Module 3: Classifiers:
K-NN classifier, Logistic regression, Perceptrons, Single layer & Multi-layer, Support Vector Machines, Linear & Non-linear.

Module 4: Unsupervised Learning:
Clustering basics (Partitioned, Hierarchical and Density based), K-Means clustering, K-Mode clustering, Self-organizing maps, Expectation maximization, Principal Component Analysis.

Module 5: Evaluation Metrics and ensemble learning:
ROC Curves, Evaluation Metrics, Significance tests, Error correction in Perceptrons- Bagging and Boosting (Random forests, Adaboost, XG boost inclusive).

Module 6: Machine learning process in practice:
Data collection, Preprocessing (Missing values, Normalization, adopting to chosen algorithm etc.,), Outlier Analysis (Z-Score), Model selection & evaluation, Optimization of tuning parameters, Setting the environment, Visualization of results.

Suggested Text Books:

(i) Ethem Alpaydin,"Introduction to Machine Learning, MIT Press, Prentice Hall of India, Third Edition 2014.
(ii) Tom Mitchell, Machine Learning‖, McGraw Hill, 3rd Edition,1997.

Suggested Reference Books:

(i) Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar "Foundations of Machine Learning", MIT Press, 2012.
(ii) Charu C. Aggarwal, Data Classification Algorithms and Applications‖, CRC Press, 2014.
(iii) Christopher M. Bishop, Pattern Recognition and Machine Learning‖, Springer Edition. 2011.

Course Outcomes:
At the end of this course, the students will demonstrate the ability to:

- Understand, visualize, analyze and preprocess the data from a real-time source.
- Apply appropriate algorithms to the data.

- Analyze the results of the algorithm and convert to appropriate information required for the real – time application.
- Evaluate the performance of various algorithms that could be applied to the data and to suggest the most relevant algorithm according to the environment.

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PCC RAI-402	Sensors and Actuators for Robotics	2L:0T:0P	2 Credits

Detailed Content:

Module 1: Anatomy of Robotic system:
links and joints in robots, types of joints, end effectors, concept of degrees of Freedom and its calculations.

Module 2: Sensors:
Pressure/contact. Resistive position. Infrared. Light. Position Sensors, optical encoders, proximity sensors, Range sensors, Ultrasonic sensors, Touch and Slip sensors. sensors for motion and position, Force, torque and tactile sensors, Flow sensors, Temperature sensing devices.

Module 3: Vision Sensors:
Vision System Devices, Image acquisition, Masking, Sampling and quantisation, Image Processing Techniques, Noise reduction methods, Edge detection, Segmentation.

Module 4: Advanced Sensor Technology:
Smart sensors, MEMS based sensors, Innovations in sensor technology
Actuators and its selection while designing a robot system. Types of transmission systems.

Module 5: Electric Actuators:
Direct current motor, Permanent magnet stepper motor, Servo Control DC motors, Linear and latching linear actuators, Rotary actuators, Piezoelectric actuators, Actuator parameters and characteristics, Stepper motors, Specifications and characteristics of Stepper Motors Servo Motors.

Module 6: Pneumatic & Hydraulic actuators:
Hydraulic and pneumatic power actuation devices:
Hydraulic Actuators, selection of linear actuating cylinders, Hydraulic Motors, Pneumatic actuators, design considerations and selection, pneumatic cylinders, pneumatic drive system, Linear & rotary actuators. Advanced actuators – Piezoelectric actuators, elastomer actuators, soft actuators, shape memory alloy based actuators, under actuated robotic hand.

Suggested Text Books:

(i) D. Patranabis, Sensors and Transducers, PHI, 2nd Edition 2013.
(ii) Jon S. Wilson, Sensor Technology Handbook, Elsevier, 2005.

Suggested Reference Books:

(i) Mc Comb, G. Robot builder's bonanza. 5th ed. New York: McGraw-Hill, 2019. ISBN 9781260135015.
(ii) Braünl, T. Embedded robotics: mobile robot design and applications with embedded systems. 3rd edition Berlin; Heidelberg: Springer, 2008. ISBN 9783540705338.
(iii) Martin, F.G. Robotic explorations: a hands-on introduction to engineering. Upper Saddle River, N.J.: Prentice-Hall, 2001. ISBN 0130895687.
(iv) Gerard C., M. Meijer, Smart Sensors System, Wiley, 2008.

(v) Andrzej M. Pawlak, Sensors and Actuators in mechatronics, Taylor & Francis Group, 2007.
(vi) S. R. Ruocco, Robot Sensors & Transducers, Springer, 2013.

Course Outcomes:

At the end of this course, the students will be able to:

- Analyze sensory systems in robotics.
- Select the sensor for robotic application and design the systems.
- Analyze actuators and configuring the parameters of Actuators.

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PCC RAI-403	Microcontrollers and its Applications	2L:0T:0P	2 credits

Course Content:

Module 1: Fundamentals of Microprocessors:
Fundamentals of Microprocessor architecture, 8-bitMicroprocessor and Microcontroller architecture, comparison of 8-bit microcontrollers, 16-bit and 32-bit microcontrollers, definition of embedded system and its characteristics, role of microcontrollers in embedded Systems, overview of the 8051 family, introduction to ARM7, Intel I (i3, i5, i7) series processors.

Module 2: The 8051 Architecture:
Internal Block Diagram, CPU, ALU, address, data and control bus, working registers, SFRs, Clock and RESET circuits, Stack and Stack Pointer, Program Counter, I/O ports, RAM- ROM organization, Memory Structures, Data and Program Memory, Timing diagrams and Machine Cycles.

Module 3: Instruction Set:
Addressing modes: Instruction syntax, Data types, Subroutines Immediate addressing, Register addressing, Direct addressing, Indirect addressing, Relative addressing, Indexed addressing, bit inherent addressing, bit direct addressing, 8051 Instruction set, Instruction timings, Data transfer instructions, Arithmetic instructions, Logical instructions, Branch instructions, Subroutine instructions, Bit manipulation instruction, Interrupts.

Module 4: Programming:
Assembly language programs, C language programs, Assemblers and compilers, Programming and debugging tools.

Module 5: I/O and External Communication Interface:
Memory and I/O expansion buses, control signals, memory wait states. Interfacing of peripheral devices such as General Purpose I/O, timers, counters, memory devices, Synchronous and Asynchronous Communication, serial communication, RS232, SPI, I2C. Introduction and interfacing to protocols like Blue-tooth and Zig-bee.

Module 6: Applications:
LED, LCD and keyboard interfacing, Stepper motor interfacing, DC Motor interfacing, sensor interfacing, Analog-to-Digital Convertors, Digital-to-Analog Convertors, Sensors with Signal conditioning Interface.

Suggested Text Books:

(i) Kenneth J. Ayala, "The 8051 Microcontroller Architecture, Programming & Applications", Penram International, 1991.
(ii) Raj Kamal, "Embedded Systems: Architecture, Programming and Design", Tata McGraw-Hill Education, 2008.

Suggested Reference Books:

(i) M. A. Mazidi, J. G. Mazidi and R. D. McKinlay, "The 8051 Microcontroller and Embedded Systems: Using Assembly and C", Pearson Education, 2007.
(ii) K. J. Ayala, "8051 Microcontroller", Delmar Cengage Learning, 2004.

(iii) R. Kamal, “Embedded System”, McGraw Hill Education, 2009.
(iv) R. S. Gaonkar, “, Microprocessor Architecture: Programming and Applications with the 8085”, Penram International Publishing, 1996.
(v) D. A. Patterson and J. H. Hennessy, "Computer Organization and Design: The Hardware/Software interface”, Morgan Kaufman Publishers, 2013.
(vi) D. V. Hall, “Microprocessors & Interfacing”, McGraw Hill Higher Education, 1991.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Comprehend and analyze architectures of microprocessors, microcontroller and ARM7 processor.
- Comprehend the memory organization of 8051 microcontrollers.
- Showcase the skill, knowledge and ability of programming using instruction set.
- Comprehend and use peripheral serial communication and the concepts of interrupts in 8051 microcontrollers.
- Interface 8051 microcontroller with the input and output devices such as LEDs, LCDs, 7-segment display and keypad.
- Design 8051 microcontroller based system with analog-to-digital converters and digital-to-analog converters within realistic constraints like user specification, availability of components etc.

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PCC RAI-404	Signals and Systems	2L:0T:0P	2 credits

Course Content:

Module 1: Introduction to Signals and Systems:
Signals and systems as seen in everyday life, and in various branches of engineering and science. Signal properties: periodicity, absolute integrability, determinism and stochastic character. Some special signals of importance: the unit step, the unit impulse, the sinusoid, the complex exponential, some special time-limited signals; continuous and discrete time signals, continuous and discrete amplitude signals. Classification of systems - Static and dynamic, Linear and nonlinear, Time-variant and time-invariant, Causal and non-causal, Stable and unstable, Impulse response and step response of systems. System properties: linearity: additivity and homogeneity, shift-invariance, causality, stability, realizability.

Module 2: Behavior of continuous and discrete-time LTI systems:
Impulse response and step response, convolution, input-output behavior with aperiodic convergent inputs, cascade interconnections. Characterization of causality and stability of LTI systems. System representation through differential equations and difference equations. State-space Representation of systems. State-Space Analysis, Multi-input, multi-output representation. State Transition Matrix and its Role. Periodic inputs to an LTI system, the notion of a frequency response and its relation to the impulse response.

Module 3: System Analysis of Fourier Transforms:
Fourier series representation of periodic signals, Waveform Symmetries, Calculation of Fourier Coefficients. Fourier Transform, convolution/multiplication and their effect in the frequency domain, magnitude and phase response, Fourier domain duality., Continuous-time Fourier transform (CTFT), The Discrete- Time Fourier Transform (DTFT) and the Discrete Fourier Transform (DFT). Parseval's Theorem, Inverse Fourier Transform.

Module 4: System Analysis of Laplace Transform:
Relation between Laplace and Fourier transforms, Review of the Laplace Transform for continuous time signals and systems, system functions, poles and zeros of system functions and signals, Laplace domain analysis, Inverse Laplace transform, solution to differential equations and system behavior.

Module 5: System Analysis of z-Transforms:
The z-Transform for discrete time signals and systems, system functions, poles and zeros of systems and sequences, z-domain analysis, s-plane to z-plane mapping, Inverse z-transform, Solution to difference equations using z-transform, Region of convergence, Stability analysis.

Module 6: Sampling and Reconstruction:
The Sampling Theorem and its implications. Spectra of sampled signals. Reconstruction: ideal interpolator, zero-order hold, first-order hold. Aliasing and its effects. Relation between continuous and discrete time systems. Introduction to the applications of signal and system theory: modulation for communication, filtering, feedback control systems.

Suggested Text Books:

(i) Michael J. Robert, “Introduction to Signals and Systems”, TMH, Second edition, 2003.
(ii) Tarun Kumar Rawat “Signals and Systems”, Oxford University Press, First edition, 2010.

(iii) Alan V Oppenhein, Alan S Wiilsky, "Signals and systems" PHI, Second edition, 2009.

Suggested Reference Books:

(i) A. V. Oppenheim, A. S. Willsky and S. H. Nawab, "Signals and systems", Prentice Hall India, 1997.
(ii) S. Haykin and B. V. Veen, "Signals and Systems", John Wiley and Sons, 2007.
(iii) A. V. Oppenheim and R. W. Schafer, "Discrete-Time Signal Processing", Prentice Hall, 2009.
(iv) B. P. Lathi, "Linear Systems and Signals", Oxford University Press, 2009.
(v) J. G. Proakis and D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Pearson, 2006.
(vi) H. P. Hsu, "Signals and systems", Schaum's series, McGraw Hill Education, 2010.
(vii) M. J. Robert "Fundamentals of Signals and Systems", McGraw Hill Education, 2007.

Course Outcomes:

At the end of the course, the students will be able to:

- Classify systems based on their properties: in particular, to understand and exploit the implications of linearity, time-invariance, causality, memory, and bounded-input, bounded-out (BIBO) stability.
- Analyze and realize discrete system using z transform.
- Determine Fourier transforms for continuous-time and discrete-time signals (or impulse-response functions), and understand how to interpret and plot Fourier transform magnitude and phase functions.
- Understand the sampling theorem and how it links continuous-time signals to discrete-time signals.

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PCC RAI-405	Robot Safety and Maintenance	2L:0T:0P	2 credits

Course Content:

Module 1: Introduction to Robot Safety:
Introduction, Safety-Related Terms and Definitions, Organizations Concerned with Safety, Introduction, Robotic Safety Problems and Hazards, Use of Robots to Promote Safety, Weak Points in Planning and Design, \Operations Causing Safety Problems, The Manufacturer's and User's Role in Robot Safety, Safety Considerations in Robot Design, Installation, Programming, and Operation and Maintenance, Robot Safeguard Methods.

Module 2: Robot Accidents:
Introduction. Real-Life Examples of Robot Accidents Robot Accidents in Japan, Western Europe, and the United States Causes and Characteristics of Robot Accidents Effects of Robot Accidents and Periods Off Work Due to Robot Accidents Robot Accidents at Manufacturer and User Sites Robot Accident Analysis and Prevention.

Module 3: Robot Safety and Safety devices:
Introduction, Robot Safety Education, Safety Considerations in Robot Testing and Start-Up, Commissioning, and Acceptance, Safety Considerations in Robot Welding Operations, Robot Safety in the Automobile Industry, Stopping Grippers of Industrial Robots Not Dropping Throwing Work Items When Experiencing Energy Loss or Not Gripping on the Return of Energy , Robot Standardization and Safety Standards, , Safety Devices, STOP type of a Robot, Emergency Stop, Mode select switch, Deadman switch, Safeguards, Operation inside of the safety fence, Safety Procedures for entering the safety fence.

Module 4: Human Factors in Robotics:
Introduction, Robots Versus Humans , Human Factors' Issues During the Factory Integration of Robotic Systems, Built-In Human Biases and Some Design Improvement Guidelines for Improving Robot Operator Comfort and Productivity, Benefits and Drawbacks of Robotization from the Standpoint of Human Factors and Rules of Robotics with Respect to Humans, Humans at Risk from Robots and Guidelines for Safeguarding the Operator and the Teacher, Human Factors' Considerations to Robotic Safety, Training for Reducing Human Error in Robotics and Human Error Data in Robotics, Reliability Analysis of a Robot System with Human Error.

Module 5: Robot Maintenance:
Introduction, General Maintenance Functions and Types of Maintenance, Robot Maintenance Needs and Types, Robot Parts and Special Tools for Maintenance and Repair, Robot Warranty Coverage and Preventive Maintenance Kits, Robot Inspection, Some Guidelines for Safeguarding Robot Maintenance Personnel, Some Models Useful in Performing Robot Maintenance.

Module 6: Safety Standards for Robotic Technology:
BIS and ISO safety standards for Robots, Safety management system, Hazard identification, Risk analysis and Evaluation, Audit Programme, Preventive Maintenance of Robots, Accident Prevention Techniques, Ergonomics of robots handling, Safety management and management principles, Major accident control, Safety Training, Robotics Safety Requirements.

Suggested Text Books:

(i) B.S. Dhillon, "Robot Reliability and Safety", CRC Press, 2015.
(ii) Paolo Barattini et. al., "Human Robot Interaction: Safety, Standardization and Benchmarking", CRC Press, 2019.

Suggested Reference Books:

(i) Nicholas Odrey, "Industrial Robotics -Technology, Programming and Applications", 2017.
(ii) Mikell Groover, "Industrial Robotics, Tata McGraw Hill, 2008.
(iii) Tom Taulli, "The Robotic Process Automation Handbook: A Guide to Implementing RPA Systems", Springer India, 31 December 2021.

Course Outcomes:

At the end of this course, the students will be able to:

- Understand the safety factors of robots.
- Know the safety standards in case of Robots.
- Understand the concept of how to do maintenance.
- Analyze and rectify the Human errors causing accidents.

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LC RAI-401	Sensors and Actuators Laboratory	0L:0T:2P	1 credit

Course Content:

- Robot Gripper design and considerations.
- Touch Sensors interfacing and feedback system.
- Manipulator kinematics analysis.
- Use of object detection and Image processing using Vision sensors in Robot system.
- Trajectory planning and analysis.
- Pick and place / path tracking using robot.
- Virtual lab experiments on Robot kinematics for Movemaster, PUMA 560 and KGP 50: http://vlabs.iitkgp.ernet.in/mr/#

Suggested Text Books:

(i) D. Patranabis, Sensors and Transducers, PHI, 2nd Edition, 2013.
(ii) Jon S. Wilson, Sensor Technology Handbook, Elsevier, 2005.

Suggested Reference Books:

(i) Mc Comb, G. Robot builder's bonanza. 5th edition New York: McGraw-Hill, 2019. ISBN 9781260135015.
(ii) Braünl, T. Embedded robotics: mobile robot design and applications with embedded systems. 3rd ed. Berlin; Heidelberg: Springer, 2008. ISBN 9783540705338.
(iii) Martin, F.G. Robotic explorations: a hands-on introduction to engineering. Upper Saddle River, N.J.: Prentice-Hall, 2001. ISBN 0130895687.
(iv) Gerard C., M. Meijer, Smart Sensors System, Wiley, 2008.
(v) Andrzej M. Pawlak, Sensors and Actuators in mechatronics, Taylor & Francis Group, 2007.
(vi) S. R. Ruocco, Robot Sensors & Transducers, Springer, 2013.

Course Outcomes:

At the end of this course, the students will be able to:

- Design a gripper for different applications using design considerations.
- Learn working of touch sensors and their interfacing and feedback.
- Perform kinematic analysis.
- Perform trajectory planning.
- Detect the object and path tracing using vision sensor.

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LC RAI-402	Microcontrollers & its Applications Laboratory	0L:0T:2P	1 credit

Detailed Content:

List of Practical: Based on 8051 and PIC microcontroller mini-cards/kits by downloading the binary file in flash memory:

- Assignment exploiting the various addressing modes for accessing internal as well as external memory and unconditional/conditional branch, loop control instructions.
- Stack and Stack arithmetic operations, Subroutines and parameter passing via register, stack.
- Timers and its applications, PWM generation.
- Serial Communication.
- Interfacing – Push buttons LEDs Key Matrix Seven segment display LCD ADC/DAC Stepper motor.

Suggested Text Books:

(i) Kenneth J. Ayala, "The 8051 Microcontroller Architecture, Programming & Applications", Penram International, 1991.
(ii) Raj Kamal, "Embedded Systems: Architecture, Programming and Design", Tata McGraw-Hill Education, 2008.

Suggested Reference Books:

(i) M. A. Mazidi, J. G. Mazidi and R. D. McKinlay, "The 8051 Microcontroller and Embedded Systems: Using Assembly and C", Pearson Education, 2007.
(ii) K. J. Ayala, "8051 Microcontroller", Delmar Cengage Learning, 2004.
(iii) R. Kamal, "Embedded System", McGraw Hill Education, 2009.
(iv) R. S. Gaonkar, "Microprocessor Architecture: Programming and Applications with the 8085", Penram International Publishing, 1996.
(v) D. A. Patterson and J. H. Hennessy, "Computer Organization and Design: The Hardware/Software interface", Morgan Kaufman Publishers, 2013.
(vi) D. V. Hall, "Microprocessors & Interfacing", McGraw Hill Higher Education, 1991.

Course Outcomes:

At the end of laboratory course, the students will demonstrate the ability to:

- Understand and apply the fundamentals of assembly level programming of microprocessors and microcontrollers.
- Work with microcontroller real time interfaces including GPIO, serial ports, digital-to-analog converters and analog-to-digital converters.
- Analyze problems and apply a combination of hardware and software to address the problem.

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LC RAI-403	Signals and Systems Laboratory	0L:0T:2P	1 credit

Detailed Content:

- List of experiments to be performed on Matlab.
- To find convolution of two sequences.
- To check linearity property of Fourier transform.
- To check whether the system y[n] = cos(x[n]) is time varying or time-invariant.
- To find Fourier transform of given sequence.
- To plot unit delta sequence, unit step sequence & unit ramp sequence.
- To study convolution property of Fourier transform.
- To study Discrete Fourier transform.
- To study inverse Discrete Fourier transform.
- To study time-shift property of Fourier transform.

Suggested Text Books:

(i) Michael J. Robert, "Introduction to Signals and Systems", TMH, Second edition, 2003.
(ii) Tarun Kumar Rawat "Signals and Systems", Oxford University Press, First edition, 2010.
(iii) Alan V Oppenhein, Alan S Wiilsky, "Signals and systems" PHI, Second edition, 2009.

Suggested Reference Books:

(i) A. V. Oppenheim, A. S. Willsky and S. H. Nawab, "Signals and systems", Prentice Hall India, 1997.
(ii) S. Haykin and B. V. Veen, "Signals and Systems", John Wiley and Sons, 2007.
(iii) A. V. Oppenheim and R. W. Schafer, "Discrete-Time Signal Processing", Prentice Hall, 2009.
(iv) B. P. Lathi, "Linear Systems and Signals", Oxford University Press, 2009.
(v) J. G. Proakis and D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Pearson, 2006.
(vi) H. P. Hsu, "Signals and systems", Schaum's series, McGraw Hill Education, 2010.
(vii) M. J. Robert "Fundamentals of Signals and Systems", McGraw Hill Education, 2007.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Understand the concepts of 'Signals and Systems' by experimentation.
- Develop application based knowledge on theoretical concepts learned.

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PROJ RAI-401	Mini Project	0L:0T:4P	2 Credits

Guidelines:

- The mini-project is a team activity having 3-4 students in a team. Mini projects should include mainly Mechanical Engineering but can be multi-disciplinary too.
- The mini project may be a complete hardware or a combination of hardware and software. The software part in the mini project should be less than 50% of the total work.
- Mini Project should cater to a small system required in laboratory or real life.
- It should encompass components, devices etc. with which functional familiarity is introduced.
- After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of the mini-project.
- Students are expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within the first week of the semester.
- The student is expected to exert on design, development and testing of the proposed work as per the schedule.
- Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

- Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
- Design, implement and test the prototype/algorithm in order to solve the conceived problem.
- Write a comprehensive report on mini project work.

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HSMC-401	Innovation and Creativity	1L:0T:0P	1 credit

Detailed Content:

- Introduction to concepts of creativity / invention / innovation and their importance in the present knowledge world. Components of the creative process, Analogy/model to represent the creative process.
- Understanding persons' Creative potential. Blockages in practicing the creative process – Mindset and belief systems. Myths and misconceptions about creativity.
- Practical Tips to discover and apply one's creative potential, remove blockages, deal with external factors. Importance of synergistically working in a team. Harnessing creativity from nature.
- Idea conception, Idea Brainstorming sessions, Idea Evaluation, Protection/Patent review, Principles of innovation, Review of systematic strategies and methods for innovation, Innovation case study, Review of Idea/Prototype /Product and Market Plan.
- Applications Exercise / Assignment: at the end of the course, the student will create teams, present their innovative ideas, and apply their learning in practice.

Suggested Text Books:

(i) Paul B. Paulus, Bernard A. Nijstad, The Oxford Handbook of Group Creativity and Innovation, Oxford University Press, 2019.
(ii) Ashwini Kumar Singh, "Creativity & Innovation" , Notion Press, 9 March 2021.

Suggested Reference Books:

(i) Jeff Dyer, Hal Gregersen, Clayton M. Christensen, " The Innovator's DNA: Mastering the Five Skills of Disruptive Innovators, Harvard Business Review Press, 2011.
(ii) Paddy Miller, Thomas Wedell-Wedellsborg, "Innovation as Usual: How to Help Your People Bring Great Ideas to Life, Harvard Business Review Press, 2013.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Understand creativity and innovation terminologies.
- Explore personal and organizational roadblocks in participating in the creative process.
- Apply practical tips to discover the innovative potential within the human being.
- Study frameworks, strategies, techniques for conceiving ideas.
- Develop new ways of thinking and Learn the entire innovation cycle.
- Understand different ways to protect innovation, basics on Patents and process.
- Apply techniques learnt in the course to articulate, refine and pitch a new product or service project.

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SEMESTER – V

SEMESTER V

PCC RAI-501	Data Structures, Files and Algorithms	2L:1T:0P	3 credits

Course Content:

Module 1: Introduction:
Basic Terminologies: Elementary Data Organizations, Data Structure Operations: insertion, deletion, traversal etc.; Analysis of an Algorithm, Asymptotic Notations, Time-Space trade off. Searching-Linear Search and Binary Search Techniques and their complexity analysis.

Module 2: Stacks and Queues:
ADT Stack and its operations: Algorithms and their complexity analysis, Applications of Stacks: Expression Conversion and evaluation – corresponding algorithms and complexity analysis. ADT queue, Types of Queue: Simple Queue, Circular Queue, Priority Queue; Operations on each types of Queues: Algorithms and their analysis.

Module 3: Linked Lists:
Singly linked lists: Representation in memory, Algorithms of several operations: Traversing, Searching, Insertion into, Deletion from linked list; Linked representation of Stack and Queue, Header nodes, Doubly Linked List: operations on it and algorithmic analysis; Circular Linked Lists: all operations their algorithms and the complexity analysis.

Module 4: Trees:
Basic Tree Terminologies, Different types of Trees: Binary Tree, Threaded Binary Tree, Binary Search Tree, AVL Tree; Tree operations on each of the trees and their algorithms with complexity analysis. Applications of Binary Trees. B Tree, B+ Tree: definitions, algorithms and analysis.

Module 5: Sorting, Hashing and Graph:
Objective and properties of different sorting algorithms: Selection Sort, Bubble Sort, Insertion Sort, Quick Sort, Merge Sort, Heap Sort; Performance and Comparison among all the methods, Hashing. Basic Terminologies and Representations in graph, Graph search and traversal algorithms and complexity analysis.

Suggested Text Books:

(i) Ellis Horowitz, Sartaj Sahni, "Fundamentals of Data Structures", Computer Science Press, 1988.
(ii) R. G. Dromey, "How to Solve it by Computer", 2nd Impression, Pearson Education, 1982.

Suggested Reference Books:

(i) Algorithms, Data Structures, and Problem Solving with C++", Illustrated Edition by Mark Allen Weiss, Addison-Wesley Publishing Company, 2014.
(ii) Alfrared V. Aho et.al., "Data Structures & Algorithms", Pearson Education India, 2002.
(iii) Robert Sedgewick, "Algorithms", 4th Edition, Pearson, 2019.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Analyze the algorithms to determine the time and computation complexity and justify the correctness.
- Implement for a given Search problem (Linear Search and Binary Search).
- Implement for a given problem of Stacks, Queues and linked list it and Analyze the same to determine the time and computation complexity.
- Write an algorithm Selection Sort, Bubble Sort, Insertion Sort.
- Quick Sort, Merge Sort, Heap Sort and compare their performance in terms of Space and Time complexity.
- Implement Graph search and traversal algorithms and determine the time and computation complexity.

*****

PCC RAI-502	Theory of Machines & Machine Design	3L:0T:0P	3 credits

Course Content:

Module 1: Fundamentals of Kinematics and mechanisms:
Kinematic Link, Kinematic Pair, Kinematic chain, Structure, mechanism, machine, Types of Constrained Motions, Degrees of Freedom, Grubler's Criterion for Plane Mechanisms, Equivalent linkage Mechanism, Inversions of Four BarChain, Single Slider Crank Chain, Double Slider Crank Chain Difference between Spatial and Planar Mechanism. Pantograph, Straight Line Motion mechanisms. Hooke's Joint / Universal Joint.

Module 2: Velocity and Acceleration Analysis in Mechanisms:
Relative Velocity (Velocity polygon) for Kinematic link. Acceleration Diagram for a Link. Coriolis component of Acceleration. Velocity and acceleration in a Slider Crank Mechanism by Klein's construction. Instantaneous Centre of Rotation (ICR). Angular Velocity Ratio Theorem, Methods of Locating ICR in a Mechanism. Velocity analysis of a Kinematic Link by ICR Method, Body and Space Centrode.

Module 3: Static and Dynamic Force Analysis:
Introduction, Static Equilibrium, Equilibrium of Two Force and Three-Force Members, Resultant effect forces acting on a rigid body, D' Alembert's Principle, Equivalent Dynamic System, Compound Pendulum, Bifilar and Trifilar suspension methods. Static and Dynamic Analysis of inertia forces of Slider-Crank Mechanism by analytical and graphical method.

Module 4: Simple stresses and strains:
Concept of stress and strain linear, lateral, shear and volumetric, Hooke's law. Elastic constants and their relationship. Thermal stresses, deflections Shear force and bending moment diagrams: UDL, uniformly varying loads and couples. Relation between SF, BM and intensity of loading, construction of SF, and BM diagrams for cantilevers, and simple beams. Theory of simple bending, Bending stress distribution diagram. Moment of resistance and section modulus calculations. Theory of torsion, torsional stresses and torsional deflections.

Module 5: Fundamental aspect of design:
Types of loads, static, shock, impact and fluctuating loads, types of stresses, tensile, compressive, direct and torsional shear, bending stresses. Combined effect of direct, bending and torsional stresses. Design concepts, material and process selection design process, factor of safety & design codes, materials. Design of shafts and different types of levers based on torsional and lateral rigidity, combined loadings. Design of keys, keyways and splines. Standard threads, stresses in threads, preloaded fasteners in tension, joint stiffness factor, power screws.

Module 6: Introduction to Gears:
Classification, Terminology, Gear Characteristics, Gear Calculations, Gear Tooth Systems, Gear Tooth Profiles, Gear Materials, Law of Gearing, Gear trains and its types, Calculation of velocity ratio for different gear trains, Gear Trains with bevel gears: Differential Gear Box.

Suggested Text Books:

(i) R. S. Khurmi and J. K. Gupta, "A Text Book of Theory of Machines", S. Chand, 14th Revised Edition, 2005.

(ii) S.S. Ratan, "Theory of Machines", Tata McGraw Hill Education Private Limited, 3rd Edition, 2009.

Suggested Reference Books:

(i) Ulicker Jr., J.J., Penock, G.R. and Shigley, J.E. "Theory of Machines and Mechanisms", Tata McGraw Hill Education Private Limited, 2009.
(ii) John Hannah and Stephens, R.C. "Mechanics of Machines: Advance Theory and Examples" Edward Arnold London.
(iii) Ramamurthy, V. "Mechanics of Machines", Narosa Publishing House, 2009.
(iv) Thomas Beven, "Theory of Machines", Pearson Education Ltd, 3rd edition, 2017.
(v) Spotts M.F. – "Design of Machine Elements" – Prentice Hall International, 2019.
(vi) Black P.H. and O. Eugene Adams – "Machine Design" – McGraw Hill Book Co. Ltd.
(vii) "Design Data" – P.S.G. College of Technology, Coimbatore, 2020.
(viii) Hall A.S.; Holowenko A.R. and Laughlin H.G. – "Theory and Problems of Machine Design" – Schaum's outline series.
(ix) Shigley J.E. and Mischke C.R. – "Mechanical Engineering Design" McGraw Hill Publ. Co. Ltd.

Course Outcomes:

At the end of this course, the students will be able to:

- Draw velocity and acceleration diagrams for simple and complex mechanisms.
- Use graphical and analytical methods for solving problems in static and dynamic force analysis.
- Apply basic concepts and theory regarding friction, lubrication, belt, rope and chain drives.
- Evaluate the different types of stresses induced in a component due to different types of static loading conditions.
- Apply the principles of static loading to design couplings, screws, springs and welded joints.
- Apply balancing concept to various types of rotating and reciprocating machine element.

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PCC RAI-503	Industrial Electronics and Power Convertors	3L:0T:0P	3 credits

Detailed Content:

Module 1: Conventional DC and AC Traction:
Electric traction services, Nature of traction load, Coefficient of adhesion, Load sharing between traction motors, Main line and suburban train configurations, Calculation of traction drive rating and energy consumption. Important features of traction drives, Conventional DC and AC traction drives, Diesel electric traction.

Module 2: Switched Mode Power Supplies (SMPS):
DC Power supplies and Classification; Switched mode dc power supplies - with and without isolation, single and multiple outputs; Closed loop control and regulation; Design examples on converter and closed loop performance.

Module 3: AC-DC Converters:
Switched mode AC-DC converters. synchronous rectification - single and three phase topologies - switching techniques - high input power factor. reduced input current harmonic distortion. improved efficiency. with and without input-output isolation. performance indices design examples.

Module 4: DC-AC Converters:
Multi-level Inversion - concept, classification of multilevel inverters, Principle of operation, main features and analysis of Diode clamped, flying capacitor and cascaded multilevel inverters; Modulation schemes.

Module 5: AC-AC Converters:
Matrix converters. Basic topology of matrix converter; Commutation – current path; Modulation techniques - scalar modulation, indirect modulation; Matrix converter as only AC-DC converter; AC-AC converter with DC link - topologies and operation - with and without resonance link - converter with dc link converter; Performance comparison with matrix converter with DC link converters.

Module 6: Soft-Switching Power Converters:
Soft switching techniques. ZVS, ZCS, quasi resonant operation; Performance comparison hard switched and soft switched converters.AC-DC converter, DC-DC converter, DC-AC converter.; Resonant DC power supplies.

Suggested Text Books:

(i) Paul, B., Industrial Electronic and Control, Prentice Hall of India Private Limited 2004.
(ii) Narayanswami Iyer, “Power Electronic Converters”, CRC Press, 2018.

Suggested Reference Books:

(i) Power Electronics Handbook, M.H. Rashid, Academic press, New York, 2000.
(ii) Advanced DC/DC Converters, Fang Lin Luo and Fang Lin Luo, CRC Press, New York, 2004.
(iii) Control in Power Electronics- Selected Problem, Marian P. Kazmierkowski, R. Krishnan and Frede Blaabjerg, Academic Press (Elsevier Science), 2002.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Simulate and analyze the semiconductor controlled ac and DC drive system.
- Equip the skill to design and develop a regulated power supply.
- Suggest converters for AC-DC conversion and SMPS.

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PCC RAI-504	Advances in Robotics and Artificial Intelligence	2L:1T:0P	3 credits

Course Content:

Module 1: Humanoid Robotics Technology and Social Robots:
Sensors in Humanoid Robot, Control of Humanoid Robot, actuation types for humanoid Robot, System Integration in Humanoid Robot, Social Robot, Need of Social Robots, Assistive and Social Robots in the Healthcare Sector and other, Case study On Humanoid Robot.

Module 2: Swarm Robotics:
Characteristics, Swarm Robotics and Multi-Robotic Systems, Experimental Platforms in Swarm Robotics, Tasks in Swarm Robotics, Swarm Robots used in Real world applications, Smart Robots, Smart Robots applications, Robotics for Warfare Applications.

Module 3: Human Robot Interaction (HRI):
Definition, History, Need of HRI, Ethical Issues for HRI, Multi-Modal Perception, Social, Service, and Assistive Robotics, HRI Architecture, Collaborative Robots, Definition, Types of Collaboration, Applications of collaborative robots, collaborative Robot Technology.

Module 4: Industry 4.0 and Internet of Robotic things (IORT):
Introduction, Internet of Things and Robotics, Applications and developments of the Internet of Robotic Things.

Module 5: Natural Language Processing:
Introduction, Classical Approaches to Natural Language Processing, Text Preprocessing, Lexical Analysis, Syntactic Parsing, Semantic Analysis, Natural Language Generation, Applications.

Module 6: Logics for AI and Automated Reasoning:
What is Automated Reasoning, methods of Reasoning, reasoning types, use of Automated reasoning in AI, Reasoning and its types, applications for Automated Reasoning, Mathematical consideration.

Suggested Text Books:

(i) Luger " Artificial Intelligence", Edition 5, Pearson, 2008.
(ii) Ralf Herbrick, Thore Graepel, “A Handbook on Natural Language Processing”, Second Edition, CRC Press, 2010.

Suggested Reference Books:

(i) Elmer P. Dadios, “Humanoid Robot: Design and Fuzzy Logic Control Technique for Its Intelligent Behaviors”, 2012.
(ii) Iñaki Navarro and Fernando Matía, “An Introduction to Swarm Robotics”, ISRN Robotics, 2013.
(iii) Automation and Collaborative Robotics, Springer Publication, 2020.
(iv) Jeff Faneuff, Jonathan Follett, “Designing for collaborative robotics”, O'Reilly Media, 2016.
(v) David Feil-Seifer, “Human-Robot Interaction”, 2010.
(vi) Maria Paola Bonacina, “Automated Reasoning for Explainable Artificial Intelligence”, 2018.

(vii) David Gunning, "Explainable Artificial Intelligence (XAI)", 2017.
(viii) Conference Proceedings on "Artificial Intelligence, Automated Reasoning, and Symbolic Computation", Springer Publication, 2002.

Course Outcomes:

At the end of this course, the students will able to:

- Understand the technologies used in advanced robots.
- Understand the technology used in Natural Language processing.
- Study NLP techniques and understand its utility in industrial applications.
- Apply automated reasoning in AI based programming.

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PCC RAI-505	Control Systems	2L:0T:0P	2 credits

Course Content:

Module 1: Introduction to Control System:
Introduction to control system block diagram. Importance of Control Systems. Components of control. Explanation with the help of the liquid level control system. Significance of actuators and sensors. Types of actuators, Types of sensors. Open loop control and closed loop control. Use of relays, switches and contactors for simple and sequential control systems.

Module 2: Control system representation:

Mathematical representation of simple mechanical, electrical, thermal, hydraulic systems. Block diagram representation and reduction. Signal flow graph. Transfer function of these systems. Pole zero concepts.

Module 3: Time domain analysis:

Time response of first order, second order systems. Analysis of steady state error, Type of system and steady state error, Time response specifications. Effect of parameter variation on open loop and closed loop system response, sensitivity. Effect of feedback on system response, stability and disturbance.

Module 4: Stability:

Concept of stability, Effect of pole zero location on stability, Routh- Hurwitz criterion. Root Locus method for analysis of gain margin, phase margin and stability.

Module 5: Control system analysis in frequency domain:

Concept of frequency domain behavior, Bode Plot for analyzing systems in frequency domain. Frequency domain performance specifications. Correlation between time domain and frequency domain specification. Nyquist Analysis.

Module 6: State Space Approach:

Representation of system in state space, Converting transfer function model into state space model. Non uniqueness of state space model, Canonical representation, Eigenvalues, Solution of state equations, Concept of State feedback control, controllability, Observability.

Suggested Text Books:

(i) Nagrath & M. Gopal “Control System Engineering”, Anshan, 2008.
(ii) Norman S. Nice, “Control System Engineering”, Wiley, 2008.

Suggested Reference Books:

(i) Smarajit Ghosh, “Control Systems Theory & Applications”, Pearson Education, 2007.
(ii) Katsuhiko Ogata,” Modern Control Engineering”, Prentice Hall, 2010.
(iii) Norman S. Nise, “Control System Engineering”, Wiley, 2014.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Appreciate the role of the control system.
- Analyze the mathematical model of the control system.
- Solve to get a time domain response.
- Analyze stability of the system.
- Use bode plot for frequency domain analysis.
- Analyze the control system in state space.

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PCC RAI-506	Hydraulic & Pneumatic Drives for Robots	2L:0T:2P	3 credits

Pre-Requisites	Basic Fluid Mechanics and Electrical Engineering

Detailed Course Content:

Module 1: Introduction:
Robot Actuation, Robotic Grippers, Characteristics of Actuating Systems, Comparison of Actuating Systems.

Module 2: Fluid Power Systems:
Introduction of Fluid Power Systems, Properties of Fluids and Selection, Pascal's Law and Pressure Measurement, Fluid Flow and Measurement, Gas Laws.

Module 3: Control Valves:
Fluid power control elements and standard graphical symbols, Directional, Pressure and Flow Control Valves – Construction and Working, Rotary Valves, Pilot-Operated Valves Servo-valves.

Module 4: Hydraulic and Pneumatic Power Supplies:
Hydraulic Power Packs, Hydraulic Loading Valve and Filters, Air Compressors & Receivers, Air Treatment and FRL Units, Pressure Regulation in Fluid Power Circuits.

Module 5: Fluid Power Actuators:
Linear actuators and their Construction, Rotary actuators and their Construction, Mounting Arrangements, Cylinder Dynamics, Speed Control.

Module 6: Fluid Power Circuits & Control:
Control of Single and Double Acting Hydraulic Cylinders, Control of Single and Double Acting Pneumatic Cylinders, Electrical Controls for Fluid Power Circuits, Electro-hydraulic and Electro-Pneumatic Circuits, Examples of Fluid Power Circuits in Robotics.

Suggested Text Books:

(i) Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010.
(ii) R. Mittal, Nagrath, "Robotics and Control", McGraw Hill Education, 2017.

Suggested Reference Books:

(i) Hydraulics and Pneumatics, Jagadeesha T; I. K. International Publishing House Pvt. Ltd., 2015.
(ii) Hydraulics and Pneumatics, Andrew Parr; Jaico Books, 1993.

Course Outcomes:

After the completion of this course, the students will be able to:

- Select a fluid power actuation system for a given robotic application.
- Select components for designing a fluid power circuit.
- Assemble and operate a fluid power actuation system.
- Design fluid power actuation system for robotic application.

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LC RAI-501	Control Systems Laboratory	0L:0T:2P	1 credit

Experiments:

- To study input out characteristic of various control system components.
- To obtain step response and find time response specification of electrical system, hydraulic system, pneumatic system and thermal system.
- To obtain transfer function and poles zeros of DC motor experimentally.
- To obtain root locus experimentally.
- Use Matlab to study the effect of feedback gain on system response.
- Use Matlab to study the effect of damping factor zeta on time control performance specifications.
- Use Matlab to obtain root locus for a given system and find performance specifications there from. Study effect of addition of zero and pole on root locus.
- Use Matlab to get a bode plot and obtain gain margin and phase margin for various systems.
- Use Matlab to obtain state space representation from transfer function, find Eigenvalues, Analyze controllability, observability and stability.

Suggested Text Books:

(i) Nagrath & M. Gopal "Control System Engineering", Anshan, 2008.
(ii) Norman S. Nice, "Control System Engineering", Wiley, 2008.

Suggested Reference Books:

(i) Smarajit Ghosh, "Control Systems Theory & Applications", Pearson Education 2007.
(ii) Katsuhiko Ogata," Modern Control Engineering", Prentice Hall, 2010.
(iii) Norman S. Nise, "Control System Engineering", Wiley, 2014.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Develop the mathematical model of different components of linear feedback control system using simulation and experiments.
- Analyze the transient characteristics of different first order and second order systems using simulation and experiments.
- Determine the performance of system using root locus.
- Carry out the stability analysis of linear feedback control system using Bode plot and Nyquist plot.
- Carry out the stability analysis of linear feedback control system using Modern control techniques.
- Analyze the different types of controllers like PI, PD, PID and tuning of these controllers using simulation and experiments.
- Describe various applications like temperature controller experimentally.
- Demonstrate an industrial application (like Bottle filling/ Pick and Place control) using PLC Write and present effective technical reports.

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LC RAI-502	Industrial Electronics Laboratory	0L:0T:2P	1 credit

Detailed Content:

- Study of CRO and its applications-measurement of frequency, phase difference, voltage, vibration signals, temperature measurement using thermocouple etc. Instruments: 20 MHz dual trace CRO, Function-generator.
- Study of UPS systems Instruments: UPS kit, CRO, DMM.

Or

- Controlled rectifiers using SCR with UJT triggering for Lamp load. Instruments: Power-Scope, DMM.
- Applications of Op-Amp using 741 (Any two) Square wave generators/ramp generator Instrumentation Amplifier.
- Op-Amp as comparator and Schmidt trigger.
- Instruments: Dual trace CRO, Dual Power supply. Function Generator.
- Sequential timer using IC555 and square wave generator Instruments: Power supply, Dual trace CRO, stop-watch.
- Application of logic gates (One-bit Comparator) and combinational circuits, e.g. traffic lights, combinational lock lift, control, code conversion.
- PLC Programming.
- Shift register IC7495 and its application as a sequence generator.

Or

- Programmable counter (frequency and time measurement).
- Instruments for digital experiments: Power supply, dual trace CRO, Pulse generator, DMM.
- Minimum two circuits of level detector, proximity detector, electronic weighing machine, non- contact type, Tachometer Annunciator.

Or

- Study and demonstration of resistance welding, R.F. Heating.

Suggested Text Books:

(i) Paul, B., Industrial Electronic and Control, Prentice Hall of India Private Limited, 2004.
(ii) Narayanswami Iyer, “Power Electronic Converters”, CRC Press, 2018.

Suggested Reference Books:

(i) Power Electronics Handbook, M.H. Rashid, Academic press, New York, 2000.
(ii) Advanced DC/DC Converters, Fang Lin Luo and Fang Lin Luo, CRC Press, New York, 2004.
(iii) Control in Power Electronics- Selected Problem, Marian P. Kazmierkowski, R. Krishnan and Frede Blaabjerg, Academic Press (Elsevier Science), 2002.

Course Outcomes:

At the end of the laboratory work, the students will demonstrate the ability to:

- Perform basic Electrical Machines experiments and evaluate their suitability for a specified job from their electrical and mechanical characteristics.
- Get hands-on experience in using op amps and timer circuits in industrial electronics experiments.
- Predict, analyze, and test the performance of sensors of various kinds, including strain gages, thermocouples, tachometers, displacement transducers, dynamometers, pressure gages and transducers, Flow meters etc. Understand working of fully controlled half wave rectifier and circuits using triacs.

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LC RAI-503	Artificial Intelligence Laboratory	0L:0T:2P	1 credit

Suggested List of Assignments

- Implement A* algorithm.
- Implement AO* algorithm.
- Implementation of other Searching algorithms.
- Implementation of Min/MAX search procedure for game Playing.
- Implementation of variants of Min/ Max search procedure.
- Implementation of a mini Project using the concepts studied in the AI course.

This list is a guideline. The instructor is expected to improve it continuously.

Suggested Text Books:

(i) Luger "Artificial Intelligence", Edition 5, Pearson, 2008.
(ii) Michael Negnevitsky, “Artificial Intelligence: A Guide to Intelligent Systems”, Addison-Wesley, May 2011.

Suggested Reference Books:

(i) Russell, Stuart and Norvig, Peter, “Artificial Intelligence: A Modern Approach" Prentice Hall, 2003.
(ii) Bench-Capon, T. J. M., “Knowledge Representation: An approach to artificial intelligence”, Academic Press, 1990.
(iii) Mohamad H. Hassoun, “Fundamentals of Artificial Neural Networks”, The MIT Press, 1995.

Course Outcomes:

Upon successful completion of the course, the students will be able to:

- Develop an Explanation of what is involved in learning models from data.
- Implement a wide variety of learning algorithms.
- Apply principles and algorithms to evaluate models generated from data.
- Apply the algorithms to a real-world problem.

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LC RAI-504	Hydraulic & Pneumatic Drives Laboratory	0L:0T:2P	1 credit

PRACTICE TASKS

- To study components and functioning of a hydraulic power pack.
- To study components and functioning of a pneumatic fluid power supply.
- To study different types of DC control valves and actuators in hydraulic fluid power systems.
- To study different types of DC control valves and actuators in pneumatic fluid power systems.
- To study the working of speed and pressure control valves in fluid power circuits.
- To study a pneumatic logic circuit using a pilot operated DC valve.
- To operate a linear hydraulic actuator using 4/2 and 4/3 DC valves.
- To operate rotary pneumatic or hydraulic motors using two and three position DC valves.
- To operate single acting and double acting linear pneumatic actuators using 3/2 and 5/2 DC electro pneumatic valves respectively.
- To study the application of fluid power circuits in robots.

Suggested Text Books:

(i) Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010.
(ii) R. Mittal, Nagrath, "Robotics and Control", McGraw Hill Education, 2017.

Suggested Reference Books:

(i) Hydraulics and Pneumatics, Jagadeesha T; I. K. International Publishing House Pvt. Ltd., 2015.
(ii) Hydraulics and Pneumatics, Andrew Parr; Jaico Books, 1993.

Course Outcomes:

After the completion of this Lab, the students will be able to:

- Select a suitable DC control valve.
- Select a suitable actuator for a given robotic application.
- Understand the functioning of different valves, actuators and fluid power circuits.
- Design fluid power actuation system for robotic application.

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LC RAI-505	Theory of Machines & Mechanism Laboratory	0L:0T:2P	1 credit

Detailed Content:

List of Experiments (Any 3 experiments from the given list):

- Determination of Moment of Inertia of rigid bodies by bifilar or trifilar suspension method.
- Compound Pendulum.
- Experimental Verification of displacement relation for different shaft angles for single Hooke's Joint.
- Developing a computer program for velocity and acceleration of the slider crank mechanism.
- Graphical solution of problems on velocity & acceleration in mechanisms by Relative velocity & relative acceleration method including problem with Coriolis component of acceleration.
- Graphical solution of problems on velocity in mechanisms by ICR method.
- Klein's constructions for the slider crank mechanism.
- Inertia force analysis with graphical methods.
- Straight line motion mechanisms.

Suggested Text Books:

(i) R. S. Khurmi and J. K. Gupta, "A Text Book of Theory of Machines", S. Chand, 14th Revised Edition, 2005.
(ii) S.S. Ratan, "Theory of Machines", Tata McGraw Hill Education Private Limited, 3rd Edition, 2009.

Suggested Reference Books:

(i) Ulicker Jr., J.J., Penock, G.R. and Shigley, J.E. "Theory of Machines and Mechanisms", Tata McGraw Hill Education Private Limited, 2009.
(ii) John Hannah and Stephens, R.C. "Mechanics of Machines: Advance Theory and Examples" Edward Arnold London.
(iii) Ramamurthy, V. "Mechanics of Machines", Narosa Publishing House, 2009.
(iv) Thomas Beven, "Theory of Machines", Pearson Education Ltd, 3rd edition, 2017.
(v) Spotts M.F. – "Design of Machine Elements" – Prentice Hall International, 2019.
(vi) Black P.H. and O. Eugene Adams – "Machine Design" – McGraw Hill Book Co. Ltd.
(vii) "Design Data" – P.S.G. College of Technology, Coimbatore, 2020.

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

- Determine Moment of Inertia of rigid bodies by bifilar or trifilar suspension method.
- Verify displacement relation for different shaft angles for single Hooke's Joint.

- Develop a computer program for velocity and acceleration of slider crank mechanism Non-destructive tests like Magnaflux testing, Dye penetrant test and Ultrasonic test.
- Graphical solution to problems on velocity & acceleration in mechanisms by Relative velocity & relative acceleration method including problem with Coriolis component of acceleration.
- Analyzing Inertia force with graphical methods.

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SEMESTER – VI

SEMESTER VI

PCC RAI-601	Kinematics of Robotics	3L:0T:0P	3 credits

Pre-Requisites	Basic Engineering Mathematics Engineering Mechanics

Course Content:

Module 1: Introduction
Vector Representations and Operations, Transformations, Translational and Rotational, Coordinate Reference Frames, Properties of Transformation Matrices, Matrix Creation and Manipulation using MATLAB.

Module 2: Homogeneous Transformations
Pure Translation, Pure Rotation about an Axis, Representation of Combined Transformations, Transformations Relative to a Moving Frame, Homogeneous Transformations using MATLAB.

Module 3: Kinematics:
Kinematic Parameters, The Denavit-Harternberg (DH) Representation, Forward & Inverse Kinematic Equations: Position, Cartesian Coordinates, Cylindrical Coordinates, Spherical Coordinates, Articulated Coordinates, Kinematics of Industrial Robots, Kinematics using MATLAB.

Module 4: Forward & Inverse Kinematic:
Orientation Description, Forward & Inverse Kinematic Equations Orientation, Roll, Pitch and Yaw (RPY) Angles, Euler Angles, Geometric Approach to Inverse Kinematics, Forward and Inverse Kinematics of Industrial Robots, Design Project: A 3-DOF Robot.

Module 4: Velocity & Acceleration Analysis:
Differential Motions and Relationships, Jacobian, Forward and Inverse Velocity Analysis, Acceleration Analysis, Design Project: A 3-DOF Robot.

Suggested Text Books

(i) S. K. Saha, "Introduction to Robotics", McGraw Hill Education (India) Pvt. Ltd., 2014.
(ii) John J. Craig, "Introduction to Robotics – Mechanics and Control", Pearson Education, 2004.

Suggested Text Books

(i) Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010.
(ii) Reza N. Jazar, "Theory of Applied Robotics: Kinematics, Dynamics, and Control", Springer July 2010.
(iii) Tuna Balkan, "Robot Kinematics: Forward and Inverse Kinematics", Intech, Dec. 2006.

Course Outcomes:

After the completion of this course, the students will be able to:

- Explain position and orientation parameters for describing the pose of industrial robots.
- Apply mathematical tools for solving robot kinematics problems.
- Assign the coordinate frames to industrial robots and derive their forward and inverse kinematic equations.
- Use software tools for obtaining solutions to forward and inverse kinematics problems.

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PCC RAI-602	Embedded Systems Design	3L:0T:0P	3 credits

Course Content:

Module 1: ARM-Cortex Series Architecture:
Embedded systems, classification, ARM 32-bit microcontroller Tiva, architecture technology overview, Architectural Features of ARM Cortex M series: Tiva Block Diagram, CPU modes, register organization, ROM, RAM, timers, data and address bus, Memory and I/O interfacing concepts, memory mapped I/O. CISC Vs RISC design philosophy, Von-Neumann Vs Harvard architecture, instruction set, pipelining, exceptions and its handling, memory, I/O's and addressing modes.

Module 2: Operating system based development:
Operating systems fundamentals, operating system services, memory management, process management, device management, file management, operating system services- program execution, I/O operation, file manipulation, communication, operating system properties- multitasking, parallel programming, interactivity, scheduling and scheduling algorithms. Linux: An overview of Red Hat Linux, installing Ubuntu, Linux commands, shell scrip programming, embedded Linux.

Module 3: Development Tools (Open Source):
GNU tools, text editors-vi, nano, pico, etc. IDE-Eclipse, code lite, compilers-gcc, g++, debuggers, cross- compilers, gcc- arm specific tool chains and in line assembly, Writing and compiling C/C++ programs, cross-compilation for ARM development board, Basics of make file, static and dynamic libraries.

Module 4: Kernel programming:
Kernel, basic functionalities of kernel, kernel module programming, Linux kernel sources, kernel configuration, booting kernel, kernel booting parameters, root file system, bootloader, U- boot, porting Linux ARM board, device driver programming, architecture, I/O communication, writing simple character device driver.

Module 5: RTOS:
RTOS concepts using Tiva: foreground and background systems, critical section, shared resources, tasks, multitasking, context switching, kernels, pre-emptive and non- pre-emptive schedulers, static and dynamic priorities, priority inversion, mutual exclusion, synchronization, inter task communication mechanisms, Interrupts: latency, response and recovery, clock tick, memory requirements.

Module 6: Interfacing and application development
Interfacing of peripherals using Tiva: LED and sensors, ADC, Timer, PWM, UART, SPI, I2C.Development of web server, wireless module interfacing, camera interfacing, open CV on Beagle Bone Black. Control application, Java programming on Beagle Bone Black, porting android for mobile applications like controlling Beagle Bone Black I/O through mobile.

Suggested Text Books:

(i) Sloss Andrew N, Symes Dominic, Wright Chris, "ARM System Developer's Guide: Designing and Optimizing", Morgan Kaufman Publication, 2004.

(ii) Michael Beck, "Linux Kernel Programming", Addison-Wesley Professional, 3rd ed., 2002.

Suggested Reference Books:

(i) Raj Kamal, "Embedded Systems – Architecture: Programming and Design", Tata McGraw-Hill Education, 3rd edition, 2003.
(ii) Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers, 2014, Jonathan W Valvano Create space publications ISBN: 978-1463590154.
(iii) Embedded Systems: Introduction to ARM Cortex - M Microcontrollers, 5th edition Jonathan W Valvano, Create space publications ISBN-13: 978-1477508992.

Course Outcomes:

- Hands on usage of IDE of processors and algorithm development.
- To understand the concept of OS, RTOS and application perspectives.
- Understanding of RISC architecture of processor, its features and application.
- Study, design, analyze and prototype various embedded systems.

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PCC RAI-603	Data Science	2L:1T:0P	3 credits

Pre-Requisites	Probability, Statistics

Detailed Course Content:

Module 1: Introduction to Data Science

Introduction to Data Science – Applications - Data Science Process – Exploratory Data analysis – Collection of data, Graphical presentation of data – Classification of data – Storage and retrieval of data – Big data – Challenges of Conventional Systems - Web Data – Evolution Of Analytic Scalability - Analytic Processes and Tools - Analysis vs Reporting - Modern Data Analytic Tools - Statistical Concepts: Sampling Distributions - Re-Sampling - Statistical Inference - Prediction Error.

Module 2: Predictive Modeling and Machine Learning

Linear Regression – Polynomial Regression – Multivariate Regression – Multilevel Models – Data Warehousing Overview – Bias/Variance Trade Off – K Fold Cross Validation – Data Cleaning and Normalization – Cleaning Web Log Data – Normalizing Numerical Data – Detecting Outliers – Introduction to Supervised and Unsupervised Learning – Reinforcement Learning – Dealing with Real World Data – Machine Learning Algorithms -Clustering -Python Based Application.

Module 3: Data Mining Techniques

Rule Induction - Neural Networks: Learning and Generalization - Competitive Learning - Principal Component Analysis and Neural Networks - Fuzzy Logic: Extracting Fuzzy Models from Data - Fuzzy Decision Trees - Stochastic Search Methods- Neuro-Fuzzy Modeling – Association rule mining – Clustering – Outlier Analysis – Sequential Pattern Mining – Temporal mining – Spatial mining – Web min.

Module 4: Frameworks and Visualization

Map Reduce – Hadoop, Hive, MapR – Sharding – NoSQL Databases – Cloud databases - S3 - Hadoop Distributed File Systems – Visualizations - Visual Data Analysis Techniques - Interaction Techniques – Social Network Analysis – Collective Inferencing – Egonets - Systems and Applications.

Module 5: Data Science Using Python

Introduction to Essential Data Science Packages: Numpy, Scipy, Jupyter, Statsmodels and Pandas Package – Data Munging: Introduction to Data Munging, Data Pipeline and Machine Learning in Python – Data Visualization Using Matplotlib – Interactive Visualization with Advanced Data Learning Representation in Python.

Suggested Text Books:

(i) Seema Acharya, Subhashini Chellapan, “Big Data and Analytics”, Wiley, 2015.

(ii) Frank Pane, “Hands On Data Science and Python Machine Learning”, Packt Publishers, 2017.

(iii) S. N. Sivanandam, S. N Deepa, “Introduction to Neural Networks Using Matlab 6.0”, Tata McGraw- Hill Education, 2006.

Suggested Reference Books:

(i) Michael Berthold, David J. Hand, "Intelligent Data Analysis", Springer, 2007.
(ii) Anand Rajaraman and Jeffrey David Ullman, "Mining of Massive Datasets", Cambridge University Press, 2012.
(iii) Bill Franks, "Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics", John Wiley & Sons, 2012.
(iv) Jiawei Han, Micheline Kamber "Data Mining Concepts and Techniques", Second Edition, Elsevier, Reprinted 2008.
(v) Rachel Schutt, Cathy O'Neil, "Doing Data Science", O'Reilly Publishers, 2013.
(vi) Foster Provost, Tom Fawcet, "Data Science for Business", O'Reilly Publishers, 2013.
(vii) Bart Baesens, "Analytics in a Big Data World: The Essential Guide to Data Science and its Applications", Wiley Publishers, 2014.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

- Work with a data science platform and its analysis techniques.
- Design efficient algorithms for mining the data from large volumes.
- Model a framework for Human Activity Recognition.
- Development with cloud databases.

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PCC RAI-604	Dynamics and Trajectory Planning	2L:0T:0P	2 credits

Pre-Requisites	Robot Kinematics and Basic Engineering Mathematics

Detailed Course Content:

Module 1: Statics and Manipulator Design
Forces and Moments Balance, Equivalent Joint Torques, Role of Jacobian in Statics, Manipulator Design.

Module 2: Dynamics
Inertia Properties, Euler-Lagrange Formulation, Newton-Euler Formulation, Recursive Newton-Euler Algorithm, Dynamic Algorithms.

Module 3: Robot Configuration Space
Specifying a Robot's Configuration, Obstacles and the Configuration Space, The Dimension of the Configuration Space, The Topology of the Configuration Space, Example Configuration Spaces, Transforming Configuration and Velocity Representations.

Module 4: Trajectory Planning
Path and Trajectory, Basics of Trajectory Planning, Joint Space Trajectory Planning, Cartesian Space Trajectory Planning, Point-to-Point vs Continuous Path Planning.

Module 5: Motion Control System
Open and Closed Loop Control, Laplace Transforms and Transfer Function, Characteristics of Dynamic Systems, Proportional-Integral-Derivative Controllers, State-Space Control, Digital Control, Robot Actuation and Control.

Suggested Text Books:

(i) Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010.
(ii) S. K. Saha, "Introduction to Robotics", McGraw Hill Education (India) Pvt. Ltd., 2014.

Suggested Reference Books:

(i) Choset, Lynch, Hutchinson, Kantor, Burgard, Kavraki and Thrun, "Principle of Robot Motion", PHI Learning Pvt. Ltd., 2005.
(ii) K Fujimura , "Motion Planning in Dynamic Environments",Springer-Verlag, 2012.
(iii) Wayne Adams, "Robot Kinematics & Motion Planning", Nova Science Publishers Inc., Nov. 2012.

Course Outcomes:

After the completion of this course, the students will be able to:

- Formulate dynamic models of industrial robots.
- Formulate robot motion planning models using different schemes.
- Understand the theory and components of open and closed loop control systems.
- Understand different types of robot motion control approaches.

******

PCC RAI-606	Knowledge Engineering and Expert System	2L:0T:0P	2 credits

Detailed Course Content:

Module 1:
Introduction, the history of knowledge-based expert systems, Characteristics of current expert systems, Basic concepts for building expert systems.

Module 2:
Building and Expert System, the architecture of expert systems, constructing an expert system, including computer inference and knowledge acquisition.

Module 3:
Knowledge representation schemes; conceptual data analysis; plausible reasoning techniques, Tools for building expert systems.

Module 4:
Evaluating an Expert System, Reasoning about reasoning, validation and measurement methods.

Module 5:
Production-rule programming, Issues and case studies, Language and Tools for Knowledge Engineering.

Module 6: A Case Study in Knowledge Engineering.

Suggested Text Books:

(i) Davis, R. & Lenat, D. B., "Knowledge-Based Systems in Artificial Intelligence", McGraw-Hill, 1989.

(ii) Hayes-Roth, F., Waterman, D. A. & Lenat, D. B. (eds) Building Expert Systems. Addison-Wesley Publishing Company, Inc., 1984.

Suggested Reference Books:

(i) Buchanan, B. B. & Shortliffe, E. H., "Building Expert Systems with Production Rules: The Mycin Experiments", Wesley Publishing Company, 1983.

(ii) Torsun, I. S. Expert Systems: State of the Art, Addison-Wesley Publishing Company, 1983.

Course Outcomes:
At the end of the course the students will be able to:

- Explain and describe the concepts central to the creation of knowledge bases and expert systems.
- Use the tools and the processes for the creation of an expert system.
- Conduct an in-depth examination of an existing expert system with an emphasis on basic methods of creating a knowledge base.
- Examine properties of existing systems in a case-study manner, comparing differing Approaches.
- Demonstrate proficiency developing applications in expert system shell.

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PCC RAI-605	Robot Operating Systems	1L:0T:2P	2 credits

Laboratory Experiments:

1. Endowing mobile autonomous robots with planning, perception, and decision- making capabilities.
2. Trajectory optimization.
3. Robot motion planning and perception.
4. Robot, localization, and simultaneous localization and mapping.
5. Robot Operating System (ROS) for demonstrations and hands-on activities.

Suggested Text Books:

(i) Morgan Quigley, "Programming Robots with ROS: A Practical Introduction to the Robot Operating System" , O'Reilly Media, 2015.
(ii) Carol Fairchild, Dr. Thomas L. Harman, "ROS Robotics by Example", Packt, 2016.

Suggested Reference Books:

(i) Anis Koubaa, "Robot Operating System", Springer link, 2016.
(ii) Anil Mahtani, "Effective Robotics Programming with ROS", Packt Publishing, 2016.
(iii) Ramkumar Gandhinathan , Lentin Joseph , " ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality", Packt Publishing Limited, December 2019.

Course Outcomes:

At the end of the course the students will be able to:

- Learn fundamentals, including key ROS concepts, tools, and patterns.
- Program robots that perform an increasingly complex set of behaviors, using the powerful packages in ROS.
- See how to easily add perception and navigation abilities to your robots.
- Integrate your own sensors, actuators, software libraries, and even a whole robot into the ROS ecosystem.
- Learn tips and tricks for using ROS tools and community resources, debugging robot behavior using C++ in ROS.

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PEC RAI-601	Elective Course-I Mobile and Micro-Robotics (Tract: Robotics)	2L:0T:0P	2 credits

Detailed Course Content:

Module 1:
Introduction to Mobile Robots - Tasks of mobile robots, robots manufacturers, type of obstacles and challenges, tele-robotics, philosophy of robotics, service robotics, types of environment representation. Ground Robots: Wheeled and Legged Robots, Aerial Robots, Underwater Robots and Surface Robots.

Module 2:
Kinematics and Dynamics of Wheeled Mobile Robots (two, three, four - wheeled robots, omni-directional and macanum wheeled robots). Sensors for localization: magnetic and optic position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, GNSS and Sensors for navigation: tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual system.

Module 3:
Localization and Mapping in mobile robotics. Motion Control of Mobile Robots (Model and Motion based Controllers): Lyapunov-based Motion Control Designs and Case Studies. Understand the current application and limitations of Mobile Robots. Introduction to Mobile Manipulators and Cooperative Mobile Robots.

Module 4:
Micro-robotics: Introduction, Task specific definition of micro-robots - Size and Fabrication Technology based definition of micro-robots - Mobility and Functional-based definition of micro-robots - Applications for MEMS based micro-robots. Implementation of Micro-robots: Arrayed actuator principles for micro-robotic applications – Micro-robotic actuators.

Module 5:
Design of locomotive micro-robot devices based on arrayed actuators. Micro-robotics devices: Micro- grippers and other micro-tools - Micro-conveyors - Walking MEMS Micro-robots – Multi-robot system: Micro-robot powering, Micro-robot communication. Microfabrication and Micro-assembly: Micro-fabrication principles - Design selection criteria for micromachining - Packaging and Integration aspects – Micro-assembly platforms and manipulators.

Suggested Reference Books:

(i) Roland Siegwart, Illah Reza Nourbakhsh, Davide Sacramuzza, Introduction to Autonomous Mobile Robots, MIT press, 2nd edition, 2011.

(ii) Howie Choset, Kevin Lynch Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun, ―Principles of Robot Motion-Theory, Algorithms, and Implementation, MIT Press, Cambridge, 2005.

Suggested Reference Books:

(i) Atnaik, Srikanta, "Robot Cognition and Navigation: An Experiment with Mobile Robots", Springer-Verlag Berlin and Heidelberg, 2007.
(ii) Spyros G. Tzafestas, “Introduction to Mobile Robot Control”, Elsevier, 2021.
(iii) Margaret E. Jefferies and Wai-Kiang Yeap, "Robotics and Cognitive Approaches to Spatial Mapping", Springer-Verlag Berlin Heidelberg, 2008.

Course Outcomes:

At the end of the course students will be able to:

- Identify and design a suitable manufacturing process for micro robots.
- Understand the importance of visual perception and recognition for cybernetic view.
- Program a robot for wandering and teleoperation.

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PEC RAI-602	Elective Course-I Data Analytics (Tract: AI)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Fundamentals of Data Analytics
Descriptive, Predictive, and Prescriptive Analytics, Data Types, Analytics Types, Data Analytics Steps: Data Pre-Processing, Data Cleaning, Data Transformation, and Data Visualization.

Module 2: Data Analytics Tools
Data Analytics using Python, Statistical Procedures, NumPy, Pandas, SciPy, Matplotlib.

Module 3: Data Pre-Processing
Understanding the Data, Dealing with Missing Values, Data Formatting, Data Normalization, Data Binning, Importing and Exporting Data in Python, Turning categorical variables into quantitative variables in Python, Accessing Databases with Python.

Module 4: Data Visualization
Graphic representation of data, Characteristics and charts for effective graphical displays, Chart types- Single variable: Dot plot, Jitter plot, Error bar plot, Box-and whisker plot, Histogram, Two-variable: Bar chart, Scatter plot, Line plot, Log-log plot, More than two variables: Stacked plots, Parallel coordinate plot.

Module 5: Descriptive and Inferential Statistics
Probability distributions, Hypothesis testing, ANOVA, Regression.

Module 6: Machine Learning Concepts
Classification and Clustering, Bayes‟ classifier, Decision Tree, Apriori algorithm, K-Means Algorithm, Logistics regression, Support Vector Machines, Introduction to recommendation system.

Suggested Text books:

(i) Anil Maheshwari, “Data Analytics made accessible,” Amazon Digital Publication, 2014.
(ii) James R. Evans, “Business Analytics: Methods, Models, and Decisions”, Pearson 2012.
(iii) Song, Peter X. K, “Correlated Data Analysis: Modeling, Analytics, and Applications”, Springer-Verlag New York 2007.

Suggested Reference Books:

(i) Glenn J. Myatt, Wayne P. Johnson, “Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining”, Wiley 2009.
(ii) Thomas H. Davenport, Jeanne G. Harris and Robert Morison, “Analytics at Work: Smarter Decisions, Better Results”, Harvard Business Press, 2010.
(iii) Rachel Schutt, Cathy O’Neil, “Doing Data Science”, O’REILLY, 2006. Shamanth Kumar Fred Morstatter Huan Liu “Twitter Data Analytics”, Springer-Verlag, 2014.

Course Outcomes:

At the end of the course the students will be able to:

- Examine and compare various datasets and features.
- Analyze the business issues that analytics can address and resolve.
- Apply the basic concepts and algorithms of data analytics.
- Interpret, implement, analyze and validate data using popular data analytics tools.

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PEC RAI-603	Elective Course-I Intelligent Manufacturing (Tract: Mechatronics)	2L:0T:0P	2 credits

Detailed Course Content:

Module 1:
Computer Integrated Manufacturing Systems Structure and functional areas of CIM system, - CAD, CAPP, CAM, CAQC, ASRS. Advantages of CIM. Manufacturing Communication Systems - MAP/TOP, OSI Model, Data Redundancy, Top- down and Bottom-up Approach, Volume of Information. Intelligent Manufacturing System Components, System Architecture and Data Flow, System Operation.

Module 2:
Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition. Automated Process Planning - Variant Approach, Generative Approach, Expert Systems for Process Planning, Feature Recognition, Phases of Process planning. Knowledge Based System for Equipment Selection (KBSES) - Manufacturing system design. Equipment Selection Problem, Modeling the Manufacturing Equipment Selection Problem, Problem Solving approach in KBSES, Structure of the KRSES.

Module 3:
Group Technology: Models and Algorithms Visual Method, Coding Method, Cluster Analysis Method, Matrix Formation - Similarity Coefficient Method, Sorting-based Algorithms, Bond Energy Algorithm, Cost Based method, Cluster Identification Method, Extended CI Method. Knowledge Based Group Technology - Group Technology in Automated Manufacturing System. Structure of Knowledge based system for group technology (KBSC IT) — Data Base, Knowledge Base, Clustering Algorithm.

Suggested Text Books:

(i) Andrew Kusiak, “Intelligent Manufacturing Systems”, Prentice Hall, 1990.
(ii) Pat Langley, “Computational Intelligence and Intelligent Systems”, 2006.

Suggested Reference Books:

(i) Mohammad Jamshidi, “Design and Implementation of Intelligent Manufacturing Systems: From Expert Systems, Neural Networks to Fuzzy Logic”, 1st Edition, 1995.
(ii) Lucia Knapčíková, Michal Balog, “Industry 4.0: Trends in Management of Intelligent Manufacturing Systems”, Springer, 2019.

Course Outcomes:

After completion of the course, the students will be able to:

- Summarize the concepts of computer integrated manufacturing systems and manufacturing communication systems.
- Identify various components of knowledge based systems.
- Demonstrate the concepts of artificial intelligence and automated process planning.
- Select the manufacturing equipment using knowledge based system for equipment selection.
- Apply various methods to solve group technology problems and demonstrate the structure for knowledge based system for group technology.

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PEC RAI-604	Elective Course-I Microcontrollers Architecture and Programming (Tract: Control Systems)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Introduction to Microprocessors:
Registers - File registers - Memory Organization - Tristate logic – Buses - Memory Address register – Read/Write operations. ROM, RAM, PROM, EPROM, E2PROM. Introduction to elementary processor – Organization - Data Transfer Unit (DTU)operation - Enhanced Data Transfer Unit (EDTU) – opcode - machine language - assembly language - pipeline and system clock. Architecture of 8085 – Addressing modes - Data transfer, data processing and program flow control instructions - Simple assembly language programs.

Module 2: Introduction to Microcontrollers:
PIC16F877 Architecture - Program and Data memory organization - Special Function Registers - Addressing modes, Instruction set. MPLAB Integrated Development Environment – Introduction to Assembly language and Embedded C programming – Stack – Subroutines - Interrupt structure – Peripherals – Input/ Output Ports.

Module 3: PIC Peripherals:
Timers/Counters - Watchdog Timer – Capture/Compare/PWM (CCP) - Analog to Digital Converter(ADC) – EEPROM - Serial Communication – USART - Development of Application Programs and interfacing - LED, LCD, Keyboard, DC and Stepper motor interface. Introduction to 8051 Microcontroller: Architecture – Ports - Timers.

Suggested Text Books:

(i) Rajkamal, “Microcontrollers - Architecture, Programming, Interfacing and System Design”, Pearson India, January 2011.
(ii) Valdes Perez, “The 8051 and MSP430 Microcontrollers: Architecture, Program”, T and F India, Jan 2013.

Suggested Reference Books:

(i) Kenneth J Ayala The 8051 Microcontroller Architecture, Programming and Architecture, 1996.
(ii) Raj Kamal, Embedded systems Architecture, Programming and design, Tata McGraw hill Education, 2008.

Course Outcomes:

After completion of the course, the students will be able to:

- Understand the basic principles of Microcontroller based design and development.
- Design real world applications using Microcontroller.
- Understand interfacing technologies and its applications.
- Identify problem and strategy for designing the solution using appropriate microcontrollers.

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LC RAI-601	Robotic Simulation Laboratory	0L:0T:2P	1 credit

Laboratory Experiments:

1. Dynamic model development and simulation of simple mechanical systems using Matlab and Mathematica.
2. Numerical simulation of simple mechanical systems.
3. Stability analysis of simple mechanical systems using linear system theory namely root locus and Bode plot.
4. State space model development and dynamic simulation using Simulink.

Suggested Text Books:

(i) Daniel L. Ryan, "Robotic Simulation", CRC Press, 1993.
(ii) Agam Kumar Tyagi, "Matlab And Simulink For Engineers, Oxford Press, 2011.

Suggested Reference Books:

(i) Emilson Pereira Leite, "MATLAB - Modelling, Programming and Simulations", Sciyo, 2010.
(ii) Jinkun Liu, "Intelligent Control Design and MATLAB Simulation", Springer, 2018.

Course Outcomes:

After completion of the course, the students will be able to:

- Do Simulation in Matlab.
- Apply simulation theory concepts practically.
- Perform simulation of each task given to them.

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LC RAI-602	Embedded Systems Laboratory	0L:0T:2P	1 credit

Laboratory Experiments:

1. Study of ARM evaluation system.
2. Interfacing ADC and DAC.
3. Interfacing LED and PWM.
4. Interfacing real time clock and serial port.
5. Interfacing keyboard and LCD.
6. Interfacing EPROM and interrupt.
7. Mailbox.
8. Interrupt performance characteristics of ARM and FPGA.
9. Flashing of LEDS.
10. Interfacing stepper motor and temperature sensor.
11. Implementing ZigBee protocol with ARM.

Suggested Text Books:

(i) Sloss Andrew N, Symes Dominic, Wright Chris, "ARM System Developer's Guide: Designing and Optimizing", Morgan Kaufman Publication, 2004.
(ii) Michael Beck, "Linux Kernel Programming", Addison-Wesley Professional,3rd edition 2002.

Suggested Reference Books:

(i) Raj Kamal, "Embedded Systems – Architecture: Programming and Design", Tata McGraw-Hill Education, 3rd edition,2003.
(ii) Embedded Systems: Real-Time Interfacing to ARM Cortex-M Microcontrollers, 2014, Jonathan W Valvano Create space publications ISBN: 978-1463590154.
(iii) Embedded Systems: Introduction to ARM Cortex - M Microcontrollers, 5th edition Jonathan W Valvano, Create space publications ISBN-13: 978-1477508992.

Course Outcomes:

- Write programs in ARM for a specific Application.
- Interface memory and Write programs related to memory operations.
- Interface A/D and D/A convertors with ARM system.
- Analyze the performance of interrupt.
- Write programmes for interfacing keyboard, display, motor and sensor.
- Formulate a mini project using embedded system.

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PROJ RAI-601	Mini Project	0L:0T:4P	2 credits

Detailed Content:

- The mini-project is a team activity having 3-4 students in a team. Mini projects should include mainly Mechanical Engineering contains but can be multi-disciplinary too.
- The mini project may be a complete hardware or a combination of hardware and software. The software part in mini project should be less than 50% of the total work.
- Mini Project should cater to a small system required in laboratory or real life.
- It should encompass components, devices etc. with which functional familiarity is introduced.
- After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of the mini-project.
- Students are expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within the first week of the semester.
- The student is expected to exert on design, development and testing of the proposed work as per the schedule.
- Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

- Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
- Design, implement and test the prototype/algorithm in order to solve the conceived problem.
- Write a comprehensive report on mini project work.

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HSMC-601	Entrepreneurship	1L:0T:0P	1 credit

Course Education Objectives (CEO)

- To introduce and understand Entrepreneurship and its types.
- To understand how to evaluate risk in entrepreneurial ventures.
- To understand different type of finances available and financing methods.
- To understand marketing, digital marketing and their analytics.
- To understand detailed information about the principles, practices and tools involved in all aspects of the sales processes.
- To understand basics of operations management.
- To understand the nuances of Start-up.
- To understand how to use proven tools for transforming an idea into a product / service that creates value for others.

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

- Students would understand different types of Entrepreneurial ventures and would be able to discover, develop, and assess opportunities.
- Students would learn about opportunity and risk analysis.
- Students would understand the strategies for valuing your own company, and how venture capitalist and angel investors use valuations in negotiating milestones, influence and control.
- Students would understand to pick correct marketing mix and how to position the company in the market by using analytical tools.
- Students would learn how to sale themselves and the product/service and to handle objections.
- Students would get to know how organizations operates and their process matrices.
- Students will learn how start new ventures.
- Students will learn how to write winning business plans.

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SEMESTER – VII

SEMESTER VII

PCC RAI-701	Smart Manufacturing	2L:0T:0P	2 credits

Pre-Requisites	Manufacturing Processes, Engineering Design, Basic Knowledge of Computers

Detailed Course Content:

Module 1: Introduction:
Types of manufacturing systems and their characteristics, Computer aided Manufacturing (NC, CNC, DNC and adaptive control systems), Computer Network architectures and protocols, Industry 4.0 – Concept and elements.

Module 2: Computer Aided Engineering:
Design processes and computer aided design, Introduction to SolidWorks CAD Software, Finite Element Modeling & Analysis, Computer Aided Process Planning.

Module 3: Group Technology and Cellular Manufacturing:
Parts classification and part coding – approaches and systems, Benefits of group technology, Cellular manufacturing-basics, layout considerations, Cell formation approaches and evaluation of cell designs, Planning and control in cellular manufacturing.

Module 4: Flexible Manufacturing Systems:
FMS and its Components, Layout considerations in FMS, Material Handling in FMS.

Module 5: Reverse Engineering & Rapid Prototyping:
Reverse Engineering – Principles and Technology, Rapid Prototyping – Principles and Classification, Steps in Additive Manufacturing, Benefits and Applications.

Module 6: Cloud Based Design & Manufacturing:
Internet of Things, Data Storage and Analytics, Cloud computing, Cyber-Physical Systems.

Suggested Text Books:

(i) Groover M. P. and Zimmers E. W., "CAD/CAM: Computer Aided Design and Manufacturing", Pearson Education, New Delhi, 2003.

(ii) Groover M. P., "Automation, Production Systems and Computer Aided Manufacturing", Pearson Education, New Delhi, 2015.

Suggested Reference Books:

(i) Kalpakjian and Schmid, "Manufacturing Engineering and Technology", Pearson Education, 2020.
(ii) Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress, 2016.

Course Outcomes:

After the completion of this course, the students will be able to:

- Carry out modeling and analysis of simple components.
- Understand the operation of machines used in smart manufacturing.
- Comprehend the various CAM technologies and their features.
- Understand the various stages of product development from design to manufacturing including the interconnections in smart manufacturing.

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PCC RAI-702	Internet of Robotic Things (RIoT)	2L:0T:0P	2 credits

Detailed Content:

Module 1: IoT Foundations:
Introduction to Internet of Things, An Overview Introduction – Definition and characteristics of IoT, Physical design of IoT- Things in IoT, IoT protocol, Logical design of IoT – IoT functional blocks, IoT Communication Models, Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud, Fog Computing, Examples of IoT based Systems: Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT.

Module 2: IoT Architecture and its Protocols:
Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications, Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi.

Module 3: Sensors for IoT:
Sensing and actuation, types of sensors, Occupancy Sensors, Motion sensor, velocity, temperature, pressure, chemical, Gyroscopic sensor, Optical sensors, Humidity, Water Quality sensors, Sensor applications.

Module 4: Actuator for IoT:
Actuator types, working principle of actuators, integration of sensors and actuators with arduino, formation of actuators, selection criteria for right actuator, maintenance of actuators, smart material actuators.

Module 5: Applications of IoT in Robotics:
Future farming with the Internet of things, drones for surveillance, Soft low-power robotics, Tracking sensors for underwater robotics, Disaster response, Medical services, Smart restaurant, Analysis of IoT applications and Sensors, Space robotics for science and space exploration, Satellite based Internetworking, Tele operators, Space component systems like rover mobility, locomotion and guidance.

Module 6: Future of RIOT:
Powering insect-scale wireless robotics, Big data analysis, Augmented Reality, Additive manufacturing, Cyber security, the industrial internet of things, the cloud, Horizontal and vertical system integration, simulation, Autonomous robot.

Suggested Text Books:

(i) Vijay Madisetti and Arshdeep Bahga, Internet of Things (A Hands-on Approach), 1st Edition, VPT, 2014.

(ii) Korf Richard, "Space Robotics", Carnegie-Mellon University, The Robotics Institute, 1982.

Suggested Reference Books:

(i) Lewin A.R.W. Edwards, "Open source robotics and process control cookbook", Elsevier Publications, 2005.
(ii) Francis DaCosta, Rethinking the Internet of Things: A Scalable Approach to Connecting Everything, 1st Edition, Apress Publications, 2013.
(iii) Wimer Hazenberg, Menno Huisman and Sara Cordoba Rubino, Meta Products: Building the Internet of Things, BIS publishers, 2012.
(iv) Pethuru Raj and Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2017.
(v) Arshdeep Bahga and Vijay Madisetti Internet of Things: A Hands-on Approach", Universities Press, 2014.

Course Outcomes:
At the end of the course, the students will be able to:

- Understand the drivers and enablers of Industry 4.0.
- Appreciate the smartness in Smart Factories, Smart cities, smart products and smart services.
- Able to outline the various systems used in a manufacturing plant and their role in an Industry 4.0 world.
- Appreciate the power of Cloud Computing in a networked economy.
- Understand the opportunities, challenges brought about by Industry 4.0 and how organizations and individuals should prepare to reap the benefits.

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PCC RAI-703	Data Modeling and Visualization	2L:0T:0P	2 credits

Detailed Course Content:

Module 1: Introduction Data Modeling:
Entity Relationship Model: Types of Attributes, Relationship, Structural Constraints – Relational Model, Relational model Constraints - Mapping ER model to a relational schema – Integrity constraint.

Module 2: Introduction to Data Visualization:
Overview of data visualization - Data Abstraction -Analysis: Four Levels for Validation- Task Abstraction - Analysis: Four Levels for Validation.

Module 3: Visualization Techniques:
Scalar and point techniques Color Maps Contouring Height Plots – Vector visualization techniques Vector Properties Vector Glyphs Vector Color Coding Stream Objects.

Module 4: Visual Analytics:
Visual Variables- Networks and Trees - Map Color and Other Channels- Manipulate View Arrange Tables Geo Spatial Data Reduce Items and Attributes.

Module 5: Types of Visual Analysis:
Time- Series data visualization -Text data visualization- Multivariate data visualization and case studies.

Module 6: Visualization Tools and Techniques:
Introduction to data visualization tools- Tableau - Visualization using R- Dashboard creation using visualization tools for the use cases: Finance-marketing-insurance- healthcare etc.

Suggested Text Books:

(i) Tamara Munzer, Visualization Analysis and Design, CRC Press 2014 Alexandru Telea, Data Visualization Principles and Practice CRC Press 2014.
(ii) Paul J. Deitel, Harvey Deitel, Java SE8 for Programmers (Deitel Developer Series) 3rd Edition, 2014.

Suggested Reference Books:

(i) Y. Daniel Liang, Introduction to Java programming-comprehensive version- Tenth Edition, Pearson Ltd. 2015.
(ii) Paul Deitel Harvey Deitel, Java, How to Program, Prentice Hall; 9th edition, 2011.
(iii) Cay Horstmann BIG JAVA, 4th edition, John Wiley Sons, 2009.
(iv) Nicholas S. Williams, Professional Java for Web Applications, Wrox Press, 2014.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

- Illustrate the design principles for data modeling, ER model and normalization and differentiate data types, visualization types to bring out the insight.
- Relate the visualization towards the problem based on the dataset.
- Identify and create various visualizations for geospatial and table data.
- Ability to visualize categorical, quantitative and text data. Illustrate the integration of visualization tools with hadoop.
- Ability to create and interpret plots using R/Python.

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PCC RAI-704	Image Processing & Computer Vision	2L:0T:2P	3 credits

Detailed Course Content:

Module 1: Image Formation and Representation:
Image acquisition, review of the digital camera, sampling and quantization, Image quality, Color Camera, Color Balance, Point Operators, Pixel transform, Color Transform, Histogram Equalization, Bandpass filters ,2D Convolution: Discrete & continuous, Segmentation: Edge detection, Linking, Thresholding, Region Based Segmentation.

Module 2: Shapes and Regions:
Binary shape analysis, connectedness, object labeling and counting, size filtering, distance functions, skeletons and thinning, deformable shape analysis, boundary tracking procedures, active contours, shape models and shape recognition – centroidal profiles, handling occlusion, boundary length measures, boundary descriptors, chain codes, Fourier descriptors region descriptors, moments.

Module 3: Hough Transform:
Line detection, Hough Transform (HT) for line detection, foot-of-normal method, line localization, line fitting, RANSAC for straight line detection, HT based circular object detection, accurate center location, speed problem, ellipse detection.

Module 4: Case study:
Human Iris location, hole detection, generalized Hough Transform (GHT), spatial matched filtering GHT for ellipse detection, object location, GHT for feature collation.

Module 5: 3D Vision and Motion:
Methods for 3D vision, projection schemes, shape from shading, photometric stereo, shape from texture, shape from focus, active range finding, surface representations, point-based representation, volumetric representations, 3D object recognition, 3D reconstruction, introduction to motion, triangulation, bundle adjustment, translational alignment, parametric motion, spline-based motion, optical flow, layered motion.

Module 6: Computer Vision Applications:
Face and Facial recognition application: personal photo collections – Instance recognition application: Object recognition, Object Tracking, Biometric Authentication, Emotion Recognition, Intelligent Surveillance.

Suggested Text Books:

(i) D. L. Baggio et al. “Mastering OpenCV with Practical Computer Vision Projects‖”, Packt Publishing, 2012.
(ii) E. R. Davies, “Computer & Machine Vision‖, Fourth Edition”, Academic Press, 2012.

(iii) Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012.

Suggested Text Books:

(i) Mark Nixon and Alberto S. Aquado, "Feature Extraction & Image Processing for Computer Vision", Third Edition, Academic Press, 2012.
(ii) R. Szeliski, "Computer Vision: Algorithms and Applications", Springer 2011.
(iii) Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference‖", Cambridge University Press, 2012.
(iv) Rafael C. Gonzalez & Richard E. Woods, "Digital Image Processing", Pearson Education 3rd Edition, 2009.
(v) Computer Vision "A Modern Approach, Forsyth, Ponce", Pearson Education, 2012.
(vi) David A. Forsyth and Jean Ponce, "Computer Vision: A Modern Approach", Prentice Hall, Pearson Education, 2nd Edition, 2012.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Understand theory and models in image processing.
- Interpret and analyze 2D signals in Spatial and frequency domain through image transforms.
- Apply quantitative models of image processing for segmentation and restoration for various applications.
- Find shape using various representation techniques and classify the object using different classification methods.

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OEC RAI-701	Elective Course-II Autonomous Robotics and Telecherics (Tract: Robotics)	2L:0T:0P	2 credits

Detailed Content:

Module 1:
Introduction to the fundamentals of mobile robotics, basic principles of locomotion, Kinematics and Mobility, Classification of mobile robots, AI for Robot Navigation.
Introduction to modern mobile robots: Swarm robots, cooperative and collaborative robots, mobile manipulators, Current challenges in mobile robotics.

Module 2:
Autonomous Mobile Robots – need and applications, sensing, localisation, mapping, navigation and control. The Basics of Autonomy (Motion, Vision and PID), Programming Complex Behaviors (reactive, deliberative, FSM), Robot Navigation (path planning), Robot Navigation (localization), Robot Navigation (mapping), Embedded electronics, kinematics, sensing, perception, and cognition.

Module 3:
Telecheric robots – Concepts of teleoperations, Need and applications of Telecheric robots, Humanoid Robots, Swarm Robotics, Robot Applications and Ethics.

Suggested Text Books:

(i) Nicolas Korell, "Introduction to Autonomous Robots", MIT Press, 2016.
(ii) Roland Siegwart, Illah Reza Nourbakhsh, Davide Sacramuzza, Introduction to Autonomous Mobile Robots, MIT press, 2nd edition, 2011.

Suggested Reference Books:

(i) Designing Autonomous Mobile Robots, John M Holland, Elsevier, 2004.
(ii) Autonomous Mobile Robots,Edited by Shuzi Sam Ge, Frank L Lewis, Tylor and Francis, 2006
(iii) Peter Corke, Robotics Vision and Control, Springer 2011.

Course Outcomes:
At the end of this course, the students will be able to:

- Learn principles of working of autonomous robots.
- Demonstrating the sensing, perception, and cognition of autonomous robots.
- Understand the anatomy of autonomous robots.

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OEC RAI-702	Elective Course-II Deep Learning (Tract: AI)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Introduction:
Biological Neuron, Idea of computational units, McCulloch–Pitts unit and Thresholding logic, Linear Perceptron, Perceptron Learning Algorithm, Linear Separability. Convergence theorem for Perceptron Learning Algorithm.

Module 2: Neural Network:
Introduction to neural network and multilayer perceptrons (MLPs), representation power of MLPs, sigmoid neurons, gradient descent, feedforward neural networks representation, Backpropagation.

Module 3: Gradient Descent:
Gradient Descent, Batch Optimization, Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization).

Module 4: Autoencoders:
Autoencoders, Regularization in autoencoders, De noising autoencoders, Sparse autoencoders, Contractive autoencoders, Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Dropout, Greedy Layer Wise Pre-training, Better activation functions, Better weight initialization methods, Batch Normalization.

Module 5: Convolutional Neural Network:
Introduction to CNN, Building Blocks of CNN, Transfer Learning, LeNet, AlexNet, ZF-Net, VGGNet, GoogLeNet, ResNet, Visualizing CNNs, Guided Backpropagation, Fooling Convolutional Neural Network.

Module 6: Recurrent Neural Network:
Introduction to RCNN, Backpropagation through time (BPTT), Vanishing and Exploding Gradients, Truncated BPTT, Long Short Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs, Encoder Decoder Models, Attention Mechanism.

Suggested Text Books:

(i) Yoshua Benjio, Aaron Courville, “Deep Learning- Ian Goodfellow”, The MIT Press, 2016.
(ii) A.C. Faul, “A Concise Introduction to Machine Learning”, CRC Press, 2019.

Suggested Reference Books:

(i) Neural Networks: A Systematic Introduction, Raúl Rojas, 1996.
(ii) Pattern Recognition and Machine Learning, Christopher Bishop, 2007.

Course Outcomes:

At the end of this course, the students will be able to:

1. Understand the fundamentals of neural networks.
2. Design feed forward networks with backpropagation.
3. Analyze neural networks for performance.
4. Apply attention mechanism to the neural network.

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OEC RAI-703	Elective Course-II Mechatronics System Design (Tract: Mechatronics)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Mechanical Systems and Design:
Mechatronics approach - Control program control, adaptive control and distributed systems - Design process - Types of Design - Integrated product design - Mechanisms, load conditions, design and flexibility Structures, load conditions, flexibility and environmental isolation – Man machine interface, industrial design and ergonomics, information transfer from machine from machine to man and man to machine, safety.

Module 2: Real Time Interfacing:
Introduction Elements of data acquisition and control Overview of I/O Process-Installation of I/O card & software - Installation of application software, Over framing.

Module 3: Microcontrollers:
Introduction to use of open source hardware (Arduino & Raspberry Pi); shields/modules for GPS, GPRS/GSM, Bluetooth, RFID, and Xbee, integration with wireless networks, databases and web pages; web and mobile phone apps.

Module 4: Case studies on Data Acquisition:
Transducer calibration system for Automotive Applications Strain Gauge weighing system - Solenoid force - Displacement calibration system - Rotary optical encoder - Inverted pendulum control - Controlling temperature of a hot/cold reservoir -Pick and place robot - Carpark barriers.

Module 5: Case studies on Data Acquisition and Control:
Thermal cycle fatigue of a ceramic plate - pH control system - De-Icing Temperature Control System - Skip control of a CD Player - Autofocus Camera, exposure control.

Module 6: Case studies on design of Mechatronics products:
Motion control using D.C. Motor, A.C. Motor & Solenoids - Car engine management - Barcode reader.

Suggested Text Books:

(i) Brian Morris, “Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics”, McGraw Hill International Edition, 1995.

(ii) Gopal, “Sensors- A Comprehensive Survey Vol I & Vol VIII”, BCH Publisher, 2008.

Suggested Reference Books:

(i) W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering, 2nd Edition, Addison Wesley Longman Ltd., 1999.

(ii) Bradley, D. Dawson, N.C. Burd and A.J. Loader, "Mechatronics: Electronics in Products and Processes", Chapman and Hall, London, 1991.

(iii) Devdas Shetty, Richard A. Kolk, "Mechatronics System Design", PWS Publishing Company, 1997.

Course Outcomes:

At the end of this course, the students will be able to:

- Demonstrate how mechatronics integrates knowledge from different disciplines in order to realize engineering and consumer products that are useful in everyday life.
- Apply theoretical knowledge: understanding selection of suitable sensors and actuators; designing electro-mechanical systems.
- Work with mechanical systems that include digital and analogue electronics as a data acquisition model.

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OEC RAI-704	Elective Course-II Control of Robotic Systems (Tract: Control Systems)	2L:0T:0P	2 credits

Detailed Content:

Module 1:
Basics of robotic system's kinematics and dynamics: Forward and inverse dynamics. Properties of the dynamic model and case studies. Introduction to nonlinear systems and control schemes. Symbolic Modeling of Robots for Direct Kinematic Model and inverse kinematics.

Module 2:
System Stability and Types of Stability Lyapunov stability analysis, both direct and indirect methods. Lemmas and theorems related to stability analysis, Joint Space and Task Space Control Schemes Position control, velocity control, trajectory control and force control. Description of Force Control tasks, Force Control Strategies, Hybrid Position / Force Control, Impedance Force / Torque Control.

Module 3:
Nonlinear Control Schemes Proportional and derivative control with gravity compensation, computed torque control, sliding mode control, adaptive control, observer based control and robust control, Optimal Control: Introduction - Time varying optimal control – LQR steady state optimal control – Solution of Ricatti's equation – Application examples.
Nonlinear Observer Schemes: Design based on acceleration, velocity and position feedback. Numerical simulations using software packages.

Suggested Text Books:

(i) R K Mittal, I J Nagrath, Robotics and Control, TMH Publishing Co. Ltd., 2003.

(ii) R Kelly, D. Santibanez, LP Victor and Julio Antonio, "Control of Robot Manipulators in Joint Space", Springer, 2005.

(iii) A Sabanovic and K Ohnishi, "Motion Control Systems", John Wiley & Sons (Asia), 2011.

Suggested Reference Books:

(i) R M Murray, Z. Li and SS Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 1994.

(ii) J J Craig, "Introduction to Robotics: Mechanics and Control", Prentice Hall, 2004. 3. J J E Slotine and W Li, "Applied Nonlinear Control", Prentice Hall, 1991.

(iii) Sebastian Thrun, Wolfram Burgard, Dieter Fox, "Probabilistic Robotics", MIT.

(iv) Carlos, Bruno, Georges Bastin, "Theory of Robot Control", Springer, 2012.

Course Outcomes:

At the end of this course, the students will be able to:

- Demonstrate non-linear system behavior by phase plane and describing function methods.
- Perform the stability analysis nonlinear systems by Lyapunov method.
- Derive discrete-time mathematical models in both time domain (difference equations, state equations) and z domain (transfer function using z-transform).
- Predict and analyze transient and steady-state responses and stability and sensitivity of both open-loop and closed-loop linear, time-invariant, discrete-time control systems.
- Acquire knowledge of state space and state feedback in modern control systems, pole placement, design of state observers and output feedback controllers.

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LC RAI-701	Smart Manufacturing Laboratory	0L:0T:2P	1 credit

Detailed Content:

- Solid Design in Autodesk Fusion.
- Advanced Solid Design in Autodesk Fusion.
- Freeform Design in Autodesk Fusion (Advance Freeform Design in Autodesk Fusion (Advanced Modeling).
- Machining Simulation in Autodesk Fusion (3 axis Milling).
- Machining Simulation in Autodesk Fusion (4+ axis Milling).
- Machining Simulation in Autodesk Fusion (Turning).
- Machining Simulation in Autodesk Fusion (Mill-Turning).

Suggested Text Books:

(i) Groover M. P. and Zimmers E. W., "CAD/CAM: Computer Aided Design and Manufacturing", Pearson Education, New Delhi, 2003.

(ii) Groover M. P., "Automation, Production Systems and Computer Aided Manufacturing", Pearson Education, New Delhi, 2015.

Suggested Reference Books:

(i) Kalpakjian and Schmid, "Manufacturing Engineering and Technology", Pearson Education, 2020.

(ii) Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress, 2016.

Course Outcomes:

At the end of this course, the students will be able to:

- Explain Autodesk Fusion software and its different tools.
- Perform simulation in the software.
- Describe different machining processes through simulation.
- Use Autodesk fusion software for multiple uses.

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LC RAI-702	Robotics and AI case studies with RIoT	0L:0T:2P	1 Credit

Detailed Content:

Case study of:

- Collaborative Robot Systems
- Industry 4.0
- Autonomous vehicles
- Tesla Car

Suggested Text Books:

(i) Vijay Madisetti and Arshdeep Bahga, Internet of Things (A Hands-on Approach), 1st Edition, VPT, 2014.
(ii) Korf Richard, "Space Robotics", Carnegie-Mellon University, The Robotics Institute, 1982.

Suggested Reference Books:

(i) Lewin A.R.W. Edwards, "Open source robotics and process control cookbook", Elsevier Publications, 2005.
(i) Francis DaCosta, Rethinking the Internet of Things: A Scalable Approach to Connecting Everything, 1st Edition, Apress Publications, 2013.
(ii) Wimer Hazenberg, Menno Huisman and Sara Cordoba Rubino, Meta Products: Building the Internet of Things, BIS publishers, 2012.
(iii) Pethuru Raj and Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2017.
(iv) Arshdeep Bahga and Vijay Madisetti Internet of Things: A Hands-on Approach", Universities Press, 2014.

Course Outcomes:

At the end of this course, the students will be able to:

- Understand the concept of IoT.
- Implement theoretical concepts in real life applications.
- Differentiate IoT and RIoT.

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LC RAI-703	Data Modeling and Visualization Laboratory	0L:0T:2P	1 credit

Detailed Content:

- Find and describe 3 datasets that you'd like to potentially visualize for your project. Load and parse those 3 datasets using D3.js.
- Re-create one of the small graphics from Figure 5.1 (page 94) using D3.js.
- Create a visualization of the dataset you chose for your project using D3.js, including axes and legends.
- Add one of the interaction techniques discussed to your project using D3.js.
- Combine your 2 visualizations from week 4 with some form of linked interaction.
- Create a histogram or aggregated bar chart of your project dataset.
- Machining Simulation in Autodesk Fusion (Mill-Turning).

Suggested Text Books:

(i) Tamara Munzer, Visualization Analysis and Design -, CRC Press 2014 Alexandru Telea, Data Visualization Principles and Practice CRC Press 2014.

(ii) Paul J. Deitel, Harvey Deitel, Java SE8 for Programmers (Deitel Developer Series) 3rd Edition, 2014.

Suggested Reference Books:

(i) Y. Daniel Liang, Introduction to Java programming-comprehensive version- Tenth Edition, Pearson Ltd. 2015.

(ii) Paul Deitel Harvey Deitel, Java, How to Program, Prentice Hall; 9th edition, 2011.

(iii) Cay Horstmann BIG JAVA, 4th edition, John Wiley Sons, 2009.

(iv) Nicholas S. Williams, Professional Java for Web Applications, Wrox Press, 2014.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

- Illustrate the design principles for data modeling, ER model and normalization and differentiate data types, visualization types to bring out the insight.
- Relate the visualization towards the problem based on the dataset.
- Identify and create various visualizations for geospatial and table data.
- Ability to visualize categorical, quantitative and text data. Illustrate the integration of visualization tools with hadoop.
- Ability to create and interpret plots using R/Python.

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PROJ RAI-701	Project Stage – I	0L:0T:4P	2 credits

Detailed Content:

To familiarize the students about the standards and practices used in industry/ research organization/ in-house research. The study leads towards finalization of the problem statement for project work, which is helpful to establish a link between industry and academia for low cost solution, identification of current needs of the society as well as industrial research.

Course Outcomes:

At the end of this course, the students will demonstrate the ability to:

1. Ability to work effectively in a various team (may be multidisciplinary teams).
2. Identify, formulate and solve a problem of Robotics and Artificial Intelligence.
3. Understand the impact of Robotics and Artificial Intelligence solutions in a global, economic, environmental and societal context.

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MLC RAI-701	Intellectual Property Rights (Audit Course)	1L:0T:0P	0 credit

Detailed Content:

- Introduction to the concepts Property and Intellectual Property, Nature and Importance of Intellectual Property Rights, Objectives and Importance of understanding Intellectual Property Rights.
- Understanding the types of Intellectual Property Rights: -Patents-Indian Patent Office and its Administration, Administration of Patent System – Patenting under Indian Patent Act, Patent Rights and its Scope, Licensing and transfer of technology, Patent information and database. Provisional and Non Provisional Patent Application and Specification, Plant Patenting, Idea Patenting.
- Integrated Circuits, Industrial Designs, Trademarks (Registered and unregistered trademarks), Copyrights, Traditional Knowledge, Geographical Indications, Trade Secrets, Case Studies
- New Developments in IPR, Process of Patenting and Development: technological research, innovation, patenting, development.
- International Scenario: WIPO, TRIPs, Patenting under PCT.

Suggested Text Books:

(i) Aswani Kumar Bansal, “Law of Trademarks in India”, JBA, 2014.

(ii) B. L. Wadehra, “Law relating to Patent, Trademarks, Copyrights, Designs and Geographical Indications”, Universal Law Publishing Co Ltd, 2014.

Suggested Reference Books:

(i) GVG Krishnamurthy, “The law of trademarks, Copyright, Patents and designs”, 2012.

(ii) Satyawrat Ponkse, “The management of Intellectual Property”, Bhate & Ponkshe, 1991.

(iii) S K Roy Chaudhary and H K Saharay, “The law of Trademarks, Copyrights” ,World Intellectual Property Organization, 2018.

(iv) Manual of Patent Office Practice and Procedure, LexisNexis, 2014.

(v) WIPO:WIPO guide to Patent Information, World Intellectual Property Organization, 2014.

(vi) Mayali, “Industrial Designs”, McGraw Hill, 2013.

(vii) Niebel, “Product Design by Niebel”, McGraw Hill, 1974.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Understand research problem formulation and approaches of investigation of solutions for research problems.
- Learn ethical practices to be followed in research.
- Apply research methodology in case studies.
- Acquire skills required for presentation of research outcomes (report and technical paper writing, presentation etc.).
- Discover how IPR is regarded as a source of national wealth and mark of an economic leadership in context of global market scenario.
- Study the national and international IP system.

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LLC RAI-701	**Liberal Learning Course (Audit Course)**	**1L:0T:0P**	**0 credit**

Detailed Content:

Identification of topic and resources, scope, and synthesize viewpoints for the areas such as performing arts, basic Sciences, business, philosophy, sports and athletics, defense studies and education.

Course Outcomes:

At the end of the course, the students will demonstrate the ability to:

- Exhibit self-learning capabilities and its use in effective communication.
- Inculcate impact of various areas to relate with society at large.

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SEMESTER – VIII

SEMESTER VIII

PCC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping)	2L:0T:0P	2 credits

Pre-Requisites	Robot Kinematics, Robot Dynamics, Computer Programming

Detailed Course Content:

Module 1: Introduction:

Industrial Applications of Robots, Industrial Environments and Constraints, Free Open Source Software for Robot Simulation, Robotic Operating System (ROS), Gazebo, MoveIt, Ubuntu, Python, Installing and Configuring Simulation Softwares.

Module 2: Robotic Operating System:

Robotic Operating System (ROS) Fundamentals, Building a ROS Application, ROS Services, ROS Actions, Unified Robot Description Format (URDF).

Module 3: Robot Navigation:

Slam: Simultaneous Localization and Mapping (SLAM) implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts, Introduction to the Mapping and SLAM concepts and algorithms. Occupancy Grid Mapping, Mapping an environment with the Occupancy Grid Mapping algorithm, Grid-based FastSLAM: Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based FastSLAM algorithm, Self-Localisation, Path Planning and Obstacle Avoidance, Map-Building and Map Interpretation, Simultaneous Localization and Mapping, Navigation using Software Tools.

Module 4: Manipulation:

Object Manipulation, Manipulation Planning Algorithms, Prehension, Manipulation using Software Tools.

Module 5: Robot Vision:

Object Detection, Pose Estimation, Logical Camera, ROS Tools for Vision.

Suggested Text Books:

(i) Morgan Quigley, “Programming Robots with ROS: A Practical Introduction to the Robot Operating System” , O'Reilly Media, 2015.

(ii) Carol Fairchild, Dr. Thomas L. Harman, “ROS Robotics by Example”, Packt, 2016.

Suggested Reference Books:

(i) Anis Koubaa, "Robot Operating System", Springer link, 2016.
(ii) Anil Mahtani, "Effective Robotics Programming with ROS", Packt Publishing, 2016.
(iii) Ramkumar Gandhinathan , Lentin Joseph , " ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality", Packt Publishing Limited, December 2019.
(iv) SLAM for dummies: https://dspace.mit.edu/bitstream/handle/1721.1/119149/16-412j-spring-2005/contents/projects/1aslam_blas_repo.pdf
(v) ROS Robot Programming; YoonSeok Pyo I HanCheol Cho I RyuWoon Jung I TaeHoon Lim; https://community.robotsource.org/t/download-the-ros-robot-programming-book-for-free/51

Course Outcomes:

After the completion of this course, the students will be able to:

- Understand the features and uses of Robotic Operating System (ROS) and allied software tools.
- Generate a robot manipulator and its working environment using simulation tools.
- Implement robot navigation and object manipulation for a given application.
- Incorporate and use robot vision for real-world applications.

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PEC RAI-801	Elective Course-III Advanced Robotics Programming (Tract: Robotics)	2L:0T:0P	2 credits

Detailed Course Content:

Module 1: Introduction to ROS2:
Architectural overview of the Robot Operating System, Framework and setup with ROS2 environment, ROS2 workspace structure, essential command line utilities. ROS2 nodes, topics, services, parameters, actions and launch files. Programming nodes, topics, services, actions with C/C++/Python. Real time programming with ROS2.

Module 2: Robot Simulation Engines:
Physics simulations of Robots with Gazebo, Mujoco and Pybullet C++/Python APIs. Intro to Path Planning and Navigation, Classic Path Planning, Number of classic path planning approaches that can be applied to low-dimensional robotic systems. Coding the BFS and algorithms in C++. Sample-Based and Probabilistic Path Planning and improvement using the classic approach. Programming in Moveit framework.

Module 3: Motion Planning, Mapping and SLAM:
Use of the EKF ROS package to a robot to estimate its pose. Monte Carlo Localization: The Monte Carlo Localization algorithm which uses particle filters to estimate a robot's pose. Build MCL in C++: Coding the Monte Carlo Localization algorithm in C++. Simultaneous Localization and Mapping (SLAM) implementation with ROS2 packages and C++. Combining mapping algorithms with the localization concepts. Introduction to the Mapping and SLAM concepts and algorithms. Occupancy Grid Mapping: Mapping an environment with the Occupancy Grid Mapping algorithm. Grid-based FastSLAM: Simultaneous mapping an environment and localize a robot relative to the map with the Grid-based FastSLAM algorithm.
Concepts of microros, Client library, features of microros, real time operating systems (RTOS- Free RTOS, Zephyr), implementation of microros on ARM/ESP32 based microcontrollers.

Suggested Text Books:

(i) Aaron Martinez, Enrique Fernandez, “Learning ROS for Robotic Programming”, PACKT publishing, 2013.
(ii) Morgan Quigley, Brian Gerkey, William D Smart, “Programming Robots with ROS”, SPD Shroff Publishers and distributors Pvt. Ltd., 2016.
(iii) Lentin Joseph, “Mastering ROS for Robotics Programming: Design, Build and simulate complex robots using ROS”, PACKT publishing, 2013.

Suggested Reference Books:

(i) Anis Koubaa, “Robot Operating System”, Springer link, 2016.
(ii) Anil Mahtani, “Effective Robotics Programming with ROS”, Packt Publishing, 2016.

(iii) Ramkumar Gandhinathan, Lentin Joseph , " ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality", Packt Publishing Limited, December 2019.

Course Outcomes:

After the completion of this course, the students will be able to:

- Understand the basic principles of Robotics programming and development.
- Design real world applications using available software.
- Understand integration technologies and its applications.
- Identify problems in integrating the system / simulations / programming.

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PEC RAI-802	Elective Course-III Advanced Artificial Intelligence (Tract: AI)	2L:0T:0P	2 credits

Detailed Course Content:

Module 1:
Overview of Probability Theory, Bayes Networks, Independence, I-Maps, Undirected Graphical Models, Bayes Networks and Markov Networks, Local Models, Template Based Representations, Exact Inference: Variable Elimination; Clique Trees, Belief Propagation Tree Construction.

Module 2:
Intro to Optimization, Approximate Inference: Sampling, Markov Chains, MAP Inference, Inference in Temporal Models, Learning Graphical Models: Intro Parameter Estimation, Bayesian Networks and Shared Parameters.

Module 3:
Structure Learning, Structure Search Partially Observed Data, Gradient Descent, EM, Hidden Variables, Undirected Models, Undirected Structure Learning, Causality, Utility Functions, Decision Problems, Expected Utility, Value of Information, Decision- Making: basics of utility theory, decision theory, sequential decision problems, elementary game theory, sample application.

Suggested Text Books:

(i) Russell, Stuart and Norvig, Peter, Artificial Intelligence: A Modern Approach" Prentice Hall, 2003.
(ii) Zhongzhi Shi, “Advanced Artificial Intelligence”, World Scientific Publishing Company, March 2011.
(iii) Luger " Artificial Intelligence", Edition 5, Pearson, 2008.

Suggested Reference Books:

(i) Daphne Koller and Nir friedman, “Probabilistic Graphical Models”, MIT Press, 2009.
(ii) Russell and P. Norvig, “Artificial Intelligence”, Pearson Publication, 2020.
(iii) Cristopher Bishop: pattern Recognition and machine Learning, Springer, 2006.

Course Outcomes:
After the completion of this course, the students will be able to:

- Explain in detail how the techniques in the perceive-inference-action loop work.
- Choose, compare, and apply suitable basic learning algorithms to simple applications.
- Ability to explain how deep neural networks are constructed and trained, and apply deep neural networks to work with large scale datasets.
- Understand and develop deep reinforcement learning algorithms for suitable applications.

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PEC RAI-803	Elective Course-III Micro Electro Mechanical Systems (Tract: Mechatronics)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Introduction:
Overview of MEMS & Microsystems: Evolution of Micro sensors, MEMS & microfabrication typical MEMS and Microsystems and miniaturization – applications of Microsystems. Materials demand for Extreme conditions of operation, material property mapping, Processing, strengthening methods, treatment and properties.

Module 2: MEMS materials:
Overview of Smart Materials, Structures and Products Technologies Smart Materials (Physical Properties) Piezoelectric Materials, Electrostrictive Materials, Magnetostrictive Materials, Magneto electric Materials, Magneto rheological Fluids Electro Rheological Fluids, Shape Memory Materials, Bio-Materials, metal matrix composites (MMC), their applications in aerospace and automobiles, Superplastic materials.

Module 3: Micro manufacturing/Micro fabrication:
Preparation of the substrate, Physical Vapor Deposition, Chemical Vapor Deposition, Ion Implantation, Coatings for high temperature performance, Electrochemical and spark discharge and Plasma coating methods, electron beam and laser surface processing, Organic and Powder coatings, Thermal barrier coating, LIGA process.

Module 4: Micro sensors:
Smart Sensor, Actuator and Transducer Technologies, Smart Sensors: Accelerometers; Force Sensors; Load Cells; Torque Sensors; Pressure Sensors; Microphones; Sensor Arrays Micro actuators.

Module 5: Smart Actuators:
Displacement Actuators; Force Actuators; Power Actuators; Vibration Dampers; Shakers; micro Fluidic Pumps; micro Motors Smart Transducers: Ultrasonic Transducers; Sonic Transducers.

Suggested Text Books:

(i) Tai Ran Hsu, “MEMS and Microsystems: Design and Manufacture”, Tata McGraw Hill, 2002.

(ii) Westbrook J.H & Fleischer R.L., “Micro sensors, MEMS and smart Devices”, Julian W. Gardner & Vijay K. Varadan, John Wiley & Sons, 2001.

Suggested Reference Books:

(i) M.V. Gandhi and B.S. Thompson, "Smart Materials and Structures", Chapman & Hall, London; New York, 1992.

(ii) A.V. Srinivasan, "Smart Structures: Analysis and Design", Cambridge University Press, Cambridge; New York, 2001 (ISBN: 0521650267). B. Culshaw, "Smart Structures and Materials", Artech House, Boston, 1996.

Course Outcomes:

At the end of the course, the students will be able to:

- Explain MEMS technology and challenges in it.
- Understand and explain micro sensors, micro actuators, their types and applications.
- Explain about fabrication processes for producing micro sensors and actuators.
- Do material selection appropriately according to fabrication processes.

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PEC RAI-804	Elective Course-III Advanced Control Systems (Tract: Control Systems)	2L:0T:0P	2 credits

Detailed Content:

Module 1:
State space Analysis State Space Representation, Solution of State Equation, State Transition Matrix, Canonical Forms – Controllable Canonical Form, Observable Canonical Form, Jordan Canonical Form. Tests for Controllability and Observability for Continuous Time, Systems – Time Varying Case, Minimum Energy Control, Time Invariant Case, Principle of Duality, Controllability and Observability form Jordan Canonical Form and Other Canonical Forms. Describing Function Analysis -Introduction to Nonlinear Systems, Types of Nonlinearities, Describing Functions, Describing Function Analysis of Nonlinear Control Systems. Phase-Plane Analysis Introduction to Phase-Plane Analysis, Method of Isoclines.

Module 2:
For Constructing Trajectories, Singular Points, Phase-Plane Analysis of Nonlinear Control Systems. Stability Analysis Stability in the Sense of Lyapunov., Lyapunov's Stability and Lypanov's Instability Theorems. Direct Method of Lyapunov for the Linear and Nonlinear Continuous Time Autonomous Systems. Modal Control Effect of State Feedback On Controllability and Observability, Design of State Feedback Control Through Pole Placement. Full Order Observer and Reduced Order Observer. Calculus of Variations Minimization of Functionals of Single Function, Constrained Minimization. Minimum Principle. Control Variable Inequality Constraints. Control and State Variable Inequality Constraints.

Module 3:
Euler Lagrange Equation. Optimal Control Formulation of Optimal Control Problem. Minimum Time, Minimum Energy, Minimum Fuel Problems. State Regulator Problem. Output Regulator Problem. Tracking Problem, Continuous-Time Linear Regulators.

Suggested Text Books:

(i) M. Gopal, Digital Control and State Variable Methods, Tata Mc Graw-Hill Companies, 1997.
(ii) M. Gopal Modern Control System Theory, New Age International Publishers, 2nd edition, 1996.

Suggested Reference Books:

(i) K. Ogata, "Modern Control Engineering", Prentice Hall of India, 3rd edition, 1998.
(ii) I.J. Nagrath and M. Gopal, "Control Systems Engineering", New Age International (P) Ltd, 2017.
(iii) Stainslaw H. Zak, "Systems and Control", Oxford Press, 2003.

Course Outcomes:

At the end of the course, the students will be able to:

- Demonstrate non-linear system behavior by phase plane and describing function methods.
- Perform the stability analysis nonlinear systems by Lyapunov method.
- Develop design skills in optimal control problems.
- Derive discrete-time mathematical models in both time domain (difference equations, state equations) and z domain (transfer function using z-transform).
- Predict and analyze transient and steady-state responses and stability and sensitivity of both open-loop and closed-loop linear, time-invariant, discrete-time control systems.
- Acquire knowledge of state space and state feedback in modern control systems, pole placement, design of state observers and output feedback controllers.

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OEC RAI-801	Elective Course-IV Biomedical Robotics (Tract: Robotics)	2L:0T:0P	2 credits

Pre-Requisites	Modeling and control of robot

Detailed Content:

Module 1:
Rigid Motions, Homogeneous transformations Forward/Inverse Kinematics Jacobian, redundant motions and singularities. Forward/Inverse Dynamics Force/Motion Control.

Module 2:
Biological movement control Robots for biomedical research teleoperation, cooperative manipulation, robots for endoscopy Physical human-robot interaction. Issues in the Control of Prosthetic Limbs.

Module 3:
Surgical Robots Biomimetic Systems Neuro-Rehabilitation Robotics Prosthetics Assistive robotics soft robotics for biomedical applications Biomimetic Robotics Surgery robotics.

Suggested Text Books:

(i) Maki Habib, "Handbook of Research on Biomimetics and Biomedical Robotics", IGI Global, 2017.
(ii) Yi Guo, "Selected Topics in Micro/Nano-robotics for Biomedical Applications", Springer, 2013.

Suggested Reference Books:

(i) Siciliano, B., Sciavicco, L. Villani, L. and Oriolo, "Robotics, Modeling, Planning and Control", Springer. 2009.
(ii) Habib, "Handbook of Research on Biomimetics and Biomedical Robotics Advances in Computational Intelligence and Robotics" (2327-0411), Maki Publishers, 2017.

Course Outcomes:

At the end of the course, the students will be able to:

- Identify and describe different types of medical robots and their potential applications.
- Know basic concepts in kinematics, dynamics, and control relevant to medical robotics.
- Understanding and analyzing biological signals (motion, muscle and brain activity).

- Control robots with bio signals.
- Develop the analytical and experimental skills necessary to design and implement robotic assistance for different biomedical applications.
- Be familiar with the state of the art in applied medical robotics and medical robotics research.
- Understand the various roles that robotics can play in healthcare.

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OEC RAI-802	Elective Course-IV Augmented Reality and Virtual Reality (Tract: AI)	2L:0T:0P	2 credits

Detailed Content:

Module 1: Introduction to Augmented Reality:
Defining augmented reality, history of augmented reality, The Relationship Between Augmented Reality and Other Technologies-Media, Technologies, Other Ideas Related to the Spectrum Between Real and Virtual Worlds, applications of augmented reality, Working, Concepts Related to Augmented Reality, Ingredients of an Augmented Reality Experience.

Module 2: Augmented Reality Architecture:
Audio Displays, Haptic Displays, Visual Displays, Other sensory displays, Visual Perception, Requirements and Characteristics, Spatial Display Model. Processors – Role of Processors, Processor System Architecture, Processor Specifications. Tracking & Sensors - Tracking, Calibration, and Registration, Characteristics of Tracking Technology, Stationary Tracking Systems, Mobile Sensors, Optical Tracking, Sensor Fusion.

Module 3: AR Techniques:
Marker-based approach- Introduction to marker-based tracking, types of markers, marker camera pose and identification, visual tracking, mathematical representation of matrix multiplication Marker types- Template markers, 2D barcode markers, imperceptible markers. Marker-less approach- Localization based augmentation, real world examples Tracking methods- Visual tracking, feature based tracking, hybrid tracking, and initialisation and recovery.

Module 4: Introduction to Virtual Reality:
Defining Virtual Reality, History of VR, Human Physiology and Perception, Key Elements of Virtual Reality Experience, Virtual Reality System, Interface to the Virtual World-Input & output- Visual, Aural & Haptic Displays, Applications of Virtual Reality.

Module 5: Virtual World Motion tracking:
Representation of the Virtual World, Visual Representation in VR, Aural Representation in VR and Haptic Representation in VR, Motion in Real and Virtual Worlds- Velocities and Accelerations, The Vestibular System, Physics in the Virtual World, Mismatched Motion and Vection Tracking- Tracking 2D & 3D Orientation, Tracking Position and Orientation, Tracking Attached Bodies.

Module 6: Virtual Worlds & Human Vision:
Geometric Models, Changing Position and Orientation, Axis-Angle Representations of Rotation, Viewing Transformations, Chaining the Transformations, Human Eye, eye movements & implications for VR.

Suggested Text Books:

(i) Oliver Bimber and Ramesh Raskar, "Spatial Augmented Reality: Merging Real and Virtual Worlds", 2005.
(ii) Developing Virtual Reality Applications: Foundations of Effective Design, Alan B Craig, William R Sherman and Jeffrey D Will, Morgan Kaufmann, 2009.

Suggested Reference Books:

(i) Gerard Jounghyun Kim, "Designing Virtual Systems: The Structured Approach", 2005.
(ii) Steven M. LaValle, "Virtual Reality", Cambridge University Press, 2016.
(iii) Burdea, Grigore C and Philippe Coiffet, "Virtual Reality Technology", Wiley Interscience, India, 2003.
(iv) William R Sherman, Alan B Craig, "Understanding Virtual Reality: Interface, Application and Design", "The Morgan Kaufmann Series in Computer Graphics", Morgan Kaufmann Publishers, San Francisco, CA, 2002.

Course Outcomes:
At the end of the course, the students will be able to:

- Understand and analyze the hardware requirement of AR.
- Describe AR systems work and list the applications of AR.
- Understand the design and implementation of the hardware that enables VR systems to be built.
- Explain the concepts of motion and tracking in VR systems.

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OEC RAI-803	Elective Course-IV Advanced Mechatronics (Tract: Mechatronics)	2L:0T:0P	2 credits

Detailed Content:

Module 1:
Introduction to theoretical and applied mechatronics, design and operation of mechatronics systems; mechanical, electrical, electronic, and opto-electronic components; sensors and actuators including signal conditioning and power electronics.

Module 2:
Microcontrollers—fundamentals, programming, and interfacing; and feedback control. Includes structured and term projects in the design and development of proto-type integrated mechatronic systems.

Module 3:
Introduction to applications of, and hands-on experience with microcontrollers and single-board computers for embedded system applications. Specifically, gain familiarity with the fundamentals, anatomy, functionality, programming, interfacing, and protocols for the Arduino microcontroller, multi-core Propeller microcontroller, and single-board computer Raspberry Pi. Includes mini-projects and term projects in the design and development of proto-type integrated mechatronic systems.

Suggested Text Books:

(i) William Bolton, "Mechatronics (Electronic Control Systems in Mechanical and Electrical Engineering)", Pearson.
(ii) Raj Kamal, "Embedded systems Architecture, Programming and design", Tata McGraw hill Education 2008.

Suggested Reference Books:

(i) Kenneth J Ayala, "The 8051 Microcontroller Programming and Architecture", 1996.
(ii) W. Bolton, Mechatronics - Electronic Control systems in Mechanical and Electrical Engineering, 2nd Edition, Addison Wesley Longman Ltd., 1999.
(iii) Devdas Shetty, Richard A. Kolk, Mechatronics System Design, PWS Publishing company, 1997.
(iv) Bradley, D. Dawson, N.C. Burd and A.J. Loader, Mechatronics: Electronics in Products 4. and Processes, Chapman and Hall, London, 1991.
(v) Brian Morris, Automated Manufacturing Systems - Actuators, Controls, Sensors and Robotics, Mc Graw Hill International Edition, 1995.
(vi) Gopal, Sensors- A Comprehensive Survey Vol I & Vol VIII, BCH Publisher, 2013.

Course Outcomes:

At the end of the course, the students will be able to:

- Acquire knowledge of Mechatronic systems and its design.
- Gain Knowledge of Microcontrollers and its operation.
- Perform experiments on Microcontrollers.

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OEC RAI-804	Elective Course-IV Robot Dynamics and Control (Tract: Control Systems)	2L:0T:0P	2 credits

Detailed Content:

Module 1:
Introduction Rigid-body, DoF, Rotation and Forward Kinematics. (DH par.) Inverse Kinematics Workspace, Rigid Body Dynamics.Dynamics of Robot Arms.

Module 2:
System Dynamics and Control - Modeling of electrical, mechanical, and electromechanical systems. Analytic solution of open loop and feedback type systems. Root Locus methods in design of systems and evaluation of system performance. Time and frequency domain.

Module 3:
Introduction to Linear Control, State Space Modeling and Multivariable Systems, Nonlinear Control, Stability Theory Quadrotor Control Trajectory Generation Planning and Control of a Quadrotor design of control systems.

Suggested Text Books:

(i) Saeed B. Niku, "Introduction to Robotics – Analysis, Control, Applications", Wiley India Pvt. Ltd., 2010.
(ii) S. K. Saha, "Introduction to Robotics", McGraw Hill Education (India) Pvt. Ltd., 2014.
(iii) Choset, Lynch, Hutchinson, Kantor, Burgard, Kavraki and Thrun, "Principle of Robot Motion", PHI Learning Pvt. Ltd., 2000.

Course Outcomes:

After the completion of this course, the students will be able to:

- Select, design, analyze, implement, and evaluate effective controllers for a number of different robotics platforms and applications.
- The dynamics of robot arms, mobile robots and quadrotors.
- Position and force control for robots.
- How to generate complex trajectories.
- The basics of configuration spaces for robotic systems.
- Controller synthesis and stability.

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LC RAI-801	Robot System Design and SLAM (Simultaneous Localization and Area Mapping) Laboratory	0L:0T:2P	1 credit

Detailed Content:

- To install ROS and set-up a ROS workspace on a computer.
- To write ROS talker-listener code in python.
- To create a mobile robot base URDF model.
- To create a 3-DOF robot arm URDF model.
- To simulate a mobile robot base in Gazebo.
- To attach the robot arm to base and simulate the complete mobile robot in Gazebo.
- To create an environment in Gazebo for simulating a mobile robot for an industrial application.
- To implement SLAM for industrial application using ROS open-source packages.
- To configure and interface a webcam with ROS.
- To use OpenCV with ROS for a vision application.

Suggested Text Books:

(i) Morgan Quigley, "Programming Robots with ROS: A Practical Introduction to the Robot Operating System" , O'Reilly Media, 2015.
(ii) Carol Fairchild, Dr. Thomas L. Harman, "ROS Robotics by Example", Packt, 2016.

Suggested Reference Books:

(i) Anis Koubaa, "Robot Operating System", Springer link, 2016.
(ii) Anil Mahtani, "Effective Robotics Programming with ROS", Packt Publishing, 2016.
(iii) Ramkumar Gandhinathan , Lentin Joseph , " ROS Robotics Projects: Build and control robots powered by the Robot Operating System, machine learning, and virtual reality", Packt Publishing Limited, December 2019.
(iv) SLAM for dummies: https://dspace.mit.edu/bitstream/handle/1721.1/119149/16-412j-spring-2005/contents/projects/1aslam_blas_repo.pdf
(v) ROS Robot Programming; YoonSeok Pyo I HanCheol Cho I RyuWoon Jung I TaeHoon Lim; https://community.robotsource.org/t/download-the-ros-robot-programming-book-for-free/51

Course Outcomes:

After the completion of this course, the students will be able to:

- Understand the features and uses of Robotic Operating System (ROS) and allied software tools.
- Generate a robot manipulator and its working environment using simulation tools.
- Implement robot navigation and object manipulation for a given application.
- Incorporate and use robot vision for real-world applications.

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PROJ RAI-801	Project Stage – II	0L:0T:16P	8 credits

Detailed Content:

Project should be research oriented experimental work, involving detail analysis or development of the industrial case studies related to Robotics & Artificial Intelligence.

Course Outcomes:

At the end of the course, the students will be able to:

- Apply the techniques learned during the course.
- Provide solution to the problem.
- Publish their work in conferences and Journals.

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LC RAI-802	Seminar	0L:1T:0P	1 credit

Detailed Content:

Seminar topic would be an emerging technology/ research/ product, study and finalization of the topic, sharing of knowledge with peers and discussion, documentation in the form of a report.

Course Outcomes:

At the end of the course, the students will be able to:

- Understand the contemporary / emerging technology for various processes and systems.
- Share knowledge effectively in oral and written form and formulate documents.

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LLC RAI-801	**Liberal Learning Course (Audit Course)**	**1L:0T:0P**	**0 credit**

Detailed Content:

Identification of topic and resources, scope, and synthesize viewpoints for the areas such as performing arts, basic Sciences, business, philosophy, sports and athletics, defense studies and education.

Course Outcomes:

At the end of the course, the students will be able to:

- Exhibit self-learning capabilities and its use in effective communication.
- Inculcate impact in various areas to relate with society at large.

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Appendix – I

A Guide to Induction Program

Appendix – III: A Guide to Induction Program

1. Introduction

(*Induction Program was discussed and approved for all colleges by AICTE in March 2017. It was discussed and accepted by the Council of IITs for all IITs in August 2016. It was originally proposed by a Committee of IIT Directors and accepted at the meeting of all IIT Directors in March 2016.*[1] *This guide has been prepared based on the Report of the Committee of IIT Directors and the experience gained through its pilot implementation in July 2016 as accepted by the Council of IITs. Purpose of this document is to help institutions in understanding the spirit of the accepted Induction Program and implementing it.)*

Engineering colleges were established to train graduates well in the branch/department of admission, have a holistic outlook, and have a desire to work for national needs and beyond.

The graduating student must have knowledge and skills in the area of his study. However, he must also have broad understanding of society and relationships. Character needs to be nurtured as an essential quality by which he would understand and fulfill his responsibility as an engineer, a citizen and a human being. Besides the above, several meta-skills and underlying values are needed.

There is a mad rush for engineering today, without the student determining for himself his interests and his goals. This is a major factor in the current state of demotivation towards studies that exists among UG students.

The success of gaining admission into a desired institution but failure in getting the desired branch, with peer pressure generating its own problems, leads to a peer environment that is demotivating and corrosive. Start of hostel life without close parental supervision at the same time, further worsens it with also a poor daily routine.

To come out of this situation, a multi-pronged approach is needed. One will have to work closely with the newly joined students in making them feel comfortable, allow them to explore their academic interests and activities, reduce competition and make them work for excellence, promote bonding within them, build relations between teachers and students, give a broader view of life, and build character.

[1] *A Committee of IIT Directors was setup in the 152nd Meeting of IIT Directors on 6th September 2015 at IIT Patna, on how to motivate undergraduate students at IITs towards studies, and to develop verbal ability. The Committee submitted its report on 19th January 2016. It was considered at the 153rd Meeting of all IIT Directors at IIT Mandi on 26 March 2016, and the accepted report came out on 31 March 2016. The Induction Program was an important recommendation, and its pilot was implemented by three IITs, namely, IIT(BHU), IIT Mandi and IIT Patna in July 2016. At the 50th meeting of the Council of IITs on 23 August 2016, recommendation on the Induction Program and the report of its pilot implementation were discussed and the program was accepted for all IITs.*

2. Induction Program

When new students enter an institution, they come with diverse thoughts, backgrounds and preparations. It is important to help them adjust to the new environment and inculcate in them the ethos of the institution with a sense of larger purpose. Precious little is done by most of the institutions, except for an orientation program lasting a couple of days.

We propose a 3-week long induction program for the UG students entering the institution, right at the start. Normal classes start only after the induction program is over. Its purpose is to make the students feel comfortable in their new environment, open them up, set a healthy daily routine, create bonding in the batch as well as between faculty and students, develop awareness, sensitivity and understanding of the self, people around them, society at large, and nature.[2]

The time during the Induction Program is also used to rectify some critical lacunas, for example, English background, for those students who have deficiency in it.

The following are the activities under the induction program in which the student would be fully engaged throughout the day for the entire duration of the program.

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[2]*Induction Program as described here borrows from three programs running earlier at different institutions: (1) Foundation Program running at IIT Gandhinagar since July 2011, (2) Human Values course running at IIIT Hyderabad since July 2005, and (3) Counselling Service or mentorship running at several IITs for many decades. Contribution of each one is described next.*

IIT Gandhinagar was the first IIT to recognize and implement a special 5-week Foundation Program for the incoming 1st year UG students. It took a bold step that the normal classes would start only after the five week period. It involved activities such as games, art, etc., and also science and other creative workshops and lectures by resource persons from outside.

IIIT Hyderabad was the first one to implement a compulsory course on Human Values. Under it, classes were held by faculty through discussions in small groups of students, rather than in lecture mode. Moreover, faculty from all departments got involved in conducting the group discussions under the course. The content is non-sectarian, and the mode is dialogical rather than sermonising or lecturing. Faculty were trained beforehand, to conduct these discussions and to guide students on issues of life.

Counselling at some of the IITs involves setting up mentor-mentee network under which 1st year students would be divided into small groups, each assigned a senior student as a student guide, and a faculty member as a mentor. Thus, a new student gets connected to a faculty member as well as a senior student, to whom he/she could go to in case of any difficulty whether psychological, financial, academic, or otherwise.
The Induction Program defined here amalgamates all the three into an integrated whole, which leads to its high effectiveness in terms of building physical activity, creativity, bonding, and character. It develops sensitivity towards self and one's relationships, builds awareness about others and society beyond the individual, and also in bonding with their own batch-mates and a senior student besides a faculty member.

Scaling up the above amalgamation to an intake batch of 1000 plus students was done at IIT(BHU), Varanasi starting from July 2016.

2.1. Physical Activity

This would involve a daily routine of physical activity with games and sports. It would start with all students coming to the field at 6 am for light physical exercise or yoga. There would also be games in the evening or at other suitable times according to the local climate. These would help develop team work. Each student should pick one game and learn it for three weeks. There could also be gardening or other suitably designed activity where labour yields fruits from nature.

2.2. Creative Arts

Every student would choose one skill related to the arts whether visual arts or performing arts. Examples are painting, sculpture, pottery, music, dance etc. The student would pursue it every day for the duration of the program.
These would allow for creative expression. It would develop a sense of aesthetics and also enhance creativity which would, hopefully, flow into engineering design later.

2.3. Universal Human Values

It gets the student to explore oneself and allows one to experience the joy of learning, stand up to peer pressure, take decisions with courage, be aware of relationships with colleagues and supporting staff in the hostel and department, be sensitive to others, etc. Need for character building has been underlined earlier. A module in Universal Human Values provides the base.

Methodology of teaching this content is extremely important. It must not be through do's and don'ts, but get students to explore and think by engaging them in a dialogue. It is best taught through group discussions and real life activities rather than lecturing. The role of group discussions, however, with clarity of thought of the teachers cannot be over emphasized. It is essential for giving exposure, guiding thoughts, and realizing values.
The teachers must come from all the departments rather than only one department like HSS or from outside of the Institute. Experiments in this direction at IIT(BHU) are noteworthy and one can learn from them.[3]

Discussions would be conducted in small groups of about 20 students with a faculty mentor each. It is to open thinking towards the self. Universal Human Values discussions could even continue for rest of the semester as a normal course, and not stop with the induction program.

Besides drawing the attention of the student to larger issues of life, it would build relationships between teachers and students which last for their entire 4-year stay and possibly beyond.

[3]The Universal Human Values Course is a result of a long series of experiments at educational institutes starting from IIT-Delhi and IIT Kanpur in the 1980s and 1990s as an elective course, NIT Raipur in late 1990s as a compulsory one-week off campus program. The courses at IIT(BHU) which started from July 2014, are taken and developed from two compulsory courses at IIIT Hyderabad first introduced in July 2005.

2.4. Literary
Literary activity would encompass reading, writing and possibly, debating, enacting a play etc.

2.5. Proficiency Modules
This period can be used to overcome some critical lacunas that students might have, for example, English, computer familiarity etc. These should run like crash courses, so that when normal courses start after the induction program, the student has overcome the lacunas substantially. We hope that problems arising due to lack of English skills, wherein students start lagging behind or failing in several subjects, for no fault of theirs, would, hopefully, become a thing of the past.

2.6. Lectures by Eminent People
This period can be utilized for lectures by eminent people, say, once a week. It would give the students exposure to people who are socially active or in public life.

2.7. Visits to Local Area
A couple of visits to the landmarks of the city, or a hospital or orphanage could be organized. This would familiarize them with the area as well as expose them to the under privileged.

2.8. Familiarization to Dept./Branch & Innovations
The students should be told about different method of study compared to coaching that is needed at IITs. They should be told about what getting into a branch or department means what role it plays in society, through its technology. They should also be shown the laboratories, workshops & other facilities.

3. Schedule
The activities during the Induction Program would have an Initial Phase, a Regular Phase and a Closing Phase. The Initial and Closing Phases would be two days each.

3.1. Initial Phase

Day	Time	Activity
Day 0	Whole Day	Students Arrive – Hostel Allotment (Preferably do pre-allotment)
Day 1	09:00 AM – 03:00 PM	Academic Registration
	04:30 PM – 06:00 PM	Orientation
Day 2	09:00 AM – 10:00 AM	Diagnostic test (for English etc.)
	10:00 AM – 12:25 PM	Visit to respective depts.
	12:30 PM – 01:55 PM	Lunch
	02:00 PM – 02:55 PM	Director's address
	03:00 PM – 03:30 PM	Interaction with parents
	03:30 PM – 05:00 PM	Mentor-Mentee Groups - Introduction within group. (Same as Universal Human Values Group)

3.2. Regular Phase
After two days is the start of the Regular Phase of Induction. With this phase there would be regular program to be followed every day.

3.2.1. Daily Schedule

Some of the activities are on a daily basis, while some others are at specified periods within the Induction Program. We first show a typical daily timetable.

DAY 3 Onwards

Session	Time	Activity	Remarks
	06:00 AM	Wake up Call	
I	06:30 AM – 07:10 AM	Physical Activity (Mild Exercise / Yoga)	
	07:15 AM – 08:55 AM	Bath, Breakfast etc.	
II	09:10 AM – 10:55 AM	Creative Arts / Universal Human Values	Half the groups do creative arts
III	11:00 AM – 12:55 PM	Creative Arts / Universal Human Values	Complementary Alternate Groups
	01:00 PM – 02:25 PM	Lunch	
IV	02:30 PM – 03:55 PM	Afternoon Session	See below
V	04:00 PM – 05:00 PM	Afternoon Session	See below
	05:00 PM – 05:25 PM	Break / Light Tea	
VI	05:30 PM – 06:45 PM	Games / Special Lectures	
	06:50 PM – 08:25 PM	Rest and Dinner	
VII	08:30 PM – 09:25 PM	Informal Interactions (In hostels)	

Sundays are off. Saturdays have the same schedule as above or have outings.

3.2.2. Afternoon Activities (Non-Daily)

The following five activities are scheduled at different times of the Induction Program, and are not held daily for everyone:

1. Familiarization to Dept./Branch & Innovations
2. Visits to Local Area
3. Lectures by Eminent People
4. Literary
5. Proficiency Modules

Here is the approximate activity schedule for the afternoons (may be changed to suit local needs):

Session	Activity	Remarks
IV	Familiarization with Dept./Branch & Innovations	For 3 Days (Day 3 to Day 5)
IV, V and VI	Visit to Local Area	For 3 Days – interspersed (e.g. Saturdays)
IV	Lectures by Eminent People	As scheduled 3-5 lectures

IV	Literary (Play / Literature / Book Reading)	For 3-5 Days
V	Proficiency Modules	Daily, but only for those who need it.

3.3. Closing Phase

Day	Time	Activity
Last But One Day	08:30 AM – 12:00 PM	Discussions and finalization of presentation within each group
	02:00 AM -05:00 PM	Presentation by each group in front of 4 other groups besides their own (about 100 students)
Last Day	Whole Day	Examinations (if any). May be extended to last 2 days, in case needed.

3.4. Follow Up after Closure

A question comes up as to what would be the follow up program after the formal 3-week Induction Program is over? The groups which are formed should function as mentor- mentee network. A student should feel free to approach his faculty mentor or the student guide, when facing any kind of problem, whether academic or financial or psychological etc. (For every 10 undergraduate first year students, there would be a senior student as a student guide, and for every 20 students, there would be a faculty mentor.) Such a group should remain for the entire 4-5-year duration of the stay of the student. Therefore, it would be good to have groups with the students as well as teachers from the same department/discipline[4].

Here we list some important suggestions which have come up and which have been experimented with:

3.4.1. Follow Up after Closure – Same Semester

It is suggested that the groups meet with their faculty mentors once a month, within the semester after the 3-week Induction Program is over. This should be a scheduled meeting shown in the timetable. (The groups are of course free to meet together on their own more often, for the student groups to be invited to their faculty mentor's home for dinner or tea, nature walk, etc.)

3.4.2. Follow Up – Subsequent Semesters

It is extremely important that continuity be maintained in subsequent semesters.
It is suggested that at the start of the subsequent semesters (up to fourth semester), three days be set aside for three full days of activities related to follow up to Induction Program. The students be shown inspiring films, do collective art work, and group discussions be conducted. Subsequently, the groups should meet at least once a month.

4. Summary

Engineering institutions were set up to generate well trained manpower in engineering with a feeling of responsibility towards oneself, one's family, and society. The incoming undergraduate students are driven by their parents and society to join engineering without

understanding their own interests and talents. As a result, most students fail to link up with the goals of their own institution.

The graduating student must have values as a human being, and knowledge and meta- skills related to his/her profession as an engineer and as a citizen. Most students who get demotivated to study engineering or their branch, also lose interest in learning.

The Induction Program is designed to make the newly joined students feel comfortable, sensitize them towards exploring their academic interests and activities, reducing competition and making them work for excellence, promote bonding within them, build relations between teachers and students, give a broader view of life, and building of character.

The Universal Human Values component, which acts as an anchor, develops awareness and sensitivity, feeling of equality, compassion and oneness, draw attention to society and nature, and character to follow through. It also makes them reflect on their relationship with their families and extended family in the college (with hostel staff and others). It also connects students with each other and with teachers so that they can share any difficulty they might be facing and seek help.

References:

Motivating UG Students Towards Studies, Rajeev Sangal, IITBHU Varanasi, Gautam Biswas, IIT Guwahati, Timothy Gonsalves, IIT Mandi, Pushpak Bhattacharya, IIT Patna, (Committee of IIT Directors).
31 March 2016, IIT Directors' Secretariat, IIT Delhi.

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