B. Tech. in Mechatronics (2026 Scheme)

Year	THIRD SEMESTER						FOURTH SEMESTER					
	Sub. Code	Subject Name	L	T	P	C	Sub. Code	Subject Name	L	T	P	C
II	SMS 2109	Engineering Mathematics - III	2	1	0	3	SMS 2210	Engineering Mathematics - IV	2	1	0	3
	MET 2101	Kinematics and Dynamics of Machines	2	1	0	3	MET 2201	Energy and Heat Transfer	2	1	0	3
	MET 2102	Digital System Design	2	1	0	3	MET 2202	Analog System Design	3	0	0	3
	MET 2103	Control Systems	3	0	0	3	MET 2203	Microcontroller based System Design	2	1	3	4
	MET 2104	Industrial Automation	3	0	0	3	MET 2204	Engineering Design of Mechanical Systems	3	1	0	4
	MET 2105	Mechanics of Robotic Systems	2	1	3	4	MET 2211	ROS Integrated Systems and Simulation	3	0	3	4
	MET 2111	CAD and Kinematics' Simulation Lab	0	0	3	1	MET 2212	Analog and Digital Electronics Lab	0	0	3	1
	MET 2112	Sensors and PLC Lab	0	0	3	1						
			14	**4**	**9**	**21**			**15**	**4**	**9**	**22**
	Total Contact Hours (L + T + P) = 27						**Total Contact Hours (L + T + P) = 28**					
	FIFTH SEMESTER						SIXTH SEMESTER					
III	SMS 3001	Engg. Economics and Financial Management	2	1	0	3	SMS 3002	Essentials of Management	2	1	0	3
	MET 3101	Digital Signal Processing	2	1	0	3	MET 3201	Electric Drives	3	0	3	4
	MET 310X	Flexicore -1	3	0	0	3	MET 320X	Flexicore -2	3	0	0	3
	MET 3104	Computational Intelligence for Mechatronics	3	1	0	4	MTP 4XXX	Program Elective - 1 / Minor Specialization	3	0	0	3
	MET 3105	Hydraulics and Pneumatics Systems	3	0	0	3	MTP 4XXX	Program Elective - 2 / Minor Specialization	3	0	0	3
	IOE 3XXX	OE-1	3	0	0	3	IOE 3XXX	Open Elective-2	3	0	0	3
	MET 3111	IIoT Lab	0	0	3	1	MET 3211	Hydraulics Lab	0	0	3	1
	MET 3112	Mechatronic Systems Design Lab	0	0	3	1	MET 3212	Pneumatics Lab	0	0	3	1
			16	**3**	**6**	**21**			**17**	**1**	**9**	**21**
	Total Contact Hours (L + T + P) + OE		**25**				**Total Contact Hours (L + T + P) + OE**		**27**			
	SEVENTH SEMESTER						EIGHTH SEMESTER					
IV	MTP 4XXX	Program Elective - 3 / Minor Specialization	3	0	0	3	MES 4299	Industrial Training (MLC)				1
	MTP 4XXX	Program Elective - 4 / Minor Specialization	3	0	0	3	MET 4999	Project Work				12
	MTP 4XXX	Program Elective - 5	3	0	0	3	MET 5999	Project Work (B Tech - Honours) **				20
	MTP 4XXX	Program Elective - 6	3	0	0	3	MEH 5XXX	B Tech - Honours Theory - 1** (V semester)				4
	MTP 4XXX	Program Elective - 7	3	0	0	3	MEH 5XXX	B Tech - Honours Theory - 2** (VI semester)				4
	IOE 3XXX	Open Elective-3	3	0	0	3	MEH 5XXX	B Tech - Honours Theory - 3** (VII semester)				4
	*** 4199	Mini Project (Minor specialization) *				8						
			18	**0**	**0**	**18 /26**						**13 /33**
	Total Contact Hours (L + T + P) +OE		**= 18**									

*Applicable to students who opted for minor specialization
**Applicable to eligible students who opted for and successfully completed the B Tech - honours requirements

<table>
<tr><th>Minor Specializations</th><th>Minor Specializations (Institute Level)</th><th>Other Program Electives</th></tr>
<tr><td>I. Industrial IoT Systems
MET 4301 : Database Management and Data Mining
MET 4302 : Cybersecurity and Cryptography for Industrial Applications
MET 4303 : Industrial Communication
MET 4304: Smart Industrial IoT

II. Robotics and Automation
MET 4305: Artificial Intelligence for Robotic Vision
MET 4306: Robot Dynamics and Control
MET 4307: Autonomous Mobile Robots
MET 4308: Soft Robotics

III. Micro and Nano Systems
MET 4309: Semiconductor and VLSI systems
MET 4310: Smart Materials for Micro and Nano Systems
MET 4311: Design of Micro and Nano Devices
MET 4312: Fabrication and Testing of Micro Systems</td><td>I. Robotics
MET 4401: Introduction to Robotics Systems
MET 4402: IOT for Robotics
MET 4403: Robotics Design and Simulation
MET 4404: AI for Robotics</td><td rowspan="3">Program Specific
MTP 4401: Augmented Reality and Virtual Reality
MTP 4402: Biomechatronics
MTP 4403 : Fractional Order Modelling and Control
MTP 4404 : Human Robot Interaction
MTP 4405 : Mechatronic System Dynamics
MTP 4406: Production and Operations Management
MTP 4407: Machine Vision
MTP 4408: Automobile Engineering
MTP 4409: Engineering Materials
MTP 4410: Sustainable Manufacturing
MTP 4411: Micro Electro Mechanical Systems
MTP 4412: Modelling of Hybrid and Electric Vehicles
MTP 4413: Smart Manufacturing
MTP 4414: AI-Driven Cobots and Quadruped Robotics
MTP 4415: Smart Mobility & Autonomous Navigation

Common Across School
MTP 4421: Heavy Vehicle Technology
MTP 4422: Alternative Fuels and Green Energy Systems
MTP 4423: Product Design and Development</td></tr>
<tr><td>Minor Specializations (School Level)</td><td>FLEXICORE</td></tr>
<tr><td>Precision Agriculture Technology
MET 4313: Smart Farming Machinery
MET 4314: Robotics and Automation in Agriculture
MET 4315: Food Process Automation
MET 4316: Digital Agriculture</td><td>FLEXICORE I
MET 3102: Autotronics
MET 3103: Digital Twins for Mechatronics

FLEXICORE II
MET 3202: Unmanned Aerial Vehicles
MET 3203: AI-powered Robotics</td></tr>
</table>

THIRD SEMESTER

SMS 2109: ENGINEERING MATHEMATICS III [2 1 0 3]

Vector Calculus – gradient, divergence and curl, physical meaning and identities, line, surface and volume integrals, Green's, Divergence and Stokes' theorems, flow kinematics, and introduction to quaternions. Fourier Series – Review, Fourier integrals, sine and cosine integrals, Fourier Sine and Cosine Transforms, Parseval's identity, Harmonic analysis. Partial Differential Equations – basic concepts, classification, transformations, separation of variables, derivation and solution of one-dimensional wave and heat equations using Gauss divergence theorem, and D'Alembert's solution. Numerical Methods – finite difference expressions for first and second order derivatives, boundary value problems, classification of second order PDEs, and numerical solutions of Laplace, Poisson, heat and wave equations using explicit methods with MATLAB.

References:

- Erwin Kreyszig: *Advanced Engineering Mathematics*, 10th edn. 2010 Wiley Eastern.
- S.S.Sastry : *Introductory Methods of Numerical Analysis* 5th edn. 2012, Prentice Hall.
- B.S.Grewal *: Higher Engg. Mathematics*, 45th edn., 2024 Khanna Publishers
- Murray R.Spiegel : *Vector Analysis*, 1 edn. 2009, Schaum Publishing Co.
- Steven C. Chapra & Raymond P. Canale, *Numerical Methods for Engineers*, 8th ed., McGraw-Hill (2020).
- NPTEL: https://onlinecourses.nptel.ac.in/noc22_ma03/preview

MET 2101: KINEMATICS AND DYNAMICS OF MACHINES [2 1 0 3]

Introduction to mechanisms and machines. Four-link planar mechanisms and their inversions. Mobility and range of movement – Kutzbach and Grubler's criterion, Grashof's criterion, and transmission angle. Straight-line mechanisms, toggle mechanism, pantograph, Hooke's joint, Ackermann and Davis steering gear, Geneva mechanism, and ratchet mechanism. Analysis and synthesis of planar mechanisms. Velocity and acceleration analysis, including Coriolis component of acceleration. Dimensional synthesis of mechanisms. Balancing and dynamic force analysis: static and dynamic balancing, power smoothing by flywheels. Vibrations. Gears and gear trains: gears, interference and undercutting, minimum number of teeth, contact ratio, bevel, helical, spiral, and worm gears. Gear trains – simple, compound, and epicyclic gear trains. Cams and followers.
Self-Study: Mechanisms used in robotic applications and analysis of velocity and acceleration of various links used in industrial robots

References:

- John J. Uicker Jr., Gordon R. Pennock, Joseph E. Shigley, *Theory of Machines and Mechanisms*, (5e) OUP USA, 2017.
- Rattan. S. S, *Theory of Machines*, (4e), Tata Mc Graw Hill, New Delhi, 2017.
- Bevan. T, *Theory of Machines*, (4e), Laxmi Publications, New Delhi, 2016.
- Ghosh and Mallick. A. K, *Theory of Machines and Mechanisms*, (3e), Affiliated East West Private Limited New Delhi, 2008.
- NPTEL Course: *Kinematics of Mechanisms and Machines*, IIT Kharagpur, https://nptel.ac.in/courses/112105268

MET 2102: DIGITAL SYSTEM DESIGN [2 1 0 3]

Logic families: TTL, CMOS, logic-gate performance, number systems, and e-waste management in the semiconductor industry. Combinational logic: minimization using K-maps, NAND/NOR implementation, adders, subtractors, BCD adder, decoders, encoders, multiplexers, comparators, parity circuits, and variable-entered maps. Introduction to HDL (VHDL, Verilog, System Verilog) with structural, data-flow, and behavioral modelling. Sequential logic: latches, flip-flops, counters, shift registers, FSMs (Mealy/Moore), and STA. Digital implementation: full-custom/semicustom design, PLDs, ASICs, CPLDs, and FPGA architectures (Artix-7, ACTEL, Xilinx) including logic modules and switching technologies.

References:

- Zvi Kohavi, Niraj K Jha, *Switching and Finite Automata Theory*, (3e), Cambridge, 2010.
- Donald .D. Givone, *Digital Principles and Design*, TMH, 2002.
- M. Morris Mano and Michael D. Ciletti, *Digital Design*, 6th Edition, Pearson Education, 2017.
- Floyd and Jain, *Digital Fundamentals*, (11e), Pearson Education, 2015.
- Anand Kumar, *Switching Theory and Logic Design*, (2e), Prentice Hall of India, 2009
- Bhasker. J, *A Verilog HDL Primer*, (3e), Star Galaxy, 2016.
- Stephen. Brown and Zvonko Vranesic, *Fundamentals of Digital Logic with Verilog Design*, (3e), Tata McGraw Hill, 2014.
- Samir Palnitkar, *Verilog HDL: A Guide to Digital Design and Synthesis*, (2e), Pearson Education, 2003.
- M. J. S. Smith, *Application Specific ICs*, Pearson Education, 2004.
- Stuart Sutherland, Simon Davidmann and Peter Flake, *System Verilog for Design*, Boston, MA: Springer US, 2006.
- NPTEL: https://onlinecourses.nptel.ac.in/noc26_ee71/preview

MET 2103: CONTROL SYSTEMS [3 0 0 3]

Feedback control systems terminologies, control system design process. Differential equations of physical systems, linear approximation, frequency domain representation, Time domain analysis and design, first and second order system response analysis, time domain and Steady State Error (SSE), stability, RH criteria, root locus technique. Introduction to compensator design, design of lag, lead, and lag-lead compensating networks. Frequency domain analysis- frequency response, Bode plot construction and interpretation of system behaviour, gain margin & phase margin, relation between time domain & frequency domain specification, SSE characteristics from frequency response, P, PI, and PID Controllers and their tuning.

Self-study:

- Macdonald, Dave. Practical Industrial Safety, Risk Assessment, and Shutdown Systems. Elsevier, 2003.
- Functional Safety in Industrial Automation by Yasushi Nakagawa, 2022. Link: Functional Safety in Industrial Automation.

References:

- Norman S. Nise, *Control Systems Engineering*, (6e), Wiley India, 2010
- R.C Dorf, R. H. Bishop, *Modern Control Systems*, (12e), PEARSON, India, 2011.
- B.C. Kuo, F. Golnaraghi, *Automatic Control Systems*, (10e), TMH, India, 2017.
- K. Ogata, *Modern Control Engineering*, (5e), PEARSON, India, 2010.
- M. Gopal, *Control System: Principles and Practices*, (4e), TMH, India, 2016.

MET 2104: INDUSTRIAL AUTOMATION [3 0 0 3]

Introduction to industrial automation, types of automation; architecture of industrial automation, Industrial revolutions, advantages and limitations of Automation, and trends in industrial automation. Sensors and actuators used in industry: Sensors, Transmitters, Actuators and Signal Conditioning: Measurements with Industrial Field Instruments, Data Acquisition Systems. Drives and motors: Types of motors and Drives. Industrial Controllers and drives: PLC, PID, DCS, Industrial monitoring: HMI and SCADA. Industrial Communication and networking: Device network: CAN, PROFIBUS-PA, HART, Control network: ControlNet, PROFIBUS-DP, Ethernet, Interfaces: RFID, Barcode. Safety instrument used in automation technology. Overview of Industrial robots. Advancement industrial automation: Industry 4.0 and Industrial IoT.

Self-study:

- NPTEL, Coursera, Swayam and Edx courses
- Industrial Automation Case study problems from journals like ISA Transactions
- Industrial Automation Case Studies Link: https://www.automate.org/case-studies; https://new.abb.com/process-automation/case-studies; https://www.inovance.eu/india/case-studies.

References:

- Stamatios Manesis, George Nikolakopoulos, *Introduction to Industrial Automation*, CRC Press, 2018.
- Chanchal Dey, Sunit Kumar Sen, *Industrial Automation Technologies*, CRC Press, 2020.
- Frank Lamb, *Industrial Automation: Hands On*, McGraw-Hill Professional, 2013.
- A.K. Gupta, S.K. Arora, Jean Riescher Westcot, *Industrial Automation and Robotics: An Introduction*, Mercury Learning & Information, 2016.
- NPTEL : Industrial Automation and Control - Course

MET 2105: MECHANICS OF ROBOTICS SYSTEMS [2 1 3 4]

Introduction to robotics: robot types, specifications, DoF, configurations, accuracy, repeatability, actuators, sensors, drives, and transmissions. Kinematics: rotation matrices, Euler angles, quaternions, homogeneous transformations, Joint and Cartesian space, Denavit–Hartenberg parameters, inverse kinematics, constraints, workspace, holonomic robots, Jacobian matrix, singularities, and Jacobian-based solutions. Trajectory generation in joint and Cartesian space. Dynamics: Newton–Euler and Lagrangian formulations, iterative and closed-form solutions, inertia tensor, and 3D rigid-body dynamics. Modeling of planar and spatial parallel manipulators, four-bar, slider-crank, and Stewart platform. AI-based robotics applications, including machine-learning-driven inverse kinematics.

Lab Component:

Introduction to Robot Studio an offline Programming Tool, Defining Targets and Trajectory Generation, Creating a Custom Tool and Defining a Work object, Conveyor Tracking using Robot Studio. Manual programming using Teach pendant for IRB2600, Control of Digital Inputs and Outputs through IRB2600 Robot, automation applications with industrial robot IRB2600 and collaborative robot Universal Robot UR5. Control of Stepper Motor and servo motor actuators using Raspberry PI. PID Control of Lego Line Following Robot. Robot Vision- with image processing software or Open CV.

References:

- John J. Craig, *Introduction to Robotics: Mechanics and Control*, (3e), PHI, 2005.
- C. Peter., *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*. Vol. 73. Springer, 2011.
- G. Ashitava, Robotics*: Fundamental Concepts and Analysis*, Oxford University Press, 2006.
- Murray, Richard M., Zexiang Li, S. Shankar Sastry, and S. Shankara Sastry, *A Mathematical Introduction to Robotic Manipulation*, CRC press, 1994.
- Mittal, R. K., and I. J. Nagrath. *Robotics and Control*. Tata McGraw-Hill, 2003.
- Niku, Saeed B. *Introduction to robotics: analysis, control, applications*. John Wiley & Sons, 2020.
- Operating manual RobotStudio, ABB Robotics, 2021
- NPTEL: https://nptel.ac.in/courses/112106304

MET 2111: CAD AND KINEMATICS' SIMULATION LAB [0 0 3 1]

2D sketcher exercises of simple machine components, solid modeling and assembly exercise of machine components. Kinematic analysis of simple mechanisms like slider crank mechanism, 4 bar mechanism, cam and follower mechanism. Simulation of standard robots like SCARA and 6 Axis Robots

References:

- Gopalkrishna K. R., *Machine Drawing*, Subhas Publications, Bangalore, 2002.
- Bhat N.D., *Machine Drawing*, Charotar Publishing House, Anand, 2002.
- Venugopal K., *Engineering drawing and graphics + Auto CAD*, Newage International ublishers, Delhi 2002.
- Narayana K.L. and Kannaiah P, *Text Book on Engineering drawing*, Scitech Publications, Chennai 2002.

MET 2112: SENSORS AND PLC LAB [0 0 3 1]

Behaviour of inductive, magnetic, reflection light scanners, one-way barriers, reflection light barrier OBS, and ultrasonic sensors. Path-power characteristic curve of inductive analog encoders; reduction factor of reflection light scanner OJ fitted with an optical waveguide. Response curves of inductive, capacitive, and magnetic field sensors. Switching frequency, switching distance, and hysteresis characteristics of NBN, CJ, MB, and OJ sensors. Calculation of the maximum admissible velocity of an object using an ultrasonic sensor. Introduction to PLCs; study of basic components, networking, and different programming techniques of PLCs. Study of NO, NC, and holding circuit programs. Implementation of simple ladder programs to study basic functions of timers, counters, mathematical, logical, and program control instructions. Study of different applications using ladder logic

Self-study:

- Siemen and Allen Bradely manual
- https://instrumentationtools.com

References:

- Siemens PLC manual, Siemens.
- PLC training practice module, BOSCH REXROTH manual Germany 2011.
- John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications*, (5e), PHI, 2005.
- Sensorics training system practice module, BOSCH REXROTH manual, Germany 2011.
- Sensors in theory and practice, BOSCH REXROTH AG Germany 2007.

FOURTH SEMESTER

SMS 2210: ENGINEERING MATHEMATICS FOR MECHATRONICS [2 1 0 3]

Difference equations and Z-transform – formulation and solution of difference equations, properties of Z-transform, initial and final value theorems, convolution theorem, and real-time applications. Special functions – series solutions of ODEs, Bessel's and Legendre's equations, Rodrigues's formula, recurrence relations, generating functions, orthogonal properties, and MATLAB illustrations. Probability, random variables and distributions – finite sample space, conditional probability, Bayes' theorem, discrete and continuous distributions (Binomial, Poisson, Normal, etc.), covariance, correlation, regression, moment generating functions, sampling theory, and Central Limit Theorem with real-time applications.

References:

- Kreyzig E -. *Advanced Engineering Mathematics,* (10e). 2010, Wiley Eastern.
- Meyer P.L. - *Introduction to Probability and Statistical applications*, (2e). 1970, American Publishing Co.
- Ross, S.M. *Introduction to Probability and Statistics for Engineers and Scientists*, (6e), Academic Press, 2023.
- Grewal B.S - *Higher Engineering Mathematics*, Khanna Publishers.
- Hogg & Craig - *Introduction of Mathematical Statistics*, (7e).2013. MacMillan
- Simmons, G.F. *Differential Equations with Applications and Historical Notes*, 4th Ed., CRC Press, 2023.
- NPTEL course **:** https://nptel.ac.in/courses/111102160

MET 2201: ENERGY AND HEAT TRANSFER [2 1 0 3]

Work, heat, thermodynamic systems, Zeroth and First Laws, internal energy, enthalpy, and the Steady Flow Energy Equation with applications. Entropy, Carnot theorem, and Clausius inequality build foundations in energy efficiency. Fluid mechanics covers properties, viscosity, compressibility, continuity, momentum and energy equations, laminar flow, boundary layers, hydraulic gradients, Darcy–Weisbach relations, and pipe network losses. Heat transfer modules include conduction, convection, radiation, composite walls, critical insulation, fins, and heat exchangers with LMTD and effectiveness. Virtual labs and sensor-based experiments support real-time measurement and analysis of thermal-fluid systems.

References:

- Cengel, Y. A., and Boles, M. A. *Thermodynamics: An Engineering Approach*, (9e), McGraw Hill Education, 2019.
- Moran, M. J., and Shapiro, H. N. *Fundamentals of Engineering Thermodynamics*, (9e), Wiley India Pvt. Ltd., 2021.
- Holman, J. P. *Heat Transfer*, (10e), McGraw Hill Education, 2016.
- White, F. M. *Fluid Mechanics*, (9e), McGraw Hill Education, 2021.
- Nag, P. K. *Engineering Thermodynamics*, (6e), McGraw Hill Education, 2017.
- NPTEL : https://onlinecourses.nptel.ac.in/noc26_me53/preview

MET 2202: ANALOG SYSTEM DESIGN [3 0 0 3]

Fundamentals of CMOS and Analog Circuit Design: CMOS technology, MOSFET characteristics, analog vs. digital design, current mirrors, and voltage-current characteristics. CMOS Digital Circuit Design: NMOS and CMOS inverters, noise margins, pass transistors, Boolean function realization, combinational circuits, and dynamic/clocked logic. CMOS Fabrication and Layout Techniques: P-well, N-well, twin-tub processes, stick diagrams, inverter delay, design rules, and parasitic effects. Operational Amplifiers – Linear Applications: Op-amp architectures, ideal and practical characteristics, voltage followers, summing and difference amplifiers, instrumentation amplifiers, integrators, differentiators, and V–I and I–V converters. Nonlinear Applications, Filters, and Analog Building Blocks: Precision rectifiers, comparators, Schmitt triggers, log and antilog amplifiers, waveform generators, active filter design (LP, HP, BP, BS, all-pass), and advanced analog blocks (VFOA, CFOA, CCII, OTA). Data Converters and Mixed-Signal Interface Design: DACs (binary-weighted, R–2R), ADCs (dual-slope, successive approximation), performance specifications, and low-power mixed-signal integration trends.
Self-learning: Applications of CCII, OTA, and Gm–C filters.

References:

- Pucknell, D. A., and Eshraghian, K., *Basic VLSI Design*, 3rd Edition, PHI, 2015.
- R. Jacob Baker, Harry W. Li, and David E. Boyce, *CMOS: Circuit Design, Layout, and Simulation*, Wiley-IEEE Press, 2019.
- Ramakant A. Gaikwad, *Op-Amps and Linear Integrated Circuits*, 4th Edition, Prentice Hall of India, 2015.
- Sergio Franco, *Design with Op-Amps and Analog Integrated Circuits*, 3rd Edition, McGraw Hill, 2017.
- Roy D. Choudhury and Shail B. Jain, *Linear Integrated Circuits*, 4th Edition, Wiley Eastern, 2018.

MET 2203: MICROCONTROLLER-BASED SYSTEM DESIGN [2 1 3 4]

Introduction to Embedded Systems Design, modular architecture and microcontroller-based implementation. The Six-Box model: embedded systems, input/output devices, embedded computing, communication, storage, and power supply. Power supply design, including linear and switching topologies tailored for embedded applications. The MSP430 microcontroller as the core platform, detailed architecture, programming methods, and development tools, including Code Composer Studio. Physical interfacing—connecting switches, LEDs, SSDs, and advanced components like shaft encoders and multiplexed displays. Embedded C programming, version control with Git, and interrupt-driven design. The MSP430’s clock, reset, and timer modules enable PWM generation, ADC/ DAC interfacing, and the creation of custom waveforms. Low-power modes and display interfacing. Serial communication protocols (UART, SPI, I2C).
Lab Component:
Assembly programming for arithmetic, logical, control, loop operations. Introduction to Embedded C programming using Code Composer Studio. Programming for LED, SWITCH interfacing, timers, PWM, Communication using UART, SPI, and I2C, ADC/ DAC interfacing.

References:

- John Catsoulis, *Designing Embedded Hardware*,.(2e), Shroff Publishers and Distributors. ISBN-10: 9788184042597
- Tony Givargis and Frank Vahid, *Embedded System Design: A Unified Hardware / Software Introduction*. Wiley. ISBN-10: 812650837X
- John H. Davies, *MSP430 Microcontroller Basics*, Elsevier. ISBN-10: 9789380501857.
- Micheal Barr, *Programming Embedded Systems in C and C++,* Shroff Publishers and Distributors. ISBN-10: 817366076X
- MSP430™ MCUs Development Guidebook.
- James Kretzschmar · Jeffrey Anderson · Steven F. Barrett, *MSP430 Microcontroller Lab Manual*, [https://link.springer.com/content/pdf/10.1007/978-3-031-26643-0.pdf]
- NPTEL- Introduction to Embedded System Design, Prof. Dhananjay V. Gadre, and Prof. Badri Subudhi from Netaji Subhas University of Technology & IIT Jammu, https://onlinecourses.nptel.ac.in/noc20_ee98/preview

MET 2204: ENGINEERING DESIGN OF MECHANICAL SYSTEMS [3 1 0 4]

Introduction to stresses and strains, shear force and bending moments, types of loads, bending and torsional stresses, beam types, simple bending theory, torsion in shafts, and shear stress distribution. Beam deflection using double integration and Macaulay’s method. Static and dynamic loading, stress concentration, fatigue, and S–N curves. Design of transmission shafts under bending and torsion using ASME codes. Design of helical springs and power screws, including torque, friction, and efficiency. Spur gear design using Lewis equation. Bearings: lubrication, journal bearings, rolling-contact bearings, load capacity, life estimation, and bearing selection.
Self-study: Mechanical components used in robotic applications and design of these components used in industrial robots

References:

- Timoshenko and Young, *Elements of Strength of Materials*, Tata McGraw Hill, New Delhi, 2003.
- Popov E.P., *Engineering Mechanics of Solids*, Prentice Hall India, New Delhi, 2001.
- Beer F. P. and Jonhston R, *Mechanics of Materials*, (3e), MacGraw Hill Book Company, 2002
- Shigley J. E. and Mischke C. R., *Mechanical Engineering Design*, (5e), McGraw Hill Inc, New York. 2004.
- Bhandari V B., *Design of Machine Elements*, (2e), Tata McGraw-Hill Publishing Company Limited, New Delhi, 2007.

MET 2211: ROS INTEGRATED SYSTEMS AND SIMULATION [3 0 3 4]

Introduction to Linux, Shell Programming, Git and Github, DOcker. Python programming for robotics: Data Types, Flow Control, Functions, Classes, Modules, numpy and panda, WeBots simulator, UR_SIM control with Python. ROS2 core concepts: ROS2 development using Python, ROS2 package, nodes, publisher, subscriber, topics, services, actions, parameters, launch files, rosbags, turtlesim. Create a custom robot with ROS2: TFs, Rviz, Gazebo Sim, URDF, sensor integration, PID control, ROS2 deployment in ESP32/ Raspberry Pi.

Lab Component:

Linux Commands, Git and Github, Docker, Python programming for WeBots, UR_SIM, ROS2 publisher, subscriber, services, actions, parameters, URDF, Gazebo Sim, ROS2 in ESP32/Raspberry Pi.

References:

- Renard, E. (2024). *ROS 2 from Scratch: Get started with ROS 2 and create robotics applications with Python and C++*. Packt Publishing.
- Corke, P. (2023*). Robotics, vision and control: Fundamental algorithms in Python* (3e). Springer. https://doi.org/10.1007/978-3-031-06469-2
- Rico, F. M. (2024). *A concise introduction to robot programming with ROS 2*. Routledge. https://doi.org/10.1201/9781003451488
- Herath, D., & St-Onge, D. (Eds.). (2022). *Foundations of robotics: A multidisciplinary approach with Python and ROS*. Springer. https://doi.org/10.1007/978-981-19-1983-1
- Sarwar, S. M., & Koretsky, R. M. (2020). *Linux: The textbook* (2e). CRC Press.
- Blum, R., & Bresnahan, C. (2021). *Linux command line and shell scripting bible* (4e). Wiley.

MET 2212: ANALOG AND DIGITAL ELECTRONICS LAB [0 0 3 1]

Introduction to operational amplifier (Op-Amp) using 741 IC, characteristics, and analysis of linear and non-linear applications of Op-Amp. Design timer circuits using 555 IC, Simulation and analysis of combinational and sequential circuits using SPICE simulation tools. Design and implementation of combinational and sequential logic circuits using standard digital ICs and verification through hardware testing. Introduction to Verilog HDL for digital circuit design, simulation, and basic FPGA-based implementation.

References

- Ramakanth A. Gayakwad, *Op-Amps and Linear Integrated Circuits*, (4e), Pearson Education, 2015.
- Robert L. Boylestad and Louis Nashelsky, *Electronic Devices and Circuit Theory*, (11e), Pearson Education, 2015.
- Muhammad H. Rashid, *SPICE for Circuits and Electronics Using PSPICE*, (3e), Pearson Education, 2008.
- Stephen Brown and Zvonko Vranesic, *Fundamentals of Digital Logic with Verilog Design*, (3e), McGraw Hill, 2013.

FIFTH SEMESTER

SMS 3001: ENGINEERING ECONOMICS AND FINANCIAL MANAGEMENT [3 0 0 3]

Role of economics in engineering decisions, Nature of engineering decisions, Decision-making process, Types of costs, Cost–volume relationships, Cash flow concepts and diagramming. Interest & Equivalence, Nominal vs effective interest rate, Types of Interest formulas, Inflation, Relationship between interest and inflation. Bases for comparison, Decision Techniques - Present Worth (NPV) method, Annual Worth method, Internal Rate of Return (IRR), Incremental analysis (basic), Replacement analysis, Minimum cost analysis, Benefit–Cost Analysis. Financial Decision Making and Valuation - Discounted cash flow (DCF) concept (basic), Return on Investment (ROI), Payback period (simple), Basic valuation of bonds and equities. Risk & Uncertainty, Sensitivity analysis, Scenario analysis, Basic decision tree. Costing & Depreciation. Lifecycle costing, Environmental and social cost considerations, sustainable engineering decisions, Introduction to techno-economic thinking.

References:

- L. T. Blank and A. J. Tarquin, Engineering Economy, 8th ed. New York, NY, USA: McGraw-Hill, 2018.
- W. G. Sullivan, E. M. Wicks, and C. P. Koelling, Engineering Economic Analysis, 14th ed. Boston, MA, USA: Pearson, 2019.
- Chan S. Park, Contemporary Engineering Economics, 6th ed. Boston, MA, USA: Pearson, 2015.
- P. Chandra, Financial Management-Theory and Practice, 9th Edition, Tata McGraw Hill Education, 2016.
- Daniel A. Vallero and Chris Brasier (2008). Sustainable Engineering: Concepts and Practices, John Wiley & Sons.
- M. Martín, Ed., LCA and TEA for Sustainable Development. Cham, Switzerland: Springer, 2023.

MET 3101: DIGITAL SIGNAL PROCESSING [2 1 0 3]

Fundamentals of digital signals and systems, operations, and properties, Impulse Response, convolution, Transform domain analysis of discrete-time systems, Z-transform, Sampling, Aliasing, frequency-domain analysis of signals using DFT and FFT, design and implementation of IIR and FIR digital filters using classical and modern techniques, characteristics of IIR and FIR filters, Classical filter design using Butterworth approximation. Bilinear transformation, Frequency transformation technique for low-pass, high-pass, band-pass and band-stop filter design, Applications of digital signal processing- speech, image, video, communication, acoustics and vibration with emphasis on ethics, safety and risk mitigation in its design.

References:

- John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, 4th Edition, Pearson Education, 2013.
- Alan V. Oppenheim and Ronald W. Schafer, *Discrete-Time Signal Processing*, 3rd Edition, Pearson Education, 2014.
- S. Palani, *Discrete Time Systems and Signal Processing*, 2nd Edition, Springer Cham, 2023.
- A. Nagoor Kani, *Digital Signal Processing*, 3rd Edition, CBS Publishers, 2021.
- B. P. Lathi, *Signal Processing and Linear Systems*, 2nd Edition, Oxford University Press, 2018.

FLEXICORE - 1: MET 3102: AUTOTRONICS [3 0 0 3]

Evolution of automotive electronics; vehicle electrical architecture; role of electronics in performance, safety, and emissions; automotive wiring systems; batteries, charging, and starting systems. Classification and working principles of sensors – temperature, pressure, speed, position, oxygen, and knock sensors, signal conditioning. ECU architecture and functions; automotive microcontrollers; input-output interfacing; basics of embedded systems; introduction to automotive power electronics. Electronic fuel injection systems; ignition and spark timing control; engine management systems; emission control electronics; introduction to hybrid and electric vehicle electronics. Automotive safety systems – ABS, airbags and traction control; body electronics; vehicle communication protocols (CAN, LIN), on-board diagnostics and fault codes.

References:

- Bosch Automotive Handbook, Robert Bosch GmbH.
- William B. Ribbens, *Understanding Automotive Electronics: An Engineering Perspective*, Butterworth-Heinemann; (7e), 2012.
- Tom Denton, *Automobile Electrical and Electronic Systems,* Routledge, 2017.

FLEXICORE – 1: MET 3103: DIGITAL TWINS FOR MECHATRONICS [3 0 0 3]

Introduction to digital twin, classifications of digital twin includes component, product, process, design, and service twins, along with architecture, workflows, industrial applications, and use-case selection. Data acquisition involves DAQ systems, microcontroller interfacing, IoT protocols (MQTT, Kafka, Wi-Fi), and cloud-based database management integrated with SCADA/PLC, real-time streaming, and visualization. Physics-based modeling includes system dynamics, state-space equations, causal and acausal modeling, hybrid approaches, FMU-based co-simulation, and optimization. Surrogate modeling covers engineering data science, graph neural networks, and reduced-order modeling for rapid simulation and deployment. Data-driven techniques include regression, clustering, decision trees, and neural networks with industrial case studies and predictive analytics. Integration focuses on hybrid physics-AI models, fault diagnosis, anomaly detection, and maintenance strategies.

References -

1. Tao, F., Zhang, M., & Nee, A. Y. C. (2019). *Digital twin driven smart manufacturing*. Academic Press.
2. Tao, F., Liu, A., Hu, T., & Nee, A. Y. C. (2020). *Digital twin driven smart design*. Elsevier.
3. Tao, F., Qi, Q., & Nee, A. Y. C. (2022). *Digital twin driven service*. Academic Press.
4. Raghunathan, V., & Deb Barma, S. (2019). *Digital twin: A complete guide for the complete beginner*. Notion Press. *(Indian-authored)*
5. Borole, Y., Borkar, P., Raut, R., Balpande, V. P., & Chatterjee, P. (2023). *Digital twins: Internet of things, machine learning, and smart manufacturing*. Walter de Gruyter.
6. Géron, A. (2022). *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow* (3rd ed.). O'Reilly Media.

MET 3104: COMPUTATIONAL INTELLIGENCE FOR MECHATRONICS [3 1 0 4]

Artificial Intelligence applications in Mechatronic systems, decision-making, and control. Overview of mechatronic and intelligent systems, machine learning paradigms—supervised, unsupervised, and reinforcement learning—and data acquisition and preprocessing, self-study on Python, MATLAB, and Simulink. Machine learning for modelling and diagnostics, regression, classification, clustering, feature extraction from sensor signals, fault detection, and predictive maintenance using vibration, temperature, and motor current analysis, case studies. Metaheuristics, neural networks (including MLP, CNN, RNN, and Transformers), transfer learning, sensor fusion, and generative design concepts, as well as object detection and gesture recognition. Intelligent control systems, fuzzy logic, rule-based decision-making, neural network adaptive control, and data-driven modelling, MATLAB/Simulink implementations. Risk, safety, and ethical considerations in AI deployment with standards such as ISO 61508 and IEEE codes for responsible and sustainable integration.

References:

- Azar, A. T., & Koubaa, A. (Eds.). (2023). *Artificial Intelligence for Robotics and Autonomous Systems Applications*. Springer.
- Michelucci, U. (2018). *Applied Deep Learning: A Case-Based Approach to Understanding Deep Neural Networks*. Apress.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.

MET 3105: HYDRAULICS AND PNEUMATICS SYSTEMS [3 0 0 3]

Pneumatics controls components, actuators, directional and flow control valves, dual pressure, shuttle, and time delay valves, design of manual and electro-pneumatic circuits using sensors and logic elements. Hydraulic systems components, power packs, pump types and performance, actuators, directional, pressure, and flow control valves, accumulators, and pilot-operated valves. solenoid, proportional and servo type electro-hydraulic valves, Design of hydraulic circuits for position, speed, and pressure control, including sequencing, counterbalance, regenerative, and electro-hydraulic application.

References:

- *Fundamentals of Pneumatics and Hydraulics,* Md. Abdus Salam, Springer, 2023
- *Pneumatic Systems and Circuits - Basic Level and Advanced Level*, Joji Parambath, Atlantic Publishers and Distributors (P) Ltd, 2020
- *Fluid Power with Applications,* Anthony Esposito, Pearson Education Limited, Seventh Edition, 2013
- Industrial hydraulics textbook and training manual, Danfoss / IFPS, 2023
- *Hydraulic Servo Systems – Theory and Applications.* Rydberg, K.-E., Linköping University published, 2008

MET 3111: IIOT LAB [0 0 3 1]

Computer Networking fundamentals. Simulation of network devices viz., hub, switch and router using Cisco packet Tracer. Simulation of IIoT environment using Cisco Packet tracer. Operation of MSP432 microcontroller from TI. Interfacing of communication booster packs for Wi-Fi and Radio communication. Sensor data logger using STM32 microcontroller.

Self-study:

Coursera course entitled: The Bits and Bytes of Computer Networking

References:

- MSP432 Manual by Texas Instrumentation.
- STM32 Manual by STMicroelectronics

MET 3112: MECHATRONIC SYSTEMS DESIGN LAB [0 0 3 1]

This laboratory course is designed to provide hands-on exposure to modeling, simulation, and intelligent control of mechatronic and robotic systems using modern computational tools. The course emphasises the use of MATLAB for robotics-oriented system modeling, kinematics, dynamics, and control, and Python for machine learning (ML) techniques applied to mechatronic data and decision-making problems. Through a sequence of structured experiments, students gain practical skills in simulation, algorithm development, data-driven modeling, and performance evaluation relevant to contemporary mechatronic system design.

List of Experiments

Experiment 1: To familiarise with the MATLAB environment and basic robotic control system concepts.
Experiment 2: To develop a mathematical model of robotic systems using MATLAB.
Experiment 3: To design and analyse feedback controllers for dynamic systems.
Experiment 4: To synthesise and implement optimisation techniques in MATLAB.
Experiment 5: To design and optimise a feedback control system using optimisation techniques.
Experiment 6: Familiarisation with Python for Mechatronic and ML Applications
Experiment 7: Data Preprocessing and Visualisation for Mechatronic Systems
Experiment 8: Supervised Learning for Mechatronic System Prediction
Experiment 9: Classification of Mechatronic System States
Experiment 10: Performance Evaluation of ML Models for Mechatronic Applications

References:

- Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*, (2e), O'Reilly Media, 2019.
- Sebastian Raschka and Vahid Mirjalili, *Python Machine Learning*, (3e), Packt Publishing, 2019.
- scikit-learn Developers, scikit-learn User Guide and Documentation,
- Wes McKinney, Python for Data Analysis, 2nd Edition, O'Reilly Media, 2017.
- Marghitu, D. B. (2009). *Mechanisms and Robots Analysis with MATLAB.* London: Springer London.

SIXTH SEMESTER

SMS 3002: ESSENTIALS OF MANAGEMENT [3 0 0 3]

Introduction to Business, Classification of Industries, Importance of management for an engineer, Manager Roles External Environment, Social Responsibility of managers, Ethics in managing, International Business, Strategies and Policies, Strategic Planning Process & tool, Quality Management, Span of Management, Departmentation, Recruitment, Selection, Induction, Orientation. Leadership and Motivational tools and Techniques, Group Decision, Communication, Management Control Techniques.

References:

- Subrata Das (2022), "Ethics and Human Values in Engineering Practices", Woodhead Publishing India in Textiles, New Delhi.
- Harold Koontz & Heinz Weihrich (2020), "Essentials of Management", Mc Graw Hill, New Delhi.
- Poornima M Charantimath (2018), "Entrepreneurship Development", Pearson Education.
- Mike W.Martin and Ronald Schinzinger (2017), "Ethics In Engineering", 4th Edition, Tata Mcgraw Hill, New Delhi.
- Vasant Desai (2011), "Dynamics of Entrepreneurial Development & Management", Himalaya Publishing House.
- Peter Drucker (2004), "The Practice of Management", Harper and Row, New York.

MET 3201: ELECTRIC DRIVES [3 0 3 4]

Fundamentals of electric drives, basic components, advantages, closed loop control, speed, torque conventions, steady state equilibrium, and determination of motor power rating. Introduction to power electronics, Power Diode, SCR, BJT, MOSFET and IGBT, Uncontrolled and controlled rectifiers, loads, freewheeling diodes. Choppers, Inverters and AC-AC converters. DC motors, operating principles, torque speed characteristics, speed control concepts, Control of DC motor using choppers and controlled rectifiers. AC motors, three phase induction motors, operating principles, torque speed characteristics, speed control, single phase induction motors, synchronous motors, linear induction motors, PM synchronous motors, BLDC motors, switched reluctance motors and synchronous reluctance motors. Servo motors, stepper motors and universal motors.

Lab component:

Modeling of RL and RLC circuits, Power Electronics. Closed loop PID control. DC Motor Modelling and Control. AC Induction Motor Control. Industrial PLC Based PMSM motor control. V/f Control of Induction Motor. PWM Based DC Motor Control. Advanced drives: BLDC, Switched Reluctance Motor, Stepper, Servo and Linear Motor Drives.

References:

- Gopal K. Dubbey, *Fundamentals of Electric Drives*, (2e), Narosa Publishers, 2010.
- Bimbra P.S., *Power electronics*, (3e), Khanna Publishers, 2010.
- P. C. Sen, *Principles of Electrical Machines,* (3e), Wiley, 2020.
- L. Umanand, *Power Electronics: Essentials & Applications,* Wiley 2009.
- Drives and Control training system- Practice module, BOSCH REXROTH manual, Germany 2011.
- Matlab Documentation, Mathworks.
- PLC training practice module, BOSCH REXROTH manual Germany 2011.

FLEXICORE – 2: MET 3202: UNMANNED AERIAL VEHICLES [3 0 0 3]

Introduction to UAVs: Classification of UAVs, Fixed-wing UAVs, Rotary-wing UAVs, Flapping-wing UAVs, Hybrid UAVs, Components of UAVs, Sensors and payloads, Communication systems, Ground control systems, Applications of UAVs in various domains. Coordinate systems in UAVs: Inertial and body frames, UAV kinematics, Translational dynamics, Rotational dynamics, Newton-Euler equations, Aerodynamic forces and moments, Modelling of fixed-wing UAVs, Modelling of rotary-wing UAVs, Modeling of flapping-wing UAVs, MATLAB-based trajectory simulation, Visualization of UAV motion in 3D. Flapping-wing mechanisms, Bio-inspired designs:Wing kinematics, Stroke plane and flapping angle, Lift and drag modelling in flapping motion, Quasi-steady aerodynamic modelling, Wing-body interaction effects, MATLAB simulation of flapping profiles, Simscape Multibody simulation of wing motion, Frequency and amplitude variation effects. PID control for UAVs: Altitude and attitude stabilization, Tuning control parameters, Introduction to nonlinear control, Fuzzy and adaptive control basics, Simulink control system for flapping-wing UAVs.

References

- R. W. Beard and T. W. McLain, *Small Unmanned Aircraft: Theory and Practice*, 1st ed. Princeton, NJ, USA: Princeton Univ. Press, 2015.
- P. Corke, *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*, 2nd ed. Cham, Switzerland: Springer, 2017.
- K. Sridhar and L. S. Raja, *Modeling and Control of Unmanned Aerial Vehicles*, 1st ed. Chennai, India: Notion Press, 2021.
- K. Mohseni and R. Mittal, Eds., *Bio-Inspired Aerospace Systems*, 1st ed. Cambridge, U.K.: Cambridge Univ. Press, 2015.
- M. S. Shafer, *MATLAB for Engineers: Applications in Control, Electrical Engineering, and Flight Dynamics*, 1st ed. Boca Raton, FL, USA: CRC Press, 2016.

FLEXICORE – 2: MET 3203: AI-POWERED ROBOTICS [3 0 0 3]

AI in robotics, supervised, unsupervised, and reinforcement learning, perceptron, activation functions, delta learning rule, multi-layer perceptron, loss functions, backpropagation, optimizers, regularization, neural network frameworks, Robotic vision and perception: image representation (pixels, RGB, HSV, grayscale, depth), filtering, edge/corner detection, morphological operations, CNN fundamentals, convolution, pooling, fully connected layers, LeNet, AlexNet, ZFNet, VGG, Inception Nets, ResNets, DenseNets. Object recognition and segmentation, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet, implementation using deep learning libraries. Path planning and navigation, graph-based methods (Dijkstra, A*), sampling-based methods, obstacle avoidance, motion control, SLAM, probabilistic mapping, visual and LiDAR-based SLAM, SLAM frameworks, autonomous mobile robot case studies, AI ethics in robotics, ethical decision making in autonomous systems.

References:

- Sebastian Thrun, Wolfram Burgard, Dieter Fox, *Probabilistic Robotics*, MIT Press, 2022
- Ian Goodfellow, Yoshua Bengio, Aaron Courville, *Deep Learning*, MIT Press, 2016.
- Anand Tamboli, *Deep Learning for Robot Vision*, Packt Publishing, 2021.
- Francis X. Govers, *Artificial Intelligence for Robotics: Build Intelligent Robots That Perform Human Tasks Using AI Techniques*, Packt Publishing, 2018.
- Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction,* 2nd edition, MIT Press, 2015.
- Maxim Lapan, *Deep Reinforcement Learning Hands-On,* 3rd edition, Packet Publishing, 2024

MET 3211: HYDRAULICS LAB [0 0 3 1]

Operation of various valves like directional control valves, flow control valves, pressure control valves and switches like pressure switches, proximity switches. Operations of timers and counters. Rigging of manual hydraulics and electro-hydraulics circuits using above valves and switches. Working principles of hydraulic pumps, hydraulic motors, pressure switch, pressure reducing valve, accumulator, proximity switch, throttle valves, pressure compensated flow control valves and direction control valves. Rigging of proportional hydraulics circuits using various hydraulic components and sensors.

References:

- Hydraulic Fluid Power by Andrea Vacca and Germano Franzoni

- Open Channel Hydraulics by R.H. French

MET 3212: PNEUMATICS LAB [0 0 3 1]

Operations of various valves like directional control valves, flow control valves, pressure control valves and switches like pressure switches, proximity switches. Operations of timers and counters. Building manual pneumatic and electro-pneumatic circuits using pneumatic valves, sensors and switches. Interfacing solenoid valve with programable logic controller and relay controls.

References:

- Practice for Professional Pneumatics Trainee's manual, BOSCH REXROTH manual, Germany 2011.
- Practice for Professional Electro-Pneumatics Trainee's manual, BOSCH REXROTH manual, Germany 2011.
- Training system for pneumatics, BOSCH REXROTH manual, Germany 2014
- Pneumatics Basic Level TP101 training manual, Festo, 2024.

SEVENTH SEMESTER

There are five program electives and one open elective with total of 18 credits to be taught in this semester.

EIGTH SEMESTER

MES 4299: INDUSTRIAL TRAINING (MLC)

Each student has to undergo industrial training for a minimum period of 4 weeks. This may be taken in a phased manner during the vacation starting from the end of third semester. Student has to submit to the department a training report in the prescribed format and also make a presentation of the same. The report should include the certificates issued by the industry.

MET 4999: PROJECT WORK

MINOR SPECIALIZATIONS

I. INDUSTRIAL IOT SYSTEMS

MET 4301: DATABASE MANAGEMENT AND DATA MINING [3 0 0 3]

Introduction: Database-System Applications, Relational Databases, Data Storage and Querying, Transaction Management, Database Architecture, Database Users and Administrators. Relational Model: Structure of Relational Databases, Database Schemas, Keys, Relational Query Languages, Relational Operations. Database Design and The E-R Model: SQL: SQL Data Definition, SQL Data Types and Schemas, Integrity Constraints, Basic Structure of SQL Queries, Set Operations, Aggregate Functions, Nested Subqueries, Additional Basic Operations Null Values, Atomic Domains and First Normal Form, Decomposition Using Functional Dependencies, Functional Dependency Theory, Algorithms for Decomposition, Decomposition Using Multivalued Dependencies. Transaction Management: Transaction Concept. Data mining: Introduction, Association rules mining, market based analysis, Apriori Algorithm, Partition Algorithm, Pincer –Search Algorithm, Dynamic item set counting algorithm, FP-tree growth Algorithm, PC Tree, Multilevel association rules, Clustering Techniques: Introduction, Clustering paradigms, Partitioning Algorithms, k – Medoid & k- means Algorithms, CLARA, CLARANS, Hierarchical Clustering, DBSCAN.

Self-study:

Topics related to Ethics in Database management from O'Keefe, O Brien, Ethical Data and Information Management: Concepts, Tools and Methods, (1e), Kogan Page, 2018.

References:

- Silberschatz, Korth, Sudarshan, *Database System Concepts*, (7e), McGrawHill, New York, 2019.
- Ramez Elmasri and Shamkant Navathe, Durvasula V L N Somayajulu, Shyam K Gupta, *Fundamentals of Database Systems*, (6e), Pearson Education, United States of America,2011.
- Thomas Connolly, Carolyn Begg, *Database Systems – A Practical Approach to Design, Implementation and Management*, (4e), Pearson Education, England, 2005.
- Peter Rob, Carlos Coronel, *Database Systems–Design, Implementation and Management*, (10e), Course Technology, Boston , 2013.

MET 4302: CYBERSECURITY AND CRYPTOGRAPHY FOR INDUSTRIAL APPLICATIONS [3 0 0 3]

Introduction to Security and Cryptography: Security goals, attacks, services and mechanisms; Classical encryption techniques (substitution, transposition); SDLC vs. SecSDLC. Symmetric-Key Cryptography: Symmetric cipher model, DES, Triple DES, AES structure and key expansion, Block cipher modes (ECB, CBC, CFB, OFB), Stream ciphers (RC4). Cryptographic Mathematics: Modular arithmetic, GCD, Fermat's and Euler's theorems, Chinese Remainder Theorem, Number theory fundamentals for cryptography. Public-Key Cryptography and Key Management: RSA, Diffie–Hellman, ElGamal, Key exchange protocols, PKI framework, and Security services. Hash Functions and Digital Signatures: SHA family, CBC-MAC, Message authentication codes, Digital signature schemes, Integrity and non-repudiation. Cyber Threats and Intrusion Models: Malware, intrusion detection systems (HIDS/NIDS), Attack vectors, SQL injection, Database and transport layer security (SSL/TLS). Applied Cryptography in Industrial Security: Firewalls, VPNs, IPSec, IKE, cybercrime case studies, risk analysis, multi-layer security for IoT, SCADA, and healthcare. Case Studies and Applications.

Self-learning: Industrial cybersecurity standards (ISA/IEC 62443), Best practices for securing automation and control systems.

References:

- William Stallings, *Cryptography and Network Security: Principles and Practice*, 7th Edition, Pearson, 2017.
- Behrouz A. Forouzan and Debdeep Mukhopadhyay, *Cryptography and Network Security*, 2nd Edition, McGraw Hill, 2010.

- Bruce Schneier, *Applied Cryptography*, 2nd Edition, John Wiley & Sons, 2015.
- Charles P. Pfleeger and Shari Lawrence Pfleeger, *Security in Computing*, 5th Edition, PHI, 2015.
- Global Cyber Security Alliance, *Quick Start Guide: An Overview of ISA/IEC 62443 Standards – Security of Industrial Automation and Control Systems*, ISA, 2022.

MET 4303: INDUSTRIAL COMMUNICATION [3 0 0 3]

Introduction to Computer Networks**:** Types of networks, Types of transmission media, Concept and types of Multiplexing, Concept and types of Multiple Access techniques, Principles and types of Analog and Digital Modulation. ISO/OSI model: Physical layer: Types of cables, Types of connectors, Communication standards, Data-Link layer, Network Layer: IPv4, IPv6, Routing and Subnetting, Transport Layer: TCP, UDP. Networks in Industrial Process Automation: Introduction to networks in Industrial Process Automation, Networks and Protocols: AS-i, CAN, DeviceNet, Interbus, LON, Foundation Fieldbus, HART, PROFIBUS-PA, BACnet, ControlNet, IndustrialEthernet, Ethernet/IP, MODBUS, PROFIBUS-DP. Fiber Optic Communication: Principles of Fiber-Optic networks, Types of Fiber-Optic cables, Fiber-Optic Network design, Fiber cable installation and setup, Splices and Connectors, Inspection and testing. Radio, Satellite and Infrared Communication: Radio systems, Spread Spectrum techniques, Satellite LANs, Communication bands in satellite communication, Infrared Systems, Very fast Infrared.

References:

- Liptak, B.G. (Ed.), *Instrument engineers' handbook, Vol. 3: Process software and digital networks*, (4e) CRC Press, Boca Raton, London, 2012.
- Andrew S. Tanenbaum, *Computer Networks*, (5e), Prentice Hall of India Pvt. Ltd., 2011.
- William Stallings, *Data and Computer Communications*, (8e), Prentice Hall of India Pvt. Ltd., 2014.
- James F. Kurose, Keith W. Ross, *Computer Networking (A Top-Down Approach Featuring the Internet)*, (3e), Pearson Education, 2005.
- Todd Lammle, *Cisco Certified Network Associate-Study Guide*, (2e), Sybex Inc. Publishing. 2000.

MET 4304: SMART INDUSTRIAL IOT [3 0 0 3]

Evolution of IoT and IIoT, Difference between IoT and Industrial IoT, IIoT architecture and layers, Key enabling technologies (sensors, embedded systems, cloud, edge, AI/ML), Industrial IoT ecosystem and standards (IIC, RAMI 4.0, ISO/IEC 30141). Smart sensors, actuators, and gateways; Edge and Fog computing; Cloud platforms for IIoT; Industrial controllers (PLC, DCS, SCADA) and their IoT integration; Real-time data processing; Cyber-Physical Systems (CPS) and Digital Twins. D**ata Acquisition and Analytics:** Data collection methods and sensor interfacing; Industrial data formats; Edge data preprocessing; Cloud data storage and big data analytics; Predictive maintenance and condition monitoring using AI/ML; Visualization tools and dashboards. **Security and Privacy in IIoT:** Security threats and vulnerabilities; Authentication and encryption techniques; Secure device identity; Blockchain for IIoT security; Industrial standards (IEC 62443, NIST guidelines). **Applications of Smart IIoT**

References:

- Alasdair Gilchrist, *Industry 4.0: The Industrial Internet of Things*, Apress, 2016.
- Jan Holler et al., *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, Elsevier, 2014.
- Sabina Jeschke, Christian Brecher, Tobias Meisen, *Industrial Internet of Things (IIoT): Cybermanufacturing Systems*, Springer, 2017.
- Ovidiu Vermesan and Peter Friess (Eds.), *Internet of Things – From Research and Innovation to Market Deployment*, River Publishers, 2014.
- Mukesh Saini, *Industrial Internet of Things: Technologies and Applications,* CRC Press, 2020.

II. ROBOTICS AND AUTOMATION

MET 4305: ARTIFICIAL INTELLIGENCE FOR ROBOTIC VISION [3 0 0 3]

Image Processing Fundamentals: Image Formation, Linear Filtering, Correlation, and Convolution, Visual Features: Edge, Blobs, Corner Detection Algorithms, SIFT, SURF, HOG, Geometric transformation, Implementation using OpenCV Libraries, integration with ROS2. Convolutional Neural Networks: Perceptron, Delta learning rule, multi-layer perceptron, Backpropagation, optimizers and Regularization, Data augmentation, Introduction to CNN: Evolution of CNN Architectures, Implementation using Deep Learning Libraries. Object Recognition and Segmentation: Background of Object Detection, CNN for Recognition and Detection, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet; CNNs for Segmentation: FCN, SegNet, U-Net, Mask-RCNN, Review of RNNs; CNN + RNN Models for Video Understanding, Vision Transformers, Swin Transformers, 3D object detection and segmentation. Ethical and Responsible AI in Robotic Vision: Sim2Real and Synthetic data generation, Dataset bias and fairness in vision, Responsible AI deployment in surveillance and autonomous robots, Explainable AI: Grad-CAM, SHAP for vision models.

Prerequisite:

1. Probability, linear algebra, and calculus
2. Experience of programming in Python

References:

- Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep learning*. MIT Press, 2016.
- Nielsen, Michael A. *Neural networks and deep learning*. San Francisco, CA, USA: Determination Press, 2015.
- Adrian Rosebrock. *Deep Learning for Computer Vision with Python – Starter Bundle*. PyImageSearch, 2017.
- Adrian Rosebrock. *Deep Learning for Computer Vision with Python – Practitioner Bundle*. PyImageSearch, 2017.
- Szeliski, Richard. *Computer Vision: Algorithms and Applications.* Springer Science & Business Media, 2010.

MET 4306: ROBOT DYNAMICS AND CONTROL [3 0 0 3]

Overview of robotic systems, coordinate transformations between joint space and task space, forward and inverse kinematics, Jacobians, trajectory generation, and serial and parallel robot kinematics. Robot dynamics including force, inertia, and energy modeling, Lagrange–Euler and Newton–Euler formulations, equations of motion, state-variable representations, dynamics of actuated robotic systems, and application-oriented design modeling. Robot control problems covering regulation and tracking, PD and PID controllers, closed-loop control, gain tuning, performance and simulation analysis, set-point tracking using PD and feedforward control, torque and computed-torque control, discretization of outer-loop PD/PID controllers, actuator saturation, integrator anti-windup compensation, and quadratic optimal control. Nonlinear dynamics and control including Lyapunov stability theory, robust control, feedback linearization, Lyapunov-based controller design, variable-structure control, and saturation-type controllers.

Self-study:

Robo Analyzer software model-based software to learn the Robotics concepts. http://www.roboanalyzer.com/

References:

- Mark W. Spong, Seth Hutchinson, M. Vidyasagar, *Robot Modeling and Control*, (2e), John Wiley and sons, 2009.
- Frank L. Lewis, *Robot Manipulator Control- Theory and Practice*, (2e), CRC Press, 2003.
- Mark W. Spong, *Robot Dynamics and Control*, (2e), John Wiley and sons, 2009.
- Yoshikawa, *Foundations of Robotics: Analysis & Control*, (1e), Prentice Hall India, 2009.

MET 4307: AUTONOMOUS MOBILE ROBOTS [3 0 0 3]

Introduction to locomotion in autonomous systems; mobile robots (definition, types, applications); legged robots (structure, gait patterns, stability); wheeled mobile robots (types, configurations, motion models); mobile robot kinematics (forward and inverse kinematics); motion in global coordinates (position and orientation representation); kinematic models and constraints (holonomic and non-holonomic systems); robot maneuverability (degrees of freedom and control); robot workspace (reachability and limits); dynamics of quadrotor-type robots (forces, moments, stability); perception in robotics (role and importance); sensors for mobile robots (LIDAR, camera, IMU, GPS); SLAM concepts and techniques; path planning methods; navigation (classification and principles); AI algorithms for navigation (search, optimization, decision-making); obstacle avoidance and goal-oriented navigation; introduction to reinforcement learning in robotics and its application to autonomous navigation.

References:

- Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. *Introduction to Autonomous Mobile Robots* (3rd Edition). MIT Press, 2024.
- Corke, P. *Robotics, Vision and Control: Fundamental Algorithms in Python* (3rd Edition). Springer Nature, 2023.
- Kagan, E., Shvalb, N., & Ben-Gal, I. (Eds.). *Autonomous Mobile Robots and Multi-Robot Systems: Motion-Planning, Communication, and Swarming*. John Wiley & Sons, 2019.
- Thrun, S., Burgard, W., & Fox, D. *Probabilistic Robotics*. MIT Press, 2005 (Classic Reference).
- LaValle, S. M. *Planning Algorithms*. Cambridge University Press, 2006 (Updated online versions available 2020).
- Dudek, G., & Jenkin, M. *Computational Principles of Mobile Robotics*. Cambridge University Press, 2010.

MET 4308: SOFT ROBOTICS [3 0 0 3]

Introduction to Soft Robotics, distinction from rigid robotics; bioinspired design and morphological computation. Materials for Soft Robotics : Mechanical behavior of elastomers, hydrogels, and shape-memory materials; electroactive polymers and smart textiles; fundamentals of polymer mechanics and selection criteria for soft robot design. Soft Sensing and Actuation : Principles and mechanisms of soft sensing; actuation methods; integration of sensing and actuation in compliant structures. Structural Design and Locomotion Principles: Design strategies using solid mechanics and thermodynamics; chamber and layer configuration for deformation control; bioinspired architectures and locomotion, modeling, FEA, and simulation of compliant mechanisms. Control of Soft Robots : Architectures, actuation control, feedback integration, adaptive and learning-based control strategies, motion planning using CPGs, and proprioceptive feedback systems. Mathematical Modeling and Kinematics : Continuum mechanics, hyper-redundant kinematics, elasticity formulations, inverse kinematics, eigenvalue-based analysis, dimensionality reduction, and bio-mimetic modeling of flexible manipulators.

References:

- F. Boyer and F. Renda, *Continuum Mechanics for Soft Robotics*. Cambridge, UK: Cambridge University Press, 2022.
- C. Della Santina, C. Duriez, and D. Rus, "Control of soft robots: From model-based to data-driven approaches," *Annu. Rev. Control. Robot. Auton. Syst.*, vol. 6, pp. 1-28, May 2023.
- F. Stella and J. Hughes, "The science of soft robot design: A review of motivations, methods and enabling technologies," *Front. Robot. AI*, vol. 9, art. no. 1059026, Jan. 2023.
- Y. Zhang et al., "Stimuli-responsive materials for soft robotics: From actuators to integrated systems," *Nat. Rev. Mater.*, vol. 10, no. 2, pp. 88-105, Feb. 2025.
- B. J. Caasenbrood, *Design, Modeling, and Control Strategies for Soft Robots*. Eindhoven, NL: Eindhoven University of Technology, 2024.
- J. Wang et al., "Embodying physical computing into soft robots," *Adv. Intell. Syst.*, vol. 8, no. 1, art. no. 2500412, Jan. 2026.

- T. G. Thuruthel, S. H. Sadati, and F. Iida, "Control strategies for soft robotic manipulators: A survey," *Soft Robot.*, vol. 8, no. 2, pp. 149-163, Apr. 2021.
- M. Armani et al., *Soft Robotics: Materials, Fabrication, and Applications*. Weinheim, Germany: Wiley-VCH, 2024.

III. MICRO AND NANO SYSTEMS

MET 4309: SEMICONDUCTOR AND VLSI DESIGN [3 0 0 3]

Semiconductor Fundamentals: Energy bands, charge carriers, effective mass, Fermi–Dirac distribution, intrinsic and extrinsic semiconductors, carrier concentration, Fermi level, doping effects. Carrier Transport & PN Junction: Carrier drift and diffusion, mobility, conductivity, Einstein relation, continuity equation, PN junction equilibrium, built-in potential, depletion region, electric field, I–V characteristics, junction capacitance, breakdown. MOS Capacitor & MOSFET: MOS structure, band diagrams, accumulation, depletion and inversion, surface charge, flat-band and threshold voltage, C–V and I–V characteristics, transconductance, non-ideal effects. CMOS Logic Design: CMOS inverter, DC transfer characteristics, noise margin, static and dynamic logic, pass transistor logic, transmission gates, sequential circuits, latches, registers, clocking strategies. VLSI Design Concepts: Power dissipation, scaling, sheet resistance, capacitance, RC and Elmore delay, delay estimation, arithmetic circuits, memory elements, stick diagrams, layout design rules, fabrication introduction.

References:

- D. A. Neamen, Semiconductor Physics and Devices: Basic Principles, 4th ed. New York, NY, USA: McGraw-Hill Education, 2012.
- S. M. Sze and K. K. Ng, Physics of Semiconductor Devices, 3rd ed. Hoboken, NJ, USA: Wiley, 2007.
- B. G. Streetman and S. Banerjee. Solid State Electronic Devices. 7th ed. Upper Saddle River, N.J.: Pearson/Prentice Hall, 2015.
- J. M Rabaey, “Digital Integrated Circuits”, Prentice Hall India, 2003.
- N Weste and K Eshraghian, “Principles of CMOS VLSI Design: A Systems Perspective”, Addiso-Wesley Pub. Company, 1993.
- S. M. Kang, Y. Leblebici, “CMOS Digital Integrated Circuits Design and Analysis”, Tata Mcgraw Hill, 1996.
- D. A. Pucknell and K. Eshraghian,“Basic VLSI Design”, PHI publication, 2009.
- John P Uyemura, "Introduction to VLSI Circuits and Systems." Wiley, 2002.

MET 4310: SMART MATERIALS FOR MICRO AND NANO SYSTEMS [3 0 0 3]

Introduction to smart materials and systems; definitions, intelligent behavior, sensitivity, reversibility, adaptability, and response to external stimuli; types and properties of smart materials including piezoelectric materials, shape memory alloys and polymers, chromoactive, photoactive, magnetorheological materials, magnetic materials and hysteresis, dielectric, ferroelectric, piezoelectric and pyroelectric properties; nanomaterials in smart systems including synthesis methods, nanoscale properties, carbon nanostructures and nanoparticles for applications; micro and nano systems including microsystem fundamentals, design, modeling, signal conditioning and control; fabrication and characterization including micro/nano fabrication, spectroscopy, microscopy, XRD, thermal analysis, and deposition techniques; applications including sensors, actuators, wearable systems, SHM, biomedical systems, integration and packaging

References:

- Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, *Smart Material Systems & MEMS: Design and Development Methodologies*.
- G. K. Ananthasuresh, K. J. Vinoy, S G.S. Gopalakrishnan, K N Bhat, V.K. Aatre. *Micro and Smart Systems* Technology and Modeling ,2011
- Sergey Edward Lyshevski, *Nano- and Micro-Electromechanical Systems: Fundamentals of Nano- and Microengineering*
- Stelios K. Georgantzinos” *Micro/Nano Structures and Systems: Analysis, Design, Manufacturing, and Reliability”* January 2023
- V. R. Remya, H. Akhina, and Oluwatobi Samuel Oluwafemi” *Nanostructured Smart Materials: Synthesis, Characterization, and Potential Applications”* September 2023
- NPTEL, edX, Coursera, and related journal papers

MET 4311: DESIGN OF MICRO AND NANO DEVICES [3 0 0 3]

Introduction to micro and nano systems; evolution, MEMS and NEMS overview, applications, scaling laws and size effects; materials and mechanical design including thin films, nanomaterials, micro beams, diaphragms, cantilevers, residual stress and thermal effects, material selection (Si, SiO_2, Si_3N_4, polymers, graphene); fabrication and packaging including bulk and surface micromachining, lithography, etching, deposition, bonding, nanofabrication techniques (e-beam lithography, nanoimprint, self-assembly), integration challenges; sensors and actuators including electrostatic, piezoelectric, thermal and magnetic actuation, pressure sensors, accelerometers, resonators, microgrippers, interfacing and signal conditioning, reliability; modeling and simulation using lumped parameter and multiphysics approaches, coupled effects, noise, calibration.

References:

- M. Madou, *Fundamentals of Microfabrication and Nanotechnology*, CRC Press.
- N. Maluf and K. Williams, *An Introduction to Microelectromechanical Systems Engineering*, Artech House.
- S. Senturia, *Microsystem Design*, Springer.
- S. E. Lyshevski, *MEMS and NEMS: Systems, Devices, and Structures*, CRC Press.

- J. Gardner et al., *Microsensors, MEMS and Smart Devices*, Wiley.
- Research papers from IEEE Sensors Journal, JMEMS, and Nanotechnology.
- NPTEL, edX, Coursera, and related journal papers

MET 4312: FABRICATION AND TESTING OF MICRO SYSTEMS [3 0 0 3]

Fundamentals of microfabrication, cleanroom practices, contamination control, silicon crystal structure and orientation, microsystem materials (SiO_2, Si_3N_4, polysilicon, GaAs, InP, SiC, SOI, polymers, metals), thermal oxidation, photolithography, mask design (L-edit, K-Layout), thin film deposition (PVD, CVD, ALD), doping (ion implantation, diffusion), epitaxial growth, etching (RIE, DRIE, wet etching with KOH, TMAH, Al, Au), and wafer bonding (fusion, adhesive, eutectic, thermocompression). Testing and characterization methods including SEM, TEM, interferometry, ellipsometry, I–V and C–V analysis, AFM, nanoindentation, and failure analysis. AI-powered MEMS design and process optimization, flexible and stretchable electronics, intelligent MEMS and edge AI, Bio-MEMS (Lab-on-chip, Organ-on-chip), SiC-based harsh environment sensors, and novel material integration (AlN, PZT). Case studies on MEMS accelerometers, pressure sensors, tactile sensors, and Lab-on-chip systems, including process documentation and PDK interpretation.

References:

- Marc J. Madou, *Fundamentals of Microfabrication and Nanotechnology, Three-Volume Set (3rd Edition)*, CRC Press, 2021
- Sami Franssila, *Introduction to Microfabrication, 2nd Edition,* Wiley-VCH, 2010
- **Stephen A. Campbell,** *The Science and Engineering of Microelectronic Fabrication*, 2nd Edition, Oxford University Press, 2001.
- **Marc F. Trietley and Nadim Maluf,** *An Introduction to Microelectromechanical Systems Engineering*, 2nd Edition, Artech House, 2004.

MINOR SPECIALIZATION (SCHOOL LEVEL)
I. PRECISION AGRICULTURE TECHNOLOGY

MET 4313: SMART FARMING MACHINERY [3 0 0 3]

Significance of agriculture as an industry, soil properties, soil fertility, and essential plant nutrients. Soil-water-plant relationships, horticultural crop types and life cycles, and farm machinery principles for soil preparation, sowing, cultivation, fertilizer application, pesticide spraying, and weed control. Climate-controlled agriculture, greenhouse design, plant responses, measurement instruments for pH, electrical conductivity, gas analysis, humidity, leaf area, chlorophyll, soil moisture and temperature, along with automated control systems, smart irrigation, and hydroponics. Harvesting machinery principles, material handling equipment, conveyors, and elevators are discussed, followed by post-harvest technologies including grain drying systems such as deep bed, flat bed, tray, fluidized bed, recirculatory, and solar dryers.

References:

- R.K. Sharma & A.K.Soni, R. Bhagat, N. Pandey and V.K. Pandey, *Basics of Agriculture for Engineers*, , 2014 Daya Publishing House, New Delhi.
- Sanjay Kumar, *Farm Power & Machinery*, 2018, Kalyani Publications.
- Cecilia Stanghellini; Bert Van 't Ooster; Ep Heuvelink, *Greenhouse horticulture Technology for optimal crop production*, Wageningen academic publishers, 2019.
- Basavaraj; Srigiri, D.; P.R., Jayan, *Textbook Of Farm Machinery And Power Engineering*, New India Publishing Agency, 2019
- Amalendu Chakraverty, Arun S. Mujumdar, Hosahalli S. Ramaswamy, *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*, CRC Press, 2003.
- Prabhat K. Nema, Barjinder Pal Kaur, Arun S. Mujumdar, *Drying Technologies for Foods, Fundamentals and Application*s, 2019, CRC press.
- Farm Power and Machinery ICAR e-Course.

MET 4314: ROBOTICS AND AUTOMATION IN AGRICULTURE [3 0 0 3]

General robotic architecture, sensors, drive systems, kinematics, task and trajectory planning, robot controller and operating system; Classification and working of the electric and pneumatic drive used in robots, different types of pneumatic control valves and design of pneumatic control circuits; working principles of different types of end-effectors, Design and development of robotic end-effector for harvesting different crops; Working principals of thermal, depth, real-sense and multi-spectral cameras, capturing, processing and analysis of different images, integration of vision system with the end effector and drive system; Working Principles of drone, classification of agriculture drones, components of drones, application of drones in agriculture for surveillance and pesticide application. Self-study: Mobile robots, servo motors, actuators, robotic manipulators, machine vision.

References:

- Inamuddin, R. Boddula, and A. M. Asiri, Eds., *Actuators and Their Applications: Fundamentals, Principles, Materials, and Emerging Technologies*. Wiley-Scrivener, 2020.
- K. R. Krishna, *Agricultural Drones: A Peaceful Pursuit*. Apple Academic Press, 2018.
- R. K. Mittal and I. J. Nagrath, *Robotics and Control*, (1e) New Delhi, India: McGraw-Hill, 2003.
- P. Joji, *Pneumatic Controls*. New Delhi, India: Wiley India Pvt. Ltd., 2008.
- S. K. Pillai, *A First Course on Electrical Drives*, 3rd ed. New Delhi, India: New Age Publishers, 2012.

MET 4315: FOOD PROCESS AUTOMATION [3 0 0 3]

Food product quality and inspection, covering automated evaluation, quantization, and process control, challenges in quality assessment. Product quality parameters and measurement techniques including sampling, ultrasonic signal acquisition, electronic nose for odor detection, snack food frying data acquisition, and image acquisition with data analysis methods like preprocessing, static and dynamic analysis, image segmentation, and feature extraction. Modeling and prediction strategies include theoretical and empirical approaches, static and dynamic modeling, linear statistical models, and ANN-based prediction and classification for grading and quality evaluation. Automation in thermal and non-thermal food processing encompasses pasteurization, sterilization, freezing, drying, high-pressure processing, and advanced process control systems such as internal model control, predictive control, and neuro-fuzzy PDC, along with systems integration for quality quantization and process control. Packaging machinery and systems, future trends like 3D food printing using extrusion, inkjet, binder jetting, and selective laser sintering.

References:

- R. P. Singh and D. R. Heldman, *Introduction to Food Engineering*, Academic Press, 5th Edition, 2014.
- G. L. Robertson, Food Packaging: *Principles and Practice*, CRC Press, 4th Edition, 2023.
- D. E. Rumsey, C. D. Watkins, and M. H. Tunick, *Food Quality: Balancing Health and Disease*, Springer, 2021.
- R. D. King and G. A. P. Masson (Eds.), *Computerized Control Systems in the Food Industry*, CRC Press, 2000.
- M. Valand, A. Suvarnakuta, and P. Mehta, *Food Process Monitoring Systems*, Woodhead Publishing, 2018.
- R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, Pearson, (4e), 2018.
- C. Braddock, *Mathematical Modelling and Simulation in Food Processing*, CRC Press, 2012.
- M. L. Rooney (Ed.), *Active Food Packaging*, Springer, 2019.
- B. Sun and J. Peng, *3D Printing in Food Engineering: Principles and Applications*, Elsevier, 2023.

MET 4316: DIGITAL AGRICULTURE [3 0 0 3]

Use of electrical energy in agriculture, electro-mechanical energy conversion, Electrical motors, pumps, Selection of motors for different farming applications, remote controlled intelligent irrigation systems, machine learning approach for efficient water usage, renewable energy sources. Precision farming, GIS/GPS positioning system for precision farming, Yield monitoring and mapping, soil sampling and analysis, Computers and Geographic information systems, Precision Farming-Issues and conditions, Role of electronics in farm machinery for precision farming.; Design and development of IoT system for fully automatic farm. Data acquisition systems, Test sites, Common measurements, Geologic investigations, Agriculture and Forestry investigations, Atmospheric investigation, visual image interpretation, digital image processing, Earth resource satellite, Ground water level monitoring.; The digital agriculture revolution, challenges of digital transformation, key drivers of digital agriculture transformation, ICT, Mobile Technology and its impact on agriculture and rural development, AI based farming, adoption of ICTs and digital technologies in agriculture.

Self-study:

Soil sensors calibration, irrigation scheduling, crop water estimation. Water quality management in irrigation etc.

References:

- Singh Brahma and Balraj Singh, *Advances in Protected Cultivation*, New India Publishing Company, 2014.
- Sharma P. *Precision Farming*, Daya Publishing House New Delhi, 2007.
- Qin Zhang, *Precision Agriculture Technology for Crop Farming*, (1e), 2016.
- Narendra Singh Rathore, Sunil Joshi, Naveen Choudhary, *Digital Technologies for Agriculture*, 2022.
- Annamaria Castrignano, Gabriele Buttafuoco, Raj Khosla, Abdul Mouazen, Dimitrios Moshou, Olivier Naud, *Agricultural Internet of Things and Decision Support for Precision Smart Farming*, (1e), 2020.
- Pradeep Tomar, Gurjit Kaur, *Artificial Intelligence and IoT-Based Technologies for Sustainable Farming and Smart Agriculture*, 2021.

MINOR SPECIALIZATION (INSTITUTE LEVEL)

I. ROBOTICS

MET 4401: INTRODUCTION TO ROBOTICS SYSTEMS [3 0 0 3]

Robot fundamentals and classification: History, evolution, and scope of robotics; types of robots – industrial, mobile, service, and collaborative; anatomy of robots, links, joints, degrees of freedom, workspace, and coordinate frames. Robot components and actuators: Mechanical structure, joint types, actuators (electric, hydraulic, pneumatic), transmission systems; sensors – position, velocity, proximity, force/torque, and vision. Kinematics and dynamics: Homogeneous transformations, Denavit–Hartenberg (DH) parameters, forward and inverse kinematics of serial manipulators; introduction to robot dynamics, torque and motion equations, trajectory planning, and PID control. Robot programming and simulation: Introduction to programming languages and simulation environments; path planning, motion generation, and task-level programming using open-source tools such as *RoboDK, CoppeliaSim, Webots, Gazebo, MATLAB/Octave,* and *ROS*. Applications and trends: Robotics in manufacturing, healthcare, agriculture, logistics, and service sectors; collaborative and intelligent robots, AI and ML in robotics, human–robot interaction, and ethical considerations.

References

- John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson Education.
- Mikell P. Groover, *Industrial Robotics: Technology, Programming, and Applications*, McGraw-Hill.
- S. R. Deb and S. Deb, *Robotics Technology and Flexible Automation*, Tata McGraw-Hill.
- Richard D. Klafter, Thomas A. Chmielewski, Michael Negin, *Robotic Engineering: An Integrated Approach*, Prentice Hall.
- Bruno Siciliano and Lorenzo Sciavicco, *Robotics: Modelling, Planning and Control*, Springer.
- Peter Corke, *Robotics, Vision and Control*, Springer.
- ROS Documentation and Online Tutorials (for hands-on learning).

MET 4402: IOT FOR ROBOTICS [3 0 0 3]

Introduction to IoT and Robotics. Fundamentals of robotic systems. IoT vs traditional robotic control with Use cases. IoT Architectures and Communication Protocols: IoT layered architecture (perception, network, application). Communication technologies: Wi-Fi, Bluetooth, ZigBee, LoRa, 5G. Protocols: MQTT, CoAP, HTTP, WebSocket, DDS for robotics. Cloud and edge computing platforms for robotic control. Sensors, Actuators, and Embedded Systems for Robotics. Actuator control through IoT interfaces. Microcontrollers and embedded boards (Arduino, Raspberry Pi, ESP32). Data acquisition, signal conditioning, and wireless transmission. IoT Platforms and Cloud Integration: IoT middleware platforms (ThingSpeak, Blynk, AWS IoT, Google Cloud IoT). Data visualization and dashboards. Remote robot monitoring and control through web/mobile apps. Applications and Advanced Trends. Edge-AI and digital twins for real-time robot analytics. Security and privacy issues in IoT-enabled robotic systems. Future trends: Tactile Internet, Human–Robot–Cloud interaction.

Laboratory work:

Interfacing of basic sensors with ESP32 and MQTT dashboard. Remote control of a robotic arm/mobile robot using IoT platform. Real-time data logging from robot sensors to the cloud. IoT-based obstacle avoidance using ultrasonic sensors. Mini project: IoT-enabled robotic prototype (group-based).

References:

- Pethuru Raj and Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, 1st Edition, CRC Press, 2017. ISBN: 978-1-4987-4983-6.
- M. Srinivasan, *Introduction to Robotics and IoT*, 1st Edition, Wiley India Pvt. Ltd., 2020. ISBN: 978-93-89827-18-4.
- C. S. R. Prabhu, *Internet of Things*, 2nd Edition, PHI Learning Pvt. Ltd., 2016. ISBN: 978-81-203-5284-5.
- Vijay Madisetti and Arshdeep Bahga, *Internet of Things: A Hands-On Approach*, 1st Edition, VPT (University Press), 2014. ISBN: 978-0996025515.
- Rajesh Singh, Anita Gehlot, Bharat Rawal, and Dinesh Singh Solanki, Internet of Things with Raspberry Pi and Arduino, 1st Edition, Packt Publishing, 2019. ISBN: 978-1789139130.

MET 4403: ROBOTICS DESIGN AND SIMULATION [3 0 0 3]

Kinematic Modelling: Forward and inverse kinematics, Denavit–Hartenberg (D-H) representation, Differential kinematics and Jacobians, Velocity and acceleration analysis. Jacobian and Differential Motions: Mapping between configuration-space to operational-space, Jacobian matrix and Pseudo inverse concepts, Introduction to workspace singularities, Differential (velocity) kinematics, Forward differential kinematics and inverse differential kinematics. Dynamic Modelling: Lagrange and Newton–Euler formulations, Dynamic equations of motion for manipulators, Actuator modelling and joint dynamics, Dynamic parameter identification. Control and Motion Planning: Joint space and Cartesian control, Trajectory generation and path planning, Control algorithms for position, velocity, and torque control. Robot Simulation Techniques and Mini Project /Case Studies: Simulation platforms: MATLAB/Simulink, Robot Analyzer/ Robot Studio, ROS, Simulation-based performance testing and validation, Case studies of industrial robots, Simulation of a robotic manipulator, Design and analysis of robot workspace, trajectory, and control

Laboratory work:

Kinematic modelling using MATLAB or Python, Dynamic simulation of robotic arms, Trajectory generation and control simulation, Integration of robot models in Robo Analyzer/ Robot Studio, Mini project: modelling and simulating a complete robot system

Recommended Software Tools:

- MATLAB/Simulink
- Robo Analyzer/ Robot Studio
- ROS (Robot Operating System)/ Gazebo
- SolidWorks Motion or Fusion 360 Simulation

References:

- John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson.
- Bruno Siciliano & Lorenzo Sciavicco, *Robotics: Modelling, Planning and Control*, Springer.
- S. K. Saha, *Introduction to Robotics*, McGraw Hill.
- Peter Corke, *Robotics, Vision and Control*, Springer.
- K. S. Fu, R. C. Gonzalez & C. S. G. Lee, *Robotics: Control, Sensing, Vision and Intelligence*, McGraw Hill.

MET 4404: AI FOR ROBOTICS [3 0 0 3]

AI in robotics, supervised, unsupervised, and reinforcement learning, perceptron, activation functions, delta learning rule, multi-layer perceptron, loss functions, backpropagation, optimizers, regularization, neural network frameworks, Robotic vision and perception: image representation (pixels, RGB, HSV, grayscale, depth), filtering, edge/corner detection, morphological operations, CNN fundamentals, convolution, pooling, fully connected layers, LeNet, AlexNet, ZFNet, VGG, Inception Nets, ResNets, DenseNets. Object recognition and segmentation, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet, implementation using deep learning libraries. Path planning and navigation, graph-based methods (Dijkstra, A*), sampling-based methods, obstacle avoidance, motion control, SLAM, probabilistic mapping, visual and LiDAR-based SLAM, SLAM frameworks, autonomous mobile robot case studies, AI ethics in robotics, ethical decision making in autonomous systems.

References:

- Sebastian Thrun, Wolfram Burgard, Dieter Fox, *Probabilistic Robotics*, MIT Press, 2022
- Ian Goodfellow, Yoshua Bengio, Aaron Courville, *Deep Learning*, MIT Press, 2016.
- Anand Tamboli, *Deep Learning for Robot Vision*, Packt Publishing, 2021.

- Francis X. Govers, *Artificial Intelligence for Robotics: Build Intelligent Robots That Perform Human Tasks Using AI Techniques*, Packt Publishing, 2018.
- Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction,* 2nd edition, MIT Press, 2015.
- Maxim Lapan, *Deep Reinforcement Learning Hands-On*, 3rd edition, Packt Publishing, 2024

PROGRAM ELECTIVES

MTP 4401: AUGMENTED REALITY AND VIRTUAL REALITY [3 0 0 3]

Introduction to AR/VR/MR/XR: Augmented Reality, Virtual Reality, Mixed Reality, Extended Reality, History, Hardware and Software, IDE, Devices, Temporal and Spatial Resolution, Motion, Depth, Colour, Auditory and Haptics Perception, Locomotion Interfaces, Display, Tracking. Unity3D and Unreal Engine: Editor, Game Objects, Components, Materials, Texturing, Lighting, Skybox, Import/Export, Modelling, Physics, Probuilder, Terrain, Asset Store, Avatar, Animator, Particle Systems, C# Scripting, Vuforia, ARKit, ARCore, Workflow, Asset Libraries, Plug-ins, Blueprint, Lighting and Shading. Extended Reality: XR Toolkit, Teleoperation, UI Interaction, UX Design, Testing, Oculus, SteamVR, OpenXR, Deployment Workflows, Test Cases. Use Cases: Industry 4.0, Automobile, Robotics.

References:

- Steven M. LaValle, *Virtual Reality*, 2016
- Schmalstieg, D., & Höllerer, T. (2016). *Augmented reality: Principles and practice*. Pearson Education.
- Aukstakalnis, S. (2016). *Practical augmented reality: A guide to the technologies, applications, and human factors for AR and VR*. Addison-Wesley Professional.
- Vince, J. (2008). *Virtual reality systems* (1st ed.). Dorling Kindersley (India) Pvt. Ltd.
- LaViola, J. J., Jr., Kruijff, E., McMahan, R. P., Bowman, D. A., & Poupyrev, I. (2017). *3D user interfaces: Theory and practice* (2nd ed.). Addison-Wesley Professional.
- Moshayedi, A. J., & Kolahdooz, A. (2023). *Unity in embedded system design and robotics: A step-by-step guide*.
- Mather, G. (2016). *Foundations of sensation and perception* (2nd ed.). Routledge.

MTP 4402: BIOMECHATRONICS [3 0 0 3]

Biomechatronics fundamentals, physiological systems (biochemical, nervous, cardiovascular, respiratory, musculoskeletal), bio‑mechatronics integration, components of biomechatronic systems (sensors, actuators, controllers, signal processors), application areas. Sensor technologies for biological signal acquisition (EMG, EEG, ECG, EOG, nerve cuff, brain arrays), oxygen and chemical sensors, force and pressure sensors, motion sensors (accelerometers, gyroscopes), optical and tactile sensors, signal processing and feature extraction. Actuator technologies for function replacement and augmentation, motors, electromagnetic and fluidic actuators, shape memory alloys, electroactive polymers, piezoelectric and biological actuators. Control of biomechatronic systems, system modeling, model-based open-loop and closed-loop control, human-in-the-loop control, representative control case studies. Safety and regulatory standards in biomechatronics, ISO 13485, ISO 14971, IEC 60601, cybersecurity in medical devices, FDA and CE certification. Case studies in biomechatronics, brain‑computer interfaces, prosthetic devices, upper and lower limb exoskeletons, assistive robotic systems, wearable health monitoring devices, ethical considerations.

References:

- Jacob Segil, *Handbook of Biomechatronics*, Academic Press, 2019.
- Marko B. Popovic, *Biomechatronics*, Academic Press, 2019
- Graham m. Brooker, *Introduction to Biomechatronics*, Scitech Publishing, 2012
- Shane Xie, Wei Meng, *Biomechatronics in Medical Rehabilitation*, Springer, 2017

MTP 4403: FRACTIONAL ORDER MODELLING AND CONTROL [3 0 0 3]

Fractional Order Calculus: Integer-order derivatives and integrals, geometric and physical interpretations, Riemann–Liouville integration, RL, Caputo and Grunwald–Letnikov derivatives, interpretations, computation for basic functions, Laplace transforms. Fractional-Order Modeling: Complex analysis, multivalued functions, branch points, branch cuts, Riemann surfaces, fractional-order transfer functions, commensurate and noncommensurate systems, FO models of electrical elements, circuits, mechanical systems, heat transfer, biological systems. Fractional-Order Control: Comparison with integer-order control, closed-loop performance, robustness, stability, FO PID control, FO state-feedback design, realization and implementation methods, comparative study, case studies.
Self-study:
Risk management in the industrial control system.

Texts/References:

- K. B. Oldham and J. Spanier. *The Fractional Calculus*, Dover Publications, USA, 2006.
- Kilbas, H. M. Srivastava, and J. J. Trujillo. *Theory and Applications of Fractional Differential Equations*, Elsevier, Netherlands, 2006.
- Podlubny. *Fractional Differential Equations* . Academic Press, USA, 1999.
- C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. *Fractional-order Systems and Control: Fundamentals and Applications* Springer-Verlag London Limited, UK, 2010.
- R. L. Magin. *Fractional Calculus in Bioengineering*. Begell House Publishers, USA, 2006.
- R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. *Fractional Order Systems: Modeling and Control Applications*. World Scientific, Singapore, 2010.
- K. S. Miller and B. Ross. *An Introduction to the Fractional Calculus and Fractional Differential Equations*. John Wiley & Sons, USA, 1993.

MTP 4404: HUMAN ROBOT INTERACTION [3 0 0 3]

I/O channels in human-computer interaction; HCI frameworks and systematic design flow; ergonomics focusing on user comfort, efficiency, and safety; prototyping methods including low- and high-fidelity prototypes and overall system lifecycle; usability engineering principles for user-centered design; various HCI models and interaction paradigms; cognitive aspects such as perception, memory, and decision-making, along with socio-organizational issues; evaluation techniques including heuristic evaluation, user testing, and design rules; collaborative HCI models supporting group interaction; application frameworks in HCI development; mobile HCI design principles with relevant case studies; virtual layout design for interfaces; and process flow in web interfacing design for effective user experience.

References:

- Bartneck, C., Belpaeme, T., Eyssel, F., Kanda, T., Keijsers, M., & Sabanovic, S., *Human-Robot Interaction: An Introduction*, (1e), Cambridge University Press, 2020.
- Siciliano, B., & Khatib, O., *Springer Handbook of Robotics*, (2e), Springer-Verlag (Includes dedicated sections on HRI and Social Robotics), 2016.
- Goodrich, M. A., & Schultz, A. C., *Human–Robot Interaction: A Survey*, Foundations and Trends in Human-Computer Interaction, Now Publishers, 2023 (Updated Edition/Review).
- Holzinger, A., *Human-AI Interaction: Basics and Fundamentals*, (1e), Springer, 2023.
- Abbas, S., *Design and Safety of Human-Robot Collaboration*, (1e), CRC Press, 2022.

MTP 4405: MECHATRONICS SYSTEM DYNAMICS [3 0 0 3]

Single Degree of Freedom: Degrees of freedom, examples, natural frequency (Newton's method, energy method), longitudinal, lateral, torsional systems, damped free vibration, viscous damping types. Forced Vibration: Harmonic excitation, steady-state response, rotating and reciprocating unbalance, force transmissibility, isolation, seismic instruments, base excitation, accelerometer and vibrometer design. Two Degrees of Freedom Systems: Natural frequencies, mode shapes (classical method), forced vibration, dynamic vibration absorber, centrifugal pendulum absorber. Multi-Degree of Freedom Systems: Influence coefficient method, Holzer's method, matrix iteration method, Rayleigh's and Dunkerley's methods for lumped and distributed systems. Self-study: Case studies on vibration experiments.

References:

- Grover G.K., *Mechanical Vibrations*, Nemchand and Bros, Roorkee, 2012.
- Singirisu Rao S, *Mechanical Vibration*, Pearson Education, Delhi, 2004.
- Dukkapatti Rao V., *Text Book of Mechanical Vibration*. Prentice Hall of India Ltd, 2004.
- Daniel Imnan J. *Engineering Vibration*, Prentice Hall, New Delhi, 2001.
- Thomson W.T., *Theory of Vibrations with Applications*, Chapman and Hall, 4th Edition, 1993.

MTP 4406: PRODUCTION AND OPERATIONS MANAGEMENT [3 0 0 3]

Introduction to Production and Operations Management: Types of production systems, production cycle, functions. Forecasting: Importance, types, qualitative methods (historical, sales force, market research, Delphi), quantitative methods (moving averages, exponential smoothing, regression, correlation, seasonality), forecast accuracy. Capacity Planning: Design and system capacity, efficiency, factors, planning steps, equipment and manpower, decision tree, breakeven analysis, P-V charts. Aggregate Planning: Pure and mixed strategies, trial and error, transportation method. Scheduling: Job shop factors, sequencing rules (FCFS, SPT, EDD, CR), flow time, lateness. Inventory Management: EOQ models, shortages, discounts, safety stock, reorder level, ABC analysis. MRP: Inputs, outputs, logic. Line Balancing: Cycle time, precedence, efficiency. Facility Location and Layout: Methods, load distance, centre of gravity, layout planning.

References:

- Monks Joseph G. (2020) *Operations Management* (2e), Tata McGraw-Hill Publishing Co. Ltd., New Delhi. India.
- Chase Richard B., Aquilano Nicholas J. and Jacobs F. Roberts (2016) *Production and Operations Management* (5e), Tata McGraw-Hill Publishing Co. Ltd., New Delhi. India.
- Krajewski Lee J. and Ritzman Larry P. (2015) *Operations Management* (11e), Pearson Education (Singapore) Pte. Ltd., New Delhi. India.
- P. K. Gupta and D. S. Hira (2015) *Operations Research* 2011 Ed., S. Chand & Co. Ltd., New Delhi. India.
- R. Panneerselvam (2012), *Production and Operations Management*, PHI Learning PVT. LTD. New Delhi. India.

MTP 4407: MACHINE VISION [3 0 0 3]

Image Acquisition and Analysis: Vision system components, pinhole camera model, image acquisition, sampling and quantization, color image processing, color space conversion, basic image operations, geometrical transformations, image enhancement, spatial and frequency domain processing, noise, restoration, morphological operations, segmentation, feature extraction (Harris, SIFT, SURF, HOG). **3D Vision:** Linear camera model, RGB-D and ToF cameras, camera calibration, intrinsic and extrinsic parameters, stereo vision, epipolar geometry, fundamental matrix, depth computation, optical flow, structure from motion, observation matrix. **Motion Estimation and Tracking:** Background subtraction, optical flow, Kalman filter tracking, localization. **Machine Learning for Robot Vision:** ML fundamentals, image classification, CNNs, architectures. **Tools and Applications:** Detection, tracking, calibration, depth estimation, stereo correspondence.

References:

- Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing*, (4e), Pearson Education, 2018.
- Szeliski, *Computer Vision: Algorithms and Applications*, Springer, (2e) 2022.
- Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision*, (4e), 2017.
- Corke, Peter I., and Oussama Khatib. *Robotics, Vision and Control Fundamental Algorithms in Python*: (3e), Springer
- David A. Forsyth, Jean Ponce, *Computer vision: A modern approach*, Pearson Education Limited, (2e), 2012.
- Adrian Rosebrock, *Deep Learning for Computer vision with Python*- Starter Bundle, Pyimagesearch, 2017.
- E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities*, (4e), University of London, 2012.
- NPTEL Courses: Computer Vision and Image Processing - Fundamentals and Applications offered by IIT Kharagpur. https://nptel.ac.in/courses/108103174

MTP 4408: AUTOMOBILE ENGINEERING [3 0 0 3]

Introduction to automobile engineering: vehicle construction and layouts, chassis, frame, and body. Vehicle power supply systems. Transmission systems, clutch types & construction, gearboxes. Hydrodynamic Clutches, Torque Converter. Heating and air conditioning systems. Steering geometry and types of steering gear box, power steering, types of front axle, types of suspension systems, pneumatic and hydraulic braking systems. Desirable tyre properties, conventional tubed & tubeless tyre. Noise, vibration and harshness in automobiles, Fundamentals of regenerative braking. Bearing and lubrication systems, environmental management, and service information systems. Electrical and lighting systems, Industrial Fabric, ergonomics, and safety standards in the automotive industry.

References:

- Jack Erjavec, Rob Thompson, *Automotive Technology - A Systems Approach*, Cengage (7 ed.), 2018.
- Trelle Borg, *Automotive Vibration Control Technology: Fundamentals, Materials, Construction, Simulation, and Applications* (1e), Vogel Business Media GmbH & Co. KG, 2015.
- Kripal Singh, *Automobile Engineering* (4e), Vol-1 and 2, Standard Publishers, Delhi, 2011.

MTP 4409: ENGINEERING MATERIALS [3 0 0 3]

Structure of Crystalline Solids: Unit cell, crystallographic directions and planes, diffraction, Bragg's law. Imperfection in Solids: Point, linear and volume defects, microscopic examination (SEM, TEM, OM). Composite Materials: Particle reinforced, fiber reinforced composites, polymer, metal and ceramic matrix composites, structural composites (sandwich panel, laminar composites). Smart Materials: Piezoelectric materials, magnetostrictive materials, coupling coefficients, Joule, Villari, Matteucci, Wiedemann effects, Terfenol-D, shape memory alloys, electro-active polymers. Electrical and Electronic Materials: Conductive materials (cladded, bimetals, sintered), semiconductors (Si, Ge, Se, Sb, GaAs, InSb), dielectric materials (ceramics, mica, porcelain, glass), insulating materials (rubber, paper).

References:

- William D Callister Jr., David G. Rethwisch, *Material Science and Engineering: An Introduction*, (10e), John Wiley & Sons Inc., 2018.
- K.M. Gupta and Nishu Gupta, *Advanced Electrical and Electronics Materials: Processes and Applications*, (1e), Wiley – Scrivener Publication, 2015.
- Mel Schwartz, *Encyclopaedia of Smart Materials, Volume 1 and Volume 2*, John Wiley & Sons, Inc., 2002.

MTP 4410: SUSTAINABLE MANUFACTURING [3 0 0 3]

Fundamentals of Sustainable Manufacturing: Concept and need for sustainability, triple bottom line (environmental, social, economic), green, lean and sustainable manufacturing, global frameworks and indicators, role in SDGs. Sustainable Product and Process Design: Design for environment, disassembly and recycling, QFD, R3 and R6 cycles, sustainable materials selection, value engineering, cost–benefit analysis. Environmental Impact Assessment and Standards: EIA methods, CML, Eco-indicator, ReCiPe, ISO 14001, PAS 2050, EMS, impact parameters, CSR, risk assessment. Life Cycle Assessment and Tools: LCA concepts, scope, inventory, impact assessment, tools (SimaPro, GaBi, OpenLCA), carbon and water footprint, exergy and energy analysis. Sustainable Factory and Supply Chain: Factory layout, energy and material flow, green productivity, waste minimization, green supply chain, recycling, packaging. Case Studies and Trends: Circular economy, cleaner production, sustainability indicators, Industry 4.0.

References:

- Dornfeld, D. A. (2012). *Green Manufacturing: Fundamentals and Applications.* Springer.
- Jayal, A. D., Badurdeen, F., Dillon, O. W., & Jawahir, I. S. (2010). *Sustainable Manufacturing: Modeling and Optimization Challenges. Journal of Manufacturing Science and Engineering*, ASME.
- Fiksel, J. (2015). *Design for Environment: A Guide to Sustainable Product Development.* McGraw-Hill Education.
- Gupta, S. M. (Ed.). (2013). *Reverse Supply Chains: Issues and Analysis.* CRC Press.
- Ashby, M. F. (2012). *Materials and the Environment: Eco-Informed Material Choice.* Elsevier.
- Bakshi, B. R., Gutowski, T. G., & Sekulić, D. P. (2011). *Thermodynamics and the Destruction of Resources.* Cambridge University Press.
- Hillis, D. R., & DuVall, J. B. (2012). *Improving Profitability through Green Manufacturing.* Wiley.
- Thompson, R., & Thompson, M. (2013). *Sustainable Materials, Processes and Production.* Thames & Hudson.
- Allwood, J. M., & Cullen, J. M. (2012). *Sustainable Materials: With Both Eyes Open.* UIT Cambridge.
- Kumar, S., & Dave, D. (2020). *Sustainable Manufacturing: Challenges, Solutions, and Implementation Perspectives.* CRC Press.

MTP 4411: MICRO ELECTRO MECHANICAL SYSTEMS [3 0 0 3]

MEMS and Microsystems applications, Review of Mechanical concepts, Actuation and Sensing techniques, Scaling laws in miniaturization, Materials for MEMS, Micro System fabrication techniques, Micro manufacturing, Micro system Packaging, Bonding techniques for MEMS, Overview of MEMS areas.

References:

- Chang Liu, *Foundations of MEMS*, Pearson 2012.
- Tai-Ran Hsu, *MEMS and Microsystems Design and Manufacture*, TMH, 2002.
- Chang C Y and Sze S. M., *VLSI Technology*, McGraw-Hill, New York, 2000.
- Julian W Gardner, *Microsensors: Principles and Applications*, John Wiley & Sons, 1994.
- Mark Madou, *Fundamentals of Micro fabrication*, CRC Press, New York, 1997.
- Stephen D. Senturia, *Microsystem design*, Springer (India), 2006.
- Thomas B. Jones, *Electromechanics and MEMS*, Cambridge University Press, 2001
- James J Allen, *MEMS Design*, Taylor and Francis, 2005.

MTP 4412: MODELLING OF HYBRID AND ELECTRIC VEHICLES [3 0 0 3]

History of Hybrid and Electric Vehicles technology, Economics and Environmental aspects of vehicle technologies. Vehicle dynamics-vehicle resistance, dynamic equation, tire ground adhesion, maximum tractive effort, vehicle speed, transmission characteristics, vehicle performance. Model the Electric propulsion unit: different motors, configuration and control of dc and induction motor drives. Introduction to power modulators, control, advanced motor drives for EV: PMSM, BLDC, SRM and SyncRel Motor drives. Modelling of energy storage systems such as batteries and fuel cells, including their control and management through battery management systems. Hybrid electric vehicle architectures and levels of hybridization. System-level models of EVs and HEVs and analyse their performance through real-world case studies.

References:

- Shuvra Das, *Modeling for Hybrid and Electric Vehicles Using Simscape,* Morgan & Claypool Publishers, 2021.
- Tom Denton, *Electric and Hybrid Vehicles,* Taylor and Francis, 2020.
- Mehrdad Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles- Fundamentals, Theory and Design*, (3e), CRC Press, 2018.
- Gianfranco Pistoia, *Behaviour of Lithium ion batteries in Electric Vehicles: Battery Health, Performance, Safety, Cost,* (1e), Springer, 2018.
- Amir Khajepour, Saber Fallah and Avesta Goodarzi, *Electric And Hybrid Vehicles Technologies, Modeling And Control: A Mechatronic Approach,* Wiley 2014.
- Research Articles for case studies.

MTP 4413: SMART MANUFACTURING [3 0 0 3]

Smart Factory, Industry 4.0, Digital Manufacturing, Productivity, Competitiveness, Transformation Roadmap, Change Management, ERP Integration, IIoT Architecture, Sensors, Communication Protocols, Edge vs Cloud, Cybersecurity, Vulnerabilities, Encryption, VLAN, Authentication, Data Backup, Industrial Cyberattack Case Studies, Industrial Automation, Robots, Cobots, AMR, Additive Manufacturing (3D Printing), Automation Layout Planning, Cyber-Physical Systems, Big Data in Manufacturing, AI/ML for Maintenance, AI/ML for Quality, Generative AI, Predictive Maintenance Case Study, Digital Twin, Digital Shadow, Digital Thread, Product Twin, Process Twin, System Twin, Digital Twin Architecture (Physical System, Digital Model, Connectivity Layer), IoT Integration (Sensors, SCADA, MES, ERP), Enabling Technologies, ISO 23247, IEC 62890, Simulation Tools, KPIs (OEE, Energy Efficiency, Downtime, Cycle Time, Process Variation, Predictive Indicators), ROI, Cost–Benefit Analysis, Business Impact, Industrial Applications, Digital Transformation Roadmap.

References:

- Ajay, K., Singh, H., Parveen, P. & Al Mangour, B., 2023. *Handbook of Smart Manufacturing: Forecasting the Future of Industry 4.0*. London: Routledge. DOI: 10.1201/9781003333760 Taylor & Francis
- Tyagi, A.K., 2026. *Industrial Robotics in Smart Manufacturing*. London: Routledge. Routledge
- Islam, M.M.M., Baptista, M.L. & Tariq, F. (eds.), 2024. *Artificial Intelligence for Smart Manufacturing and Industry X.0*. Cham: Springer.
- Mishra, A., El Barachi, M. & Kumar, M. (eds.), 2024. *Transforming Industry Using Digital Twin Technology*. Cham: Springer.
- Kanagachidambaresan, G.R., Anand, R., Balasubramanian, E. & Mahima, V. (eds.), 2020. *Internet of Things for Industry 4.0: Design, Challenges and Solutions*. Cham: Springer. DOI: 10.1007/978-3-030-32530-5 SpringerLink
- Zaman, U.K.u., Siadat, A., Baqai, A.A., Naveed, K. & Kumar, A.A. (eds.), 2024. *Handbook of Manufacturing Systems & Design: An Industry 4.0 Perspective*. London: Routledge / Academic Press. DOI: 10.1201/9781003327523

MTP 4414: AI-DRIVEN COBOTS AND QUADRUPED ROBOTICS [3 0 0 3]

ROS-based architectures for collaborative robots: workspace creation, package management, catkin/colcon build systems. ROS communication models: publishers–subscribers, services, actions. Robot modeling: URDF, Xacro, link-joint definitions, inertial and collision properties, RViz. Simulation: Gazebo, controller integration, joint position and velocity controllers. Control Systems: PID control, ROS control plugins. Motion Planning: MoveIt, kinematic chains, collision models, trajectory planning, constrained motion. Perception and Manipulation: RGB-D sensing, object detection, localization, inverse kinematics, redundancy resolution, pick-and-place. Interaction: Force–torque sensing, compliant control, human–robot interaction, gesture, voice, fiducial interfaces. Quadruped Robotics:

Morphology, actuation, gait generation. Learning-based Control: Reinforcement learning, imitation learning, visual policies, domain randomization, safety-constrained learning, supervisory control.

References:

- S. K. Saha, *Introduction to Robotics*, 2nd ed., McGraw-Hill, 2008.
- B. Siciliano et al., *Robotics: Modelling, Planning and Control*, Springer, 2009.
- N. Correll, B. Hayes, G. Habibi, *Introduction to Autonomous Robots*, (3e) (online text).
- L. Armada, P. González de Santos*, Quadrupedal Locomotion: An Introduction to the Control of Four-Legged Robots*, Springer, 2011.
- A. B. Kala, *Autonomous Mobile Robots: Planning, Navigation and Simulation*, Elsevier, 2023 (chapters on ROS, planning, and MoveIt).
- M. Mistry et al. (eds.), *Intelligent Robots and Cobots: Industry 5.0 Applications*, Scrivener/Wiley, 2024.

MTP 4415: SMART MOBILITY AND AUTONOMOUS NAVIGATION [3 0 0 3]

Smart mobility and autonomous navigation systems covering AGVs, service robots, autonomous vehicles, and drones. System architectures, V2X communication, and safety and regulatory aspects. Mobile robot kinematics and dynamics including nonholonomic constraints, state-space modeling, and motion control. Navigation perception using LiDAR, RGB-D, IMU, encoders, and GNSS with calibration, obstacle detection, semantic perception, and occupancy grids. Localization and mapping using probabilistic methods and 2D/3D SLAM in ROS. Path planning and trajectory generation using Dijkstra, A*, PRM, and RRT with time parameterization. Reactive navigation and obstacle avoidance using local planners and social navigation. ROS navigation stack including costmaps, planners, controllers, and tuning. Vision-based navigation for lanes, curbs, and traffic signs, and end-to-end visual navigation. Learning-based navigation using reinforcement learning and safe decision-making. Multi-agent and connected mobility including platooning and cooperative navigation. Human-centered, ethical principles.

References:

- R. Siegwart, I. Nourbakhsh, D. Scaramuzza, *Introduction to Autonomous Mobile Robots*, (2e), MIT Press, 2011.
- A. B. Kala, *Autonomous Mobile Robots: Planning, Navigation and Simulation*, Elsevier, 2023.
- B. Siciliano, O. Khatib (eds.), *Springer Handbook of Robotics*, (2e), Springer, 2016 (sections on mobile robots and navigation).
- S. Thrun, W. Burgard, D. Fox, *Probabilistic Robotics,* MIT Press, 2005 (for localization and SLAM).

PROGRAM ELECTIVES (COMMON ACROSS SCHOOL)

MTP 4421: HEAVY VEHICLE TECHNOLOGY [3 0 0 3]

Heavy Vehicle Technology: Classification, applications, axle configurations, tandem axle drive, propeller shafts, differentials, hub reduction, rear and steering axles, fuel cell vehicles. Propulsion Systems: Engine and transmission configurations, components, lubrication, cooling, engine braking, sensors, control systems, performance, diagnostics, ignition technologies. Transmission Systems: Manual, automatic, semi-automatic, overdrive, CVT, clutch, ECU, power take-off, retarders, troubleshooting. Braking Systems: Pneumatic, air-over-hydraulic, components, response time, safety regulations, ABS, EBS, service and auxiliary braking. Suspension and Steering: Ladder chassis, ride dynamics, tandem suspension, shock absorbers, adaptive and active suspension. Vehicle Systems: Cabin design, safety standards, sensors, actuators, power management, HMI, diagnostics, OBD, chassis control, case studies.

References:

- M.J. Nunney, *Light and Heavy Vehicle Technology*, Elsevier, (4e) 2006.
- Jack Erjavec, Cengage Learning, *Automotive Technology*, (5e), 2009.
- Anthony E. Schwaller, Delmar, *Motor Automotive technology*, (3e), 1998.
- Thomas W. Birch, Delmar Cengage Learning, *Automotive suspension and steering systems*, (3e), 1998.
- T Denton, Butterworth-Heinemann, *Automobile electrical and electronic systems*, (4e) 2011.
- William H. Grouse, *Automotive mechanics*, TMH, (10e), 2017.

MTP 4422: ALTERNATIVE FUELS AND GREEN ENERGY SYSTEMS [3 0 0 3]

Hydrogen Fuel Cell Technology: Alternative fuels (solid, liquid, gaseous), hydrogen fuel cells, working principles, types (PEMFC, SOFC), thermodynamics, applications, material, design and safety challenges. Liquid Alternative Fuels: Ethanol, methanol, butanol, biodiesel, SVO, production methods (fermentation, transesterification, catalytic), fuel properties, combustion characteristics, engine compatibility, storage, emissions, energy comparison. Green Hydrogen: Generation and Storage: Definition, electrolysis (PEM, alkaline), biomass reforming, solar-thermal, storage (compressed, liquefied, hydrides, carbon materials), safety. Green Hydrogen and Gaseous Fuels: SI and CI engines, injection methods, dual-fuel systems, combustion, emissions, gaseous fuels (CNG, LNG, ANG, LPG, LFG), engine modifications. Future Fuels and Powertrains: Ammonia, PMF, boron, liquid nitrogen, e-fuels, hybrid systems, LCA, industry practices, regulations.

References:

- Hodge, B. Keith. *Alternative energy systems and applications*. John Wiley & Sons, 2017.
- S.S. Thipse, *Alternative Fuels*, Jaico Publishing, 2015.
- G.D. Rai, *Non-Conventional Energy Sources*, Khanna Publishers, 2010.
- Shah, Maulin P., ed. *Green approach to alternative fuel for a sustainable future*. Elsevier, 2023.
- Twidell, John. *Renewable energy resources*. Routledge, 2021.

- R. Bechtold, *Alternative Fuels Guide*, SAE, 2005.
- M. Poulton, *Alternative Fuels for Vehicles*, Professional Engineering Publishing.

MTP 4423: PRODUCT DESIGN AND DEVELOPMENT [3 0 0 3]

Product Development: Characteristics of successful product development, design and development, duration, cost, challenges. Development Processes and Organizations: Generic development process, concept development, front-end process, AMF development process, product development organizations. Product Planning: Opportunity identification, project evaluation, prioritization, resource allocation, timing, pre-project planning. Customer Needs: Data gathering, interpretation, needs hierarchy, importance. Product Specifications: Definition, timing, target and final specifications. Concept Generation: Problem clarification, internal and external search, systematic exploration. Concept Selection and Testing: Screening, scoring, survey design, customer response. Product Architecture: Definition, implications, platform planning, quality assessment. Design for Manufacturing: Cost estimation, cost reduction, assembly, production support. Prototyping and Analysis: Principles, technologies, planning, economic and financial analysis. Project Management: Task representation, planning, execution, evaluation.

References

- Ulrich, K.T., Eppinger, S.D., *Product Design and Development*, McGraw-Hill.
- Boothroyd, G., Dewhurst, P., Knight, W., *Product Design for Manufacture and Assembly*, CRC Press.
- Chitale, A.K., Gupta, R.C., *Product Design and Manufacturing*, PHI Learning.
- Otto, K., Wood, K., *Product Design: Techniques in Reverse Engineering and New Product Development*, Pearson.