

RAD415	PROJECT PHASE I	CATEGORY	L	T	P	CREDIT
		PWS	0	0	6	2

**Preamble:** The course ‘Project Work’ is mainly intended to evoke the innovation and invention skills in a student. The course will provide an opportunity to synthesize and apply the knowledge and analytical skills learned, to be developed as a prototype or simulation. The project extends to 2 semesters and will be evaluated in the 7<sup>th</sup> and 8<sup>th</sup> semester separately, based on the achieved objectives. One third of the project credits shall be completed in 7<sup>th</sup> semester and two third in 8<sup>th</sup> semester. It is recommended that the projects may be finalized in the thrust areas of the respective engineering stream or as interdisciplinary projects. Importance should be given to address societal problems and developing indigenous technologies.

### Course Objectives

- To apply engineering knowledge in practical problem solving.
- To foster innovation in design of products, processes or systems.
- To develop creative thinking in finding viable solutions to engineering problems.

**Course Outcomes [COs] :**After successful completion of the course, the students will be able to:

CO1	Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: <b>Apply</b> ).
CO2	Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: <b>Apply</b> ).
CO3	Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: <b>Apply</b> ).
CO4	Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: <b>Apply</b> ).
CO5	Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: <b>Analyze</b> ).
CO6	Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: <b>Apply</b> ).

### Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	2	2	2	1	2	2	2	1	1	1	1	2
<b>CO2</b>	2	2	2		1	3	3	1	1		1	1
<b>CO3</b>									3	2	2	1
<b>CO4</b>					2			3	2	2	3	2
<b>CO5</b>	2	3	3	1	2							1
<b>CO6</b>					2			2	2	3	1	1



**Abstract POs defined by National Board of Accreditation**

<b>PO#</b>	<b>Broad PO</b>	<b>PO#</b>	<b>Broad PO</b>
PO1	Engineering Knowledge	PO7	Environment and Sustainability
PO2	Problem Analysis	PO8	Ethics
PO3	Design/Development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO10	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Lifelong learning

**PROJECT PHASE I****Phase 1 Target**

- Literature study/survey of published literature on the assigned topic
- Formulation of objectives
- Formulation of hypothesis/ design/ methodology
- Formulation of work plan and task allocation.
- Block level design documentation
- Seeking project funds from various agencies
- Preliminary Analysis/Modeling/Simulation/Experiment/Design/Feasibility study
- Preparation of Phase 1 report

**Evaluation Guidelines & Rubrics**

Total: 100 marks (Minimum required to pass: 50 marks).

- Project progress evaluation by guide: 30 Marks.
- Interim evaluation by the Evaluation Committee: 20 Marks.
- Final Evaluation by the Evaluation Committee: 30 Marks.
- Project Phase - I Report (By Evaluation Committee): 20 Marks.

(The evaluation committee comprises HoD or a senior faculty member, Project coordinator and project supervisor).



The guide/supervisor shall monitor the progress being carried out by the project groups on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide. Project evaluation by the guide: 30 Marks. This mark shall be awarded to the students in his/her group by considering the following aspects:

**Topic Selection:** innovativeness, social relevance etc. (2)

**Problem definition:** Identification of the social, environmental and ethical issues of the project problem. (2)

**Purpose and need of the project:** Detailed and extensive explanation of the purpose and need of the project. (3)

**Project Objectives:** All objectives of the proposed work are well defined; Steps to be followed to solve the defined problem are clearly specified. (2)

**Project Scheduling & Distribution of Work among Team members:** Detailed and extensive Scheduling with timelines provided for each phase of project. Work breakdown structure well defined. (3)

**Literature survey:** Outstanding investigation in all aspects. (4)

**Student's Diary/ Daily Log:** The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide. (7)

**Individual Contribution:** The contribution of each student at various stages. (7)



**EVALUATION RUBRICS for PROJECT Phase I: Interim Evaluation**

No.	Parameters	Marks	Poor	Fair	Very Good	Outstanding
1-a	Topic identification, selection, formulation of objectives and/or literature survey. (Group assessment)  [CO1]	10	The team has failed to come with a relevant topic in time. Needed full assistance to find a topic from the guide. They do not respond to suggestions from the evaluation committee and/or the guide. No literature review was conducted. The team tried to gather easy information without verifying the authenticity. No objectives formed yet.	The team has identified a topic. The originally selected topic lacks substance and needs to be revised. There were suggestions given to improve the relevance and quality of the project topic. Only a few relevant references were consulted/ studied and there is no clear evidence to show the team's understanding on the same. Some objectives identified, but not clear enough.	Good evidence of the group thinking and brainstorming on what they are going to build. The results of the brainstorming are documented and the selection of topic is relevant. The review of related references was good, but there is scope of improvement. Objectives formed with good clarity, however some objectives are not realistic enough.	The group has brainstormed in an excellent manner on what they were going to build. The topic selected is highly relevant, real world problem and is potentially innovative. The group shows extreme interest in the topic and has conducted extensive literature survey in connection with the topic. The team has come up with clear objectives which are feasible.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
1-b	Project Planning, Scheduling and Resource/ Tasks Identification and allocation. (Group assessment)  [CO4]	10	No evidence of planning or scheduling of the project. The students did not plan what they were going to build or plan on what materials / resources to use in the project. The students do not have any idea on the budget required. The team has not yet decided on who does what. No project journal kept.	Some evidence of a primary plan. There were some ideas on the materials /resources required, but not really thought out. The students have some idea on the finances required, but they have not formalized a budget plan. Schedules were not prepared. The project journal has no details. Some evidence on task allocation among the team members.	Good evidence of planning done. Materials were listed and thought out, but the plan wasn't quite complete. Schedules were prepared, but not detailed, and needs improvement. Project journal is presented but it is not complete in all respect / detailed. There is better task allocation and individual members understand about their tasks. There is room for improvement.	Excellent evidence of enterprising and extensive project planning. Gantt charts were used to depict detailed project scheduling. A project management/version control tool is used to track the project, which shows familiarity with modern tools. All materials / resources were identified and listed and anticipation of procuring time is done. Detailed budgeting is done. All tasks were identified and incorporated in the schedule. A well-kept project journal shows evidence for all the above, in addition to the interaction with the project guide. Each member knows well about their individual tasks.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
<b>Phase 1 Interim Evaluation Total Marks: 20</b>						

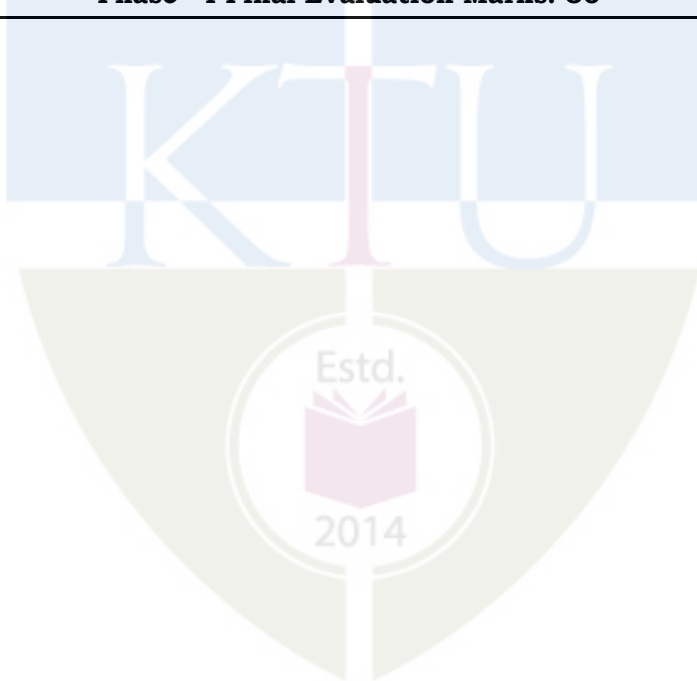


**EVALUATION RUBRICS for PROJECT Phase I: Final Evaluation**

Sl. No.	Parameters	Marks	Poor	Fair	Very Good	Outstanding
1-c	Formulation of Design and/or Methodology and Progress. (Group assessment) [CO1]	5	None of the team members show any evidence of knowledge about the design and the methodology adopted till now/ to be adopted in the later stages. The team has not progressed from the previous stage of evaluation.	The students have some knowledge on the design procedure to be adopted, and the methodologies. However, the team has not made much progress in the design, and yet to catch up with the project plan.	The students are comfortable with design methods adopted, and they have made some progress as per the plan. Their methodologies are understood to a large extent.	Shows clear evidence of having a well- defined design methodology and adherence to it. Excellent knowledge in design procedure and its adaptation. Adherence to project plan is commendable.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
1-d	Individual and Teamwork Leadership ( Individual assessment) [CO3]	10	The student does not show any interest in the project activities, and is a passive member.	The student show some interest and participates in some of the activities. However, the activities are mostly easy and superficial in nature.	The student shows very good interest in project, and takes up tasks and attempts to complete them. Shows excellent responsibility and team skills. Supports the other members well.	The student takes a leadership position and supports the other team members and leads the project. Shows clear evidence of leadership.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
1-e	Preliminary Analysis/ Modeling / Simulation/ Experiment / Design/ Feasibility study [CO1]	10	The team has not done any preliminary work with respect to the analysis/modeling/ simulation/experiment/design/feasibility study/ algorithm development.	The team has started doing some preliminary work with respect to the project. The students however are not prepared enough for the work and they need to improve a lot.	There is some evidence to show that the team has done good amount of preliminary investigation and design/ analysis/ modeling etc. They can improve further.	Strong evidence for excellent progress in the project. The team has completed the required preliminary work already and are poised to finish the phase I in an excellent manner. They have shown results to prove their progress.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)



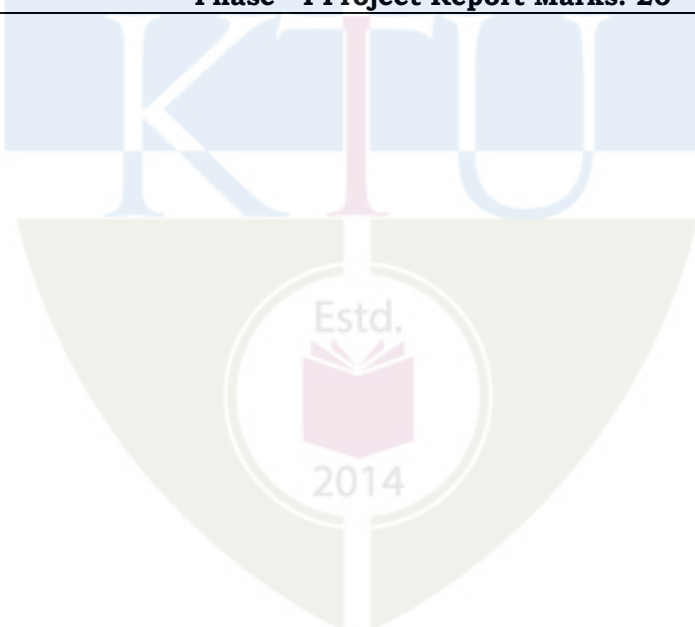
1-f	Documentation and presentation. (Individual & group assessment).  [CO6]	5	The team did not document the work at all. The project journal/diary is not presented. The presentation was shallow in content and dull in appearance. The individual student has no idea on the presentation of his/her part.	Some documentation is done, but not extensive. Interaction with the guide is minimal. Presentation include some points of interest, but overall quality needs to be improved. Individual performance to be improved.	Most of the project details were documented well enough. There is scope for improvement. The presentation is satisfactory. Individual performance is good.	The project stages are extensively documented in the report. Professional documentation tools like LaTeX were used to document the progress of the project along with the project journal. The documentation structure is well-planned and can easily grow into the project report.  The presentation is done professionally and with great clarity. The individual's performance is excellent.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
Total		30	Phase - I Final Evaluation Marks: 30			





### EVALUATION RUBRICS for PROJECT Phase I: Report Evaluation

Sl. No.	Parameters	Marks	Poor	Fair	Very Good	Outstanding
1-g	Report [CO6]	20	The prepared report is shallow and not as per standard format. It does not follow proper organization. Contains mostly Unacknowledged content. Lack of effort in preparation is evident.	Project report follows the standard format to some extent. However, its organization is not very good. Language needs to be improved. All references are not cited properly in the report.	Project report shows evidence of systematic documentation. Report is following the standard format and there are only a few issues. Organization of the report is good. Most of references are cited properly.	The report is exceptionally good. Neatly organized. All references cited properly. Diagrams/Figures, Tables and equations are properly numbered, and listed and clearly shown. Language is excellent and follows standard styles.
			(0 - 7 Marks)	(8 - 12 Marks)	(13 - 19 Marks)	(20 Marks)
<b>Phase - I Project Report Marks: 20</b>						





RAQ413	SEMINAR	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	2

**Preamble:** The course ‘Seminar’ is intended to enable a B.Tech graduate to read, understand, present and prepare report about an academic document. The learner shall search in the literature including peer reviewed journals, conference, books, project reports etc., and identify an appropriate paper/thesis/report in her/his area of interest, in consultation with her/his seminar guide. This course can help the learner to experience how a presentation can be made about a selected academic document and also empower her/him to prepare a technical report.

#### Course Objectives:

- To do literature survey in a selected area of study.
- To understand an academic document from the literature and to give a presentation about it.
- To prepare a technical report.

**Course Outcomes [COs] :** After successful completion of the course, the students will be able to:

CO1	Identify academic documents from the literature which are related to her/his areas of interest (Cognitive knowledge level: <b>Apply</b> ).
CO2	Read and apprehend an academic document from the literature which is related to her/ his areas of interest (Cognitive knowledge level: <b>Analyze</b> ).
CO3	Prepare a presentation about an academic document (Cognitive knowledge level: <b>Create</b> ).
CO4	Give a presentation about an academic document (Cognitive knowledge level: <b>Apply</b> ).
CO5	Prepare a technical report (Cognitive knowledge level: <b>Create</b> ).

#### Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	2	2	1	1		2	1					3
<b>CO2</b>	3	3	2	3		2	1					3
<b>CO3</b>	3	2			3			1		2		3
<b>CO4</b>	3				2			1		3		3
<b>CO5</b>	3	3	3	3	2	2		2		3		3



### Abstract POs defined by National Board of Accreditation

PO#	Broad PO	PO#	Broad PO
PO1	Engineering Knowledge	PO7	Environment and Sustainability
PO2	Problem Analysis	PO8	Ethics
PO3	Design/Development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO10	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Life long learning

### General Guidelines

- The Department shall form an Internal Evaluation Committee (IEC) for the seminar with academic coordinator for that program as the Chairperson/Chairman and seminar coordinator & seminar guide as members. During the seminar presentation of a student, all members of IEC shall be present.
- Formation of IEC and guide allotment shall be completed within a week after the University examination (or last working day) of the previous semester.
- Guide shall provide required input to their students regarding the selection of topic/paper.
- Choosing a seminar topic: The topic for a UG seminar should be current and broad based rather than a very specific research work. It's advisable to choose a topic for the Seminar to be closely linked to the final year project area. Every member of the project team could choose or be assigned Seminar topics that covers various aspects linked to the Project area.
- A topic/paper relevant to the discipline shall be selected by the student during the semester break.
- Topic/Paper shall be finalized in the first week of the semester and shall be submitted to the IEC.
- The IEC shall approve the selected topic/paper by the second week of the semester.
- Accurate references from genuine peer reviewed published material to be given in the report and to be verified.



**Evaluation pattern**

**Total marks: 100, only CIE, minimum required to pass 50**

**Seminar Guide:** 20 marks (Background Knowledge – 10 (The guide shall give deserving marks for a candidate based on the candidate's background knowledge about the topic selected), Relevance of the paper/topic selected – 10).

**Seminar Coordinator:** 20 marks (Seminar Diary – 10 (Each student shall maintain a seminar diary and the guide shall monitor the progress of the seminar work on a weekly basis and shall approve the entries in the seminar diary during the weekly meeting with the student), Attendance – 10).

**Presentation:** 40 marks to be awarded by the IEC (Clarity of presentation – 10, Interactions – 10 (to be based on the candidate's ability to answer questions during the interactive session of her/his presentation), Overall participation – 10 (to be given based on her/his involvement during interactive sessions of presentations by other students), Quality of the slides – 10).

**Report:** 20 marks to be awarded by the IEC (check for technical content, overall quality, templates followed, adequacy of references etc.).





RAL 411	ELECTRICAL DRIVES AND CONTROL LAB	CATEGORY	L	T	P	CREDIT
		PCC	0	0	3	2

**Preamble:** Drives and control lab will enable the students to understand the characteristics of basic components used in electric drives. They will work on AC and DC drives. They can experimentally determine the control using various drives.

**Course Outcomes:** After the completion of the course the student will be able to:-

<b>CO 1</b>	Test the basic characteristics of power semiconductor devices.
<b>CO 2</b>	Test the various techniques used for triggering SCRs and solid state devices.
<b>CO 3</b>	Test and design choppers and inverters.
<b>CO 4</b>	Test the speed control of DC motors.
<b>CO 5</b>	Design and develop different speed control schemes for DC motor drives.

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
<b>CO 1</b>	3	2	2			2			2	2		
<b>CO 2</b>	3	2	2	2		2			2	2		
<b>CO 3</b>	3	2	2	2		2			2	2		2
<b>CO 4</b>	3	2	2	2	2	2			2	2		3
<b>CO 5</b>	3	2	2	2		2			2	2		3

#### Assessment Pattern

#### Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	75	75	2.5 hours

#### Continuous Internal Evaluation Pattern:

Attendance	:	15 marks
Continuous Assessment	:	30 marks
Internal Test (Immediately before the second series test)	:	30 marks

**End Semester Examination Pattern:** The following guidelines should be followed regarding award of marks

(a) Preliminary work	: 15 Marks
(b) Implementing the work/Conducting the experiment	: 10 Marks
(c) Performance, result and inference (usage of equipment and trouble shooting)	: 25 Marks
(d) Viva voce	: 20 Marks
(e) Record	: 5 Marks



General instructions: Practical examination to be conducted immediately after the second series test covering entire syllabus given below. Evaluation is a serious process that is to be conducted under the equal responsibility of both the internal and external examiners. The number of candidates evaluated per day should not exceed 20. Students shall be allowed for the University examination only on submitting the duly certified record. The external examiner shall endorse the record.

### LIST OF EXPERIMENTS

1. Characteristics of SCR
2. Characteristics of MOSFET
3. Characteristics of IGBT
4. R and RC firing scheme for SCR control
5. Study of step up and step down chopper
6. Study of 1- $\Phi$  fully controlled bridge rectifier with RL load with SCR
7. Single-phase half bridge/full bridge inverter using power MOSFET/IGBT
8. Study of 1-phase full bridge voltage source inverter with R & RL loads.
9. Chopper controlled speed control of DC motor.
10. Study of speed control of stepper motor
11. Study of position control of Servomotor

#### Simulation experiments

1. study of 3- $\Phi$  full controlled bridge rectifier
2. V control and V/f control of Induction motor using PWM Inverter.
3. v/f control of chopper motor drive using VFD(MATLAB/Hardware)
4. Simulation of a Brushless DC Motor Drive
5. Microcontroller based speed control of DC motor

#### Text Books:

1. Ned Mohan, Tore m Undeland, William P Robbins, "Power electronics converters applications and design", John Wiley and Sons.
2. Dubey G. K. "Power semiconductor control drives" Prentice Hall, Englewood Cliffs, New Jersey, 1989
3. E. G. Janardhanan, '*Special Electrical Machines*' PHI Learning Private Limited.
4. NAGARATH.I.J & KOTHARI .D.P,"Electrical machines", Tata McGraw-Hill.1998

#### References:

1. VEDAM SUBRAMANIAM "Electric drives (concepts and applications)", Tata McGraw-Hill.2001



2. R. Krishnan, '*Permanent magnet synchronous and Brushless DC motor Drives*', CRC Press.
3. Bimal K. Bose "Modern power electronics and AC drives" Pearson Education, Asia 2003
4. Irvin L. Kosow. '*Electrical Machinery and Transformers*', Oxford Science Publications.
5. T. J. E. Miller, '*Brushless PM and Reluctance Motor Drives*'. C. Larendon Press, Oxford.
6. Dr. P. S. Bimbra "Power electronics", Khanna publishers
7. Vedam Subrahmanyam, "Electric Drives", MC Graw Hill Education, New Delhi
8. Pillai S. K. "A first course on electric drives", Wiley Eastern Ltd, New Delhi
9. Theodore Wildi, '*Electric Machines, Drives and Power Systems*', Prentice Hall India Ltd.
10. M.D. SINGH, K.B.KHANCHANDANI, "Power electronics," Tata McGraw-Hill. 1998
11. N. K. De, P. K. Sen "Electric drives" Prentice Hall of India 2002





<b>MCN401</b>	<b>INDUSTRIAL SAFETY ENGINEERING</b>	<b>Category</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>CREDIT</b>
		<b>OEC</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>3</b>

**Preamble:** The course is intended to give knowledge of various safety management principles, various safety systems, various machine guarding devices, hazard identification techniques, energy sources, systems & applications and the need in the present context. Learners will be able to compare different hazard identification tools and choose the most appropriate based on the nature of industry. It aims to equip students in working with projects and to take up research work in connected areas

**Prerequisite:** Nil

**Course Outcomes:** After the completion of the course the student will be able to

<b>CO1</b>	Describe the theories of accident causation and preventive measures of industrial accidents. (Cognitive Knowledge level: <b>Understand</b> )
<b>CO2</b>	Explain about personal protective equipment, its selection, safety performance & indicators and importance of housekeeping. (Cognitive Knowledge level: <b>Understand</b> )
<b>CO3</b>	Explain different issues in construction industries. (Cognitive Knowledge level: <b>Understand</b> )
<b>CO4</b>	Describe various hazards associated with different machines and mechanical material handling. (Cognitive Knowledge level: <b>Understand</b> )
<b>CO5</b>	Utilise different hazard identification tools in different industries with the knowledge of different types of chemical hazards. (Cognitive Knowledge level: <b>Apply</b> )



### Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2				2	2	2				1
CO2	2	1	2		1	1	1	1				1
CO3	2	2	2		1	1	1	1	1	1		1
CO4	2	2	2		1	1	1	1	1	1		1
CO5	2	2	2	1	1	1	1	1	1	1		1

Abstract POs defined by National Board of Accreditation			
PO1	Engineering Knowledge	PO7	Environment and Sustainability
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### Assessment Pattern

	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			



**Mark distribution:**

<b>Total Marks</b>	<b>CIE Marks</b>	<b>ESE Marks</b>	<b>ESE Duration</b>
<b>150</b>	<b>50</b>	<b>100</b>	<b>3 hours</b>

**Continuous Internal Evaluation Pattern:**

Attendance : 10 marks

Continuous Assessment - Test : 25 marks

Continuous Assessment - Assignment : 15 marks

**Internal Examination Pattern:**

Each of the two internal examinations has to be conducted out of 50 marks. First series test shall be preferably conducted after completing the first half of the syllabus and the second series test shall be preferably conducted after completing remaining part of the syllabus. There will be two parts: Part A and Part B. Part A contains 5 questions (preferably, 2 questions each from the completed modules and 1 question from the partly completed module), having 3 marks for each question adding up to 15 marks for part A. Students should answer all questions from Part A. Part B contains 7 questions (preferably, 3 questions each from the completed modules and 1 question from the partly completed module), each with 7 marks. Out of the 7 questions, a student should answer any 5.

**End Semester Examination Pattern:**

There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which a student should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.



## **Syllabus**

### **MCN401- Industrial Safety Engineering (35 hrs)**

#### **Module I (safety introduction- 5 hrs)**

Need for safety. Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents. Theories of accident causation. Safety organization- objectives, types, functions, Role of management, supervisors, workmen, unions, government and voluntary agencies in safety. Safety policy. Safety Officer-responsibilities, authority. Safety committee-need, types, advantages.

#### **Module II (Personal protection in work environment- 7 hrs)**

Personal protection in the work environment, Types of PPEs, Personal protective equipment- respiratory and non-respiratory equipment. Standards related to PPEs. Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, activity rate. Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping. Work permit system- objectives, hot work and cold work permits. Typical industrial models and methodology. Entry into confined spaces.

#### **Module III (safety issues in construction- 7 hrs)**

Introduction to construction industry and safety issues in construction Safety in various construction operations – Excavation and filling – Under-water works – Under-pinning & Shoring – Ladders & Scaffolds – Tunneling – Blasting – Demolition – Confined space – Temporary Structures. Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety. Relevance of ergonomics in construction safety. Ergonomics Hazards - Musculoskeletal Disorders and Cumulative Trauma Disorders.

#### **Module IV (safety hazards in machines- 8 hrs)**

Machinery safeguard-Point-of-Operation, Principle of machine guarding -types of guards and devices. Safety in turning, and grinding. Welding and Cutting-Safety Precautions of Gas



welding and Arc Welding. Material Handling-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking. Material Handling equipment-operation & maintenance. Maintenance of common elements-wire rope, chains slings, hooks, clamps. Hearing Conservation Program in Production industries.

### **Module V (hazard identification and analysis- 8 hrs)**

Hazard and risk, Types of hazards –Classification of Fire, Types of Fire extinguishers, fire explosion and toxic gas release, Structure of hazard identification and risk assessment. Identification of hazards: Inventory analysis, Fire and explosion hazard rating of process plants - The Dow Fire and Explosion Hazard Index, Preliminary hazard analysis, Hazard and Operability study (HAZOP)) – methodology, criticality analysis, corrective action and follow-up. Control of Chemical Hazards, Hazardous properties of chemicals, Material Safety Data Sheets (MSDS).

### **Text Books:**

1. R.K Jain (2000) Industrial Safety, Health and Environment management systems, Khanna Publications.
2. Paul S V (2000), Safety management System and Documentation training Programme handbook, CBS Publication.
3. Krishnan, N.V. (1997). *Safety management in Industry*. Jaico Publishing House, New Delhi.
4. John V. Grimaldi and Rollin H.Simonds. (1989) *Safety management*. All India Traveller Book Seller, Delhi.
5. Ronald P. Blake. (1973). *Industrial safety*. Prentice Hall, New Delhi.
6. Alan Waring. (1996). *Safety management system*. Chapman & Hall, England.
7. Vaid, K.N., (1988). Construction safety management. National Institute of Construction Management and Research, Mumbai.



8. AIChE/CCPS. (1992). *Guidelines for Hazard Evaluation Procedures*. (second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York.

### **Course Level Assessment Questions:**

#### **Course Outcome 1 (CO1):**

1. Which are the various accident causation theories? Explain.
2. Define terms: Accident, Reportable accident, Dangerous occurrence.

#### **Course Outcome 2 (CO2):**

1. Discuss different types of personal protective equipment
2. Discuss about how to compare the safety performance of two industries.
3. Discuss the significance of work permit system in accident prevention.

#### **Course Outcome 3 (CO3):**

1. Distinguish ladders and scaffolds along with their safety features.
2. Discuss the safety requirement for a confined space entry.
3. Explain the important provision in the National Building Code.

#### **Course Outcome 4 (CO4):**

1. Explain the various principles used in machine guarding.
2. Explain the issues in mechanical material handling.

#### **Course Outcome 5 (CO5):**

1. Selection of different types of fire extinguishers accordance to type of fire.
2. Conduct a HAZOP study for a batch reactor of your choice.
3. Determine different types of Chemical hazards associated with industries



**MODEL QUESTION PAPER**  
**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**  
**VII SEMESTER B. TECH DEGREE EXAMINATION**  
**MCN401- INDUSTRIAL SAFETY ENGINEERING**

**Maximum: 100 Marks**

**Duration: 3 hours**

**PART A**

Answer all questions, each question carries 3 marks

1. Differentiate Unsafe act and Unsafe conditions with suitable examples
2. Discuss the significance of a safety committee in improving the safety performance of an industry
3. Which are the different types of permit? Highlight its suitability.
4. Which are five 'S' used in housekeeping?
5. List the various safety features of ladders.
6. How safety of the workers can be ensured during a demolition operations.
7. Which are the hazards associated with manual material handling?
8. Discuss the safety issues of Gas welding operations.
9. Differentiate Hazard and Risk.
10. Why MSDS is mandatory for chemical products.

(10 X 3 = 30 Marks)

**PART B**

Answer one full question from each module

**Module 1**

11. List the various accident causation theories and explain any one in details. (14 Marks)
12. a) Discuss the significance of safety policy in reducing the accidents. (4 Marks)  
b) Safety and productivity are the two sides of a coin'. Are you agreeing with this statement? Explain with your arguments. (10 Marks)

**Module 2**

13. a) Classify the personal protective equipment. List the suitability of at least fifteen types of PPEs. (10 Marks)



b) How will you calculate the frequency rate? Explain with an example. (4 Marks)

14. a) How will you compare the safety performance of two industries? Explain with suitable example. (10 Marks)

b) Which are the steps to be followed in confined space entry to protect the life of a worker. (4 Marks)

### **Module 3**

15. Discuss the safety and fire protection facilities required for a high rise building as per National building code. (14 Marks)

16. a) Identify the various hazards during the different stages of building construction. (7 Marks)

b) Discuss the important types of ergonomic hazards associated with industries. (7 Marks)

### **Module 4**

17. Which are the various types of machine guarding devices used in industries. Discuss the suitability of each machine guarding device. (14 Marks)

18. With suitable sketches briefly explain seven defects of wire ropes. (14 Marks)

### **Module 5**

19. What is Hazard and Operability Analysis? How do you conduct a HAZOP analysis? (14 Marks)

20. Discuss about different types of chemical hazards. (14 Marks)



### Course Contents and Lecture Schedule

No.	Topic	No. of Lectures/ Tutorials L-T
1	<b>Introduction to Industrial safety Engineering</b>	
1.1	Need for safety. Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence. Reportable accidents	1
1.2	Theories of accident causation. Safety organization.	2
1.3	Role of management, supervisors, workmen, unions, government and voluntary agencies in safety.	3
1.4	Safety Officer-responsibilities, authority.	4
1.5	Safety committee-need, types, advantages.	5
2	<b>Personal protection in the work environment</b>	
2.1	Types of PPEs, respiratory and non-respiratory equipment.	6
2.2	Standards related to PPEs	7
2.3	Monitoring Safety Performance: Frequency rate, severity rate	8,
2.4	Monitoring Safety Performance: incidence rate, activity rate.	9
2.5	Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping.	10
2.6	Work permit system- objectives, hot work and cold work permits.	11
2.7	Typical industrial models and methodology. Entry into confined spaces.	12
3	<b>Introduction to construction industry and safety</b>	
3.1	Excavation and filling – Under-water works – Under-pinning & Shoring	13
3.2	Ladders & Scaffolds – Tunneling	14
3.3	Blasting –Demolition – Confined space	15
3.4	Familiarization with relevant Indian Standards and the National Building Code provisions on construction safety.	16
3.5	Relevance of ergonomics in construction safety.	17
3.6	Ergonomics Hazards	18
3.7	Musculoskeletal Disorders and Cumulative Trauma Disorders.	19
4	<b>Machinery safeguard</b>	



4.1	Point-of-Operation, Principle of machine guarding -	20
4.2	Types of guards and devices.	21
4.3	Safety in Power Presses, primary & secondary operations - shearing -bending - rolling – drawing.	22
4.4	Safety in turning, boring, milling, planning and grinding.	23
4.5	Welding and Cutting-Safety Precautions of Gas welding and Arc Welding,	24
4.6	Cutting and Finishing.	25
4.7	Material Handling-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking.	26
4.8	Material Handling equipment-operation & maintenance. Maintenance of common elements-wire rope, chains slings, hooks, clamps	27
5	<b>Hazard identification</b>	
5.1	Hazard and risk, Types of hazards – Classification of Fire	28
5.2	Types of Fire extinguishers fire, explosion and toxic gas release.	29
5.3	Inventory analysis, Fire and explosion hazard rating of process plants -	30
5.4	The Dow Fire and Explosion Hazard Index.	31
5.5	Preliminary hazard analysis, Hazard and Operability study (HAZOP)	32
5.6	Chemical hazard- Classifications, Control of Chemical Hazards.	33
5.7	Hazardous properties of chemicals	34
5.8	Material Safety Data Sheets (MSDS).	35



RAT445	AI FOR ROBOTICS	CATEGORY	L	T	P	CREDIT
		OEC	2	1	0	3

**Preamble:** This course will introduce selected topics in Artificial Intelligence (AI) with a focus on Robotics. Develop a basic understanding of the building blocks of AI as presented in terms of intelligent agents: Search, Knowledge representation, inference, logic, and learning. Introduce concepts of expert systems and machine learning.

**Prerequisite:** Nil

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Identify and solve problems using appropriate AI methods.
CO 2	Formalize a given problem in the language/framework of different AI methods
CO 3	Describe the learning methods adopted in AI
CO 4	Perform an empirical evaluation of different algorithms on a problem formalization
CO 5	Interpret various applications of AI in Robotic Applications

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	2	1										3
CO 2	2	1										3
CO 3	2	1										3
CO 4	3	2	2									3
CO 5	3	2	2									3

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours

**Continuous Internal Evaluation Pattern:**

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Define the concept of Agent based Intelligence representation
2. Compare and contrast different types of search strategies

**Course Outcome 2 (CO2):**

1. What is planning and need of planning?
2. What is ontology in AI?

**Course Outcome 3 (CO3):**

1. What is Bayesian networks?
2. Explain different decision networks.

**Course Outcome 4 (CO4):**

1. Explain supervised, unsupervised and reinforcement learning with examples
2. Give a short note on Expert systems in AI.

**Course Outcome 5 (CO5):**

1. Ethical issues of AI in Robotics
2. Explain how robotics is a technology for future.



**SYLLABUS****Module I (7 Hours)****Introduction and Problem solving**

History, state of the art, Need for AI in Robotics. Thinking and acting humanly, intelligent agents, structure of agents.

Solving problems by searching –Informed search and exploration–Constraint satisfaction problems– Adversarial search,

**Module II (7 Hours)****Knowledge representation and Planning**

knowledge representation, first order logic.

Planning with forward and backward State space search – Partial order planning – Planning graphs– Planning with propositional logic – Planning and acting in real world.

**Module III(8 Hours)****Reasoning and Decision making**

Uncertainty – Probabilistic reasoning, Dynamic Bayesian Networks;  
Basis of utility theory, decision theory, sequential decision problems;

**Module IV(7 Hours)****Learning and Expert System**

Forms of learning – Knowledge in learning – Statistical learning methods –reinforcement learning, communication, perceiving and acting, Probabilistic language processing, and perception.

**Module V (6 Hours)****AI In Robotics and Applications**

Robotic perception, localization, mapping- configuring space, planning uncertain movements, dynamics and control of movement, Ethics and risks of artificial intelligence in robotics

**Text Books**

1. Stuart Russel, Peter Norvig, “Artificial Intelligence: A modern approach” Pearson Education, India,2016
2. Kevin Murphy, Machine Learning; A Probabilistic Perspective (MLAPP), MIT Press,2012



3. Negnevitsky, M, “Artificial Intelligence: A guide to Intelligence Systems”, Harlow: Addison Wesley, 2002
4. Introduction to Robotics by S K Saha, McGraw Hill Education
5. Introduction to Autonomous Mobile Robots, Siegwart, Roland, Cambridge, Mass. : MIT Press, 2nd ed.

### Reference Books

1. Robin Murphy, Robin R. Murphy, Ronald C. Arkin, “Introduction to AI Robotics” MIT Press, 2000
2. David Jefferis, “Artificial Intelligence: Robotics and Machine Evolution”, Crabtree Publishing Company, 1992
3. Fransis X. Govers, “Artificial Intelligence for Robotics”, Packt Publishing, 2018
4. Sicilliano, Khatib, “Handbook of Robotics”, Springer
5. John J. Craig, Introduction to Robotics – Mechanics and Control

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	<b>MODULE 1: Introduction to AI and Problem Solving</b>	
1.1	Foundations of AI, need for AI in Robotics., Thinking and acting humanly;	2
1.2	Intelligent agents: reactive, deliberative, goal-driven, utility driven and learning agent;	2
1.3	Problem solving: Solving problems by searching: Forward and backward, Informed search and exploration, Constraint satisfaction problems, Adversarial search;	3
2	<b>MODULE 2: Knowledge representation and Planning</b>	
2.1	Knowledge representations and reasoning: Ontologies, Foundations of knowledge representation and reasoning, representing and reasoning about objects, relations, events, actions, time and space. First order logic;	4
2.2	Planning with forward and backward state space search, Partial order planning, Construction and use of planning graphs, planning with propositional logic, Planning and acting in real world;	3
3	<b>MODULE 3: Reasoning and Decision making</b>	
3.1	Reasoning with uncertain knowledge: Probabilistic reasoning- Filtering and prediction,	2
3.2	Hidden Markov Models, connection to logic, Baye's rule, Dynamic	3



	Bayesian Networks	
3.3	Decision making: Basis of utility theory, decision theory, sequential decision problems, elementary game theory, sample applications;	3
4	<b>MODULE 4: Learning and Expert System</b>	
4.1	Forms of learning – Knowledge in learning – Statistical learning methods –reinforcement learning, communication, perceiving and acting, Probabilistic language processing, and perception;	4
4.2	Expert System: Introduction to expert system, Phases of expert system, characteristics of expert system and a case study;	3
5	<b>MODULE 5: AI in Robotics and its Applications</b>	
5.1	AI In Robotics: Robotic perception, localization, mapping- configuring space, planning uncertain movements, dynamics and control of movement, Ethics and risks of artificial intelligence in robotics;	3
5.2	Robotics and Its applications, DDD concept, Intelligent robots, Accuracy and repeatability of Robotics-Simple problems;	3

**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH -SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 445**

**Course Name: Artificial Intelligence For Robotics**

Max. Marks: 100

Duration: 3 Hours

**PART A**

**Answer all questions, each carries 3 marks.**

**Marks**

- |   |   |     |
|---|---|-----|
| 1 | Describe the PEAS description of a task environment.  | (3) |
| 2 | Explain depth bounded DFS (Depth Limited DFS) algorithm with an example.                            | (3) |
| 3 | Explain the concept of ontological engineering.   | (3) |
| 4 | How is description logic suitable to represent definitions and properties of categories of objects? | (3) |
| 5 | What are the problem areas of spatial reasoning?  | (3) |
| 6 | State value of perfect information and its properties   | (3) |
| 7 | Mention any five characteristics of expert system   | (3) |
| 8 | What is a near miss situation in case of Concept learning?  | (3) |



- 9 Differentiate between various types of drives used for robot system. (3)
- 10 Which design approach is similar to object-oriented design in DDD? List the common terms under design tool? (3)

### PART B

Answer any one full question from each module, each carries 14 marks.

#### MODULE I

- 11 a) What is an agent? Explain how it can interact with the environment? “Surely computers cannot be intelligent—they can do only what their programmers tell them.” Is the latter statement true, and does it imply the former? (9)
- b) For the activity named ‘Playing soccer’ give a PEAS description of the task environment and its characteristics (5)
- 12 a) The initial state and final state of an 8-puzzle problem is given below. Compute the heuristic function and solve using an informed search algorithm. (8)

Initial state

1	2	3
4	6	
7	5	8

Final state

1	2	3
4	5	6
7	8	

- b) What are the disadvantages of hill climbing approach? Is simulated annealing a better solution when compared to hill climbing? (6)

#### MODULE II

- 13 a) Using knowledge reasoning how can you reason the default information? (7)
- b) Explain knowledge-based agent. Give an example for a knowledge-based agent. Describe the environment of a knowledge –based agent. (7)
- 14 a) How is planning graph used for heuristic estimation? Explain (7)
- b) Represent the following sentences in first-order logic, using a consistent vocabulary (which you must define): (7)
- Some students took French in spring 2001.
  - Every student who takes French passes it.
  - Only one student took Greek in spring 2001.
  - The best score in Greek is always higher than the best score in French.
  - Every person who buys a policy is smart.



- f. No person buys an expensive policy.
- g. There is an agent who sells policies only to people who are not insured.

### MODULE III

- 15 a) How AI handles reasoning under uncertainty. Explain with example. (6)
- b) Explain the following with examples: (8)
  - (i) Forward reasoning
  - (ii) Non-Monotonic Reasoning
- 16 a) For the  $4 \times 3$  world shown in Figure, calculate which squares can be reached from (1,1) by the action sequence [Up, Up, Right, Right, Right] and with what probabilities. (7)  
Explain how this computation is related to the prediction task for a hidden Markov model.



- b) Illustrate decision networks with an example in detail. (7)

### MODULE IV

- 17 a) Differentiate between the various learning methods: neural networks, reinforcement learning and genetic algorithms. (7)
- b) What is an expert system? Draw the architecture and explain each block in detail. (7)
- 18 a) How forward chaining is different from backward chaining inference method? (5)
- b) Consider the following case, (9)

**"As per the law, it is a crime for an American to sell weapons to hostile nations. Country A, an enemy of America, has some missiles, and all the missiles were sold to it by Robert, who is an American citizen."**

Prove that **"Robert is criminal."** using Forward chaining algorithm.

### MODULE V



- 19 a) What is mobile robot localization? Why it is important? How the landmark is measured in robot localization? (8)
- b) Explain ethics and risks of artificial intelligence in robotics (6)
- 20 a) Describe basic structure of a robotic system with neat sketch. (7)
- b) Robots find applications not only in industry. Explain three non-industrial applications of Robots. (7)

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RAT435	INDUSTRIAL AUTOMATION	CATEGORY	L	T	P	CREDIT
		OEC	2	1	0	3

**Preamble:** The objective of this course is :

1. To provide the student with a general idea of the different automation technologies existing in the process industry.
2. To familiarize with various types of sensors and actuators and control valves which is an integral part of industrial automation
3. To learn the industrial automation and control systems.
4. To design systems using PLC.

**Course Outcomes:** After the completion of the course the student will be able to

<b>CO 1</b>	Understand the basic concepts of automation methodologies and industrial automation in robotics.
<b>CO 2</b>	Understand the working principle and applications of different types of sensors, actuators and control valves used in industry.
<b>CO 3</b>	Discuss different automated inspection methods.
<b>CO 4</b>	Explain the design aspects of modern CNC machines.
<b>CO 5</b>	Familiarize the concepts of PLC programming.

**Mapping of course outcomes with program outcomes**

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
<b>CO 1</b>	3	2										
<b>CO 2</b>	3	2	2									
<b>CO 3</b>	3	2										
<b>CO 4</b>	3	2										
<b>CO 5</b>	3	3	2									2

**Assessment Pattern**

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	25	25	30
Apply	15	15	60
Analyse			
Evaluate			
Create			

**Mark distribution**

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours



**Continuous Internal Evaluation Pattern:**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Explain how the automated flow lines are working?
2. Explain the architecture of the industrial automation system
3. Basic construction of a robot of any general application, say line follower robot.

**Course Outcome 2 (CO2):**

1. With neat diagrams explain different sensors like LVDT/strain gauge etc...
2. Compare the performance of different control valves
3. Advantages and disadvantages of pneumatic, hydraulic and electric actuators.

**Course Outcome 3 (CO3):**

1. How laser interferometer is used in inspection
2. The sensors used for thickness measurements

**Course Outcome 4 (CO4):**

1. Basic elements of CNC machines
2. Selection criteria for drives for CNC machines
3. Explain automation in CNC machines

**Course Outcome 5 (CO5):**

1. Explain the architecture of PLC system.
2. Simple PLC programs
3. Block diagrams of SCADA/ DCS and explanation of each module.



## **SYLLABUS**

### **Module I (7 Hours)**

**Introduction:** Automation overview-Requirement of automation systems - Architecture of Industrial Automation system.

**Automation methodologies:** Concept of Mechanization and Automation – Types of Automation Detroit type Automation-Automated flow lines- Fundamentals of Transfer Lines in material handling.

**Overview of Industrial automation using robots:** Basic construction and configuration of robot-Pick and place robot- Welding robot

### **Module II (7 Hours)**

**Sensors for automation:** Classification of position, proximity and motion sensors, inductive type, electromechanical switches, rotary position sensors – resolver, encoders, integrated motion systems- fundamental sensor methodologies, LVDT, RVDT, photo electric, capacitive, magnetic detectors, , linear potentiometer, strain gauges. Temperature measurements- Thermo couple, RTD and LM35 sensors, humidity measurements, smart sensors, Practical examples on design, selection and implementation of sensor systems, calibration of sensors.

### **Module III (7 Hours)**

**Sensor systems for automated inspection-** online inspection systems - laser interferometer, non-contact inspection methods. Automatic gauging and size control systems, thickness measurement, machine vision systems.

#### **Actuators of automation :**

Electrical, Hydraulic and pneumatic actuators and their comparison, Examples - use of Electrical, Hydraulic and pneumatic actuators in industrial automation.

**Elements of CNC systems:** servomotor and servo system design trends-stepper motors and controls, adaptive control, Drive systems- Automated tool changers and pallet changers-different types- Accessories, and selection of drives for CNC machines.

### **Module IV (7 Hours)**

**Pneumatic/Hydraulic Automation:** control valves – direction, pressure and flow, sequential control of single /multiple actuator systems, cascade and Karnaugh Veitch map methods, step-counter systems.

**Electro pneumatic/electro hydraulic automation:** Symbols: Basic electrical elements – relay, solenoid, timers, pneumatic – electrical converters

**Control Valves:** Valve equations, Valve characteristics- equal percentage, linear and ON-OFF control valves- Types of valves- Globe valve(construction)-Gate valve -butterfly valve-needle valve, shuttle valve.

### **Module V (7 Hours)**

**Automation Control:** Sequence control and programmable controllers – logic control and



sequencing elements, ladder diagram, PLC, programming of PLC- analog and digital I/Os, timers, counters, function blocks.

**Case studies on PLC ladder programming-** bottle filling system, packing system, car parking system.

External relays and contactors, Introduction to SCADA and DCS(only block diagram level).

### Text Books:

1. Automation, Production Systems and Computer Integrated Manufacturing, Groover M.P, Prentice – Hall Ltd., 1997.
2. Programmable Logic Controllers – Principles and Applications, John. W. Webb Ronald A Reis, Fourth edition, Prentice Hall Inc., New Jersey, 1998.
3. Industrial Instrumentation and Control By. S.K. Singh The McGraw Hill Companies

### References:

1. Computer Control of Manufacturing Systems YoramKoren, Tata McGraw-Hill Edition 2005.
2. CNC Machines, Radhakrishnan P., New Central Book Agency, 1992.
3. Mechatronics: A Multidisciplinary Approach, 4/E, W. Bolton. Pearson Education India.
4. Mechatronics, HMT, Tata McGraw-Hill, 1998.
5. Standard Handbook of Industrial Automation, Considine D M C & Considine G D C, Chapman and Hall, NJ, 1986.
6. Pneumatic Control for Industrial Automationl, Peter Rohner& Gordon Smith, John Wiley and Sons, 1987.
7. Industrial control handbook, Parr, Newnem
8. Process Control Instrumentation Technology By. C.D. Johnson, PHI.
9. Principles of Measurement Systems (English, Paperback, Bentley John P.), Pearson

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	<b>MODULE 1</b>	
1.1	<b>Introduction:</b> Automation overview, Requirement of automation systems, Architecture of Industrial Automation system	2
1.2	<b>Automation methodologies:</b> Concept of Mechanization and Automation – Types of Automation Detroit type Automation, Automated flow lines, Fundamentals of Transfer Lines.	3
1.3	<b>Overview of Industrial automation using robots:</b> Basic construction and configuration of robot, Pick and place robot, Welding robot.	2
2	<b>MODULE 2</b>	
2.1	<b>Sensors and actuators for automation:</b> Classification of position and motion sensors, inductive type, electromechanical switches, rotary position sensors – resolver, encoders, integrated motion systems.	2



2.2	<b>fundamental sensor methodologies</b> , LVDT, RVDT, photo electric, capacitive, magnetic detectors, , linear potentiometer, strain gauges	3
2.3	<b>Temperature measurements</b> - Thermo couple, RTD and LM35 sensors, smart sensors, Practical examples on design, selection and implementation of sensor systems, calibration of sensors.	2
3	<b>MODULE 3</b>	
3.1	<b>Sensor systems for automated inspection</b> - online inspection systems, laser interferometer, non-contact inspection methods. Automatic gauging and size control systems, thickness measurement, machine vision systems.	2
3.2	<b>Actuators of automation :</b> Electrical, Hydraulic and pneumatic actuators and their comparison, Examples - use of Electrical, Hydraulic and pneumatic actuators in industrial automation.	2
3.3	<b>Elements of CNC systems:</b> servomotor and servo system design trends, stepper motors and controls, adaptive control, Drive systems. Automated tool changers and pallet changers-different types . Accessories, and selection of drives for CNC machines.	3
4	<b>MODULE 4</b>	
4.1	<b>Pneumatic/Hydraulic Automation:</b> control valves – direction, pressure and flow, sequential control of single /multiple actuator systems, cascade and Karnaugh Veitch map methods, step-counter systems.	3
4.2	<b>Electro pneumatic/electro hydraulic automation:</b> Symbols: Basic electrical elements – relay, solenoid, timers, pneumatic – electrical converters P to I and I to P converters.	2
4.3	<b>Control Valves:</b> Valve equations, Valve characteristics- equal percentage, linear and ON-OFF control valves- Types of valves- Globe valve(construction)-Gate valve -butterfly valve-needle valve, shuttle valve.	2
5	<b>MODULE 5</b>	
5.1	<b>Automation Control:</b> Sequence control and programmable controllers – logic control and sequencing elements, ladder diagram, PLC, programming of PLC- analog and digital I/Os, timers, counters, function blocks.	3
5.2	<b>Case studies on PLC ladder programming</b> - bottle filling system, packing system, car parking system.	2
5.2	external relays and contactors, Introduction to SCADA and DCS(only block diagram level).	2



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 435**

**Course Name: INDUSTRIAL AUTOMATION**

Max. Marks: 100

Duration: 3 Hours

**PART A**

**Answer all questions, each carries 3 marks.**

**Marks**

- |    |   |      |
|----|---|------|
| 1  | What is the need for industrial automation systems.                                     | (3 ) |
| 2  | Explain the role of automated flow lines in material handling.                          | (3 ) |
| 3  | Compare smart sensors and conventional sensors  | (3 ) |
| 4  | Discuss the reasons for residual effects in LVDT, suggest a solution for it.            | (3 ) |
| 5  | What are the two existing applications of hydraulic actuators                           | (3 ) |
| 6  | Detail the role of computer vision in inspection.                                       | (3 ) |
| 7  | How the solenoid functions as a relay.  | (3 ) |
| 8  | Explain valve characteristics   | (3 ) |
| 9  | Draw the ladder diagram for the following logic functions.<br>$F(A,B,C,D)=\{1,4,8,15\}$ | (3 ) |
| 10 | Differentiate between relays and contractors.   | (3 ) |

**PART B**

**Answer any one full question from each module, each carries 14 marks.**

**MODULE 1**

- |    |   |     |
|----|---|-----|
| 11 | a) With a neat sketch explain the different types of automated transfer lines used in the industry. | (7) |
|    | b) How a welding system based on robotic action is developed.                                       | (7) |
| 12 | a) With a neat diagram explain the basic configuration of a robotic system                          | (6) |
|    | b) With a neat diagram explain the architecture of industrial instrumentation systems.              | (8) |



- 13 a) Explain the working of an optical absolute encoder. How the number of tracks and sectors of absolute encoder is related to the resolution of the encoder? (6)
- b) Explain the merits, demerits and applications of LVDT. An LVDT produces an RMS voltage of 2.5V for a displacement of 4mm. Calculate the sensitivity of the LVDT. (8)
- 14 a) Derive an expression for Gauge factor for a resistance strain gauge. A strain gauge has a resistance of  $100\Omega$  and a gauge factor of 2 and bounded to a structure under tensile stress. Determine the strain experienced on the structure, if the change in resistance is given as  $0.15\Omega$ . (8)
- b) Highlight the difference between thermocouples and RTD in terms of application in measurement (6)

### MODULE III

- 15 a) Sketch and explain the working of a stepper motor. (7)
- b) With neat sketches explain adaptive control of machine tools. (7)
- 16 a) Explain the role of different types of actuators in industrial automation (8)
- b) With neat sketches explain different sensors for inspection (6)

### MODULE IV

- 17 a) Design a pneumatic circuit for A+B+ B-A-.sequencing operation using the Karnaugh-Veitch method. (8)
- b) Explain with neat diagrams the construction of a globe valve. (6)
- 18 a) With neat sketches explain the basic electrical devices used in electro-pneumatic control. (8)
- b) Explain the design considerations of proportional control valve. (6)

### MODULE V

- 19 a) Design PLC ladder program for operating a coffee vending machine. (8)
- b) Two motors are to be controlled in a sequence. The second motor starts 30 seconds after the starting of first motor by a push switch. Develop a PLC ladder diagram for the following cases and describe the circuit. (6)
- Case (A): Only one motor operates at a time.
- Case (B): Second motor gets off together after 50 seconds
- Case( C ): first motor gets off after 20 seconds time



- 20 a) Design PLC based automated car parking barrier system with suitable sensors (7) and actuators. Design the ladder logic for the PLC so that the system collects coins for parking cars and the barrier prevents the entry of one vehicle for a single coin collection.
- b) Explain how different types of I/O devices interfaced to PLC (7)

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<b>RAT425</b>	<b>BASICS OF MOBILE ROBOTICS</b>	<b>CATEGORY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>CREDIT</b>
		<b>OEC</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>3</b>

**Preamble:** This course introduces the student with the computational fundamentals behind the design and control of autonomous robots. Mobile robots fall under the category of autonomous robots in the sense that they take decisions in response to their surroundings. This course takes the students through all the important concepts that is required to build an autonomous robot.

**Course Outcomes:** After the completion of the course the student will be able to

<b>CO 1</b>	Explain the challenges involved in robotic locomotion and the kinematics of robots
<b>CO 2</b>	Identify the appropriate sensors and actuators for a particular robotic application
<b>CO 3</b>	Describe the principles behind extracting information using visual techniques
<b>CO 4</b>	Explain the design of control loops that determine robotic behaviour and mapping techniques used by the robots to understand its surroundings
<b>CO 5</b>	Discuss and apply different algorithms for Localization and grasping

#### Mapping of course outcomes with program outcomes

	<b>PO 1</b>	<b>PO 2</b>	<b>PO 3</b>	<b>PO 4</b>	<b>PO 5</b>	<b>PO 6</b>	<b>PO 7</b>	<b>PO 8</b>	<b>PO 9</b>	<b>PO 10</b>	<b>PO 11</b>	<b>PO 12</b>
<b>CO 1</b>	2	2										2
<b>CO 2</b>	2		2									2
<b>CO 3</b>	3		2		2							2
<b>CO 4</b>	3	2	3	2	2							2
<b>CO 5</b>	3	2	3		2							2

#### Assessment Pattern

<b>Bloom's Category</b>	<b>Continuous Assessment Tests</b>		<b>End Semester Examination</b>
	<b>1</b>	<b>2</b>	
Remember	10	10	10
Understand	30	30	60
Apply	10	10	30
Analyse			
Evaluate			
Create			

#### Mark distribution

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours



**Continuous Internal Evaluation Pattern:**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Explain the Cartesian DoFs of an object in motion
2. Derive the forward kinematic of a robotic arm and find its Jacobian
3. Use of inverse Jacobian techniques to determine the inverse kinematics

**Course Outcome 2 (CO2):**

1. Explain the design of parallel gripper and scissor like gripper
2. Use of manipulability analysis to obtain the best configuration to reach a desired pose
3. Determine the kind of electric motor that is suitable for a robotic arm that need maximum strength and minimum weight. Justify your selection
4. Identify a sensor that can be used in a robotic application which will help you to determine the pose of the robot. Explain its working principle

**Course Outcome 3 (CO3):**

1. Identify and Explain a smoothening algorithm to smoothen small amounts of noise while maintaining the edges
2. Explain a method of extracting the metric information from an image
3. Explain the importance of lines as a feature in mobile robotics. Discuss mechanisms to extract lines from an image.

**Course Outcome 4 (CO4)**

1. Explain the use of a simple perceptron training algorithm to find a separating hyperplane for simple data
2. Explain the steps involved to implement a pick and place robot.
3. Discuss in detail about the techniques that can be used to overcome uncertainty in localization and sensing

**Course Outcome 5 (CO5):**

1. Determine the shortest path from one point to another point in a connected graph using Dijkstra's algorithm
2. Explain the sampling based path planning and its significance for mobile robots
3. Discuss the important steps for grasping by a simple gripper with 2 DoF using a stereo camera as the perception device.



**SYLLABUS****Module I: (7 Hours)**

**Locomotion, manipulation and their representation:** Static and dynamic stability – Degrees of freedom – Coordinate systems and Frames of Reference – Matrix notation – Mapping from one frame to another – Concatenation of Transformations

**Kinematics:** Forward Kinematics – The Denavit-Hartenberg notation - Inverse Kinematics – Differential Kinematics – Inverse Differential Kinematics

**Module 2 (7 Hours)**

**Forces:** Statics – Kineto- Static Duality – Manipulability Ellipsoid in Velocity Space, Force Space, Manipulability considerations

**Grasping:** The theory of grasping – Simple Grasping Mechanisms – 1-DoF scissor like gripper, Parallel Jaw, 4-bar linkage parallel gripper, Multi-fingered hands

**Actuators:** Electric Motors - Hydraulic and pneumatic actuators – Safety Considerations

**Sensors:** Terminology – Sensors that measure the robot's joint configuration – sensors that measure ego-motion, measuring force – Sensors to measure distance – Sensors to measure global pose

**Module 3 (7 Hours)**

**Vision:** Images as two dimensional signals – Translation of Signal to information - Basic image operations – Extracting structure from Vision – Computer vision and Machine learning

**Feature Extraction:** Feature detection as an information-reduction problem – Features – Line recognition – Scale-invariant feature transforms – Feature detection and Machine learning

**Module 4 (7 Hours)**

**Artificial Neural Network:** The simple perception – Activation function - Simple perceptron to multi layer neural network – Single outputs to higher dimensional data – Objective Functions and optimization

**Task Execution:** Reactive Control – Finite State Machines – Hierarchical Finite State Machine- Behaviour Trees – Mission Planning

**Mapping:** Map representations – Iterative Closest point for sparse mapping – Octomap: dense mapping of voxels – RGB-D mapping : dense mapping of surfaces

**Module 5 (7 Hours)**

**Path Planning:** The configuration space – Graph based planning algorithms – Sampling based path planning – Planning at different length scales – Coverage path planning

**Manipulation:** Non-Prehensile Manipulation – Choosing the right grasp – Pick and Place – Peg-in-hole problems



**Localization:** Markov Localization – Perception Update – Action Update – Case study  
Markov localization on a Topological Map – The Bayes Filter – Bayes filter on a grid

**Simultaneous Localization and Mapping(SLAM):** Introduction – The Covariance Matrix – EKF SLAM

### Text Books

1. Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators and Algorithms, Nikolaus Correll, Bradley Hayes, Christoffer Heckman and Alessandro Roncone,, The MIT Press

### Reference Books

1. Introduction to Mobile Robot Control, Spyros G. Tzafestas , Elsevier, USA, 2014.
2. Introduction to Autonomous Mobile Robots , R Siegwart, IR Nourbakhsh, D Scaramuzza, , MIT Press, USA, 2011.
3. Sensors for mobile robot ,HR Everett, CRC Press
4. <https://open.umn.edu/opentextbooks/textbooks/316>

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
<b>1</b>	<b>Module I</b>	
1.1	Introduction, Static and dynamic stability,Degrees of freedom	1
1.2	Coordinate systems and Frames of Reference, Matrix notation	1
1.3	Mapping from one frame to another, Concatenation of Transformations	1
1.4	Forward Kinematics, The Denavit-Hartenberg notation	1
1.5	Inverse Kinematics	1
1.6	Differential Kinematics, Inverse Differential Kinematics	2
<b>2</b>	<b>Module II</b>	
2.1	Statics , Kinetostatics Duality	1
2.2	Manipulability Ellipsoid in Velocity Space, Force Space, Manipulability considerations	1
2.3	The theory of grasping, Simple Grasping Mechanisms	1
2.4	Electric Motors	1
2.5	Hydraulic and pneumatic actuators – Safety Considerations	1
2.6	Terminology – Sensors that measure the robot's joint configuration	1
2.7	sensors that measure ego-motion, measuring force	1
2.8	measuring force – Sensors to measure distance – Sensors to measure global pose	1
<b>3</b>	<b>Module 3</b>	
3.1	Images as two dimensional signals, Translation of Signal to information	1
3.2	Basic image operations	1



3.3	Extracting structure from Vision – Computer vision and Machine learning	1
3.4	Feature detection as an information-reduction problem – Features	1
3.5	Line recognition	1
3.6	Scale-invariant feature transforms, – Feature detection and Machine learning	2
<b>4</b>	<b>Module 4</b>	
4.1	The simple perception, Activation function	1
4.2	Simple perceptron to multi layer neural network	1
4.3	– Single outputs to higher dimensional data, Objective Functions and optimization	1
4.4	Reactive Control, Finite State Machines, Hierarchical Finite State Machine	1
4.5	Behaviour Trees, Mission Planning	1
4.6	Map representations, Iterative Closest point for sparse mapping An error model for odometric position estimation,	1
4.7	Octomap: dense mapping of voxels, – RGB-D mapping : dense mapping of surfaces	1
<b>5</b>	<b>Module 5</b>	
5.1	The configuration space – Graph based planning algorithms	1
5.2	Sampling based path planning	1
5.3	Planning at different length scales – Coverage path planning	1
5.4	Non-Prehensile Manipulation – Choosing the right grasp	1
5.5	Pick and Place – Peg-in-hole problems	1
5.6	Markov Localization – Perception Update – Action Update – Case study Markov localization on a Topological Map	1
5.7	The Bayes Filter – Bayes filter on a grid, SLAM - Introduction – The Covariance Matrix – EKF SLAM	1



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 425**

**Course Name:**

**BASICS OF MOBILE ROBOTICS**

Max. Marks: 100

Duration: 3 Hours

**PART A**

Answer all questions, each carries 3 marks.

Marks

- |    |  |     |
|----|--|-----|
| 1  | Is a car statically or dynamically stable? Compare it against the stability of a motorcycle  | (3) |
| 2  | Consider a differential wheel robot with a broken motor, i.e., one of the wheels cannot be actuated anymore. Derive the forward kinematics of this platform. Assume the right motor is broken. | (3) |
| 3  | Why are singular configuration dangerous for the robot and its surroundings  | (3) |
| 4  | Why does the bandwidth of a ultrasound based distance sensor decrease significantly when increasing its dynamic range, but that of a laser range scanner does not for typical operation?       | (3) |
| 5  | Explain the use of Gaussian filter in image processing?  | (3) |
| 6  | What are scale invariant feature transforms  | (3) |
| 7  | What is a Perceptron? How does it classify the data?   | (3) |
| 8  | What do you mean by training a perceptron? Explain the steps involved in training a perceptron   | (3) |
| 9  | List out the important steps involved in accomplishing a pick and place process by a robot   | (3) |
| 10 | Explain the A* algorithm used for path planning  | (3) |

**PART B**

Answer any one full question from each module, each carries 14 marks.

**MODULE1**

- |    |   |     |
|----|---|-----|
| 11 | a) Assume two coordinate systems that are co-located in the same origin, but rotated around the z-axis by the angle $\alpha$ . Derive the rotation matrix from one coordinate system into the other and verify that each entry of this matrix is indeed the scalar product of each basis vector of one coordinate system with every other basis vector in the second coordinate system. | (8) |
|    | Consider a tri-cycle with two independent standard wheels in the rear and the steerable, driven front-wheel. Choose a suitable coordinate system and use $\phi$ as the steering wheel angle and wheel-speed $\omega'$ . Provide forward and inverse kinematics.   | (6) |
| 12 | a) Write out the entries of a rotation matrix ${}^A_B R$ assuming basis vectors $X_A, Y_A, Z_A$ , and $X_B, Y_B, Z_B$ .   | (6) |
|    | b) Write out the entries of rotation matrix ${}^B_A R$ .  |     |



- b) Consider two coordinate systems  $\{B\}$  and  $\{C\}$ , whose orientation is given (8)  
 by the rotation matrix  ${}^C_R{}^B$  and have distance  ${}^B_P{}^C$ . Provide the homogenous  
 transform  ${}^C_T{}^B$  and its inverse  ${}^B_T{}^C$ .

## MODULE II

- 13 a) With neat diagram, explain the working of a two finger parallel jaw gripper (7)  
 b) Given a laser scanner with an angular resolution of 0.01 rad and a maximum (7)  
 range of 5.6 meters, what is the minimum range  $d$  a robot needs to have from  
 an object of 1cm width to definitely sense it, i.e., hit it with at least one of  
 its rays? You can approximate the distance between two rays with the arc  
 length.
- 14 a) Explain the concept of Kineto-Statics Duality (5)  
 b) Discuss the method to analyse manipulator performance for a given joint using (9)  
 the duality property.

## MODULE III

- 15 a) Discuss in detail on how to extract structure from a visual image (14)  
 16 a) Discuss the line fitting using least square method. Explain the use of this (7)  
 algorithm in robotics  
 b) Explain the RANSAC algorithm with an example (7)

## MODULE IV

- 17 a) Discuss in detail the role of CNN for processing images. Elaborate on the (14)  
 various techniques used during the process and the need for them  
 18 a) What is a reactive control in autonomous robots? Explain its limitations. (6)  
 b) How is finite state machines useful in the design of mobile robots (8)

## MODULE V

- 19 a) Explain the Dijkstra's algorithm in finding the shortest path from one point to (9)  
 another point in a closed graph.  
 b) How does the computational complexity of Dijkstra's algorithm change when (5)  
 moving from 2D to 3D search spaces?  
 20 a) Discuss the peg-in-hole problem in robotic manipulation. Explain the steps (14)  
 involved in the tilt based peg-in-hole insertion using appropriate diagrams

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2014



RAT415	FUNDAMENTALS OF ROBOTICS	CATEGORY	L	T	P	CREDIT
		OEC	2	1	0	3

**Preamble:** The objective of this course is to expose the student to the functional elements of Robotics, impart knowledge on the direct and inverse kinematics, understand manipulator differential motion and control, learn various path planning techniques and dynamics and control of manipulators

**Prerequisite:** Multi variable calculus, Linear algebra

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Explain the functional elements of Robotics
CO 2	Describe the direct and inverse kinematics in modeling and controlling of robot manipulators
CO 3	Evaluate the position and orientation of the manipulator end-effector in relation to joint displacements.
CO 4	Discuss Collision free path planning methods
CO 5	Explain the kinematics, dynamics and control of Robots

**Mapping of course outcomes with program outcomes**

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										1
CO 2	3	3										1
CO 3	3	3										1
CO 4	3	3										1
CO 5	3	3										1

**Assessment Pattern**

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	15	15	30
Apply	21	21	42
Analyse	14	14	28
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours

**Continuous Internal Evaluation Pattern:**

- Attendance : 10 marks  
 Continuous Assessment Test (2 numbers) : 25 marks  
 Assignment/Quiz/Course project : 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Discuss the Degrees of Freedom and workspace of manipulators.
2. Compare SCARA, Cartesian and Cylindrical configurations

**Course Outcome 2 (CO2):**

1. Explain Wrists and end effectors
2. Explain two-link planar robot example

**Course Outcome 3 (CO3):**

1. Express Jacobian matrix of the manipulator
2. Discuss Wrist and arm singularities

**Course Outcome 4 (CO4):**

1. Write the Trajectory equations for point-to-point motion
2. Discuss Cubic polynomial trajectories

**Course Outcome 5 (CO5):**

1. Study the requirements for selecting the best material for bearing
2. Discuss the sensors for force feedback



**SYLLABUS****RAT415 FUNDAMENTALS OF ROBOTICS****Module 1 (7 Hours)****Basic Concepts**

Brief history, Types of Robots, Technology, Robot Configurations and Robot classifications, Robot control systems, Various manipulators, End effectors tools, Programming languages.

**Module 2 (6 Hours)****Direct and Inverse Kinematics:**

Mathematical representation of Robots, Position and orientation, Homogeneous transformation, Various joints, Representation using the Denavit Hattenberg parameters - Degrees of freedom, Direct kinematics, Inverse kinematics, SCARA robots.

**Module 3 (7 Hours)****Manipulator Differential Motion and Control:**

Robot Manipulators – Motion control and Differential motion of manipulators, Overview of Jacobian matrix, Wrist and arm singularity - Static analysis – Calculation of force and torque

**Module 4 (8 Hours)****Trajectory generation:**

Representing the position and orientation of a robotic system – Centroid of an object, Trajectory generation - Basic Problem, Solution space – Joint space and Cartesian space, Planning in any space, Polynomial trajectory in Robotics, Cubic polynomial, Cubic polynomial for a path, Joint space trajectory generation using single degree polynomial,

**Module 5 (7 Hours)****Dynamics and Control:**

Lagrangian equation of motion- Manipulator dynamics in robots, Euler-Lagrange equation for a single degree of freedom system, Properties of Robotic dynamic equations, Newton-Euler formulation for analysing the dynamics of robot manipulators, Control problem of robot manipulators, independent joint control, Closed loop system with PD/PID control

**Text Books**

1. John J. Craig, " Introduction to Robotics , Mechanics and Control", Pearson Education International, 2008
2. Dileep Kumar Pratihari, "Fundamentals of Robotics", Narosa Book, 2017



3. Niku S. B., “Introduction to Robotics, Analysis, Control, Applications”, John Wiley, 2011.
4. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, “ Robot Dynamics and Control” Wiley India Edition, 2004

### Reference Books

1. H. Asada, J. J. E. Slotine, “Robot Analysis and Control”, John Wiley & sons, 1991.
2. N. Ben- Ari, “ Elements of Robotics”, Springer, 2017
3. Bruno Siciliano, Ousama Khatib, “ Springer Handbook of Robotics”, Springer, 2008.

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	<b>Basic Concepts (7 Hours)</b>	
1.1	History of Robots and Robotics, Types of Robots	1 Hour
1.2	Robot anatomy and related attributes – Joints and links	1 Hours
1.3	Common robot configurations – Polar, Cylindrical, Cartesian co-ordinate, Jointed-arm, SCARA	2 Hours
1.4	Classification of Robots – Hydraulic drive, Electric drive, Pneumatic drive Robot Control systems – Hierarchical control structure, end effectors - tools	3 Hours
2	<b>Direct and Inverse Kinematics: (6 Hours)</b>	
2.1	Mathematical representation of Robots, Position and orientation,	2 Hours
2.2	Homogeneous transformation, Various joints, Representation using the Denavit Hartenberg (DH) parameters -Degrees of freedom,	2 Hours
2.3	Direct kinematics, Inverse kinematics, SCARA robots.	2 Hours
3	<b>Manipulator Differential Motion and Control: (7 Hours)</b>	
3.1	Robot Manipulators – Motion control and Differential motion of manipulators Overview of Jacobian matrix – conversion of angular velocities of the joint using Jacobian matrix.	3 Hours
3.2	Jacobian matrix for a 2D 2- Link manipulator example	2 Hour
3.3	Types of Robot Singularities. Wrist and arm singularity	1 Hour



3.4	Static force/torque analysis of manipulators	1 Hour
<b>4</b>	<b>Path Planning (8 Hours)</b>	
4.1	Representing position and orientation of a Robotic system, Finding the centroid of an object	1 Hour
4.2	Trajectory generation - Basic Problem, Solution space – Joint space and Cartesian space, Planning in any space,	2 Hour
4.3	Polynomial trajectory in Robotics, Cubic polynomial,	1 Hours
4.4	Cubic polynomial for a path, Joint space trajectory generation using single degree polynomial	2 Hour
4.5	Numerical examples on finding the coefficients of cubic that accomplishes the motion of a joint	2 Hour
<b>5</b>	<b>Dynamics and Control (7 Hours)</b>	
5.1	Lagrangian equation of motion- Manipulator dynamics in robots- Euler-Lagrange equation for a single degree of freedom system	2 Hour
5.2	Properties of Robotic dynamic equations	1 Hours
5.3	Newton-Euler formulation for analysing the dynamics of robot manipulators	2 Hours
5.4	Control problem of robot manipulators, independent joint control, Closed loop system with PD/PID control	2 Hours

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2014



**Model Question Paper****Course Code: RAT 415****Course Name: FUNDAMENTALS OF ROBOTICS****Max.Marks:100****Duration: 3 Hours****PART A****Answer all Questions. Each question carries 3 Marks**

1. Mention few applications of Robots.
2. Explain the role of position sensors in Robotics
3. Comment on SCARA Robots.
4. Discuss different types of robot drive systems.
5. Explain the importance of Gripper and list applications
6. List the various robot programming methods
7. Explain the geometric constraints in task and motion planning.
8. Define Joint space Trajectory generation
9. State Lagrangian formulation.
10. Explain Newton-Euler formulation for robot dynamics

**PART B****Answer any one full question from each module. Each question carries 14 Marks****Module 1**

11. a. Discuss Robot anatomy and related attributes (6)  
b. Explain in detail, common robot configurations (8)
12. a. Describe the following classification of robots.  
i) Hydraulic drive    ii) Electric drive    iii) Pneumatic drive (9)  
b. List the Hierarchical control structure of Robot control systems (5)

**Module 2**

13. Explain the use of Homogeneous transformation matrices as a tool in robotics. (14)
14. What is the difference between forward kinematics and inverse kinematics in the field of modelling and controlling of robot manipulators? (14)

**Module 3**

15. Derive the Jacobian matrix for a 2D 2- Link manipulator (14)



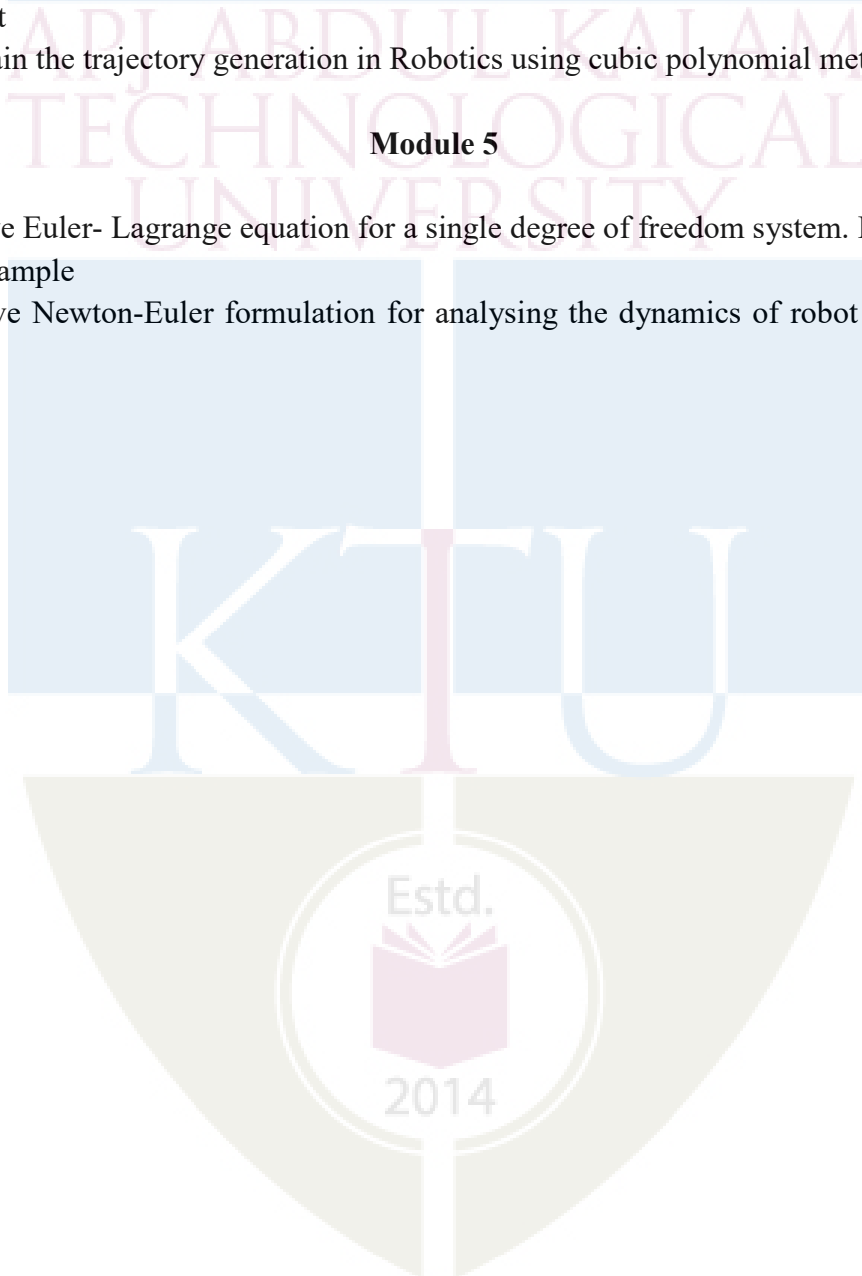
- 16 Explain the three types of Robot Singularities. Perform static force/torque analysis of manipulators and calculate the force and torque required to keep the structure in its locked position (14)

#### **Module 4**

- 17 Represent the position and orientation of a Robotic system. Find the centroid of an object (14)
- 18 Explain the trajectory generation in Robotics using cubic polynomial method (14)

#### **Module 5**

- 19 Derive Euler- Lagrange equation for a single degree of freedom system. Explain with an example (14)
- 20 Derive Newton-Euler formulation for analysing the dynamics of robot manipulators (14)





RAT473	FUNDAMENTALS OF MOMENTUM, HEAT AND MASS TRANSFER	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** This course is designed to equip the students with the basic principles of momentum, heat and mass transfer.

**Prerequisite:** Higher secondary physics, Engineering mathematics

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Discuss fluids, their properties and determine forces acting on a submerged body
CO 2	explain differential forms of continuity and momentum equations and estimate head loss in pipes
CO 3	Discuss basic equations of heat conduction and calculate heat transfer through plane walls and pipes.
CO 4	Determine convection heat transfer in external and internal flows (flat plate and pipe).
CO 5	Discuss basic laws of radiation heat transfer and mass transfer.

**Mapping of course outcomes with program outcomes**

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2										
CO 2	3	2										
CO 3	3	2										
CO 4	3	2										
CO 5	3	2										

**Assessment Pattern**

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	40
Apply	20	20	50
Analyse			
Evaluate			
Create			



Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

**Continuous Internal Evaluation Pattern:**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum 2 subdivisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Discuss Newtonian and Non-Newtonian fluids with one example.
2. Differentiate between dynamic viscosity and kinematic viscosity.
3. Define Newton's law of viscosity
4. A Newtonian fluid is filled between a shaft and a concentric sleeve. The sleeve attains a speed of 0.5 m/s when a force of 50 N is applied to the sleeve. Determine the speed if a force of 250 N is applied.

**Course Outcome 2 (CO2):**

1. Write the differential form of the general mass conservation equation and discuss the significance of each term.
2. Write the general conservation equation for momentum in differential form and discuss the physical meaning of each term.
3. Determine the size of galvanised steel pipe needed to carry water for a distance of 180 m at 85 lit./s with a head loss of 9.0. Take  $k_s = 0.15$  mm.

**Course Outcome 3 (CO3):**

1. Discuss the effect of temperature on thermal conductivity of solids and gases.
2. Discuss critical thickness of insulation
3. Calculate the rate of heat loss through the walls of a furnace of size 5 m by 5 m by 3 m high. The walls are constructed from an inner fire brick wall 25 cm thick of thermal conductivity 0.4 W/mK, a layer of ceramic insulation of thermal conductivity 0.2 W/mK and 8 cm thick, and a steel protective layer of thermal conductivity 50 W/mK and 2 mm thick. The inside temperature of the fire brick layer was measured at 600° C



and the temperature of the outside of the insulation  $50^{\circ}\text{C}$ . Also find the interface temperature of layers.

**Course Outcome 4 (CO4):**

1. Discuss the physical significance of Prandtl Number
2. Discuss the relative thicknesses of hydrodynamic and thermal boundary layer over a flat plate if  $Pr > 1$  with a neat schematic.
3. Water flows at the rate of 60 kg/min through a double pipe counter flow heat exchanger. Water is heated from  $50^{\circ}\text{C}$  to  $80^{\circ}\text{C}$  by an oil flowing through the tube. The specific heat of the oil is  $1.780\text{ kJ/kg K}$ . The oil enters at  $120^{\circ}\text{C}$  and leaves at  $70^{\circ}\text{C}$ . the overall heat transfer co-efficient is  $350\text{ W/m}^2\text{K}$ . Calculate the area of the heat exchanger and rate of heat transfer.

**Course Outcome 5 (CO5):**

1. Discuss Wiens Law and its significance.
2. Discuss any three analogies between heat and mass transfer
3. Two parallel black plates  $0.5\text{m} \times 1\text{m}$  are spaced  $0.5\text{ m}$  apart. One plate is maintained at  $1000^{\circ}\text{C}$  and the other at  $600^{\circ}\text{C}$ . Calculate the net radiant heat exchange between the two plates?

**SYLLABUS**

**Module 1 (7 Hours)**

Concept of continuum, Fluid and flow properties, Pressure variation in a static fluid, Forces on submerged surfaces, Buoyancy, Steady and unsteady flows, Streamlines, System and control volume  
Newton's law of viscosity

**Module 2 (7 Hours)**

Differential continuity equation, Navier stokes equation, Bernoulli's equation, Fluid rotation, Stream function and potential function, Reynold's experiment, Drag, Concept of boundary layer, Description of turbulence, Friction factor for laminar flow, Estimation of head loss in pipes

**Module 3 (7 Hours)**

Conduction, Fourier's law, Thermal conductivity of solids and fluids, Heat Equation (Cartesian and cylindrical), Steady state conduction through plane wall and pipes, Critical thickness of insulation, Fins, Tip conditions, Lumped analysis for transient conduction, Biot number and Fourier Number

**Module -4 (7 Hours)**

Convection heat transfer, Hydrodynamic and thermal boundary layer, Prandtl number and Nusselt number, Convective heat transfer correlations for external and internal flows, Concept of natural convection, Grashoff Number, Heat exchangers and their classification, LMTD and  $\epsilon$ - NTU methods.



**Module 5 (7 Hours)****ROBOTICS AND AUTOMATION**

Thermal radiation, Planck's law, Wien's law, Stefan-Boltzmann law, Radiative properties of surfaces

Black bodies, Kirchhoff's law, Radiant exchange between black bodies

Molecular mass transfer, Analogies between heat, momentum and mass transfer, Fick's law, Diffusion coefficient, Mass transfer into a moving gas stream, Concept of convective mass transfer

**Text Books**

1. WeltyJR, CR Wicks, RE Wilson, GL Rorrer, Fundamentals of Momentum, Heat and Mass Transfer. John Wiley & Sons Inc.
2. Modi P. N. and S. M. Seth, Hydraulics & Fluid Mechanics, S.B.H Publishers, New Delhi, 2002
3. Jain, A.K., Fluid Mechanics, Khanna Publishers, New Delhi, 1998. Roy. J Dossat, Principles of Refrigeration, Pearson Education
4. Frank.M.White, Fluid Mechanics, Mc Graw Hill, 2013.
5. Holman J.P., "Heat Transfer", Mc Graw-Hill, 9th.Ed., 2002

**References:**

1. R.K.Rajput. Heat and mass transfer, S.Chand & Co., 2015
2. Frank P. Incropera and David P. Dewitt, Heat and Mass Transfer, John Wiley and sons, 2011
3. Yunus A Cengel, Heat Transfer: A Practical Approach, McGraw Hill, 2015
4. C.P. Kothandaraman, S. Subramanya, Heat and Mass Transfer data book:, New age International publishers, 2014

**Course Contents and Lecture Plan**

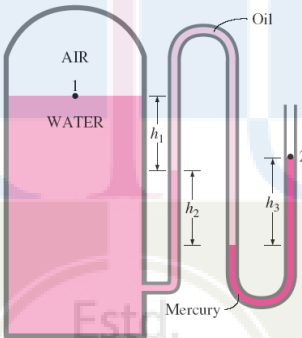
Topic	No. of Lectures
<b>Module 1</b>	
Concept of continuum, Fluid and flow properties , , Pressure variation in a static fluid	2
Forces on submerged surfaces, Buoyancy, Steady and unsteady flows, Streamlines	3
System and control volume, Newton's law of viscosity	2
<b>Module 2</b>	
Differential continuity equation, Navier stokes equation, Bernoulli's equation,	2
Fluid rotation, Stream function and potential function, Reynold's experiment, Drag, Concept of boundary layer	3



Description of turbulence , Friction factor for laminar flow, Estimation of head loss in pipes	2
<b>Module 3</b>	
Conduction, Fourier's law, Thermal conductivity of solids and fluids, Heat Equation (Cartesian and cylindrical),	2
Steady state conduction through plane wall and pipes, Critical thickness of insulation, Fins, Tip conditions,	3
Lumped analysis for transient conduction, Biot number and Fourier Number	2
<b>Module 4</b>	
Convection heat transfer, Prandtl number and Nusselt number,	2
Hydrodynamic and thermal boundary layer, Convective heat transfer correlations for external and internal flows	2
Concept of natural convection, Grashoff Number. Heat exchangers and their classification, LMTD and $\epsilon$ - NTU methods.	3
<b>Module 5</b>	
Thermal radiation, Planck's law, Wien's law, Stefan-Boltzmann law, Radiative properties of surfaces, Black bodies, Kirchhoff's law, Radiant exchange between black bodies.	4
Molecular mass transfer, Analogies between heat, momentum and mass transfer, Fick's law, Diffusion coefficient	2
Mass transfer into a moving gas stream, Concept of convective mass transfer.	1

<b>Model Question Paper</b>		
<b>APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY</b> <b>SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION</b>		
<b>Course Code: RAT473</b>		
<b>Course Name: FUNDAMENTALS OF MOMENTUM, HEAT AND MASS TRANSFER</b>		
Max. Marks: 100		Duration: 3 Hours
Heat and mass transfer data book may be permitted.		
<b>PART A</b>		
	<i>Answer all questions, each carries 3 marks.</i>	Marks
1	Differentiate between dynamic viscosity and kinematic viscosity.	(3)
2	Explain the difference between system and control volume.	(3)
3	Write the general differential form of the continuity equation. Explain the physical meaning of each term.	(3)
4	The stream function in a two dimensional flow field is given by $\phi = x^2 - y^2$ . Calculate the magnitude of velocity at point (2,1)	(3)
5	Discuss the effect of temperature on thermal conductivity of solids and gases.	(3)



6	What do you mean by lumped systems? Give two examples.	(3)
7	Explain the physical significance of Prandtl number and Reynolds number.	(3)
8	Classify heat exchangers based on direction of flow of heat transfer fluids. What do you mean by compact heat exchangers?	(3)
9	Solar radiant energy with an intensity of $1000 \text{ W/m}^2$ strikes a flat plate normally. The absorptivity is twice the transmissivity and thrice the reflectivity. Determine the rate of absorption, transmission and reflection of energy.	(3)
10	State and explain Fick's law.	(3)
<b>PART B</b>		
<i>Answer any one full question from each module, each carries 14 marks.</i>		
<b>MODULE I</b>		
11	a) Classify fluids and represent them in shear stress- deformation rate plot	(4 )
	b) A 60-cm square gate has its top edge 12 m below the water surface. It is on a $45^\circ$ angle and its bottom edge is hinged. What force P is needed to just open the gate?	(10 )
12	a) State and explain Newton's law of viscosity	(4)
	b) The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in the following figure. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 80 kPa. Determine the air pressure in the tank if $h_1$ , $h_2$ and $h_3$ are 0.1 m, 0.2 m and 0.35 m respectively. Take the densities of water, oil, and mercury to be $1000 \text{ kg/m}^3$ , $850 \text{ kg/m}^3$ , and $13,600 \text{ kg/m}^3$ , respectively.	(10)
		
<b>MODULE II</b>		
13	a) Discuss the Lagrangian and Eulerian approach in fluid mechanics. Write Navier Stokes equation in differential form. Explain the physical meaning of each term.	(7 )
	b) Discuss the concept of hydrodynamic boundary layer with a neat schematic. What do you mean by momentum thickness and energy thickness?	(7)
14	a) Three pipes of 0.5 m, 0.3 m and 0.4 m diameters and having lengths of 100 m, 60 m and 80 m respectively are connected in series between two tanks whose difference in water levels is 10 m. If the friction factor for all the pipes is equal to 0.05, calculate the flow rate through the pipes.	(14)
<b>MODULE III</b>		
15	a) Derive heat equation in cartesian coordinates	(14)



16	b)	The temperature distribution across a wall 1m thick at a certain instant of time is given by $T(x)=a+bx+cx^2$ $a=900^\circ\text{C}$ , $b=-300^\circ\text{C/m}$ , $c=-50^\circ\text{C/m}^2$ , $q=1000\text{ W/m}^2$ , $k=40\text{W/mK}$ $C_p=4\text{ kJ/kg K}$ . 1) Determine the rate of heat transfer entering the wall ( $x=0$ ) and leaving the wall ( $x=1\text{ m}$ ) 2) Determine the rate of energy storage in the wall. 3) Determine the time rate of temperature change at $x=0.25\text{ m}$ .	(14)
		<b>MODULE IV</b>	
17	a)	Air at a pressure of $6\text{ kN/m}^2$ and a temperature of $400^\circ\text{C}$ flows with a velocity of $10\text{ m/s}$ over a flat plate $0.5\text{m}$ long. Calculate the cooling rate per unit width of the plate needed to maintain it at a surface temperature of $30^\circ\text{C}$ .	(14)
18	b)	Water at the rate of $0.0625\text{ kg/s}$ is to be heated from $35^\circ\text{C}$ to $95^\circ\text{C}$ by means of a concentric tube heat exchanger. Oil at the rate of $0.0625\text{ kg/s}$ with a specific heat of $2.095\text{ kJ/kg K}$ and a temperature of $210^\circ\text{C}$ is to be used. If the overall heat transfer coefficient based on the outside dia. of inner tube is $500\text{ W/m}^2\text{K}$ , determine the length of heat exchanger. The outer dia. of the inner tube is $10\text{ cm}$ .	(14)
		<b>MODULE V</b>	
19	a)	Discuss Wiens law and its significance with suitable plot.	(7)
	b)	Discuss analogies between heat, momentum and mass transfer	(7)
20	a)	Consider a $4\text{m}\times 4\text{m}\times 4\text{m}$ cubical furnace whose surfaces are black. The base, top and side surfaces of the furnace are maintained at uniform temperatures of $800\text{K}$ , $1800\text{K}$ and $400\text{K}$ respectively. Determine a) the net rate of radiation heat transfer between the base and side surfaces. b) the net rate of radiation heat transfer between base and top surface.	(14)
*****			

Estd.



2014



RAT463	FINITE ELEMENT METHODS	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** This course helps the students to learn various modelling techniques and different numerical methods for solving a system of governing equations over the domain of a continuous physical system, which is discretized into simple geometric shapes called finite elements.

**Prerequisite:** Higher secondary physics, engineering mathematics

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Apply numerical methods to solve problems in solid mechanics
CO 2	Explain the pre-processing, solution and post processing stages of Finite Element Method
CO 3	Model and solve linear problems involving structural beams, shafts and frames using FE method.
CO 4	Model and solve two dimensional problems using CST, quadrilateral and axis-symmetric elements
CO 5	Apply isoparametric formulation for solution of 2D problems.

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	2									3
CO 2	3	1	2									3
CO 3	3	1	3									3
CO 4	3	2	3									3
CO 5	3	2	3									3

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
<b>150</b>	<b>50</b>	<b>100</b>	<b>3 hours</b>

**Continuous Internal Evaluation Pattern:**

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum 2 subdivisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. List various functional approximation methods used for solving boundary value problems.
2. State the method of Minimum potential energy applied in the finite element analysis.
3. Explain the principle used in Galerkin method.
4. What do you mean by Weak formulation? How does it differs from Strong formulation?

**Course Outcome 2 (CO2):**

5. List out various steps involved in finite element analysis
6. Compare finite element analysis and finite volume analysis.
7. What are the advantages and Dis-advantages of finite element analysis?
8. Give the applications of Finite element Analysis

**Course Outcome 3 (CO3):**

9. Enumerate the method to evaluate stiffness matrix of a beam element.
10. Specify the boundary conditions of a two noded beam element.
11. Differentiate between a frame and grid element.
12. Write the shape functions for a two-dimensional torsional bar element.



**Course Outcome 4 (CO4):**

13. Using area coordinate system, give the relations to find the shape functions for a triangular element.
14. How CST differs from LST?
15. How do you differentiate between the Plane stress and Plane Strain problem?
16. Briefly discuss about the finite element modelling of Axisymmetric solids.

**Course Outcome 5 (CO5):**

17. Define Shape functions and Isoparametric formulation.
18. Derive the shape functions for a Four-noded two-dimensional quadrilateral element.
19. What do you mean by Jacobian matrix? How it helps in Local-Global transformation?
20. Derive the shape functions for an axisymmetric triangular element.

**SYLLABUS****Module I(7 Hours)**

Basics of 2D elasticity - Equations of equilibrium- Strain displacement relations - constitutive relations- Energy Principles-Principles of virtual work- Total potential energy- Rayleigh-Ritz method- method of weighted residuals. Gauss elimination - Solution of equations

**Module II(7 Hours)**

Introduction to FEM- outline of the procedure – steps involved in FEM - Preprocessing phase – discretisation - types of elements - Element properties - - polynomial form- Development of shape functions for truss elements - Formulation of stiffness matrix (direct method, 1-D element) - formulation of load vector - assembly of global equations - implementation of boundary conditions - solution procedure – post processing phase

**Module III(7 Hours)**

Development of shape functions for torsion elements – Analysis of frames - Frame and grid equations, Transformation of coordinates – Analysis of beams - Development of Euler beam equations - Patch test - different type of refinements (h, p and r)

**Module IV(7 Hours)**

Two dimensional stress analysis - Development of the Plane Stress and Plane Strain Stiffness Equations - Lagrangian interpolation functions for two dimensional elements - constant strain triangle- Linear strain triangle – Bilinear plane rectangular elements



**Module V(7 Hours)**

Axisymmetric Elements - Natural coordinates systems, Isoparametric Formulation - Numerical integration, Full and reduced integration –Lagrange and Serendipity Elements - - Introduction to plate and shell elements - Introduction to Three-Dimensional FEM.

**Text Books**

1. Bathe K J, Finite Element Procedures in Engineering Analysis, Prentice Hall, New Delhi.,1982
2. Cook R D, Malkus D S, and Plesha M E, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, Singapore., 1981
3. Krishnamoorthy C S, Finite Element Analysis- Theory and Programming, Tata McGraw Hill, New Delhi., 1994

**References Books**

1. Chandrupatla T R and Belegundu A D, Introduction to Finite Elements in Engineering, Pearson Education, New Delhi., 1998
2. Hutton D V, Fundamentals of Finite Element Analysis, Tata McGraw Hill Education Private Ltd, New Delhi., 2005
3. Mukhopadhyay M and Abdul Hamid Sheikh, Matrix and Finite Element Analyses of Structures, Ane Books Pvt. Ltd., New Delhi, 2009
4. Rajasekharan S, Finite Element Analysis in Engineering Design, Wheeler, New Delhi., 1998
5. Reddy J N, An Introduction to FEM, McGraw Hill Book Co. New York, 1984
6. Zienkiewicz O C and Taylor R W., Finite Element Method, Elsevier Butterworth-Heinemann, UK., 2005

**Course Contents and Lecture Schedule**

Module	Contents	Hrs
1	Basics of 2D elasticity - Equations of equilibrium- Strain displacement relations - constitutive relations- Energy Principles- Principles of virtual work-	4
	Total potential energy- Rayleigh-Ritz method- method of weighted residuals. Gauss elimination - Solution of equations	3
2	Introduction to FEM- outline of the procedure – steps involved in FEM - Preprocessing phase – discretisation - types of elements - Element properties - - polynomial form- Development of shape functions for truss elements	4
	Formulation of stiffness matrix (direct method, 1-D element) - formulation of load vector - assembly of global equations - implementation of boundary conditions - solution procedure – post processing phase	3
3	Development of shape functions for torsion elements – Analysis of frames - Frame and grid equations, Transformation of coordinates	4



	Analysis of beams - Development of Euler beam equations - Patch test - different type of refinements (h, p and r)	3
4	Two dimensional stress analysis - Development of the Plane Stress and Plane Strain Stiffness Equations	3
	Lagrangian interpolation functions for two dimensional elements - constant strain triangle- Linear strain triangle – Bilinear plane rectangular elements	4
5	Axisymmetric Elements - Natural coordinates systems, Isoparametric Formulation - Numerical integration, Full and reduced integration	4
	Lagrange and Serendipity Elements - - Introduction to plate and shell elements - Introduction to Three-Dimensional FEM	3

**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT463**

**Course Name: FINITE ELEMENT METHOD**

Max. Marks: 100

Duration: 3 Hours

**PART A**

*Answer all questions, each carries 3 marks.*

		Marks
1	State the Principle of Virtual work.	(3)
2	Write the Stress – Strain relations for a Three-Dimensional body acted upon loads in all three sides	(3)
3	What are the main properties of an Elemental Stiffness Matrix?	(3)
4	Specify the importance of Proper Node Numbering in the Finite element analysis.	(3)
5	What is the use of a transformation matrix?	(3)
6	Compare h, p and r type of mesh refinement.	(3)
7	How does LST differ from CST?	(3)
8	Compare Plane stress and Plane Strain problem applied in Solid Mechanics.	(3)
9	How a Three-Dimensional problem can be approximated to a Two-Dimensional Axi-Symmetric problem?	(3)
10	What do you mean by shear locking? How it can be avoided?	(3)

**PART B**

*Answer any one full question from each module, each carries 14 marks.*

**MODULE I**

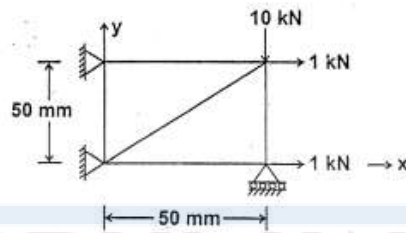
11	a)	Using the Principle of Minimum Potential Theory, derive the relation for the elemental Stiffness matrix of a Spring Element.	(8)
	b)	Solve the following simultaneous equations using gaussian elimination approach $2a+b+2c-3d = -2$ $2a+2b+c-4d = -15$ $a+2c-3d = -5$ $4a+4b-4c+d = 4$	(6)
12	a)	What do you mean by Ritz Parameter?	(2)
	b)	For a differential equation $\frac{d^2y}{dx^2} + 300x^2 = 0$ , with the limit $0 \leq x \leq 1$ and	(12)



		the boundary conditions are given as $y(0) = 0$ and $y(1) = 0$ . Using Galerkin's weighted residual technique, find the solution of the problem with a trial function as $y = ax(1-x^3)$ .	
<b>MODULE II</b>			
13	a)	Define local and global axes used in the analysis of Trusses	(2)
	b)	Determine the nodal displacements and Support reactions for the Four member Pinned truss as shown in Figure 1	(12)
		<p style="text-align: center;"><b>Figure 1</b></p>	
14	a)	Define Interpolation function.	(2)
	b)	For a system with four springs as shown in figure 2, evaluate the nodal displacements of node 2, 3 and 4. The nodal displacement of node 5 is given as 20 mm and the Spring stiffness $k$ is given as 200 kN/m.	(12)
		<p style="text-align: center;"><b>Figure 2</b></p>	
<b>MODULE III</b>			
15		Consider the cantilever beam as shown in Figure 3. The beam, fixed at one end, has uniform cross section area as shown in figure. The beam undergoes a static deflection by a downward load of 1000 N applied at the free end. Take $E = 69$ GPa. Find the displacement at free end and reactions at fixed end.	(14)
		<p style="text-align: center;"><b>Figure 3</b></p>	
16	a)	What do you mean by Mesh Convergence study? State its importance	(4)
	b)	Derive the relation for the element stiffness matrix of a frame element, which is inclined at an angle $\theta$ to the horizontal axis.	(10)
<b>MODULE IV</b>			
17	a)	What do you mean by Jacobian of a Matrix? State its use in FEA	(4)
	b)	Derive the relation for the stiffness matrix of a four noded Isoparametric quadrilateral element.	(10)
18		Determine the nodal displacements and elemental stresses for a two-	(14)



dimensional loaded plate as shown in the figure 4. Assume plane stress condition and take  $E = 210 \text{ GPa}$ ,  $\mu = 0.25$ , Thickness  $t = 10 \text{ mm}$ .

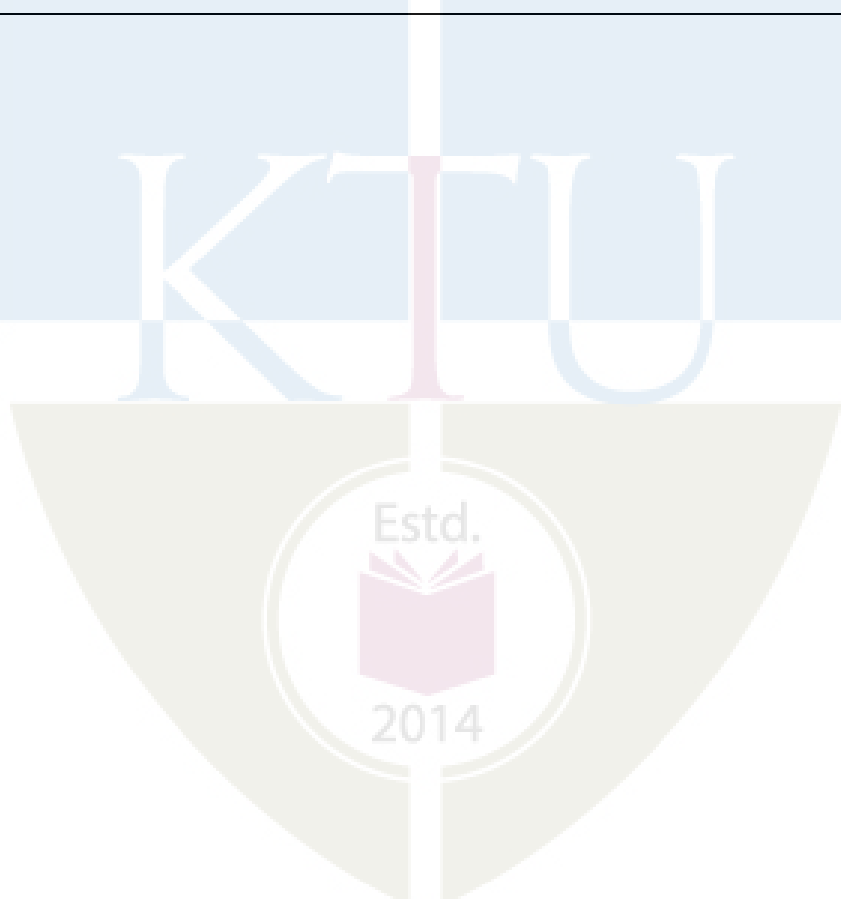


**Figure 4**

**MODULE V**

19		Using proper relations for the displacements, derive the equation for the strain displacement matrix of a three-dimensional element.	(14)
20	a)	Compare Lagrange and Serendipity Elements.	(4)
	b)	Using two point Gauss Quadrature technique Evaluate the integral $\int_{-1}^1 \int_{-1}^1 (7\xi^2 + 13\xi\eta + 64\xi^2\eta^2) d\xi d\eta$ . Take the weights $W_1 = W_2 = 1$ for the Gauss points $= \pm 0.57735$	(10)

\*\*\*\*





RAT453	TRIBOLOGY	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** The objective of this course is to expose the student to different types of bearings and bearing materials, understand friction characteristics and power losses in bearings and to learn theory and concepts about different types of lubrication.

**Prerequisite:** NIL

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Discuss the fundamentals of tribology and associated parameters.
CO 2	Apply concepts of tribology for the performance analysis and design of components experiencing relative motion.
CO 3	Classify wear mechanism and understand wear testing and reduction methods
CO 4	Analyse the requirements and design of hydrodynamic journal and plane slider bearings for a given application.
CO 5	Apply the principles of surface engineering for different applications of tribology.

**Mapping of course outcomes with program outcomes**

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3										1
CO 2	3	3										1
CO 3	3	3										1
CO 4	3	3										1
CO 5	3	3										1

**Assessment Pattern**

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	15	15	30
Apply	21	21	42
Analyse	14	14	28
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours

**Continuous Internal Evaluation Pattern:**

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Explain the importance of tribology in industry
2. Discuss the grades and selection of lubricants

**Course Outcome 2 (CO2):**

1. Various methods of measuring frictional force
2. Explain methods of friction measurement

**Course Outcome 3 (CO3):**

1. Explain the classification of wear mechanism
2. Discuss the role of wear debris in modifying friction and wear

**Course Outcome 4 (CO4):**

1. Differentiate between Full journal bearing and partial journal bearing
2. List the advantages and applications of hydrodynamic journal bearings

**Course Outcome 5 (CO5):**

1. Study the requirements for selecting the best material for bearing
2. Factors to be considered for proper selection of corrosion resistant coatings



**RAT453 TRIBOLOGY****Module 1 (7 Hours)****Introduction to tribology**

Historical background, practical importance, and subsequent use in the field. Lubricants: Types and specific field of applications. Properties of lubricants, viscosity, its measurement, effect of temperature and pressure on viscosity, lubrication types, Grease and anti seize, standard grades of lubricants, and selection of lubricants, Additives in lubricants,

**Module 2 (6 Hours)****Friction:**

Friction of Surfaces: Genesis of friction, friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction, friction of elastomers, friction of various materials, friction measurement methods, friction of non metallic materials.

**Module 3 (7 Hours)****Wear:**

Wear Mechanism: Introduction, types of wear, wear mechanism, minor forms of wear, wear debris analysis, wear testing method, wear of metals, ceramics, polymers, system approach for wear reduction.

**Module 4 (8 Hours)****Hydrodynamic journal bearings:**

Friction forces and power loss in a lightly loaded journal bearing, Petroff's equation, mechanism of pressure development in an oil film, and Reynold's equation in 2D. Introduction to idealized journal bearing, condition for equilibrium, Sommerfeld's number and its significance, end leakages in journal bearing, numerical examples on full journal bearings only.

**Module 5 (7 Hours)****Bearing Materials:**

Commonly used bearings materials, and properties of typical bearing materials. Advantages and disadvantages of bearing materials.

**Introduction to Surface engineering:**

Concept and scope of surface engineering. Surface modification – transformation hardening, surface melting, thermo chemical processes. Surface Coating – plating, fusion processes, vapor phase processes. Selection of coating for wear and corrosion resistance.



## Text Books

## ROBOTICS AND AUTOMATION

1. B. Bhushan, "Introduction to Tribology", John Wiley & Sons, Inc., New York, 2002
2. Prasanta Sahoo, "Engineering Tribology", Prasanta Sahoo, PHI Learning Private Ltd, New Delhi, 2011.
3. J. A. Williams, "Engineering Tribology", Oxford Univ. Press, 2005.
4. Gwidon W Stachowiak, "Wear : Material, Mechanism and Practise" John Wiley & Sons, Ltd, 2005

## Reference Books

1. B. C. Majumdar, "Introduction to Tribology in bearings", Wheeler Publishing.
2. Amir Hossein Pakserest, Omid Sharifahmadian, " Tribology in Coatings and Surface Treatment: Technology, Properties, and Applications, Engineering Science Reference, 2022
3. Ernest Rabinowicz, "Friction and Wear of Materials", John Wiley & sons, 1995.

## Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	<b>Introduction to tribology (7 Hours)</b>	
1.1	Historical background, practical importance, and subsequent use in the field	1 Hour
1.2	Lubricants: Types and specific field of applications. Properties of lubricants viscosity, its measurement,	2 Hours
1.3	Effect of temperature and pressure on viscosity, Lubrication types, Grease and anti seize.	2 Hours
1.4	Standard grades of lubricants, Selection of lubricants, Additives in lubricants	2 Hours
2	<b>Friction: (6 Hours)</b>	
2.1	Friction of Surfaces: Genesis of friction, friction in contacting rough surfaces, sliding and rolling friction.	2 Hours
2.2	Various laws and theory of friction, friction of elastomers, friction of various materials	2 Hours
2.3	Friction measurement methods, friction of non metallic materials.	2 Hours
3	<b>Wear: (7 Hours)</b>	



3.1	Wear Mechanism: Introduction, types of wear, wear mechanism, minor forms of wear.	3 Hours
3.2	Wear debris analysis, Wear testing methods.	2 Hour
3.3	Wear of metals, ceramics, polymers.	1 Hour
3.4	System approach for wear reduction.	1 Hour
<b>4</b>	<b>Hydrodynamic journal bearings (8 Hours)</b>	
4.1	Friction forces and power loss in a lightly loaded journal bearing.	1 Hour
4.2	Petroff's equation, mechanism of pressure development in an oil film, and Reynold's equation in 2D.	2 Hour
4.3	Introduction to idealized journal bearing, condition for equilibrium.	1 Hours
4.4	Sommerfeld's number and its significance, end leakages in journal bearing.	2 Hour
4.5	Numerical examples on full journal bearings only.	2 Hour
<b>5</b>	<b>Bearing Materials, Introduction to Surface engineering (7 Hours)</b>	
5.1	Commonly used bearings materials, and properties of typical bearing materials. Advantages and disadvantages of bearing materials.	2 Hour
5.2	Concept and scope of surface engineering.	1 Hours
5.3	Surface modification – transformation hardening, surface melting, thermo chemical processes.	2 Hours
5.4	Surface Coating – plating, fusion processes, vapor phase processes. Selection of coating for wear and corrosion resistance.	2 Hours



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 453  
Course Name: TRIBOLOGY**

Max. Marks: 100

Duration: 3 Hours

**PART A**

Answer all questions, each carries 3 marks.

Marks

- |    |  |     |
|----|--|-----|
| 1  | Distinguish between Abrasive wear and Adhesive wear.               | (3) |
| 2  | Comment on various wear mechanisms.                                | (3) |
| 3  | Distinguish between Grease and Anti-Seize                          | (3) |
| 4  | Explain the implication of stribeck curve.                         | (3) |
| 5  | Discuss the frictional behaviour of elastomers.                    | (3) |
| 6  | State the differences between static and dynamic friction.         | (3) |
| 7  | Explain the selection criteria for wear resistant powder coatings  | (3) |
| 8  | Explain the various types of bearing materials                     | (3) |
| 9  | Discuss the operating conditions of hydrodynamic journal bearings. | (3) |
| 10 | Write the Petroff's equation.                                      | (3) |

**PART B**

Answer any one full question from each module, each carries 14 marks.

**MODULE I**

- |    |  |     |
|----|--|-----|
| 11 | a) Discuss the pressure and temperature effects on the viscosity of liquids    | (8) |
|    | b) Explain the historical background and industrial importance of tribology    | (6) |
| 12 | a) With a neat sketch, explain the measurement of viscosity using a viscometer | (8) |
|    | b) List the specifications of lubricants used for selection                    | (6) |

**MODULE II**

- |    |   |     |
|----|---|-----|
| 13 | a) Explain the consequences of friction. List a few examples of occurrence of rolling friction. | (8) |
|    | b) Discuss the theory of adhesive friction  | (6) |
| 14 | a) Explain briefly the frictional behaviour of non-metallic materials                           | (8) |
|    | b) Comment on the rules of sliding friction on a solid –solid contact                           | (6) |

**MODULE III**

- |    |   |     |
|----|---|-----|
| 15 | a) Explain the various particle types generated through wear process            | (7) |
|    | b) How wear debris analysis provides information on the wear mechanism involved | (7) |
| 16 | a) Describe the tribological behaviour of alumina ceramics and SiC ceramics     | (7) |
|    | b) Discuss the strategies to minimize wear                                      | (7) |

**MODULE IV**



- 17 a) A lightly loaded full journal bearing has a journal of 50 mm, bush bore of 50.05 mm and bush length of 20 mm. If the rotational speed of the journal is 1200 rpm and the average viscosity of liquid lubricant is 0.03 Pascal-second, Calculate the power loss in Watts (10)
- b) State the significance of Sommerfeld's number (4)
- 18 A hydrodynamic journal bearing of width 40 mm operates with a shaft of 40 mm which rotates at 1800 rpm and carries a load of 2220 N. The diametral clearance is 80  $\mu$ m and the absolute viscosity of the lubricant is 28 cP. Calculate the minimum film thickness, attitude angle, volumetric flow rate, volumetric side flow rate, maximum film pressure and location of maximum film pressure. (14)
- MODULE V
- 19 a) List the standard requirements for the selection of materials for bearings. Explain the metal and non-metal category of bearing materials (9)
- b) Comment on the advantages and disadvantages of bearing materials (5)
- 20 a) Explain surface engineering (5)
- b) Write brief notes on (9)
- i) Surface modification
  - ii) Surface coating
  - iii) thermo-chemical processes





RAT443	DESIGNING THE MECHANISMS FOR AUTOMATED MACHINES	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** As automation is getting more acceptance in a wide variety of industrial environments, students need to be familiarized with the design of such automatic machines. This course is designed to build a basic understanding on the various concepts involved in the design of different mechanisms of automated machines.

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Define the principles and kinematic layout of automatic manufacturing systems.
CO 2	Select the suitable drives for automatic manufacturing systems.
CO3	Identify the suitable sensor based on the requirements of automation.
CO4	Design the kinematic model of transportation for a variety of work materials.
CO5	Select the functional systems and mechanisms for automating manufacturing processes such as assembly and automation.

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	3	3								
CO 2	3	3	3	3								
CO 3	3	3	3	3								
CO 4	3	3	3	3								
CO 5	3	3	3	3								

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	40
Apply	20	20	50
Analyse			
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours

**Continuous Internal Evaluation Pattern**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Differentiate between spherical and cylindrical manipulators.
2. What is an indexing device? Explain its role in automation.
3. What is a kinematic layout?

**Course Outcome 2 (CO2)**

1. What are the types of drives used for activating automated systems?
2. Compare hydraulic and pneumatic drives.
3. Illustrate a typical system with variable moment of inertia.

**Course Outcome 3(CO3):**

1. What is a flexible cam system?
2. What do you understand by item presence sensor?
3. Explain the working principle of force sensors.

**Course Outcome 4 (CO4):**

1. What is the role of wire tension regulation in transport of continuous wires?



2. What do you understand by vibrational transportation?
3. Explain the significance of feeding devices in automation.

**Course Outcome 5 (CO5):**

1. List the processes in automated manufacturing.
2. List the principles of assembling.
3. Enumerate the types of grippers.

**SYLLABUS**

**Module I(7 Hours)**

Introduction: Structure of automatic industrial systems, Linear and circular configurations, Non-industrial robots.

Concepts and Layouts: Processing layout, Case studies for analysis: Chain links, springs, soldering printed circuits, galvanizing steel strips, Approaches to automating manufacturing processes, Determination of productivity of manufacturing processes- Timing layout.

Kinematic layout: Selection of drives: Mechanical, Hydraulic, Pneumatic, Electrical systems. Case studies: Automation of Spring manufacturing using fixed and programmable systems.

**Module II(7 Hours)**

Dynamic Analysis of Drives: Mechanical Drives systems: Falling weight, Mass transmitted over an inclined belt, spring systems. Electromagnetic drives, Electric drives: induction motors, stepper motors, calculation of selection parameters.

Hydraulic drives, Pneumo drives, brakes. Drives with variable moment of inertia, calculation of time of braking for different systems.

**Module III(7 Hours)**

Kinematics and Control of Automatic machines: Position function, Input-output relations of drives, Analysis of 4 slot Geneva mechanism, Cam mechanisms, Flexible cam systems, Spatial cam mechanisms, amplifiers.

Dynamic accuracy, Vibrations, damping, electrical damping.

Feedback Sensors:

Displacement sensors, electrical sensors- resistance, induction, variable capacitance, optical sensors,

Pneumatic sensors, Speed and flow rate sensors, Force sensors, pressure sensors, temperature sensors- Electrical, thermal, optical, Item presence sensors.



**Module IV(8 Hours)**

Transporting devices:

Linear transportation: Wire tension regulation, length compensator for continuous processing machine, Conveyors, Chain type and chainless transportation devices, Case studies.

Rotational Transportation devices: Indexing table driven by cam, pneumatic and electric drives, sorting and measuring devices, Vibrational transportation.

Feeding and orientation devices: Feeding devices: Liquid, powder, wire, rod and oriented part feeding systems, Tray hoppers, Orientation of parts, Passive orientation, active orientation and logical orientation, orientation using electromagnetic fields- magnetostatic, electrostatic, alternating magnetic fields. Case studies: Electronic parts, stamping process.

**Module V(7 Hours)**

Functional Systems and Mechanisms: Processes in automatic manufacturing, Automatic assembling, Principles of assembling, Inspection systems, Miscellaneous systems.

Manipulators: Dynamics of cylindrical manipulators, Optimal time-trajectory of gripper, Introduction to kinematics of manipulators, vibrations in two arm serial manipulator.

Grippers: Types of grippers and their functions, Guides: Types and Functions

**Text Books:**

1. Ben-Zion Sandler, Robotics Designing the Mechanisms for Automated Machinery, Academic Press, 2<sup>nd</sup> Edition, 1999.
2. Frank Lamb, Industrial Automation: Hands On, McGraw-Hill Professional, 2013
3. Industrial Process Automation Systems: Design and Implementation, B.R. Mehta and Y. Jaganmohan Reddy, ELSEVIER, 1st Edition - November 26, 2014

**Reference Books**

1. Bolton W., "Mechatronics", Pearson Education, 6th Edition, 2015.
2. Davis G. Alciatore and Michael B. Hiestand, "Introduction to Mechatronics and Measurement systems", McGraw Hill Education, 2011.
3. Stamatiou Manesis, George Nikolakopoulos, "Introduction to Industrial Automation", CRC Press, 2018.



**Course Contents and Lecture Schedule**

No	Topic	No. of Lectures
<b>1</b>		
1.1	Introduction: Structure of automatic industrial systems, Linear and circular configurations, Non-industrial robots.	1
1.2	Concepts and Layouts: Processing layout, Case studies for analysis: Chain links, springs, soldering printed circuits, galvanizing steel strips	3
1.3	approaches to automating manufacturing processes, Determination of productivity of manufacturing processes- Timing layout.	1
1.4	Kinematic layout: Selection of drives- Mechanical, Hydraulic, Pneumatic, Electrical systems.	1
1.5	Case studies: Spring manufacturing for fixed and programmable cases.	1
<b>2</b>		
2.1	Dynamic Analysis of Drives: Mechanical Drives systems: Falling weight, Mass transmitted over an inclined belt, spring systems.	2
2.2	Electromagnetic drives, Electric drives: induction motors, stepper motors, calculation of selection parameters.	2
2.3	Hydraulic drives, Pneumo drives, brakes. Drives with variable moment of inertia, calculation of time of braking for different systems.	3
<b>3</b>		
3.1	Kinematics and Control of Automatic machines: Position function, Input-output relations of drives.	1
3.2	Analysis of 4 slot Geneva mechanism, Cam mechanisms, Flexible cam systems, Spatial cam mechanisms, amplifiers.	2
3.3	Dynamic accuracy, Vibrations, damping, electrical damping	2
3.4	Feedback Sensors: Displacement sensors, electrical sensors- resistance, induction, variable capacitance.	1
3.5	Optical sensors, Pneumatic sensors, Speed and flow rate sensors, Force sensors, pressure sensors, temperature sensors- Electrical, thermal, optical, Item presence sensors.	1
<b>4</b>		
4.1	Transporting devices: Linear transportation: Wire tension regulation, length compensator for continuous processing machine, Conveyors, Chain type and chainless	2



	transportation devices Case studies.	
4.2	Rotational Transportation devices: Indexing table driven by cam, pneumatic and electric drives, sorting and measuring devices, Vibrational transportation	2
4.3	Feeding and orientation devices: Feeding devices: Liquid, powder, wire, rod and oriented part feeding systems, Hoppers, Case studies, Tray hoppers,	2
4.4	Orientation of parts, Passive orientation, active orientation and logical orientation, orientation using electromagnetic fields- magnetostatic, electrostatic, alternating magnetic fields. Case studies: Electronic parts, stamping process.	2
5		
5.1	Functional Systems and Mechanisms: Processes in automatic manufacturing, Automatic assembling, Principles of assembling, Inspection systems, Miscellaneous systems.	3
5.2	Manipulators: Dynamics of cylindrical manipulators, Optimal time-trajectory of gripper	2
5.3	Introduction to kinematics of manipulators, vibrations in two arm serial manipulator.	1
5.4	Grippers: Types of grippers and their functions, Guides: Types and Functions	1





**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**  
**SEVENTH SEMESTER B.TECH. DEGREE**  
**EXAMINATION**

**Course Code: RAT 443**

**Course Name: Robotics    Designing the mechanisms for Automated Machines**

Max. Marks: 100

Duration  
: 3  
Hours

**PART A**

Answer all questions, each carries 3 marks.

- |    |   | Marks |
|----|---|-------|
| 1  | Differentiate between linear and circular automation systems using suitable examples.                     | (3)   |
| 2  | What is a processing layout? List the factors to be considered while deciding the processing layout.      | (3)   |
| 3  | Find the expression for time taken to displace the mass M in a spring mass system through a distance 'd'. | (3)   |
| 4  | What are the advantages of using stepper motors in robotic applications over DC motors?                   | (3)   |
| 5  | Explain the role of Geneva mechanism in automation.   | (3)   |
| 6  | Explain the working principle of induction based displacement sensor.                                     | (3)   |
| 7  | What are the problems encountered in the continuous transportation of feeds in automation?                | (3)   |
| 8  | What is meant by the phenomenon of seizure in the design of hoppers?                                      | (3)   |
| 9  | What are the types of inspection devices used in automation?  | (3)   |
| 10 | What are the types of tasks carried out by manipulators in automated industries?                          | (3)   |

**PART B**

Answer any one full question from each module, each carries 14 marks.

**MODULE I**

- |    |   |     |
|----|---|-----|
| 11 | a) Explain how the processing layout for automation is finalised using the case of a spring manufacturing industry.           | (7) |
|    | b) What are the approaches used to decide the concept of automation in manufacturing processes?                               | (7) |
| 12 | a) What is a kinematic layout in industrial automation? What are the criteria used in the selection of drives for automation? | (7) |
|    | b) With the aid of the layout diagram, explain the process of rapid prototyping and its significance in automation.           | (7) |

**MODULE II**



- 13 a) Derive the expression for the time taken to rotate through a given angle in terms of driving and resisting torques for an electric motor from its equation of motion. (8)
- b) Explain the performance of a stepper motor with regard to torque vs time and torque vs. Pulse rate variations. (6)
- 14 a) Compare the performance of pneumatic and hydraulic drives used in automation. (6)
- b) Determine the angular displacement of a rotating device with variable moment of inertia due to addition of material to the system. (8)

## MODULE III

- 15 a) Discuss the methods used for rapid cam exchange on a camshaft. (8)
- b) Explain how the pressure angle affects the kinematic design in automation. (6)
- 16 a) What is a dynamic damper? Using a two degree freedom system, show how the vibrations are controlled using a dynamic damper. (6)
- b) Explain the working principle of the following: (8)
1. Liquid flow meter with impeller.
  2. Thermal flow rate sensor.
  3. Piezo electric acceleration sensor.
  4. Pyrometers.

## MODULE IV

- 17 a) What are the techniques used to regulate wire tension and length compensation during transportation? (7)
- b) Create the kinematic design of a transportation device consisting of an indexing mechanism activated using pneumatic drive. (7)
- 18 a) With the aid of sketches, explain the method used for automatic filling of bottles with liquids. (7)
- b) What are the methods used for active and passive orientation of objects? (7)

## MODULE V

- 19 a) What are the principles applied in the automation of assembling processes? (8)
- b) Explain the role of gripper and guides used in association with manipulators? (6)
- 20 a) Explain the working of a SCARA robot. What are its applications? (8)
- b) What are the kinds of inspection devices used in automatic production? (8)
- Discuss how inspection system can be employed in grindstone wear.

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RAT433	THEORY OF ELASTICITY	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** Acquire knowledge in analysis of elastic behaviour of materials

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Define stress, strain and displacements
CO 2	Solve plane stress and plane strain problems using elasticity theory
CO3	Explain stress, strain transformations and photoelasticity
CO4	Solve problems on strain energy methods and thermal stresses
CO5	Discuss failure criteria and propagation of waves in elastic media

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	3									
CO 2	3	3	3									
CO 3	3	3	3									
CO 4	3	3	3									
CO 5	3	3	3									

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

#### Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours



Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Write the tensor representing stress and strain? Why are they symmetric?
2. What does compatibility conditions signify?
3. List the strain displacement relations.

**Course Outcome 2 (CO2)**

1. What do you understand by plane strain?
2. Explain stress concentration.
3. What is a stress function?

**Course Outcome 3(CO3):**

1. What is meant by principal stress?
2. Using a mohr circle, find the maximum shear in terms of principal stresses.
3. What do you understand by photoelasticity?

**Course Outcome 4 (CO4):**

1. Differentiate between bending and torsion.
2. What is Prandtl's membrane analogy?
3. State Castigliano's first theorem.

**Course Outcome 5 (CO5):**

1. Plot the yield surfaces of maximum shear stress theory and maximum distortion energy theory.
2. What is meant by dilatation and distortion wave in elastic media?
3. Write the elastic wave equation and explain the terms.



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE  
EXAMINATION**

**Course Code: RAT433**

**Course Name: THEORY OF ELASTICITY**

Max. Marks: 100

Duration: 3  
Hours

**PART A**

Answer all questions, each carries 3 marks.

Marks

- |    |  |     |
|----|--|-----|
| 1  | What is a stress tensor? Represent principal stresses as a stress tensor                                     | (3) |
| 2  | Explain compatibility conditions. What is its significance in solving problems on elasticity?                | (3) |
| 3  | Differentiate between plane stress, plane strain and axisymmetric problems.                                  | (3) |
| 4  | Discuss the types of displacement boundary conditions implemented on a beam                                  | (3) |
| 5  | Explain the principle of photo elasticity.   | (3) |
| 6  | What are principal stresses? How is it related to maximum shear stress?                                      | (3) |
| 7  | Explain the phenomenon of warping in torsion.  | (3) |
| 8  | Explain Castigliano's theorem?   | (3) |
| 9  | Differentiate between normal and shear stress theory.  | (3) |
| 10 | What is elastic waves? What are the factors that affect the propagation of elastic wave through a structure? | (3) |

**PART B**

Answer any one full question from each module, each carries 14 marks.

**MODULE I**

- |    |   |     |
|----|---|-----|
| 11 | a) Derive the differential equations of equilibrium in Cartesian coordinates.   | (7) |
|    | b) Determine the principal stresses for the state of stress given below:<br>$\begin{bmatrix} 3 & -10 & 0 & -10 & 0 & 30 \\ 0 & 30 & 0 & 30 & -27 & 0 \end{bmatrix}$ | (7) |
| 12 | a) The displacement field for a body is given by<br>$u = (x^2 + y)i + (3 + z)j + (x^2 + 2y)k$ Write down the displacement gradient matrix at point (2, 3, 1).       | (9) |
|    | b) Explain the differential strain displacement relations.  | (5) |

**MODULE II**



- 13 a) Show that the following are Airy's stress functions and examine the stress distribution represented by them: (8)  
a)  $\phi = Ax^2 + By^2$ , b)  $\phi = Cx^4$ , c)  $\phi = A(x^4 - 6x^2y^2)$   
b) State and explain generalised Hooke's law. Explain the modifications in the law when applied to Isotropic, orthotropic and transversely isotropic materials. (6)
- 14 a) Find the nature of stress fields represented by first, second, third and fourth degree polynomial stress functions in  $x$  and  $y$ . Also, plot the stress distributions on a square plate. (8)  
b) What is meant by stress concentration? List the boundary conditions applied to solve the problem of a plate with a hole. (6)
- MODULE III
- 15 a) What is meant by stress transformation? Explain its significance in mechanical design. (8)  
b) Find the maximum shear stress and the angle of the plane for a state of stress given by (6)  

$$\begin{bmatrix} 10 & 8 & 8 & 2 \end{bmatrix}$$
- 16 a) Show that the angle between planes of maximum shear stress and maximum normal stress is  $45^\circ$ . (6)  
b) Explain how fringe patterns are obtained for a beam using photoelastic method. (6)
- MODULE IV
- 17 a) Show that the Airy's stress function  $\phi = A(xy^3 - \frac{3}{4}xyh^2)$  represents stress distribution in a cantilever beam loaded at the free end with load  $P$ , examine the value of  $A$  if  $\tau_{xy} = 0$  at  $y = \pm h/2$  where  $b$  and  $h$  are width and depth respectively of the cantilever. (8)  
b) A simply supported beam of length  $3L$  is subjected to point loads  $P$  at  $2L$  from the left end. Determine the vertical deflection under the load using Castigliano's theorem. (8)
- 18 a) Explain the method of Prandtl's membrane analogy applied to torsion. (8)  
b) Derive the equation of torsion applied to elliptical cross section. (6)
- MODULE V
- 19 a) A machine element is subjected to the following stresses  $[50 \ 5 \ 5 \ 12]$ . Find the factor of safety if it is made of steel having yield stress of 350 MPa, using (i) Maximum principal stress theory, (ii) Maximum shear stress theory, (iii) Distortion energy theory. (9)  
b) Differentiate between waves of dilatation and distortion in isotropic media. (5)
- 20 a) Differentiate between propagation of longitudinal waves through prismatic bars and longitudinal impact of bars. (6)  
b) What is meant by theory of yielding? Explain the concept of yield surface? Compare the yield surfaces corresponding to maximum shear stress theory and distortion energy theory. (6)



## **SYLLABUS**

### **Module I (7 Hours)**

Stress and strain: Concept of stress at a point, stress tensor, stress on inclined plane, stress components on a rectangular parallelepiped in Cartesian coordinate system, derivation of stress equilibrium equations, stress invariants. The state of strain at a point, strain displacement relations, strain compatibility condition and stress compatibility conditions.

### **Module II (6 Hours)**

Stress-Strain Relationship: Generalized Hooke's law for Isotropic, Orthotropic, Transversely Isotropic materials, plane stress, plane strain and axisymmetric problems, Problems in 2D Cartesian coordinate system, Polynomial stress function, Airy's stress function, Airy's stress function approach to 2-D problems of elasticity, Simple problems of plates, stress concentration problem.

### **Module III (7 Hours)**

Transformation of stress in two dimensional problems- Principal stresses- Maximum shear stress- Mohr's circle for stress in two dimensional problems-Construction of Mohr circle for stress transformation- Construction of Mohr's circle for general state of stress- Transformation of strain in two dimensions- Strain rosettes.

Photoelastic method-Photo elastic stress measurement-Circular polariscope-Examples of photoelastic stress determination-Determination of Principal stresses-Three dimensional photoelasticity.

### **Module IV (8 Hours)**

Introduction to theories of bending and torsion.

Bending of prismatic bars- Bending of cantilever- Stress function-Circular and elliptic cross sections.

Torsion of prismatic bars- elliptic cross section- Membrane analogy.

Strain energy methods- Strain energy- Principle of virtual work- Castigliano's theorem- Applications of Castigliano's theorem.

### **Module V (7 Hours)**

Yield and fracture criteria- Maximum shear stress theory-Maximum normal stress theory-Maximum distortion energy theory

Propagation of waves in elastic solid media-Longitudinal waves in prismatic bars-Longitudinal impact of bars- Waves of dilatation and distortion in isotropic elastic media-Plane waves- Propagation of waves over the surface of an elastic solid body



**Text Books:**

1. Theory of Elasticity - S.P. Timoshenko and J.N. Goodier, Tata McGraw Hill, 2017.
2. Advanced Mechanics of Solids - L.S Srinath, Tata McGraw Hill, 2010.
3. Foundations of Solid Mechanics -Y.C.Fung, Prentice –Hall.Inc, 1977.

**Reference Books**

1. An introduction to theory of Elasticity-R J Atkin,N Fox, Dover book on Physics, 2013.
2. Mechanics of Solids- Egor P Popov, Pearson education,1998.

**Course Contents and Lecture Schedule**

No	Topic	No. of Lectures
<b>1</b>		
1.1	Stress and strain: Concept of stress at a point, stress tensor, stress on inclined plane	2
1.2	Stress components on a rectangular parallelepiped in Cartesian coordinate system, derivation of stress equilibrium equations	2
1.3	Stress invariants. The state of strain at a points	1
1.4	Strain displacement relations, strain compatibility condition and stress compatibility conditions.	2
1.5	Problems	1
<b>2</b>	<b>Module III</b>	
2.1	Stress-Strain Relationship: Generalized Hooke's law for Isotropic, Orthotropic, Transversely Isotropic materials	1
2.2	Plane stress, plane strain and axisymmetric problems, Problems in 2D Cartesian coordinate system	2
2.3	Polynomial stress function, Airy's stress function, Airy's stress function approach to 2-D problems of elasticity	2
2.4	Simple problems of plates	1
<b>3</b>	<b>Module III</b>	
3.1	Transformation of stress in two dimensional problems- Principal stresses- Maximum shear stress	1
3.2	Mohr's circle for stress in two dimensional problems-Construction of Mohr circle for stress transformation	2
3.3	Construction of Mohr's circle for general state of stress-Transformation of strain in two dimensions- Strain rosettes.	2
3.4	Photoelastic method-Photo elastic stress measurement-Circular polariscope-Examples of photoelastic stress determination-Determination of Principal stresses-Three dimensional photoelasticity.	2
<b>4</b>	<b>Module IV</b>	
4.1	Introduction to theories of bending and torsion.	2



4.2	Bending of prismatic bars- Bending of cantilever- Stress function- Circular and elliptic cross sections.	2
4.3	Torsion of prismatic bars- elliptic cross section- Membrane analogy.	2
4.4	Strain energy methods- Strain energy- Principle of virtual work- Castigliano's theorem-Applications of Castigliano's theorem.	1
<b>5</b>	<b>Module V</b>	
5.1	Yield and fracture criteria- Maximum shear stress theory-Maximum normal stress theory- Maximum distortion energy theory	2
5.2	Propagation of waves in elastic solid media-Longitudinal waves in prismatic bars- Longitudinal impact of bars	3
5.3	Waves of dilatation and distortion in isotropic elastic media-Plane waves- Propagation of waves over the surface of an elastic solid body	2





RAT423	PLC AND DISTRIBUTED CONTROL SYSTEMS	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** Acquire the skill of PLC programming and to learn DCS architecture

**Course Outcomes:** After the completion of the course the student will be able to

<b>CO 1</b>	Learn PLC hardware and its general architecture.
<b>CO 2</b>	Design logic circuits to perform industrial control functions of medium complexity and realise the same using ladder logic.
<b>CO3</b>	Apply the industrial protocols used with PLC in real applications.
<b>CO4</b>	Familiarize the DCS architecture and its functions.
<b>CO5</b>	Determine hardware and communication requirements of DCS.

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
<b>CO 1</b>	3	3										
<b>CO 2</b>	3	3	2									
<b>CO 3</b>	3	3	2									
<b>CO 4</b>	3	3										
<b>CO 5</b>	3	3										

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

#### Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours



**Continuous Internal Evaluation Pattern**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Explain the architecture of PLC?
2. Explain input/output modules of PLC.

**Course Outcome 2 (CO2):**

1. Simple PLC programs
2. Application of PLC in applications such as traffic control system.

**Course Outcome 3 (CO3):**

1. Explain Industrial Protocols
2. Explain the role of industrial protocols in automation using PLC

**Course Outcome 4 (CO4):**

1. Describe the architecture of DCS
2. Explain the functions of different modules in PLC.

**Course Outcome 5 (CO5):**

1. Explain the role of DCS in industry 4.0
2. Explain different communication protocols used in DCS.



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 423**

**Course Name: PLC AND DISTRIBUTED CONTROL SYSTEMS**

Max. Marks: 100

Duration: 3 Hours

**PART A**

Answer all questions, each carries 3 marks.

		Marks
1	What is the need for isolators in PLC I/O modules? Draw a commonly used isolator arrangement.	(3)
2	How to classify languages used in PLC programming. Give their salient features.	(3)
3	Implement a mod-2 counter using ladder logic program.	(3)
4	Write the sequential instructions in PLC.	(3)
5	Detail the role of RS-485 in PLC communication?	(3)
6	What is the requirement of signal conditioning systems in a Data Acquisition Card?	(3)
7	Discuss the performance criteria for selection of DCS	(3)
8	Explain automation pyramid.	(3)
9	What are the design considerations for displays used with high level operator interfaces in DCS?	(3)
10	Discuss how the alarm management is don in DCS?	(3)

**PART B**

Answer any one full question from each module, each carries 14 marks.

**MODULE I**

- |    |   |     |
|----|---|-----|
| 11 | a) Draw the block diagram of a PLC showing the main functional items and explain the functions of each block. | (4) |
|    | b) Explain the criteria for selecting the PLC   | (5) |
|    | c) Explain the standard procedure for installing a PLC.   | (5) |
| 12 | a) Draw the block diagram for interfacing of an analog input and output modules and explain the parts.        | (7) |
|    | b) Discuss the different power supply units used in PLC system with suitable diagrams.                        | (7) |

**MODULE II**

- |    |  |     |
|----|--|-----|
| 13 | a) Design a ladder logic program for following process: The level in two bypassed tanks is to be maintained in 5m. The two tanks have separate inlets and outlets. If there is any change in the inlet flow rate, a level sensor mounted in tank 1 will give a signal so that outlet flow of tank 2 is regulated. And if there is any change in outlet flow rate in tank 1, then also outlet flow in tank 2 is to be regulated. If the level is steady, a green LED should glow. | (8) |
|----|--|-----|



- b) With a neat diagram and a ladder logic program, explain how a stepper motor can be controlled using a PLC. (6)
- 14 A pump is to be used to fill two storage tanks. The pump is manually started by the operator from a start/stop station. When the first tank is full, the control logic must be able to automatically stop flow to the first tank and direct flow to the second tank through the use of sensors and electric solenoid valves. When the second tank is full, the pump must shut down automatically. Indicator lamps are to be included to signal when each tank is full. (14)
- With a drawing of the process, prepare a PLC ladder logic program for this control process.

## MODULE III

- 15 a) Write a program control the upper and lower levels in a tank using Sequential Function Charts(SFC) (8)
- b) Explain OPC and OPC-UA by highlighting the specialities. (6)
- 16 a) With a block diagram, explain the working of MODBUS in three configurations (8)
- b) Explain the working of a Direct Digital Control(DDC) system, with an example. (6)

## MODULE IV

- 17 a) Describe how the DCS architecture is supporting ERP. (6)
- b) Explain the basic architecture of DCS and highlight the need of LCUs and HLCUs. (8)
- 18 a) Explain the role of shared communication facilities in DCS. (8)
- b) Write short notes on 1. LCU 2. DIO 3. LHL 4. HLOI (6)

## Module V

- 19 a) Explain the different type of displays in DCS. (7)
- b) Which are the different proprietary and open communication protocols of DCS (7)
- 20 a) Explain the various operator and engineering interface requirements in DCS. (8)
- b) Highlight the reasons for using general purpose computers in DCS (6)

\*\*\*\*

2014



**SYLLABUS****Module I (7 Hours)**

Introduction to PLC -Construction of relay logic circuits with different control elements- Need for PLC –Evolution of PLC.

PROGRAMMABLE LOGIC CONTROLLERS: Architecture of PLC -Types of PLC –PLC modules, Input and Output modules –Digital and Analog Input/Output- examples of Digital and Analog Inputs/Outputs in PLC-AC- DC power supplies in PLC- isolators- PLC Configuration -Scan cycle -Capabilities of PLC-Selection criteria for PLC –PLC Communication with PC and software-PLC Wiring-Installation of PLC and its modules.

PLC programming languages: Ladder Logic, Functional Block Diagram FBD -Sequential Flow Chart SFC - Structured Text - Instruction List

**Module II(7 Hours)**

PROGRAMMING OF PLC: – Ladder Logic Programming – Realization of simple logic circuits programming on-off inputs/ outputs. Auxiliary commands and functions: PLC Basic Functions: Register basics- timer functions- counter functions.

Program control instructions- math instructions- sequencers- PLC based traffic light system, stepper motor & servo motor control using PLC, Analog sensor interfacing with PLC

APPLICATIONS OF PLC: Case studies of manufacturing automation and process automation.

**Module III(7 Hours)**

PLC programming tools as per IEC 61131-Developing programs using Sequential Function Chart and FBD

Networking PLC:usingRS232, RS485, Protocols-ethernet- Modbus,CANOpen, OPC-Open Platform Communication- OPC UA

Industrial Automation :General Block diagrams of DDC- Supervisory control- Data Acquisition system.

**Module IV(7 Hours)**

Distributed Control System- DCS - Architectures, Comparison, Local control unit, Process interfacing issues, Communication facilities- Distributed Control System Basics: DCS introduction- Various function Blocks- DCS components/block diagram- DCS Architecture of different makes- comparison of these architectures with automation pyramid- DCS specification- latest trend and developments in DCS- DCS support to Enterprise Resources Planning (ERP)- performance criteria for DCS and other automation tools.

**Module V(7 Hours)**

Interfaces In DCS : Operator interfaces- Low level and high level operator interfaces - Operator displays- Engineering interfaces- Low level and high level engineering interfaces-



General purpose computers in DCS- DCS detail Engineering- configuration and programming- DCS software function- functions including database management, reporting, alarm management, diagnosis.

Communication highway of DCS-Role of DCS in Industry4.0

### Text Books:

1. Programmable logic controllers, Frank D Petruzella, McGraw-Hill, 2011.
2. Michael P. Lukas, 'Distributed Control Systems', Van Nostrand Reinhold Co., Canada, 1986
3. Industrial Process Automation Systems: Design and Implementation, B.R. Mehta and Y. Jaganmohan Reddy, Hardcover ISBN: 9780128009390 , ELSEVIER, 1st Edition - November 26, 2014

### Reference Books

1. Programmable Controllers- An Engineers's Guide, 2<sup>nd</sup> Edition, E.A. Parr, Newnes, 1999.
2. Programmable controllers, Hardware, Software & Applications, George L. Batten Jr., Mc GrawHill, 2<sup>nd</sup> Edition, 1994.
3. Programmable logic controllers, W. Bolton, Elsevier Ltd, 2015.
4. Programmable Logic Controllers: Programming Methods and Applications. John R Hackworth and Fredrick D Hackworth Jr., Pearson Education, 2006.
5. John. W. Webb Ronald A Reis - Programmable Logic Controllers - Principles and Applications, Fourth edition, Prentice Hall Inc., New Jersey, 1998.
6. Process Control- Instrument Engineers Handbook by Bela G. Liptak, Chilton book co

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
<b>1</b>		
1.1	Introduction to PLC -Construction of relay logic circuits with different control elements- Need for PLC - PLC evolution	1
1.2	PROGRAMMABLE LOGIC CONTROLLERS: Architecture of PLC - Types of PLC –PLC modules, Input and Output modules – Digital and Analog Input/Output- examples of Digital and Analog Inputs/Outputs	2
1.3	PLC-AC- DC power supplies in PLC- isolators	1
1.4	PLC Configuration -Scan cycle -Capabilities of PLC- Selection criteria for PLC – PLC Communication with PC and software- PLC Wiring- Installation of PLC and its modules	2
1.5	PLC programming languages: Ladder Logic, Functional Block Diagram FBD -Sequential Flow Chart SFC - Structured Text - Instruction List	1
<b>2</b>		
<b>2.1</b>	PROGRAMMING OF PLC: – Ladder Programming – Realization of	2



	simple logic circuits programming on-off inputs/ outputs. Auxiliary commands and functions: PLC Basic Functions: Register basics, timer functions, counter functions	
2.2	Program control instructions- math instructions- sequencers- PLC based traffic light system, stepper motor & servo motor control using PLC, Analog sensor interfacing with PLC	3
2.3	APPLICATIONS OF PLC: Case studies of manufacturing automation and process automation	2
3		
3.1	PLC programming tools as per IEC 61131-Developing programs using Sequential Function Chart and FBD- simple programming examples	3
3.2	Networking PLC using RS232, RS485, Protocols- ethernet- Modbus, CANOpen, OPC-Open Platform Communication- OPC UA.	3
3.3	Industrial Automation : General Block diagrams of DDC- Supervisory Control- Data Acquisition system	1
4		
4.1	Distributed Control System- DCS - Architectures, Comparison, Process interfacing issues, Communication facilities. Distributed Control System Basics: DCS introduction, Various function Blocks, DCS components/block diagram	2
4.2	DCS Architecture of different makes, comparison of these architectures with automation pyramid, DCS specification, latest trend and developments,	3
4.3	DCS support to Enterprise Resources Planning (ERP), performance criteria for DCS and other automation tools.	2
5		
5.1	<b>Interfaces In DCS :</b> Operator interfaces, Low level and high level operator interfaces, Operator displays, Engineering interfaces, Low level and high level engineering interfaces	2
5.2	General purpose computers in DCS, DCS detail Engineering, configuration, and programming- DCS software functions- functions including database management, reporting, alarm management, diagnosis.	3
5.3	Communication highway of DCS, communication protocols in DCS- case studies	2



RAT413	MOBILE ROBOTICS	CATEGORY	L	T	P	CREDIT
		PEC	2	1	0	3

**Preamble:** With the increase in automation, robots are used in all walks of life. It was observed by many researches that the ability of a robot can be increased several folds if it was capable of movement. This paper introduces the student with the basic issues in bringing mobility to robots and how those issues are resolved through its various modules.

**Course Outcomes:** After the completion of the course the student will be able to

<b>CO 1</b>	Explain the fundamental computational issues involved in mobile robotics and issues related to locomotion
<b>CO 2</b>	Translate the working principle of different visual and non-visual sensors to select the appropriate ones for a particular application
<b>CO 3</b>	Explain the techniques used for representing and reasoning about space
<b>CO 4</b>	Classify the different software architecture in the development of robotic applications
<b>CO 5</b>	State the techniques used for pose maintenance and localization techniques used in robotics

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
<b>CO 1</b>	2	2										2
<b>CO 2</b>	2		2									2
<b>CO 3</b>	3		2		2							2
<b>CO 4</b>	3	2	3	2	2							2
<b>CO 5</b>	3	2	3		2							2

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	30	30	60
Apply	10	10	30
Analyse			
Evaluate			
Create			

#### Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours



**Continuous Internal Evaluation Pattern:**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Elaborate on the challenges to be addressed during the design of a mobile robot
2. Explain the concepts like Path planning, Localization for a mobile robot.
3. Identify the most suitable locomotion technique for a given scenario

**Course Outcome 2 (CO2):**

1. Differentiate between Visual and Non-Visual Sensors
2. Elaborate on the working principle of different sensors
3. Explain the various processes involved in visual image sensing

**Course Outcome 3 (CO3):**

1. Explain the representation of a robot in space
2. Explain the different methods of path planning
3. Explain the working of various algorithms for finding the optimal path

**Course Outcome 4 (CO4):**

1. Explain the need for decomposing the design of a mobile robot
2. Explain the architecture of different decomposition techniques
3. Elaborate the advantages of Hybrid Control Architectures

**Course Outcome 5 (CO5):**

1. Explain the different matching techniques possible to perform local or global localization
2. Explain the Non-Geometric methods for localization



**Module I: (7 Hours)**

**Mobile Robots:** Fundamental problems – Path Planning, Localization, Sensing, Mapping, Simultaneous Localization and Mapping

**Locomotion:** Introduction to stepper Motor and Servo Motor Control, Wheeled Mobile Robots - Differential Drive, Synchronous Drive, Steered wheels, Tricycle Drive, Car drive - Limbed Locomotion – Vehicle Stability, Number of legs, Limb design and Control, forward and inverse kinematics, Gait and Body Control, Dynamic Gaits

**Off-Board Communication:** Tethered, Untethered, Radio Modems

**Module 2(6 Hours)**

**Non Visual Sensors :** Basic concepts – Sensors: Bumpers, Accelerometers, Gyroscopes, infrared sensors, Sonar – Transducer Model, Data interpretation, Laser Rangefinders - Data Fusion: Kalman Filter

**Visual Sensors :** Perspective Camera, Planar Homography, Camera Calibration, - Object Appearance and Shading – Signals and Sampling – Image features and Their Combination – Measuring Depth – Active Vision

**Module 3(8 Hours)**

**Representation and Reasoning about Space:** Representing Space: Spatial Decomposition, Geometric Representations, Topological Representations – Representing the Robot: Configuration Space, Simplification of C-space – Path Planning for Mobile Robots: Constructing a discrete search space, Retraction Methods - Searching a Discrete State Space: Graph search, Depth-first Search, Breadth-first Search, Dijkstra's Algorithm – Searching a Continuous State Space: Vector Field Algorithm, Bug algorithm – Spatial Uncertainty – Dynamic Environments , Probabilistic path planning

**Module 4(7 Hours)**

**System Control:** Horizontal Decomposition – Vertical Decomposition – Hybrid Control Architectures – Middleware – High Level Control – Alternative Control Formalisms – The human Robot interface

**Module 5(7 Hours)**

**Pose Maintenance and Localization:** Simple landmark measurement - Servo Control – Recursive Filtering – Non-Geometric methods: Perceptual Structure – Correlation based localization – Global Localization

**Mapping:** Sensorial Maps – Geometric Maps – Topological Maps.

**Text Books**

1. Computational Principles of Mobile Robotics, Gregory Dudek and Michael Jenkin, Cambridge University Press



2. Introduction to Autonomous Mobile Robots , R Siegwart, IR Nourbakhsh, D Scaramuzza, , MIT Press, USA, 2011.

### References:

1. Introduction to Mobile Robot Control, Spyros G. Tzafestas , Elsevier, USA, 2014.
2. Sensors for mobile robot ,HR Everett, CRC Press

### Course Contents and Lecture Schedule

No	Topic	No. of Lectures
<b>1</b>	<b>Module 1</b>	
1.1	Fundamental problems – Path Planning, Localization, Sensing, Mapping, Simultaneous Localization and Mapping	1
1.2	Stepper Motors, Servo Motor Control	1
1.3	Wheeled Mobile Robots, Differential Drive, Steered wheels, Tricycle Drive, Car drive	1
1.4	Limbed Locomotion – Vehicle Stability, Number of legs, Limb design and Control, forward and inverse kinematics	2
1.5	Gait and Body Control, Dynamic Gaits	1
1.6	Tethered, Untethered, Radio Modems	1
<b>2</b>	<b>Module 2</b>	
2.1	Basic concepts – Sensors: Bumpers, Accelerometers, Gyroscopes	1
2.2	Infrared sensors, Sonar – Transducer Model, Data interpretation	1
2.3	Laser Rangefinders - Data Fusion: Kalman Filter	1
2.4	Perspective Camera, Planar Homography, Camera Calibration	1
2.5	Object Appearance and Shading – Signals and Sampling	1
2.6	Image features and Their Combination – Measuring Depth – Active Vision	1
<b>3</b>	<b>Module 3</b>	
3.1	Representing Space: Spatial Decomposition, Geometric Representations, Topological Representations	1
3.2	Representing the Robot: Configuration Space, Simplification of C-space	1
3.3	Path Planning for Mobile Robots: Constructing a discrete search space, Retraction Methods	1
3.4	Searching a Discrete State Space: Graph search, Depth-first Search, Breadth-first Search, Dijkstra's Algorithm	2
3.5	Searching a Continuous State Space: Vector Field Algorithm, Bug algorithm –	2
3.6	Spatial Uncertainty – Dynamic Environments , Probabilistic path planning	1
<b>4</b>	<b>Module 4</b>	
4.1	Horizontal Decomposition	2
4.2	Vertical Decomposition	2



4.3	Hybrid Control Architectures -- Middleware – High Level Control	1
4.4	Alternative Control Formalisms	1
4.5	The human Robot interface	1
<b>5</b>	<b>Module 5</b>	
5.1	Simple landmark measurement	1
5.2	Servo Control - Recursive Filtering	2
5.3	Non-Geometric methods: Perceptual Structure	1
5.4	Correlation based localization – Global Localization	1
5.5	Sensorial Maps – Geometric Maps – Topological Maps.	2

### Model Question Paper

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT 413  
Course Name:  
MOBILE ROBOTICS**

Max. Marks: 100

Duration: 3 Hours

**PART A**

Answer all questions, each carries 3 marks.

Marks

- |    |  |     |
|----|--|-----|
| 1  | Which point is called as the Instantaneous center of curvature of a vehicle. What is its significance?             | (3) |
| 2  | Explain the term Dead Reckoning. Explain how this technique is used in mobile robots                               | (3) |
| 3  | Differentiate between active sensing and passive sensing   | (3) |
| 4  | List out the important characteristics need to be considered while selecting a sensor for a particular application | (3) |
| 5  | Define the term 'Search method' in the context of searching a discrete state space                                 | (3) |
| 6  | What is the drawback of simple graph searching algorithm in robot path planning.                                   | (3) |
| 7  | List out the drawbacks of vertical decomposition technique used in robotic design                                  | (3) |
| 8  | What is a middleware and how is it significant in robotic software design  | (3) |
| 9  | Explain the term pose estimation   | (3) |
| 10 | List out the different matching methods used in localization process   | (3) |



## PART B ROBOTICS AND AUTOMATION

Answer any one full question from each module, each carries 14 marks.

### MODULE I

- 11 a) Explain the Bug algorithm to determine a path between two points A and B (8)  
b) Explain how different trajectories can be made using a differential drive (6)
- 12 a) For a robot at an initial position (x,y) and is following a particular path, State (9)  
any one possible reason for the error in the estimated position of the robot.  
Show the effects of errors in the x and y directions are independent in the estimate of robots position.  
b) List out any 5 periodic gaits used by quadrupeds in locomotion over flat surfaces (5)

### MODULE II

- 13 a) Explain the principle of operation of gyroscopes (8)  
b) Discuss in detail any one camera calibration technique of a single video camera (6)
- 14 a) Suppose that an object is dropped from some known height under the effect of (14)  
gravity. Develop a Kalman filter to continually estimate the state of the object if  
(a) the position of the object is measured at each time instance, (b) the velocity  
of the object is measured at each time instance, and (c) the position and the  
velocity of the object is measured at each time instant.

### MODULE III

- 15 a) Define the term Configuration Space and explain the use of it in motion (14)  
planning. Compare the configuration space of a limbed robot to that of a robot  
with only one translational and rotational motion
- 16 a) How is Topological representation better than Geometric representation? With (10)  
an example, a graph based representation of a robotic environment  
b) With an example, explain Dijkstra's algorithm to find the shortest path between (5)  
two nodes.

### MODULE IV

- 17 a) Explain with an example the process of horizontal decomposition of a robotic (8)  
control system  
b) With a block diagram, Explain the general structure of a behaviour based system (6)
- 18 What is the design principle behind reactive control paradigm. Discuss the (14)  
Subsumption architecture used in robotic design

### MODULE V

- 19 a) Describe a procedure for determining the pose of a robot in a 2D world using (14)  
only "wall following," assuming that a perfect map is available and that the  
absolute orientation of the robot can be determined at any time.
- 20 a) Explain the use of Triangulation and Trilateration for localization (14)

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RAT401	ALGORITHMS AND DATA STRUCTURES	CATEGORY	L	T	P	CREDIT
		PCC	2	0	2	3

**Preamble:** This course helps the student to have an idea of Data Structures and Algorithms. Students are introduced to the basic design consideration of algorithms. Discussion on various data structures, algorithms and their applications are also included as part of the course to get an overall idea on this topic.

**Prerequisite:** Nil

**Course Outcomes:** After the completion of the course the student will be able to

CO 1	Analyse various data structures and their applicability
CO 2	Use appropriate data structures like arrays, linked lists, stacks and queues to solve real world problems efficiently.
CO 3	Comprehend and implement various techniques for searching, sorting and Hashing
CO 4	Represent and manipulate data using nonlinear data structures like trees and graphs to design algorithms for various applications.
CO 5	Identify the appropriate data structure to design efficient algorithm for the given application

#### Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	2	1										3
CO 2	2	1										3
CO 3	2	1										3
CO 4	3	2	2									3
CO 5	3	2	2									3
CO 6	3	2	2									3

#### Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			



**Mark distribution**

<b>Total Marks</b>	<b>CIE</b>	<b>ESE</b>	<b>ESE Duration</b>
150	50	100	3 hours

**Continuous Internal Evaluation Pattern:**

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions****Course Outcome 1 (CO1):**

1. Differentiate between primitive and non-primitive data structures with the help of examples.
2. What do you mean by asymptotic notations?

**Course Outcome 2 (CO2):**

1. Differentiate between stacks and queues.

**Course Outcome 3 (CO3):**

1. Differentiate between linear search and binary search.
2. What are hash tables?

**Course Outcome 4 (CO4):**

1. What is breadth-first search?
2. What are the internal and external sorting algorithms?

**Course Outcome 5 (CO5):**

1. Characteristics of dynamic programming.
2. What is backtracking



**Model Question Paper**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
SEVENTH SEMESTER B.TECH. DEGREE EXAMINATION**

**Course Code: RAT401**

**Course Name: Algorithms and Data Structures**

Max. Marks: 100

Duration: 3 Hours

**PART A**

**Answer all questions, each carries 3 marks.**

Marks

- 1 What do you mean by asymptotic notations? Explain briefly about the asymptotic notations that are commonly used to calculate the running time complexity of an algorithm? (3)
- 2 Differentiate between primitive and non-primitive data structures with the help of examples (3)
- 3 Write an algorithm/pseudocode to delete a given element  $k$  from an array  $A$  of  $n$  elements? Assume that the element  $k$  is always present in  $A$ . (3)
- 4 How will you represent a polynomial  $3x^2 + 2xy^2 + 5y^3 + 7yz$  using a singly linked list? (3)
- 5 Draw the binary tree whose sequential representation is given below. (3)
 

1	2	3	4	5	6	7	8	9	10	11
12	13	14	15							

A	B	C	D	—	E	F	—	G	—	—	H	—	—	I
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
- 6 Define (i) Tree (ii) Binary Tree. (3)
- 7 Explain efficiency of (i) Quick sort (ii) Binary searching. (3)
- 8 Write an algorithm to search for a substring in a given string. (3)
- 9 Explain backtracking with an example. (3)
- 10 What are the steps in dynamic programming? (3)

**PART B**

**Answer any one full question from each module, each carries 14 marks.**

**MODULE I**



- 11 a) Explain in detail the substitution method for solving recurrence relations (7)  
 b) Explain the operations on Data structures with examples. (7)
- 12 a) What is a recursive algorithm? Explain different types of recursive algorithms with examples. (6)  
 b) Explain linear and nonlinear data structures. (8)

## MODULE II

- 13 a) Assume that a stack is represented using a linked list. Write algorithms for the following operations: - (i) Push (ii) Pop (7)  
 b) Explain the structure of Doubly Linked List (DLL). Differentiate the difference between DLL and Doubly Circular Linked List (DCLL). Explain the procedures to insert a node in DLL at the beginning and at the last. (7)
- 14 a) Write algorithms to perform the following operations on a doubly linked list. (i) Insert a node with data 'y' after a node whose data is 'x'. (ii) Delete a node whose data is 's'. (iii) Insert a node with data 'a' as the 1st node of the list. (7)  
 b) Explain different types of queues and their applications. (7)

## MODULE III

- 15 a) Which are the elementary graph operations? Explain in detail. (7)  
 b) What is a priority queue? Implement using a linked list. (7)
- 16 a) Explain the various ways in which a graph can be represented bringing out the advantages and disadvantages of each representation. (7)  
 b) Explain various tree traversal algorithms with examples. (7)

## MODULE IV

- 17 a) Write an algorithm to perform selection sort in an array. Using the above selection sort algorithm, sort the input file [25, 7, 46, 11, 85]. (6)  
 b) With the help of an algorithm/pseudocode and suitable example, explain how you would perform binary search on an array of n elements. Find the time complexity of binary search algorithm. (8)
- 18 a) Explain in brief how the shortest path is calculated using Dijkstra's algorithm. (7)



- b) Write an algorithm to perform binary search on a given set of 'n' numbers. (7)  
Using the algorithm search for the element 23 in the set [12, 23, 34, 44, 48, 53, 87, 99]

### MODULE V

- 19 a) Explain divide-and-conquer approach in detail. (7)  
b) Explain greedy algorithm with example. Also explain its advantages and disadvantages. (7)
- 20 a) Explain dynamic programming in detail with example. (7)  
b) What is meant by NP-complete problems? Explain in detail with examples. What are the techniques that can be applied to solve computational problems in general? (7)

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### . SYLLABUS

#### Module I (8 Hours)

**Introduction to Data Structures:** Basic Terminology, Elementary Data Structure Organization, Classification of Data Structures: Primitive and Non-primitive, Linear and Non-linear, Operations on Data structures, Asymptotic notations, Notion of recursive algorithms, Recurrence relations

#### Module II ( 10 Hours)

**Linear Data Structures:** Introduction, variations, operations and applications of array, queue, stack and linked list

Array: Representation of arrays, Applications of arrays, sparse matrix and its representation.

Stack: Stack-Definitions & Concepts, Operations On Stacks, Applications of Stacks, Polish Expression, Reverse Polish Expression And Their Compilation, Recursion, Tower of Hanoi

Queue: Representation Of Queue, Operations On Queue, Circular Queue, Priority Queue, Array representation of Priority Queue, Double Ended Queue, Applications of Queue

Linked lists: - singly linked list, doubly linked list, Circular linked list, operations on linked list, linked list with header nodes

#### Module III ( 8 Hours)

**Non-Linear Data Structures:** Concepts and types of trees, tree traversal algorithms, search trees, Priority queue implementation and applications

Graph-Matrix Representation Of Graphs, Elementary Graph operations, (Breadth First



#### **Module IV (8Hours)**

**Indexing structure:** Concepts and implementations of B-Tree, B+ tree, Hashing, Dictionary

**Graph Algorithms:** Depth-first search, strongly connected components, Breadth-first search, Dijkstra's algorithm

**Searching and Sorting Algorithms:** Linear search, Binary search, Hash tables, internal and external sorting algorithms, sorting without comparison.

#### **Module V (8 Hours)**

**Algorithm Design:** Greedy algorithm, Divide and conquer, Dynamic programming, Backtracking, Branch and bound, Randomized algorithms

**Algorithm Analysis:** Asymptotic notations, Recurrences, NP complete problems

#### **Text Books**

1. Samanta D., Classic Data Structures, Prentice Hall India, 2/e, 2009.
2. Richard F. Gilberg, Behrouz A. Forouzan, Data Structures: A Pseudocode Approach with C, 2/e, Cengage Learning, 2005.
3. Aho A. V., J. E. Hopcroft and J. D. Ullman, Data Structures and Algorithms, Pearson Publication, 1983.

#### **Reference Books**

1. Horwitz E., S. Sahni and S. Anderson, Fundamentals of Data Structures in C, University Press (India), 2008.
2. Tremblay J. P. and P. G. Sorenson, Introduction to Data Structures with Applications, Tata McGraw Hill, 1995.
3. Peter Brass, Advanced Data Structures, Cambridge University Press, 2008
4. Wirth N., Algorithms + Data Structures = Programs, Prentice Hall, 2004.



No	Topic	No. of Lectures
1	<b>MODULE 1</b>	
1.1	Introduction to Data Structures: Basic Terminology, Elementary Data Structure Organization	3
1.2	Classification of Data Structures: Primitive and Non-primitive, Linear and Non-linear	3
1.3	Operations on Data structures, Asymptotic notations, Notion of recursive algorithms, Recurrence relations	3
2	<b>MODULE 2</b>	
2.1	Introduction, variations, operations and applications of array, queue, stack and linked list, operations and applications of array, queue, stack and linked list	3
2.2	Array: Representation of arrays, Applications of arrays, sparse matrix and its representation.,	2
2.3	Stack: Stack-Definitions & Concepts, Operations On Stacks, Applications of Stacks, Polish Expression, Reverse Polish Expression And Their Compilation, Recursion, Tower of Hanoi	2
2.4	Queue: Representation Of Queue, Operations On Queue, Circular Queue, Priority Queue, Array representation of Priority Queue, Double Ended Queue, Applications of Queue	2
2.5	Linked lists:- singly linked list, doubly linked list, Circular linked list, operations on linked list, linked list with header nodes	2
3	<b>MODULE 3</b>	
3.1	Concepts and types of trees, tree traversal algorithms, search trees	3
3.2	Priority queue implementation and applications	3
3.3	Graph-Matrix Representation Of Graphs, Elementary Graph operations, ( Breadth First Search, Depth First Search, Spanning Trees, Shortest path, Minimal spanning tree ).	3
4	<b>MODULE 4</b>	
4.1	Indexing structure: Concepts and implementations of B-Tree, B+ tree, Hashing, Dictionary	3
4.2	Graph Algorithms: Depth-first search, strongly connected components, Breadth-first search, Dijkstra's algorithm	3
4.3	Searching and Sorting Algorithms: Linear search, Binary search, Hash tables, internal and external sorting algorithms, sorting without comparison.	3
5	<b>MODULE 5</b>	



5.1	Algorithm Design: Greedy algorithm, Divide and conquer, Dynamic programming, Backtracking, Branch and bound, Randomized algorithms	5
5.2	Algorithm Analysis : Asymptotic notations, Recurrences, NP complete problems	4

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