RAT 292	Sensors and Actuators for Robots	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

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

CO 1	Analyze and select the most appropriate sensors and actuators for a robotic application
CO 2	Explain fundamental principle of working of sensors and actuators for robots
CO 3	Interpret typical manufacturer's data sheet of sensors and actuators and use them for selection in typical 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	**3**	**2**	**2**									3
CO 2	**3**	**2**	**2**									3
CO 3	**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

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.

Module I

Requirement of sensors in robots used in industry, agriculture, medical field, transportation, military, space and undersea exploration, human-robot interactions, robot control, robot navigation, tele-operational robot etc.

Proprioceptive or Internal sensors Position sensors- encoders- linear, rotary, incremental linear encoder, absolute linear encoder, Incremental rotary encoder, absolute rotary encoder; potentiometers; LVDTs; velocity sensors-optical encoders, tacho generator, Hall effect sensor, , acceleration sensors,Heading sensors- Compass, Gyroscope sensor, IMU, GPS, real time differential GPS, active optical and RF beacons, ultrasonic beacons, reflective beacons; Force sensors-strain gauge based and Piezo electric based, Torque sensors- Numerical Problems; Electronic skin, micro-cantilevers;Block schematic representations; Interpreting typical manufacturer's data sheet of internal sensors; Examples - the use of Proprioceptive sensors in robots.

ModuleII

Exteroceptive or External sensors-contact type, noncontact type;Tactile, proximity- detection of physical contact or closeness, contact switches, bumpers , inductive proximity, capacitive proximity; semiconductor displacement sensor; Range sensors- IR, sonar, laser range finder, optical triangulation (1D), structured light(2D), performance comparison range sensors; motion/ speed sensors-speed relative to fixed or moving objects, Doppler radar, Doppler sound; Block schematic representations; Numerical problems;Block schematic representations; Interpreting typical manufacturer's data sheet of external sensors;Examples - use of Exteroceptive sensors in robots.

Module III

Vision based sensors- Elements of vision sensor, image acquisition, image processing, edge detection, feature extraction, object recognition, pose estimation and visual servoing, hierarchy of a vision system, CCD and CMOS Cameras, Monochrome, stereovision, night vision cameras, still vs video cameras, kinect sensor; Block schematic representations.

Criteria for selection of sensors- range, dynamic range, sensitivity, Linearity, response time, band width, accuracy, repeatability & precision, Resolution & threshold, type of output, size and weight, environmental conditions, interfacing.

Module IV

Requirement of actuators for robotic applications, Pneumatic and Hydraulic actuators, physical components, comparison of hydraulic and pneumatic systems- Components of electro hydraulic and pneumatic systems; hydraulic and pneumatic actuators with proportional control valves.

Electric actuators- advantages, DC motors, DC and AC servo motors,various types of Stepper motors; brushless DC motors ; PMSM; SRM; Motor characteristics, Selection of motors, block schematic of typical electric drive, closed loop speed and torque control.

Interpreting typical manufacturer's catalogue of actuators and using them for selection in typical applications.

Module V

Linear actuation mechanisms- Belt-driven and screw-driven actuators, Pneumatically and hydraulically driven linear actuators, Rack-and-pinion driven actuators, Linear motor driven actuators.

Transmission mechanisms-Cams and Cam followers, working principle. Gears and gear trains, ratchet and pawl, belt drive, advantages of belt drive, bearings classification and selection of bearings.

Electro thermal, electro-optical and electrochemical actuators, Piezo-actuators, pneumatic muscles

Micro-actuators- Electrostatic, Electromagnetic, Piezoelectric, Fluid, Thermal, Shape memory alloy, characteristics of microactuators- Stroke, Force/torque, Stiffness, Input energy, Efficiency, Linearity, Hysteresis, Response time, Drift, Bandwidth.

References

1. Robotics Engineering: An Integrated Approach, by Richard D. Klafter, Prentice Hall Inc.
2. Clarence W. de Silva, Sensors and Actuators: Control System Instrumentation, CRC Press 2007, ISBN-13: 978-1420044836
3. Introduction to Robotics, S K Saha, McGraw Hill Eduaction
4. D. Patranabis, “Sensors and Transducers”, PHI Learning Private Limited.
5. W. Bolton, “Mechatronics”, Pearson Education Limited.
6. Automation, Production Systems and Computer Integrated Manufacturing, Groover M.P, Prentice – Hall Ltd., 1997.
7. Pillai S. K. “A first course on electric drives”, Wieley Eastern Ltd, New Delhi
8. Journal of sensors, Special issue- Sensors for Robotics, Aiguo Song , Guangming Song, Daniela Constantinescu, Lei Wang, and Quanjun Song, Volume 2013
9. Mechatronics: Integrated mechanical electronic systems By K.P. Ramachandran, G.K. Vijayaraghavan, Wiley India
10. Linear Electric Actuators by I. Boldea
11. Piezoelectric Actuators (Electrical Engineering Developments), 2012, by Joshua E. Segel

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Proprioceptive or Internal sensors**	
1.1	Requirement of sensors in robots used in industry, agriculture, medical field, transportation, military, space and undersea exploration, human-robot interactions, robot control, robot navigation, tele-operational robot etc.	1
1.2	Position sensors- encoders- linear, rotary, incremental linear encoder, absolute linear encoder, Incremental rotary encoder, absolute rotary encoder; potentiometers; LVDTs.	2
1.3	velocity sensors-optical encoders, tacho generator, Hall effect sensor, acceleration sensors	2

1.4	Heading sensors- Compass, Gyroscope sensor, IMU, GPS, real time differential GPS,	2
1.5	active optical and RF beacons, ultrasonic beacons, reflective beacons	1
1.6	Force sensors-strain gauge based and Piezo electric based, Torque sensors- Electronic skin, micro-cantilevers. Examples - use of Proprioceptive sensors in robots.	2
	Note- Block schematic representations, Interpretation of typical manufacturer's data sheet and Numerical problems of the above mentioned sensors are to be covered.	
2	**Exteroceptive or External sensors**	
2.1	contact type, noncontact type; Tactile, proximity- detection of physical contact or closeness, contact switches, bumpers , inductive proximity, capacitive proximity; semiconductor displacement sensor;	3
2.2	Range sensors- IR, sonar, laser range finder, optical triangulation (1D), structured light(2D), performance comparison range sensors;	3
2.3	Motion/ speed sensors-speed relative to fixed or moving objects, Doppler radar, Doppler sound; Numerical problems; Examples- use of Exteroceptive sensors in robots.	3
	Note- Block schematic representations, Interpretation of typical manufacturer's data sheet and Numerical problems of the above mentioned sensors are to be covered.	
3		
3.1	Vision based sensors - Elements of vision sensor, image acquisition, image processing, edge detection, feature extraction, object recognition, pose estimation and visual servoing, hierarchy of a vision system	4
3.2	CCD and CMOS Cameras, Monochrome, stereovision, night vision cameras, still vs video cameras, kinect sensor.	3
3.3	Criteria for selection of sensors- range, dynamic range, sensitivity, Linearity, response time, band width, accuracy, repeatability & precision, Resolution & threshold, type of output, size and weight, environmental conditions, interfacing.	2
4	**Actuators for Robots**	
4.1	Requirement of actuators for robotic applications, Pneumatic and Hydraulic actuators, physical components, comparison of hydraulic and pneumatic systems- Components of electro hydraulic and pneumatic systems; hydraulic and pneumatic actuators with proportional control valves.	4
4.2	**Electric actuators**- advantages, DC motors, DC and AC servo motors, various types of Stepper motors ; brushless DC motors ; PMSM; SRM; Motor characteristics, Selection of motors, block schematic of typical electric drive, closed loop speed and torque control.	5
	Note: Interpreting typical manufacturer's catalogue of actuators and using them for selection in typical applications to be covered	

5		
5.1	Linear actuation mechanisms- Belt-driven and screw-driven actuators, Pneumatically and hydraulically driven linear actuators, Rack-and-pinion driven actuators, Linear motor driven actuators.	3
5.2	Transmission mechanisms-Cams and Cam followers, working principle. Gears and gear trains, ratchet and pawl, belt drive, advantages of belt drive, bearings classification and selection of bearings.	2
5.3	Electro thermal, electro-optical and electrochemical actuators, Piezo-actuators, pneumatic muscles	1
	Micro-actuators - Electrostatic, Electromagnetic, Piezoelectric, Fluid, Thermal, Shape memory alloy, characteristics of microactuators - Stroke, Force/torque, Stiffness, Input energy, Efficiency, Linearity, Hysteresis, Response time, Drift, Bandwidth.	2

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
THIRD SEMESTER B.TECH. DEGREE EXAMINATION

Course Code: RAT 292
Course Name: SENSORS AND ACTUATORS FOR ROBOTS

Max. Marks: 100 Duration: 3 Hours

PART A

Answer all questions, each carries 3 marks. Marks

1	How proprioceptive sensors differ fromexteroceptive sensors?	(3)
2	Mention the applications of force sensors.	(3)
3	A robot is moving in an environment amidst obstacles which are black in colour. Which sensor is preferred in this scenario for range measurement and obstacle avoidance? Justify your answer.	(3)
4	Explain the uses of tactile sensors.	(3)
5	Can we compute depth of an object using camera? Justify your answer.	(3)
6	What is visual servoing?	(3)
7	If the payload of a robotic manipulator is a car, which actuator is preferred? Justify your answer.	(3)
8	Which motors are generally used for position control applications?	(3)
9	Which are the commonly used linear actuating mechanisms for robots?	(3)
10	What are pneumatic muscles?	(3)

PART B

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

MODULE1

11	a)	What is LVDT? What are the parameters that can be measured by this? Describe with a neat diagram the principle of operation and output characteristics of the same.	(10)
	b)	A robot'scontrol memory has 8 bit storage capacity; it has two rotational joints and one linear joint. The linear link can varyits length from as short as 0.2 meters to as long as 1.2 meters. Compute the control resolution for encoder of each joint.	(4)
12	a)	What is Gyroscope? Enumerate various sources of errors in Gyroscopes? How will you rectify them while gyroscopes are used in robotic applications?	(10)
	b)	Can we use GPS sensors in indoor environments? Justify your answer.	(4)

MODULE II

13	a)	Which are the sensors used to detect closeness of objects? And how will you compute the same?	(10)
	b)	How range is measured using optical triangulation method?	(4)
14		Consider a scenario where a surveillance vehicle chases a car which violated traffic rules. Which all sensors are to be used in the surveillance vehicle to compute the position and relative velocity of the target vehicle (car)? Explain the working of the sensors being used.	(14)

MODULE III

15	a)	Which are the elements of a vision sensor? How will you extract features using vision sensor?	(10)
	b)	What are the advantages of CMOS cameras?	(8)
16		Explain the criteria for selection of sensors for different applications	(14)

MODULE IV

17	a)	Compare hydraulic and pneumatic actuators?	(8)
	b)	What is FRL unit? What are its functions?	(6)
18	a)	With the help of neat diagram explain the working of stepper motor?	(8)
	b)	In which context Brushless DC motors are used for robotic applications? Mention one application for the same.	(3)
	c)	How much power is required to lift a 20Kg weight by a DC motor if the lifting speed is 0.2m/s?	(3)

Module V

19	a)	Explain the working of Rack-and-pinion driven actuator with the help a diagram.	(8)
	b)	Explain in detail about different transmission mechanisms.	(6)
20	a)	Compare electro thermal, electro-optical and electrochemical actuators.	(7)
	b)	Which are the characteristics of micro-actuators?	(7)

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RAT393	PLC AND SCADA	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: Acquire the skill of PLC and SCADA programming

Prerequisite: Nil

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

CO 1	Understand the components of a PLC system and its working
CO 2	Design logic circuits to perform industrial control functions of medium complexity and realise the same using ladder logic
CO3	Demonstrate the use of different types of inputs/outputs and networking commonly used on PLC-based systems.
CO4	Familiarisation of SCADA architecture and communication in SCADA
CO5	Determine hardware and software requirements of SCADA and 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
CO 1	**3**	**3**	**2**									3
CO 2	**3**	**3**	**2**									3
CO 3	**3**	**3**	**2**									3
CO 4	**3**	**3**	**2**									3
CO 5	**3**	**3**	**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

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. With the help of a block diagram, explain the basic architecture of a PLC system. Discuss any three types of PLCs used in automation
2. What are the different methods used to reduce maximum off state current to the input module

Course Outcome 2 (CO2):

1. A Manual mixing operation is to be automated using sequential process control methods. The process composed of three steps.
   a. Filling a tank to a pre-determined level
   b. Agitating the liquid for 30 minutes
   c. Draining the tank for use in another part of process

   Draw the ladder logic schematic to perform the above functions properly
2. Elaborate on the Functional Block Diagram and Sequential Flow Chart programming techniques

Course Outcome 3 (CO3):

1. With appropriate diagrams, explain the CANOpen standard. List out its advantages and disadvantages.
2. An industrial automation system needs to produce rectangular metal pieces of fixed dimensions. Implement an automation system using PLC which will help to reject the pieces that do not match with the fixed length and width.

Course Outcome 4 (CO4):

1. What are the important components of a SCADA system? Explain how the control operations can be carried out at the different levels of a manufacturing process using a SCADA system
2. What do you mean by Alarm Logging and Tag Logging in a SCADA system? Explain a scenario where each of these techniques can be used.

Course Outcome 5 (CO5):

1. Differentiate between a proprietary and Open Protocols. List out the advantages and disadvantages of both schemes.
2. With diagram, explain the architecture of a Distributed Control Systems. Explain the mechanisms available to handle communication failures in the distributed control systems.

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIFTH SEMESTER B.TECH. DEGREE EXAMINATION

Course Code: RAT393

Course Name: PLC and SCADA

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	Draw the block diagram of a PLC showing the main functional items and explain the functions of each block.	(3)
3	Implement the function, F (a, b, c) = Σ (0,1,3,4,6,7) using ladder logic program.	(3)
4	Write any math instruction in a PLC with an example.	(3)
5	What is the need for HMI in industrial automation?	(3)
6	What is CANopen? What is its use?	(3)
7	List the basic blocks involved in a pressure control process using PLC.	(3)
8	Explain supervisory control system with an example.	(3)
9	What are the design considerations for displays used with high level operator interfaces in DCS?	(3)
10	What is meant by OPC with regard to SCADA?	(3)

PART B

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

MODULE1

11	a)	Which are the different control elements of an industrial automation?	(4)

	b)	Explain IEC/ ISA Standards for the various control elements.	(5)
	c)	What are relays? With the help of diagrams explain any one use of a relay in an industrial process. Also write its relay logic program.	(5)
12	a)	Draw the block diagram of an analog output module and explain the parts.	(4)
	b)	With the help of diagrams, explain any two methods used to reduce maximum off state current to the input module.	(5)
	c)	Explain using suitable diagrams, how modularity is achieved in an input module	(5)

MODULE II

13	a)	Design a ladder logic program for following process: A temperature control system consists of three thermostats. The system operates two heating units. The thermostats are set on 70°C, 75°C and 80°C. Below 70°C, two heaters are on. The temperature between 70°C and 75°C causes one heater to be on. Above 80°C, there is safety shutoff for two heaters in case one stays on by mistake. A master switch turns the system on and off.	(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. With a drawing of the process, prepare a PLC ladder logic program for this control process.	(14)

MODULE III

15	a)	Which are the different networking standards associated with a PLC?	(8)
	b)	Explain the different types of HMI used in an industrial automation system.	(6)
16	a)	With a block diagram, explain the working of PROFIBUS. Give its two advantages	(6)
	b)	How can HMI elements be interfaced with a PLC in a water level control system?	(8)

MODULE IV

17	a)	Show how the following units are interfaced in SCADA system and explain the functions of each unit: a) Human Machine Interface unit, b) Master Terminal unit, c) Remote Terminal unit	(8)
	b)	An industrial automation system produces bars of metal of fixed length, 'L'. It is required to design a system to detect and reject metal bars which has a length other than the required value. How can such a system be implemented using PLC?	(6)
18	a)	Write notes on VB & C Scripts for SCADA applications	(8)
	b)	Describe the software and hardware architectures of SCADA.	(6)

Module V

19	a)	Write notes on interfacing of SCADA with PLCs and drives.	(7)

	b)	What is meant by DDE? What is it used for?	(7)
20	a)	Explain the various operator interface requirements in DCS.	(7)
	b)	Which are the different proprietary and open communication protocols of SCADA.	(7)

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SYLLABUS

Module I

Industrial Automation -review, Control elements of Industrial Automation-IEC/ ISA Standards for Control Elements, Selection criteria for control elements-Construction of relay logic circuits with different control elements-Need for PLC -PLC evolution.

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- 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.

Module II

PROGRAMMING OF PLC: – Ladder Programming –Realization of simple logic circuits, Timers and counters–arithmetic and logic functions- PTO / PWM generation-Programming examples- High Speed Counter –Analog Scaling –Encoder Interfacing-Servo drive control –Stepper Motor Control.

Other programming types:Functional Block Diagram FBD (most commonly used in industries) -Sequential Flow Chart SFC -Structured Text (Textual) -Instruction List (Textual)

Module III

NETWORKING: PLC Networking-Networking standards & IEEE Standards -Protocols –Ethernet- Process field bus (PROFIBUS)-CANopen, different methods of interfacing with a PLC

Case studies- PLC based traffic light system, stepper motor & servo motor control using PLC, Analog sensor interfacing with PLC, encoder interfacing with PLC.

HMI SYSTEMS: Need for HMI in Industrial Automation, Types of HMI –Configuration of HMI, Screen development and navigation, Configuration of HMI elements / objects and interfacing with PLC

Module IV

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

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA):Overview –Developer and runtime packages –Architecture –Tools –Tags–Graphics -Alarm logging –Tag logging – Trends –History –Report generation, VB & C Scripts for SCADA application

Module V

COMMUNICATION PROTOCOLS OF SCADA:Proprietary and open Protocols –OLE/OPC –DDE –Server/Client Configuration –Messaging –Recipe –User administration –Interfacing of SCADA with PLC, drive, and other field devices.

DISTRIBUTED CONTROL SYSTEMS (DCS):DCS –architecture –local control unit-programming language - communication facilities -operator interface -engineering interfaces.

Case studies- Design of conveyor automation system using PLC, SCADA and Electrical drive; Design of inspection automation system using sensors, PLC, HMI/SCADA; Design of simple water management system using PLC, SCADA and Electrical drive.

Text Books:

1. Programmable Logic Devices and Logic Controllers, Enrique Mandado, Jorge Marcos, Serafin A. Peres, Prentice Hall, 1996.
2. Practical SCADA for industry, David Bailey, Edwin Bright, Newnes, Burlington, 2003.

Reference Books

3. Introduction to Programmable Logic Controllers, Gray Dunning, Delamar Thomson Learning, 1998.
4. Programmable Controllers- AnEngineers's Guide, 2nd Edition, E.A. Parr, Newnes, 1999.
5. Programmable controllers, Hardware, Software & Applications, George L. Batten Jr., McGrawHill, 2nd Edition, 1994.
6. Programmable logic controllers, W. Bolton, Elsevier Ltd, 2015.
7. Programmable logic controllers,Frank D Petruzella, McGraw-Hill, 2011.
8. Programmable Logic Controllers: Programming Methods and Applications. John R Hackworth and Fredrick D Hackworth Jr., Pearson Education, 2006.
9. Practical Modern SCADA Protocols: DNP3, 60870.5 and Related systems, Gordon Clarke, Deon Reyneders, Edwin Wright, Newnes Publishing, 2004.48
10. Designing SCADA Application Software, Stuart G McCrady, Elsevier, 2013.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1		
1.1	Industrial Automation -review, Control elements of Industrial Automation-IEC/ ISA Standards for Control Elements, Selection criteria for control elements-Construction of relay logic circuits with different control elements-Need for PLC - PLC evolution.	3
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	3
1.3	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	3
2		
2.1	PROGRAMMING OF PLC: – Ladder Programming – Realization of simple logic circuits, Timers and counters–arithmetic and logic functions- PTO / PWM generation	3
2.2	Programming examples- High Speed Counter –Analog Scaling – Encoder Interfacing-Servo drive control –Stepper Motor Control.	3
2.3	Other programming types: Functional Block Diagram FBD (most commonly used in industries) -Sequential Flow Chart SFC -Structured Text (Textual) -Instruction List (Textual)	3
3		
3.1	NETWORKING: PLC Networking-Networking standards & IEEE Standards -Protocols – Ethernet- Process field bus (PROFIBUS)- CAN open, different methods of interfacing with a PLC	3
3.2	**Case studies**- PLC based traffic light system, stepper motor & servo motor control using PLC, Analog sensor interfacing with PLC, encoder interfacing with PLC.	3
3.3	HMI SYSTEMS: Need for HMI in Industrial Automation, Types of HMI –Configuration of HMI, Screen development and navigation, Configuration of HMI elements / objects and interfacing with PLC	3
4		
4.1	APPLICATIONS OF PLC: Case studies of manufacturing automation and process automation.	3
4.2	SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA): Overview –Developer and runtime packages –Architecture –Tools –	6

	Tags–Graphics -Alarm logging –Tag logging –Trends –History –Report generation, VB & C Scripts for SCADA application	
5		
5.1	COMMUNICATION PROTOCOLS OF SCADA: Proprietary and open Protocols –OLE/OPC –DDE –Server/Client Configuration –Messaging –Recipe –User administration –Interfacing of SCADA with PLC, drive, and other field devices.	3
5.2	DISTRIBUTED CONTROL SYSTEMS (DCS): DCS –architecture –local control unit- programming language - communication facilities -operator interface - engineering interfaces.	3
5.3	**Case studies**- Design of conveyor automation system using PLC, SCADA and Electrical drive; Design of inspection automation system using sensors, PLC, HMI/SCADA; Design of simple water management system using PLC, SCADA and Electrical drive.	3

RAT394	ADVANCED CONTROL FOR ROBOTICS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: Control mechanisms plays a vital role in the design of robotic systems. With the application area of robots being very vast and divergent, design of appropriate control mechanisms is quite challenging. This course provides the students an introduction to the different control mechanisms that are specifically applicable to robot design.

Prerequisite: Basic course in Control Systems

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

CO 1	Design linear controllers for robotic manipulators
CO 2	Interpret about various nonlinear control schemes for robotic manipulators
CO 3	Illustrate force control schemes of manipulators
CO 4	Design controllers for mobile robots
CO 5	Familiarise about vision-based control schemes for 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	2	2	1	2							3
CO 2	3	2	2	1	2	1						2
CO 3	3	2	2	2	2	1						3
CO 4	3	2	2	2	1	1						2
CO 5	3	3	2	2	2	1						2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	25	25	40
Apply	15	15	40
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
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Continuous Internal Evaluation Pattern:

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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. With block diagrams, explain the closed loop and feed forward Robotic Contorl Systems
2. With an example, explain a trajectory following control used for robots.
3. Explain the architecture of an industrial-robot controller with suitable diagrams

Course Outcome 2 (CO2):

1. What is a model-based manipulator control design approach? What are the different models used in the above design process?
2. Explain one non-linear control scheme of robotic manipulator

Course Outcome 3 (CO3):

1. Explain the role of industrial robots in assembly lines in a
2. Discuss the response of a mass-Spring system with a driving force

Course Outcome 4 (CO4):

1. State and derive the expression for Lya punov stability criterion
2. Explain the use of a computed torque control in robotic design

Course Outcome 5 (CO5):

1. What is Image Segmentation? Explain the role of segmentation in Image processing applications
2. What is stereo vision and how is it useful?
3. Discuss the working of a image based visual servo mechanism that can be used in robotic application

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH. DEGREE EXAMINATION

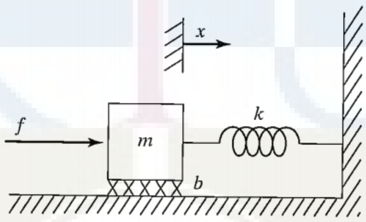
Course Code: RAT 394

Course Name: ADVANCED CONTROL FOR ROBOTICS

Max. Marks: 100 Duration: 3 Hours

PART A

Answer all questions, each carries 3 marks. Marks

1	What is the necessity of controllers in a robotic system?	(3)
2	 If m = 1, b = 1, and k = 1, find gains Kp and Kv for a position-regulation control law that results in the system's being critically damped with a closed-loop stiffness of 16.0.	(3)
3	Explain PD gravity control of a robotic manipulator.	(3)
4	Explain resolved motion rate control of robots.	(3)
5	What are the applications of industrial robots force control may be needed?	(3)
6	What do you mean by natural and artificial constraints for tasks in partially constrained environments?	(3)
7	A typical mobile robot is a linear or nonlinear system? Justify your answer.	(3)
8	Briefly explain Lyapunov Stability-Based Control Design of mobile robots.	(3)

9 What is visual servoing? (3)

10 How pose is estimated using camera? (3)

PART B

Answer any one full question, each carries14 marks.

MODULE I

11 a) Explain control law partitioning with the help of an example. (7)

b) Explain PID control of a single link manipulator (7)

12 a) Differentiate between continuous and discrete control (6)

b) A researcher has proposed the following control scheme for a serial manipulator, where [kp] and [Kv] are positive definite gain matrices (8)

$$\tau = [\mathbf{M}(\mathbf{q})]\ddot{\mathbf{q}}_d + \mathbf{C}(\mathbf{q}, \dot{\mathbf{q}}) + \mathbf{G}(\mathbf{q}) + [K_p](\mathbf{q}_d - \mathbf{q}) + [K_v](\dot{\mathbf{q}}_d - \dot{\mathbf{q}})$$

Draw the block schematic of the proposed controller and explain. What are the possible advantages of the scheme?

MODULE II

13 a) Explain any one non-linear control scheme of robotic manipulator. (7)

b) How will you design a Lyapunov based controller for a robotic system? (7)

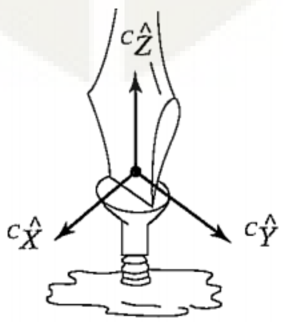
14 a) Explain about task space control schematic of robots (8)

b) Explain adaptive control of robotic manipulators (6)

MODULE III

15 a) Explain the assembly sequences used to put a round peg into a round hole (7)

b) Figure shows a manipulator tightening a screw. What are the natural and artificial constraints for this task? (7)



16	a)	Explain the force control of a typical mass spring dashpot system	(8)
	b)	A cartesian manipulator with 3 DOF is in touch with a contact surface. Explain the block schematic for a hybrid controller for a 3-DOF Cartesian arm	(6)

MODULE IV

17	a)	Obtain the kinematic model of a differentially driven mobile robot.	(8)
	b)	Check the stability of the following system using the Lyapunov method: $\dot{x} = -x$	(6)
18	a)	Explain state feedback control of robotic manipulators	(8)
	b)	Explain about computed torque control of mobile robots?	(6)

MODULE V

19	a)	Explain the configuration of a vision system in a visual servoing scenario	(7)
	b)	Explain position-based Visual Servoing using PD Control with Gravity Compensation	(7)
20	a)	Explain Image-based Visual Servoing using Resolved-velocity Control	(8)
	b)	Explain any two applications where visual servoing is employed.	(6)

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SYLLABUS

Module I (9 Hours)

Review of dynamic modelling of robots.
Introduction to robot control- Necessity of Controllers for Robots, typical block schematic closed loop and feed forward control.
Linear control of manipulators- closed-loop control, second-order linear systems, control of second-order systems, control-law partitioning, trajectory-following control, disturbance rejection, continuous vs. discrete time control, Feedback control of single link manipulator, architecture of an industrial-robot controller

Case study- Matlab simulation-PID Control of single link manipulator and planar 2R manipulator, closed loop control of wall following robot- block schematic- sensor selection etc

Module II (9 Hours)

Nonlinear Control of manipulators- the control problem for manipulators- model-based manipulator control system -computed torque control, practical considerations, current industrial-robot control systems, PD Gravity control, Lyapunov stability analysis, adaptive control.
Task Space Control Schemes – resolved motion rate control and resolved motion acceleration control.
Case study- resolved motion rate control of 2R manipulator

Module III (9 Hours)

Force control of manipulators- introduction, application of industrial robots to assembly tasks, a framework for control in partially constrained tasks, the hybrid position/force control problem, force control of a mass—spring system, the hybrid position/force control scheme, current industrial-robot control schemes
Case study- force control of peg in hole assembly task, natural and artificial constraints

Module IV (9 Hours)
Mobile Robot Control : State space modelling- Lyapunov Stability, state feedback control, Proportional plus derivative control, Lyapunov function based control, Computed torque control, Resolved motion rate control , Resolved motion acceleration control

Module V (9 Hours)

Visual Servoing - Vision for Control -Configuration of the Visual System; Image Processing- Image Segmentation, Image Interpretation; Pose Estimation; Stereo Vision-Epipolar Geometry, Triangulation -Position-based Visual Servoing- PD Control with Gravity Compensation. Resolved-velocity Control; Image-based Visual Servoing, PD Control with Gravity Compensation, Resolved-velocity Control

Text Books:

1. Introduction to Robotics Mechanics and Control, John J. Craig, 3e, Pearson
2. Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford
3. Robotics- Modelling planning and control- Bruno Siciliano , Lorenzo Sciavicco Luigi Villani, Giuseppe Oriolo, Springer-Verlag London
4. Introduction to Mobile Robot Control - S.G. Tzafestas, 2014, Elsevier
5. The Robotics Primer-Maja J Matari´c, The MIT Press

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**MODULE 1**	
1.1	Review of dynamic modelling of robots	1
1.2	Introduction to robot control-Necessity of Controllers for Robots, typical block schematic closed loop and feed forward control.	1
	Linear control of manipulators- closed-loop control, second-order linear systems, control of second-order systems, control-law partitioning, trajectory-following control, disturbance rejection, continuous vs. discrete time control	3
	Feedback control of single link manipulator, architecture of an industrial-robot controller	2
	Case study- Matlab simulation-PID Control of single link manipulator and planar 2R manipulator (Ref2), closed loop control of wall following robot- block schematic- sensor selection etc (Ref 5)	2
	Main reference books- Ref 1 and 2	
2	**MODULE 2**	
2.1	Nonlinear Control of manipulators-the control problem for manipulators	1
2.2	model-based manipulator control system -computed torque control, practical considerations, current industrial-robot control systems, PD Gravity control (ref1)	3
2.3	Lyapunov stability analysis, adaptive control (ref1)	3
2.4	Task Space Control Schemes – resolved motion rate control and resolved motion acceleration control (ref1)	1
2.5	Case study- resolved motion rate control of 2R manipulator (ref1)	1
3	**MODULE 3**	
3.1	Force control of manipulators- introduction, application of industrial robots to assembly tasks, a framework for control in partially constrained tasks, the hybrid position/force control problem, force control of a mass—spring system, the hybrid position/force control scheme, current industrial-robot control schemes (Ref 1 and 2)	7
3.2	Case study- force control of peg in hole assembly task, natural and artificial constraints (Ref 2)	2
4	**MODULE 4**	
4.1	Mobile Robot Control: State space modelling- Lyapunov Stability, state feedback control, Proportional plus derivative control,	9

	Lyapunov function based control, Computed torque control, Resolved motion rate control , Resolved motion acceleration control	
5	**MODULE 5**	
5.1	Visual Servoing - Vision for Control -Configuration of the Visual System; Image Processing- Image Segmentation, Image Interpretation; Pose Estimation; Stereo Vision- Epipolar Geometry, Triangulation -Position-based Visual Servoing- PD Control with Gravity Compensation. Resolved-velocity Control; Image-based Visual Servoing, PD Control with Gravity Compensation, Resolved-velocity Control (Ref 3)	9

RAT495	FIELD ROBOTICS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: Practical Field Robotics comprises the design and fabrication of machines that do useful work on their own, for the most part. Field Robotics separates us from robotics done in a protected laboratory environment. This course provides exposure to the students on the various challenges involved in the design of Autonomous Ground Vehicles and Unmanned Aerial Vehicles used for real time applications.

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

CO 1	Recognize the complexity of mobile robotic applications in unstructured environments
CO 2	Describe the design considerations for an autonomous ground vehicle
CO 3	Describe the design considerations for an unmanned aerial vehicle
CO 4	Explain the communication infrastructure and Data processing requirements of a UAV
CO 5	Interpret the use of Field robots for disaster recovery and in agriculture

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		2	1					
CO 2	3		2									
CO 3	3		2									
CO 4	3		2									
CO 5	3	2	3	3		3	1					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	20	20	40
Understand	30	30	60
Apply			
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 the challenges faced by mobile robots in harsh environments
2. Discuss the different design considerations for a field robot
3. Explain the working of an Autonomous Ground Vehicle

Course Outcome 2 (CO2):
1. Elaborate the need for both internal and external state sensing in an AGV
2. Discuss on the implementation of autonomy for different real world scenarios in vehicles

Course Outcome 3 (CO3):
1. Explain the requirements for maintaining the stability of a UAV
2. Elaborate on the various components and their role in an UAV
3. Describe the various Mission planning techniques used in UAV

Course Outcome 4 (CO4)
1. Explain the different communication infrastructure used in a UAV
2. Differentiate between the different types of communication infrastructure used in UAVs

Course Outcome 5 (CO5):
1. Elaborate the use of robots for disaster management
2. Elaborate the use of robots in the field of agriculture

SYLLABUS

Module I: (9 Hours)

Introduction to Field Robots: Challenges – Wheeled Mobile Robots in Agriculture – Wheeled Mobile Robots in Industry - Wheeled Mobile Robots in Domestic Environments – (Basic Setup – Sensors used – Localization and Mapping Techniques – Path Planning – Control strategies – Decision Making for all the above cases)

Autonomous Ground Vehicles: Components of Autonomy – Feedback control in Autonomous systems – Steering control using point mass model – open loop – closed loop – Polynomial tracking – Trajectory establishment

Module 2 (9 Hours)

Autonomous Ground Vehicles: System Architecture – Hybrid system formulation

Sensing – Internal State Sensing – External world Sensing – Estimation – Sensor Fusion - Autonomy Case Study – Steering Control and Lane Following – Parking

Maps and Path Planning: Map Databases – Path Planning

Module 3(9 Hours)

Unmanned Ariel Vehicles : Working of UAV – Advantages and Disadvantages – Stability and Control of UAV – Classification - Components of UAV – Measures of UAV Autonomy – Path planning in UAV - Path Planning algorithms -– Mission Planning – Flight Planning, Control of Mission and Payload

Module 4(9 Hours)

Flight Safety Operation - Intelligent Flight Control systems -UAV Communication infrastructure – Types – Wireless Sensor Network System – Free Space Optical Approach – First Person View Approach – SWARM Approach

UAV Data Collection and Processing Methods : Data Products – Data processing Approaches

Module 5(9 Hours)

Robotics in Disaster Management : Rescue Robot – Characteristics – Need for Rescue Robots – Types of Disasters – Rescue Robot Missions – Taxonomy of mission failure – Rescue robot terminal failures Reasons – Non Terminal Failure and workarounds

Robotics in Agriculture: Operational Classification – Weeding, Seeding, Disease and Insect detection, crop scouting, spraying, harvesting, plant management

Text Books

1. "Autonomous Ground Vehicles", Umit Ozguner, Tankut Acarman, Keith Redmill, Artech House Intelligent Transportation Systems Series
2. "Unmanned Aerial Vehicle – An Introduction", P. K.Garg, Mercury Learning and Information
3. "Agricultural Robotics for Field Operations", Spyros Fountas, Nikos Mylonas, Ioannis Malounas, Efthymios Rodias, Christoph Hellmann Santos, and Erik Pekkeriet – Sensors Journal, MDPI, 2020

Reference Books

1. "Fundamentals of Agricultural and Field Robotics", Manoj Karkee, Qin Zhang, Agricultural Automation and Control, Springer
2. "Practical Field Robotics – A Systems Approach", Robert H. Sturges Jr., Wiely
3. "Unmanned Aerial Vehicle: Applications in Agriculture and Environment", https://doi.org/10.1007/978-3-030-27157-2 , eBook, Springer
4. "Robotics and Mechatronics for Agriculture", Dan Zhang, Bin Wei CRC Press (2017)

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module I**	
1.1	Challenges – Wheeled Mobile Robots in Agriculture – Wheeled Mobile Robots in Industry	2
1.2	Wheeled Mobile Robots in Domestic Environments –	1
1.3	**Autonomous Ground Vehicles**: Components of Autonomy – Feedback control in Autonomous systems	2
1.4	Steering control using point mass model – open loop – closed loop	2
1.5	Polynomial tracking – Trajectory establishment	2
2	**Module II**	
2.1	Autonomous Ground Vehicles: System Architecture – Hybrid system formulation	2
2.2	Sensing – Internal State Sensing – External world Sensing	2
2.3	Estimation – Sensor Fusion	1
2.4	Autonomy Case Study – Steering Control and Lane Following – Parking	2
2.5	**Maps and Path Planning:** Map Databases – Path Planning	2
3	**Module 3**	
3.1	Working of UAV – Advantages and Disadvantages	2
3.2	Stability and Control of UAV – Classification - Components of UAV	2
3.3	Measures of UAV Autonomy	1
3.4	Path planning in UAV - Path Planning algorithms	2
3.5	Mission Planning – Flight Planning, Control of Mission and Payload	2
4	**Module 4**	
4.1	Flight Safety Operation - Intelligent Flight Control systems	2
4.2	UAV Communication infrastructure – Types – Wireless Sensor Network System	2
4.3	Free Space Optical Approach – First Person View Approach – SWARM Approach	3
4.4	UAV Data Collection and Processing Methods : Data Products – Data processing Approaches	2
5	**Module 5**	

5.1	**Robotics in Disaster Management :** Rescue Robot – Characteristics – Need for Rescue Robots – Types of Disasters – Rescue Robot Missions – Taxonomy of mission failure – Rescue robot terminal failures Reasons – Non Terminal Failure and workarounds	4
5.2	**Robotics in Agriculture:** Operational Classification – Weeding, Seeding, Disease and Insect detection, crop scouting, spraying, harvesting, plant management	5

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2014

Model Question Paper

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

Course Code: RAT495

Course Name:
FIELD ROBOTICS

Max. Marks: 100 | Duration: 3 Hours

PART A

		Answer all questions, each carries 3 marks.	Marks
1		Explain the different mapping techniques that can be used in a floor cleaning robot	(3)
2		What is swerving ? How will you calculate the look ahead distance while overtaking a stationary object?	(3)
3		List out the important characteristics that you will look for while selecting a sensor for Autonomous Ground Vehicle	(3)
4		What are the different error sources in GPS sensing?	(3)
5		What are the three angular degrees of freedom in the case of an UAV?	(3)
6		What are the different UAV classification based on the usage	(3)
7		Differentiate between active and passive remote sensing systems	(3)
8		What do you mean by Georeferencing and where is it used in UAV Data processing systems	(3)
9		Explain the different functions that you look forward in a agriculture robot	(3)
10		Explain any one robotic method used for weeding in agricultural applications	(3)

PART B

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

		MODULE1	
11	a)	Discuss in detail the issues and challenges involved in the development of a wheeled mobile robot for floor cleaning	(8)
		Discuss the feedback mechanism that can be used for speed control in an autonomous vehicle.(assume point mass and force inputs)	(6)
12	a)	Discuss in detail the steering control using point mass model using closed loop commands	(14)
		MODULE II	
13	a)	Explain the working principle of GPS and how position is determined using GPS	(14)
14	a)	With the help of a block diagram, explain a vehicle localization fusion system.	(14)
		MODULE III	
15	a)	Discuss any two path planning algorithms used in the implementation of UAVs	(14)
16	a)	What is Geofencing and how is it useful for UAVs?	(7)
	b)	Discuss the mechanisms used for collision avoidance in the design of UAVs	(7)
		MODULE IV	
17	a)	Explain the term SWARM. What is the utility of swarm in UAV-based network	(8)

	b)	Explain with the help of diagrams, the difference between MANET, VANET and FANET in Swarm technology	
18	a)	Explain the role of GCPs. How do you get GCPs for processing UAV images?	(7)
	b)	Discuss the different methods used to collect elevation data using UAVs.	(7)
		MODULE V	
19	a)	Discuss in detail about the reasons for a terminal failure of a rescue robot	(7)
	b)	Discuss in detail about any two disaster scenarios and explain how a rescue robot can be useful in those circumstances	(7)
20	a)	Explain how robots can be used for disease and Insect detection in agricultural applications	(7)
	b)	Discuss in detail about bulk harvester and selective harvester robots that are used in agriculture	(7)

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RAD496	MINI PROJECT	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	4

Preamble: Mini Project Phase I: A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The object of Project Work I is to enable the student to take up investigative study in the broad field of Robotics and Automation, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a Supervisor. This is expected to provide a good initiation for the student(s) in R&D work. The assignment to normally include:

- Survey and study of published literature on the assigned topic;
- Preparing an Action Plan for conducting the investigation, including team work;
- Working out a preliminary Approach to the Problem relating to the assigned topic;
- Block level design documentation
- Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility;
- Preparing a Written Report on the Study conducted for presentation to the Department;

CO1	Identify and synthesize problems and propose solutions to them.
CO2	Prepare work plan and liaison with the team in completing as per schedule.
CO3	Validate the above solutions by theoretical calculations and through experimental
CO4	Write technical reports and develop proper communication skills.
CO5	Present the data and defend ideas.

Mapping of course outcomes with program outcomes

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

*1-slight/low mapping, 2- moderate/medium mapping, 3-substantial/high mapping

Continuous Internal Evaluation Pattern:

Sl. No.	Level of Evaluation	Marks
1	Interim evaluation by the committee	**20**
2	Project Guide	**30**
3	Final Seminar evaluation by the committee	**30**
4	The report evaluated by the evaluation committee	**20**
	Total	**100**
	Minimum required to pass	**50**

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

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