Courses of Study

B.Tech Robotics and Automation

Batch 2024 Onwards

5th Semester

Department of Mechanical Engineering

Islamic University of Science and Technology Kashmir

Table of Contents

Detailed Course Contents for 5th Semester

Total Credits = 21+X *Total Hours Per Week = 27+X*

Course Code	Course Title	L	T	P	S	Credits
MEC302C	Design of Machine Elements	3	0	0	0	3
MEC307C	Control Systems Engineering	3	0	0	0	3
MEC308C	Probability and Statistics	3	0	0	0	3
ECE315C	Embedded and Reconfigurable Platforms for Robotics	2	0	2	0	3
MEC319C	Industrial Automation with PLC and SCADA	2	0	2	0	3
MEC309C	Economics and Financial Management	2	0	0	0	2
MEC318C	Fundamentals of Heat Transfer	2	0	0	0	2
MEC316A	Colloquium	0	0	2	0	0
MEC314C	Practicals on Control Systems	0	0	2	0	1
MEC315C	Practicals on Manufacturing Processes II	0	0	2	0	1
	Open Elective	-	-	-	-	X

Note(s):

A student has to undergo an Internship/Practical Training during vacations following the fifth semester, which shall be evaluated in the sixth semester. The minimum duration of such internship or training has to be four weeks.

MEC302C Design of Machine Elements 3-0-0-0

Course Objectives: This course equips students with empirical design principles, codes, and standards for machine elements, emphasizing safety-critical considerations and failure analysis. They will analyze shafts under static/fatigue loads, design various springs, and evaluate permanent/temporary joints—developing practical skills for robust mechanical system design.

Course Outcomes: At the end of this course, a student will be able to:

1. Apply knowledge of basic machine elements used in machine design.
2. Understand the stress and strain on machine components and identify and quantify failure modes of machine parts.
3. Design a shaft for static and fatigue loading.
4. Explain the various types of springs and design the same
5. Design temporary and permanent joints to withstand loads and deformations.

Module I
Introduction to Design: Various stages of the design process, design tools and resources, standards and codes, safety, reliability and product liability, uncertainties in design, introduction to behavior of mechanical systems.

Module II
Failure prevention in mechanical components: Failures resulting from static loads, static strength, factor of safety, theories of failure for static loads, selection of failure theories, Introduction to fatigue in materials, various approaches to fatigue failure analysis and design, endurance limit and modifying factors, stress concentration and notch sensitivity, failure criteria for fluctuating loads.

Module III
Design of shafts: Shaft design for static and fatigue loads, shafts subjected to twisting and bending moments, deflection considerations, shaft materials, design of shaft components.

Module IV
Design of springs: Types of springs, stresses induced in helical springs, spring materials, design for static and fatigue loads, extension springs, torsion springs, spiral springs, leaf springs.

Module V
Design of permanent and temporary joints : Riveted joints, failures of riveted joints, design of riveted joints for boilers and pressure vessels, welded joints, welding symbols, butt and fillet welds, screwed joints, designation of screw threads, stresses induced in screw threads, bolt strength, design of cotter and knuckle joints.

Text Books:

1. R. G. Budynas and J. K. Nisbett, Shigley's Mechanical Engineering Design, McGraw Hill Education, 10^{th} Edition, 2014.

Reference Books:

1. R. L. Mott, Machine Elements in Mechanical Design, Pearson Ed Asia, 4th Edition, 2005.
2. M. F. Spotts, T. E. Shoup and L. E. Hornberge, Design of Machine Elements, Pearson Education, 8th Edition, 2019.
3. V. B. Bhandari, Design of Machine Elements, McGraw Hill Education, 4th Edition, 2017.
4. P. C. Sharma and D. K. Aggarwal, A Textbook of Machine Design, S. K. Kataria & Sons, 2013.

Online Resources:

1. Design of Machine Elements – I by Prof. B. Maiti (IIT Kharagpur), NPTEL Course (https://archive.nptel.ac.in/courses/112/105/112105124/)

MEC307C Control Systems Engineering 3-0-0-0

Course Objectives: The objective of this course is to provide students with a comprehensive understanding of control systems, and their analysis and applications. Students will learn to mathematically model physical systems, gain insights into the time response analysis, examine steady-state and transient behaviour and perform stability analysis.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the significance of control systems and develop mathematical models of electro-mechanical systems and their transfer functions.
2. Analyse time domain performance, steady-state errors, and transient responses of first and second-order control systems.
3. Apply stability criteria such as Routh-Hurwitz, and Root Locus methods for control system analysis and design.
4. Evaluate frequency domain specifications using Bode and Nyquist diagrams to determine stability and margins.
5. Synthesise control systems to meet specified design requirements and performance criteria.

Module I

Introduction: History, applications, and classification; Mathematical modelling of physical systems; Mathematical preliminaries – Complex Variables, Laplace Transform, Transfer function; Block diagram representation; Signal flow graphs - Reduction using Mason's gain formula; Models of some Industrial Control Systems.

Module II

Time Response Analysis and Design Specifications; Standard test signals; Time domain performance of first and second order control systems; Steady state and transient response; Steady state errors and error constants.

Module III

The concept of stability, Asymptotic and BIBO stability, Relation between characteristic equation roots and BIBO stability, Routh-Hurwitz stability criterion, Relative stability analysis.

Module IV

Root Locus Technique and its Construction Principles; Angle and Magnitude Criterion, Properties of Root Loci, Construction of Root Locus Diagram, Determination of Damping ratio, Gain Margin and Phase Margin from Root Locus.

Module V

Frequency response and Frequency domain specifications; Bode diagrams and Nyquist Methods; Determination of Stability, Phase Margin and Gain Margin from the Bode Diagrams and Nyquist Methods.

Text Books:

1. N. S. Nise, Control Systems Engineering, John Wiley and Sons.
2. M. Gopal, Control Systems–Principles and Design, Tata McGraw-Hill Ltd.
3. K. Ogata, Modern Control Engineering, Prentice Hall of India Pvt. Ltd.

Reference Books:

1. B. C. Kuo, Automatic Control Systems, John Wiley & Sons.

Online Resources:

1. Control Systems, By Prof. C. S. Shankar Ram (IIT Madras), NPTEL Course (https://archive.nptel.ac.in/courses/107/106/107106081/).
2. Control Engineering, By Prof. M. Gopal (IIT Delhi), NPTEL Course, (https://nptel.ac.in/courses/108102043).

MEC308C	Probability and Statistics	3-0-0-0

Course Objectives: The objective of this course is to provide a fundamental understanding of the principles of probability theory, appreciate the interplay between probability theory and statistical analysis, and interpret the significance of statistical findings in practical terms.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain fundamental statistical concepts and probability theories.
2. Create meaningful solutions by applying conditional probability and random variable concepts to practical scenarios
3. Comprehend and interpret various probability distributions and their real-world applications.
4. Apply data analysis techniques, regression, and correlation to solve problems
5. Critically analyse and derive probability theorems, fostering strong problem-solving skills.

Module I
Statistics: Measures of central tendency and Measures of variations (Dispersions), Moments, Measures of Skewness and Kurtosis. Moment generating functions, problems.

Module II
Standard Distributions: Binomial, Poisson and Normal Distributions, Beta and Gamma Distribution, t Distribution, F-Distribution, Chi-square Distribution and their applications.

Module III
Method of Least Squares & Correlation: Methods of least squares, fitting of straight line and parabola of degree ‘p’. Regression and Correlation. Multiple and Partial Correlation.

Module IV
Probability: Random experiment, sample space, events, classical, statistical and axiomatic definitions of probability. Statements and proof of theorems on addition and multiplication of probabilities, problems.

Module V
Conditional Probability: Bayes theorem on conditional probability. Random variables, Derivation of formulae for mean, variance and moments of random variables for discrete and continuous cases. Laws of expectation problems.

Text Books:

1. S. C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, S. Chand & Sons.
2. Brownlee, Statistical Theory and Methodology in Science & Engineering, John Wiley & Sons.

Reference Books:

1. R. E. Walpole, Introduction to Mathematical Statistics, Macmillan publications.

2. Meyer, Data Analysis for Scientists & Engineers, John Wiley & Sons.

Online Resources:

1. Probability and Statistics by Prof. Somesh Kumar (IIT Kharagpur), NPTEL Course (https://archive.nptel.ac.in/courses/111/105/111105090/).

ECE315C Embedded and Reconfigurable Platforms for Robotics 2-0-2-0

Course Objectives: This course equips students with foundational knowledge and practical skills in embedded and reconfigurable hardware platforms used in robotics, enabling them to interface, program, and evaluate systems like microcontrollers, SBCs, and FPGAs for robotic applications.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain embedded architectures and memory models relevant to robotic applications.
2. Develop basic robotic interfacing using Arduino, ESP32, and Raspberry Pi platforms.
3. Analyze reconfigurable platforms like FPGAs for robotics-oriented computing.

Module I: Embedded Systems: Microcontroller architectures (CISC, RISC, ARISC), memory models (Von Neumann, Harvard). A general architecture of a microcontroller (e.g Atmega328 AVR) Embedded vs general-purpose systems comparison. Introduction to Single Board Computers and their comparison(e.g Raspberry pi, Jetson nano, LattePanda etc.)

Module II: Hardware Platforms & its OS/firmware: ATMega/Arduino board family(UNO, Nano, Due, Mega, nicla vision, nicla voice etc.) and I/O interfacing (Digital, Analog). Raspberry Pi and ESP32 board fundamentals, Arduino IDE, various Raspberry pi OSs, RoBIOS operating system basics. Introduction to FPGAs .

Module III:Introduction to Reconfigurable hardware: Study the architecture of FPGA and its comparison with other embedded hardware. Classification of FPGA boards (4th, 5th, 6th Gen boards), Introduction to Pynq Board and its features

List of Experiments (indicative):

1. Multiple LED Pattern Generation: chase effects, fading, and more complex animations, patterns based on mathematical sequences.
2. Controlling an RGB LED: Explore how to control the color of an RGB LED.
3. Interfacing a buzzer: Learn to generate sounds using a buzzer.
4. Read analog input from a potentiometer and control an LED's brightness or other parameters.
5. Learn to control the position of a servo motor using PWM signals.
6. DC motor control with L293D: Drive a DC motor using an H-bridge driver IC.
7. Use an ultrasonic sensor to measure distance and potentially control other components based on distance.
8. Interfacing of IR Line Following Sensor Module (Using Arduino)
9. Construct a robot that can detect and avoid obstacles using sensors.
10. Build a robot that can follow a line using sensors.
11. Understanding Raspberry Pi board and installing Operating System.
12. Simple experiment to turn an LED on and off using GPIO pins.
13. Reading the state of a button connected to a GPIO pin
14. Interfacing of relay module: Switching high voltage/current circuits.
15. Interfacing a 16x2 LCD display to show text.

16. Controlling a stepper motor for precise movement.
17. Design of fundamental gates using HDL.
18. Implementation of fundamental boolean logic on FPGA.

Note: The list of experiments shall be conducted using Arduino from S.No 1-S. No 10 and using raspberry Pi S.No. 10 to S.no 16 and experiments shall be conducted using HDL onwards . At the end of the course: students in groups of 2 (max) must submit a working project comprising wireless communication modules.

Text Books:

1. Embedded Robotics: From Mobile Robots to Autonomous Vehicles With Raspberry Pi and Arduino by Thomas Brunl, Springer, 2024.
2. K.V. K. K. Prasad, "Embedded Real-Time Systems: Concepts, Design & Programming", Dream Tech Press, 2005.
3. David. E. Simon, "An Embedded Software Primer", 1st Edition, Fifth Impression, Addison-Wesley Professional, 2007.

Online Resources:

1. Arduino IDE Reference Manual (https://www.arduino.cc/en/software)
2. ARM Architecture Reference Manual (https://developer.arm.com/documentation/)
3. Getting started with MDK Create applications with µVision® for ARM® Cortex®-M microcontrollers (https://www2.keil.com/docs/default-source/default-document-library/mdk5-gettingstarted.pdf?sfvrsn=2)

MEC319C Industrial Automation with PLC and SCADA 2-0-2-0

Course Objectives: The objective of this course is to provide students with a foundational understanding of industrial automation, focusing on PLC programming and SCADA systems. Students will develop skills in creating and troubleshooting automation solutions, integrating advanced PLC techniques and SCADA for real-time control in industrial applications.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the fundamentals of industrial automation, control systems, and PLC architecture.
2. Develop and troubleshoot PLC programs using ladder logic and memory functions.
3. Utilize advanced PLC techniques, such as interlocking, timers, and counters, for complex automation.
4. Configure and integrate SCADA systems with PLC for real-time control and monitoring.

Module I

Introduction to Industrial Automation and PLC Systems: Industrial automation overview; control systems and circuit types; field instruments and devices; relay logic and logical functions; PLC basics – architecture, components, and types.

Module II

PLC Programming and Interfacing Techniques: PLC programming languages (IEC 61131-3); ladder logic structure; sink/source wiring; push buttons and indicators; latching and unlatching; memory functions; discrete device interfacing.

Module III

Advanced PLC Functions and Analog Control: Timers, counters, and sequencing; interlocking and trip logic; jump, loop, and subroutine instructions; arithmetic and bit-level operations; analog input/output handling; programming in TIA Portal/Codesys.

Module IV

SCADA Systems and Industrial Applications: SCADA architecture and communication protocols; RTUs, MTUs, and OSI layers; PLC–SCADA interfacing; automation applications (traffic light, bottle filling, conveyor control); project documentation (P&ID, IO list, control narrative); introduction to emerging SCADA technologies.

List of Practicals:

1. Introduction to PLC Hardware Setup: Learn how to connect a PLC to power, input/output devices, and configure basic wiring for a simple push-button circuit.
2. Basic Ladder Logic for Light Control: Create a simple ladder logic program to control a light using a switch, turning it on and off.
3. PLC Timer Application: Program a PLC to turn on an output device (e.g., a light) after a preset delay using an on-delay timer.
4. Counter Implementation for Object Counting: Develop a basic program using a counter to count objects passing on a conveyor belt, turning on a light after counting a specific number.

5. Interfacing Push Buttons with PLC: Connect multiple push buttons to the PLC and write a program to control two different outputs, such as lights or small motors.
6. Basic Traffic Light Control (Single Intersection): Create a basic ladder logic program to control a single set of traffic lights using timers for red, yellow, and green phases.
7. Simple Start/Stop Motor Control: Wire a PLC to control the start and stop of a motor using two push buttons, one for start and one for stop.
8. Interlocking Mechanism for Two Motors: Write a PLC program that interlocks two motors, ensuring one motor can only run if the other is off.
9. Analog Signal Monitoring (Potentiometer): Interface an analog input device, such as a potentiometer, with the PLC and monitor the varying input values.
10. Basic SCADA Visualization: Create a simple SCADA screen to visualize and control the start/stop of a motor, including a real-time indicator for the motor status.

Text Books:

1. Petruzella, F. D. (2010). *Programmable Logic Controllers* (4th ed.). McGraw-Hill Education.
2. Stenerson, J. (2010). *Fundamentals of Programmable Logic Controllers, Sensors, and Communications* (3rd ed.). Pearson Education.
3. Bailey, D., & Wright, E. (2003). *Practical SCADA for Industry* (1st ed.). Elsevier.

Reference Books:

1. Stuart A. Boyer, *SCADA: Supervisory Control and Data Acquisition,* ISA – International Society of Automation, 4th Edition, 2009.
2. Hugh Jack, *Automating Manufacturing Systems with PLCs,* Creative Commons / Saylor Foundation (Open Access)

Online Resources:

1. Industrial Automation with PLC & SCADA (IAD101) by NIELIT - Online (https://www.nielit.gov.in/calicut/sites/default/files/course/IAD101.pdf)
2. Resourceful websites: https://realpars.com, instrumentationtools.com

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MEC309C Economics and Financial Management 2-0-0-0

Course Objectives: This course introduces students to core economic principles and their application in engineering projects, emphasizing financial management and decision-making. Learners will analyze costs, risks, and returns to evaluate engineering investments, using financial tools such as NPV, IRR, and cost-benefit analysis. By integrating economic theory with real-world case studies, students will develop the skills to optimize resource allocation and justify project feasibility in technical environments.

Course Outcomes: At the end of this course, a student will be able to:

1. Understand the basic concepts of microeconomics, macroeconomics, and financial management.
2. Understand the macroeconomic variables and their impact on engineering projects.
3. Comprehend basics of accounting, cost concepts, and financial statement analysis.
4. Establish the relationship between Risk & return, Time value of money, sources of finance and capital budgeting decisions.

Module I
Introduction: Economics and Financial Management, Importance of economics and financial management in engineering, Basic economic concepts and principles.

Module II
Microeconomics for Engineers: Supply and Demand Analysis, Market Structures and Competition, Cost Analysis and Production Decisions, Pricing Strategies, and Revenue Maximization.

Module III
Macroeconomics: Macroeconomics and Engineering Projects, National income and output, Unemployment and Economic growth, Inflation, Monetary and fiscal policy, Implications for engineering projects.

Module IV
Financial Management: Source of Finance: Retained Earnings, Share Capital, Term Loans, Debt: Debentures, bonds, Working Capital; Capital Budgeting: Meaning and Techniques.

Module V
Financial Statement Analysis: Ratio Analysis; Funds Flow Statement & Cash Flow Analysis.

Text Books:

1. Keat, P. G., *Managerial Economics: Economic Tools for Today's Decision Makers, 5/e*. Pearson Education India
2. Misra and Puri, *Principles Of Macro Economics*, Himalaya publishing house, New Delhi.
3. Koutsoyiannis, A., *Modern microeconomics*. Springer.

Reference Books:

1. Robert, S. P., & Daniel, L. R., *Microeconomics (-Global Edition)*. Pearson Education
2. Chandra, P., *Financial Management: Theory and Practice, 10e* (Vol. 10). McGraw-Hill Education.
3. Maheshwari, S. N., Maheshwari, S. K., & Maheshwari, S. K. (2024). *Management Accounting and Financial Control*. Sultan Chand & Sons.

MEC318C Fundamentals of Heat Transfer 2-0-0-0

Course Objectives: This course introduces students to the core principles of thermodynamics and heat transfer, covering the fundamental laws and their practical applications. Learners will explore conduction, convection, and radiation, applying these concepts to analyze and optimize thermal management in robotic systems. The curriculum combines theory and real-world problem-solving to equip students with skills for thermal design challenges in robotics and automation**.**

Course Outcomes: At the end of the course, a student will be able to:

1. Determine heat conduction and radiation in simple thermal systems.
2. Determine heat transfer through convection in simple thermal systems.
3. Apply the principles of heat transfer for thermal management of robotic systems

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Module I

Modes of heat transfer; Conduction: 1-D and 2-D steady conduction; Thermal resistance networks, 1-D unsteady conduction-Lumped capacitance and analytical methods; Fundamentals of thermal radiation: black and gray surfaces, surface properties. View factor, electric analogs, radiation shields.

Module II

Forced convection external flows: similarity parameters; laminar and turbulent boundary layers on flat surfaces; Forced convection internal flows: laminar and turbulent flow through circular and noncircular ducts, fully developed flow, hydrodynamically and thermally developing flows, empirical correlations. Free convection boundary layer equations: empirical correlations.

Module III

Heat exchangers: types, overall heat transfer coefficient; effectiveness-NTU method; Thermal management: concept of insulation, critical radius of insulation, heat dissipation, extended surfaces-types, efficiency and effectiveness, active and passive cooling devices, heat dissipation in electronic devices, thermal interface materials, management of thermal stresses, case studies.

Text Books:

1. Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, and David P. DeWitt, Fundamentals of Heat and Mass Transfer, 7th Edition, John Wiley & Sons, 2011.

Reference Books:

1. J. P. Holman, Heat Transfer, McGraw Hill, 2007.
2. F. Kreith and M. S. Von, Principles of Heat Transfer, Brook and Cole Publication, 2001.
3. Y. Cengel and A. J. Ghajar , Heat Transfer: A Practical Approach, McGraw Hill Education. 2020

Online Resources:

1. Heat and Mass Transfer by Prof. S.P. Sukhatme and Prof. U.N. Gaitonde (IIT Bombay), NPTEL Course **https://nptel.ac.in/courses/112101097**

MEC314C Practicals on Control Systems 0-0-2-0

Course Objectives: This course aims to provide practical knowledge in designing and implementing various control systems. Students will learn to build feedback control systems using sensors and actuators, and gain hands-on experience in MATLAB and Simulink to analyse system stability, design controllers, and simulate control algorithms for motors, mechanical systems, etc.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the principles of feedback control systems and the functioning of various sensors and sources in maintaining constant reference input.
2. Describe the components and operation of basic control systems using water level sensors and pumps, temperature sensors, DC motors, etc.
3. Apply knowledge of control systems to design, simulate, and implement speed regulation for a toy car, and level control for a tank.
4. Perform stability analysis, steady-state error calculations, and root locus plots to assess system behaviour and response.
5. Build customised control algorithms in MATLAB and Simulink for specific applications.

List of Practicals

1. Light Sensor Control: Build a simple feedback control system using a light sensor and a light source to maintain a constant light intensity despite varying distances between the sensor and the source.
2. Water Level Control: Create a basic control system using a water level sensor and a water pump to maintain a constant water level in a container.
3. Temperature Controller with On/Off Control: Develop an On/Off temperature control system using a temperature sensor and a heater/cooler to regulate the temperature of a small chamber.
4. Speed Control of a Toy Car: Design a control system to regulate the speed of a toy car using a simple DC motor and a potentiometer as a speed control input.
5. Water Flow Control with a Valve: Use a flow sensor and a servo-controlled valve to maintain a constant water flow rate through a pipe.
6. Introduction to MATLAB and Simulink as a tool for analysis and design of control systems.
7. Using MATLAB for analysis of the roots of the first order systems and plot the response to different parametric variations.
8. Using MATLAB for analysis of the roots of a second order system and plot the response to different parametric variations.
9. Stability Analysis of a Control System: Use MATLAB to determine the stability of the system by analysing the poles. Simulate the system in Simulink and observe the response to step and impulse inputs.
10. Steady-State Error Analysis: Use MATLAB to calculate the steady-state error for different reference inputs. Verify the results in Simulink by simulating the closed-loop system.
11. Root Locus Design: Create a transfer function for a control system with an adjustable parameter (e.g., gain). Plot the root locus using MATLAB to observe the effect of the parameter on system stability.

12. Level Control in a Tank using MATLAB and Simulink: Design a level control system for a tank in MATLAB, and implement the control algorithm in Simulink to control the liquid level.

Text Books:

1. K. Ogata, Control System Design Using MATLAB and Simulink. Pearson, 2010.

Online Resources: NA

MEC315C Practicals on Manufacturing Processes II 0-0-2-0

Course Objectives: This course equips students with hands-on experience in a range of fundamental manufacturing processes and exposes them to real-world challenges faced in the industry. It emphasizes the development of practical skills and a solid understanding of both conventional and advanced manufacturing techniques, preparing students for future roles in engineering and production environments.

Course Outcomes: At the end of this course, a student will be able to:

1. Design and make simple castings independently.
2. Compare the components manufactured using 3d printing and conventional techniques
3. Differentiate the various welding processes.
4. Inspect the weld joint defects and causes behind them.
5. Analyze the effect of varying parameters in welded joints.

List of Practicals:

1. Preparation of sand mould for the given engineering part and investigating the mould properties.
2. Estimation of molding sand properties.
3. Fabrication of Pattern for sand moulding through conventional and digital manufacturing method.
4. Evaluation of 3D printed pattern over conventional pattern for complex profiles.
5. Study of SMAW/ MMAW welding equipment and process.
6. Study of TIG / MIG welding equipment and process.
7. Making of Lap joints / T- Joints at different welding parameters.
8. To observe the effect of varying current on the butt joint made through the SMAW process and calculate the heat input.
9. Welding practice on T/Butt joints using SMAW.
10. Welding practice on T/Butt joint using MIG/GTAW welding and comparison thereof.

Online Resource:

1. Virtual labs in Mechanical Engineering at NITTTR Kolkata (http://www.nitttrkol.ac.in/virlab.php#top).
