Instrumentation and Control Engineering

Honors

Industrial Instrumentation and Control

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	HON-01	*<tbd>*	Introduction to Environmental Engineering and Science: Fundamental & Sustainability Concepts	3	-	-	1	**3**	30	20	50	--	--
IV	HON-02	*<tbd>*	Smart Sensing Technology	3	1	-	1	**4**	30	20	50		
V	HON-03	*<tbd>*	Optimal Control	3	-	2	1	**4**	30	20	50	50	50
VI	HON-04	*<tbd>*	Advanced Process Control	3	-	2	1	**4**	30	20	50	50	50
VII	HON-05	*<tbd>*	Industrial drives and Control	2	1	-	1	**3**	30	20	50		
			Total	**15**	1	**04**	**05**	**18**					

Introduction to Environmental Engineering and Science: Fundamental & Sustainability Concepts

Course Code			**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Tutorial**			--

Course Outcomes: Students will be able to:

1. Understand the total overview of the environmental issues that all our working professionals should be aware of as per the directive of the Honble Supreme Court of India.
2. Appreciate the basic concepts of Ecology, Sustainability Concepts
3. Know water Pollution, Water and Wastewater Quality and, Solid and Hazardous Waste
4. Suggest different Treatments for Water and Wastewater and Solid waste.

1. Sustainability Concepts	**[7 Hrs]**
Innovations and Challenges, Environmental Measurements from Different Disciplines.	
2. Ecology Systems	**[7 Hrs]**
Ecology, Population & Environmental Chemistry, Physical Process in Environment	
3. Environmental Concepts	**[7 Hrs]**
Environmental Biological Concepts , Environmental Risk Assessments with Concepts of EIA and LCA.	
4. Water and Waste water	**[8 Hrs]**
Water – Quantity and Quality, Water Treatment Basics, Basics of Wastewater Collection, Treatment & Resource Recovery.	
5. Solid Waste	**[7 Hrs]**
Basics of Solid Waste, Soil and Noise Pollution, Basics of Air Pollution Issues – Global and Local.	
6. Case Studies	**[8 Hrs]**
Case studies of Water and Wastewater and Solid waste treatment & methods with new technology based Ecological system and environmental applications.	

Textbooks:

[1] G. M. Masters and W. P. Ela, *Introduction to Environmental Engineering and Science*, 3rd ed. Upper Saddle River, NJ, USA: Pearson Education, 2008.

[2] J. R. Mihelcic and J. B. Zimmerman, *Environmental Engineering: Fundamentals, Sustainability, Design*, 2nd ed. Hoboken, NJ, USA: John Wiley & Sons, 2014.

[3] W. P. Cunningham and M. A. Cunningham, *Principles of Environmental Science: Inquiry and Applications*, 9th ed. New York, NY, USA: McGraw-Hill Education, 2018.

Reference Books:

[1] K. V. S. G. Murali Krishna and V. P. Venugopal, *Environmental Engineering and Technology*. Oxford, U.K.: Butterworth-Heinemann (Elsevier), 2017.

[2] S. K. Garg, *Environmental Engineering*, Vols. I and II. New Delhi, India: Khanna Publishers, 2015.

[3] Metcalf & Eddy, Inc., *Wastewater Engineering: Treatment and Resource Recovery*, 5th ed. New York, NY, USA: McGraw-Hill Education, 2014.

Smart Sensing Technology

Course Code			**Examination Scheme**			
Teaching Scheme	3-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Tutorial**			--

Course Outcomes: Students will be able to:

5. Explain the fundamentals of Smart Sensors and Transducers
6. Analyze sensing characteristics and signal conditioning methods
7. Apply smart materials and bio-mimicry concepts in sensing technology
8. Develop innovative smart sensing solutions for real world applications

7. Fundamentals of smart sensing technology	**[7 Hrs]**
Evolution from conventional to smart sensors, classification of Intelligent sensing systems, Calibration and error analysis, Overview of smart sensing applications.	
8. Smart Materials	**[7 Hrs]**
Classification, Material characteristics of piezoelectric, Shape memory alloys, Magneto strictive and Electro-strictive, nanomaterial, Application of Smart materials in sensors and actuators.	
9. Bio-mimicry and Bio-inspired materials	**[7 Hrs]**
Introduction, Natural sensing mechanisms in plants and animals, Bio-inspired sensors such as vision, olfactory, tactile, artificial sensing based on bio mimics.	
10. Sensors and signal conditioning	**[8 Hrs]**
Selection criteria for smart sensors, sensor system decision with optical, ultrasonic, temperature, humidity and moisture sensors, MEMS.	
11. Introduction to Internet of Things (IoT)	**[7 Hrs]**
Embedded system and sensor interfacing real time monitoring system, Data interpretation, Predictive analysis.	
12. Case Studies of Smart sensing technology	**[8 Hrs]**
Case studies of smart sensing technology based system for healthcare, agricultural, automotive and environmental applications.	

Textbooks:

[1]	"Sensors and Signal Conditioning", Ramon Pallàs-Areny and John G. Webster, 2nd Edition, John Wiley & Sons, 2001.
[2]	"Smart Materials", Edited by Mel Schwartz, 1st Edition, CRC Press, Boca Raton, 2008.
[3]	"Biomimicry Materials and Applications", Edited by Inamuddin, Tariq Altalhi and Ashjan Alrogi, Wiley, 2023

Reference Books:

[1]	"Sensors and Transducers", Patranabis, D. 2nd ed., PHI Learning, 2004.
[2]	"Internet of Things: Architecture and Design Principles", Kamal, R. McGraw Hill Education, 2017.
[3]	"Smart Sensors and MEMS", Bogush, H. R. CRC Press, 2001.

List of Tutorial Problems:

Students are expected to perform minimum ten problem statements

1	Design an intelligent sensing system architecture for an industrial automation application.	CO4
2	Develop a calibration and error compensation strategy for a smart temperature or pressure sensor.	CO3
3	Evaluate different smart materials and recommend the most suitable material based on industrial constraints.	CO2
4	Select an appropriate smart material and justify its performance in terms of durability, sensitivity, and response time.	CO2
5	Analyze bio-inspired sensing mechanisms observed in nature and identify their engineering relevance.	CO2
6	Propose a biomimetic sensor design for industrial or environmental monitoring applications.	CO4
7	Design a signal conditioning system including filtering, shielding, amplification, and noise reduction techniques.	CO3
8	Evaluate the role of MEMS-based sensors in healthcare systems and wearable devices.	CO3
9	Develop an IoT-based smart sensing system including sensor interfacing, embedded processing, and cloud connectivity.	CO4
10	Propose a predictive maintenance strategy using sensor data and data analysis techniques.	CO3, CO4
11	Design a complete smart sensing solution including sensor selection, system architecture, data analytics, and societal impact for a real-world problem.	CO4

Advanced Process Control						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. Develop process models and perform system identification.
2. Design state estimators, including the Kalman Filter.
3. Apply Model Predictive Control and advanced control strategies
4. Analyze and control nonlinear and industrial process systems.

Process Modeling & Identification:	**[8 Hrs]**

First-principles modeling, Empirical modeling approaches, Linear vs nonlinear models, Time-series models: ARX, ARMAX, State-space representation, Parameter estimation techniques (least squares, regression), Model validation and residual analysis

State Estimation & Observers:	**[6 Hrs]**

Need for state estimation, Observability concepts, Luenberger observer design, Estimation in noisy systems, Kalman Filter (discrete/continuous), Introduction to stochastic processes in control

Nonlinear Process Control:	**[6 Hrs]**

Nonlinear system behaviour (multiple steady states, limit cycles), Linearization of mechanistic models, Jacobian-based linearization techniques, Gain scheduling

Advanced Control Strategies:	**[6 Hrs]**

Smith Predictor and time-delay compensation, Internal Model Control (IMC), Inferential control (soft sensors), Adaptive control techniques, Model following Control

Model Predictive Control (MPC):	**[6 Hrs]**

Concept and philosophy of MPC, Prediction models (step response, state-space), Cost function formulation, Constraints handling (input/output/state), Receding horizon strategy, Stability and tuning issues, Industrial relevance of MPC

Industrial Applications:	**[8 Hrs]**

Control of distillation columns, Reactor control systems, Heat exchanger control, Process interactions and constraints, Case studies from chemical/process industries, Implementation issues (sensors, actuators, noise, delays)

Textbooks:

[1]	D.R. Coughanour, "Process Systems analysis and Control", McGraw-Hill, 2nd Edition, 1991
[2]	F. G. Shinsky, "Process Control System", Mc Graw Hills, 1996.

Reference Books:

[1]	B.G. Liptak , "Process Control", Chilton Publications, Fourth edition, 2009
[2]	D.E. Seborg, T.F. Edger, and D.A. Millichamp, ‘Process Dynamics and Control’, John Wiley and Sons, 2nd Edition, 2004

Advanced Process Control Laboratory	
Course Outcomes: Students will be able to:	
1. Develop process models and perform system identification for dynamic processes. 2. Design and implement state estimation techniques, including observers and Kalman Filters. 3. Analyse nonlinear process behaviour and apply advanced control strategies such as IMC, Smith Predictor, and adaptive control. 4. Design and evaluate Model Predictive Control and advanced control solutions for industrial process applications.	
Topic No.	**Description**
1	Obtain step-response data from a simulated process and develop a first-order-plus-dead-time (FOPDT) model. Validate the model using residual analysis and performance indices. CO1
2	Generate input-output data from a dynamic process and identify an ARX model using the least-squares method. Compare the predicted and actual process outputs. CO1
3	Develop and evaluate an advanced control strategy (IMC, MPC, or Smith Predictor) for an industrial unit such as a distillation column, heat exchanger, or reactor under realistic operating conditions.CO2
4	Develop a state-space model of an interacting tank system and determine its observability. Verify the results using simulation. CO2
5	Design and implement a Luenberger observer for a given process and evaluate the convergence of estimated states to actual states.CO2
6	Implement a Kalman Filter for a process affected by measurement noise and compare its estimation performance with raw sensor measurements.CO3
7	Linearize a nonlinear Continuous Stirred Tank Reactor (CSTR) model around a specified operating point and compare the responses of linearized and nonlinear models. CO3
8	Design a gain-scheduled controller for a nonlinear process and evaluate controller performance at different operating conditions. CO3
9	Design and implement a Smith Predictor for a process with significant time delay and compare its performance with a conventional PID controller. CO3
10	Develop an IMC-based controller for a first-order-plus-dead-time process and study the effect of filter tuning on closed-loop performance. CO4
11	Design an MPC controller for a process with input and output constraints and evaluate set-point tracking and disturbance rejection performance. CO4
12	Implement both PID and MPC controllers for a multivariable process and compare their performance in terms of overshoot, settling time, and constraint handling. CO4

Optimal Control						
Course Code			**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	4		**Laboratory**	CIE: 50	ESE: 50	--

Course Outcomes: Students will be able to:

1. To learn how to determine the *best possible control action* over time for systems that evolve dynamically.
2. To learn formulation of optimization problems with and without constraints
3. Learn how to design controllers that optimize a cost function (e.g., minimize energy, time, error, or fuel consumption).
4. Learn numerical techniques to solve complex optimal control problems that are difficult to solve analytically.

Introduction: **[8 Hrs]**

Introduction to Optimal Control, Basic concepts of control systems, Difference between classical control and optimal control, Examples of optimal control problems, Performance indices (cost functions)

Calculus of Variations **[6 Hrs]**

Functional and externals, Euler–Lagrange equation, Variation problems with constraints, Fixed and free boundary conditions. Statement and interpretation, Hamiltonian formulation, Necessary conditions for optimality, KKT Conditions, two-point boundary value problems.

Optimal Control Problem Formulation **[6 Hrs]**

State and control variables, Constraints (equality and inequality), Bolza, Mayer, and Lagrange forms

Linear Quadratic Regulator (LQR) **[6 Hrs]**

Problem formulation, Riccati equation, Finite and infinite horizon cases, Stability analysis.

Dynamic Programming **[6 Hrs]**

Principle of optimality, Bellman equation, Relationship with PMP, Time-optimal control, Bang-bang control

Applications **[8 Hrs]**

Trajectory planning (Rocket Problem), Aerospace guidance systems, Economic systems, Process control.

Textbooks:

[1] S. S. Rao, Engineering Optimization Theory and Practices‖, John Wiley & Sons, 4th ed., 2009

[2] "Optimal Control Theory" by Donald E. Kirk

Reference Books:

[1] T. F. Edgar, D. M. Himmelblau, ―Optimization of chemical Processes‖, McGraw-Hill International Edition

[2] W.L. Luyben, ―Process modeling, simulation & control for chemical engineers‖, McGraw Hill, 2nd ed.,1990.

[3] Applied Optimal Control, by Arthur E. Bryson Jr.

Optimal Control Laboratory	
Course Outcomes: Students will be able to:	
1. Analyze control system performance and formulate optimization problems using performance indices and variational methods. 2. Formulate and solve optimal control problems using Hamiltonian and constrained optimization techniques. 3. Design and evaluate optimal controllers using LQR, dynamic programming, and time-optimal control methods. 4. Apply optimal control techniques to engineering systems and assess their performance against conventional control approaches.	
Topic No.	**Description**
1	Analyze the effect of different performance indices (ISE, IAE, ITAE, ITSE) on control system performance. CO1
2	Formulate and solve a simple variational problem using the Euler–Lagrange equation. CO1
3	Formulate an optimal control problem by defining state variables, control variables, objective function, and constraints. CO2
4	Develop the Hamiltonian for a given dynamic system and determine the necessary conditions for optimality. CO2
5	Solve a constrained optimization problem and verify optimality using Karush-Kuhn-Tucker (KKT) conditions. CO1, CO2
6	Solve an optimal control problem involving fixed initial and terminal conditions using numerical techniques. CO2
7	Design an LQR controller for a linear system and evaluate closed-loop performance. CO3
8	Investigate the effect of varying Q and R matrices on system response and control effort. CO3
9	Implement Bellman's Principle of Optimality to solve a discrete-time optimal control problem. CO3
10	Design a time-optimal controller and analyze the resulting bang-bang control action. CO3
11	Determine the optimal trajectory for a rocket or vehicle subject to dynamic and control constraints. CO4
12	Develop and implement an optimal control strategy for a process control application and compare its performance with conventional control. CO4

Industrial Drives and Control						
Course Code			**Examination Scheme**			
Teaching Scheme	2-1-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**			--

Course Outcomes: Students will be able to:

- Explain the basic concepts, components, classifications, and selection of electrical drives
- Learn motor-load dynamics, torque characteristics, and multi-quadrant operation.
- Evaluate performance and control of DC motor drives.
- Analyze operation and control of induction motor drives.
- Understand operation of BLDC, PMAC, stepper, and SRM drives

Basics of Electric Drives and Control **[8 Hrs]**

Definition, advantages of electrical drives, components of electric drive system, selection factors, types and status of electrical drives, speed control, drive classifications, close loop control of drives, phase locked loop (PLL) control.

Dynamics of Electrical Drives **[6 Hrs]**

Motor-Load Dynamics, speed torque conventions and multi quadrant operation, equivalent values of drive parameters. load torque components, nature and classification of load torques, constant torque and constant power operation, steady state stability, load equalization.

Selection of Motor Power Rating **[6 Hrs]**

Thermal model of motor for heating and cooling, classes of motor duty, determination of motor ratings for various operation duty cycle.

DC Motor Drives **[6 Hrs]**

DC motors and their performance starting, transient analysis, speed control, Ward-Leonard drives, controlled rectifier fed drives, full controlled 3-phase rectifier control of dc separately excited motor, multi quadrant operation, Chopper controlled drives, closed loop speed control of DC motor, starting and braking of dc motors

Induction Motor Drives **[6 Hrs]**

Induction motor analysis, starting and speed control methods- voltage and frequency control, current control, closed loop control of induction motor drives, rotor resistance control, slip power recovery – Static Kramer and Scherbius drive, single phase induction motor starting, braking and speed control, introduction of vector control, industrial applications

Synchronous Motor and Brushless DC Motor Drives **[8 Hrs]**

Synchronous motor types, operation with fixed frequency, variable speed drives, vector control, PMAC and BLDC motor drives, Stepper motor drives, switch reluctance motor drives, industrial applications

Textbooks:

[1] G. K. Dubey, Fundamentals of Electrical Drives, Second edition (sixth reprint), Narosa Publishing house, 2001

Reference Books:

[1] M. H. Rashid, ―Power Electronics -Circuits, devices and Applications‖, 3rdEdition, PHI Pub. 2004.

[2] B. K. Bose, ―Modern Power Electronics and AC Drives‖, Pearson Education, Asia, 2003.