NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR

M.TECH PROGRAM IN PROCESS CONTROL

Effective from 2019-20

DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.

- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.

- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF CHEMICAL ENGINEERING

VISION

To attain global recognition in research and training students for meeting the challenging needs of chemical & allied industries and society.

MISSION

- Providing high quality undergraduate and graduate education in tune with changing needs of industry.
- Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.
- Fostering industry-academia relationship for mutual benefit and growth.

DEPARTMENT OF CHEMICAL ENGINEERING

M.TECH IN PROCESS CONTROL

PROGRAM EDUCATIONAL OBJECTIVES

PEO1	Pursue successful industrial, academic and research careers in specialized fields of Process Control, Instrumentation, Automation and inter-disciplinary fields
PEO2	Apply the knowledge of advanced topics in Control Engineering to meet contemporary needs of industry and research
PEO3	Attain professional competency to address the technological needs of society and industry
PEO4	Exhibit project management skills and ability to work in collaborative environment
PEO5	Pursue self-learning to remain abreast with latest developments for continuous professional growth

Mapping of Mission statements with program educational objectives

Mission Statement	PEO1	PEO2	PEO3	PEO4	PEO5
Providing high quality education in tune with changing needs of industry.	3	3	3	2	1
Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.	3	3	2	1	1
Fostering industry-academia relationship for mutual benefit and growth.	3	3	2	2	2

1: Slightly 2: Moderately 3: Substantially

PROGRAM OUTCOMES: At the end of the program the student will be able to:

PO1	Independently carry out research /investigation and development work to solve practical problems
PO2	Write and present a substantial technical report/document
PO3	Apply modern experimental, computational, simulation and design tools to address the challenges faced in industries from a control perspective
PO4	Implement control engineering and automation in a contemporary, global, economical, environmental and societal context for sustainable development.
PO5	Contribute effectively in a team and demonstrate leadership skills with professional ethics
PO6	Pursue life-long learning to update knowledge and skills

Mapping of program outcomes with program educational objectives

Programme outcomes	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	3	3	2	1	2
PO2	2	2	2	2	3
PO3	3	3	3	2	2
PO4	2	2	3	2	2
PO5	2	2	2	2	3
PO6	2	2	1	2	3

CURRICULAR COMPONENTS

The total course package M.Tech. Degree program will typically consist of the following components.

a) Core Courses ≥ 24 Credits
b) Elective Courses ≥ 15 Credits
c) Dissertation = 27 Credits

Degree Requirements for M. Tech in Process Control

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	30	30
Departmental Elective Courses (DEC)	18	18
Dissertation	27	27
Total	75	75

SCHEME OF INSTRUCTION

M.Tech. (PROCESS CONTROL) Course Structure

M. Tech. I - Year I - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	CH5201	Systems & Control Engineering	3	0	0	3	PCC
2.	CH5202	Modern Control Theory	3	0	0	3	PCC
3.	CH5103	Computational Techniques	3	0	0	3	PCC
4.		Elective – I	3	0	0	3	DEC
5.		Elective – II	3	0	0	3	DEC
6.		Elective – III	3	0	0	3	DEC
7.	CH5203	Process Control Laboratory – I	0	1	2	2	PCC
8.	CH5104	Computational Lab	0	1	2	2	PCC
9.	CH5241	Seminar - I	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. I - Year II - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	CH5251	Advanced Process Control	3	0	0	3	PCC
2.	CH5252	Computer Control of Processes	3	0	0	3	PCC
3.	CH5253	Logic and Distributed Control Systems	3	0	0	3	PCC
4.		Elective – III	3	0	0	3	DEC
5.		Elective – IV	3	0	0	3	DEC
6.		Elective – V	3	0	0	3	DEC
7.	CH5254	Process Control Laboratory – II	0	1	2	2	PCC
8.	CH5255	Process Control Simulation Laboratory	0	1	2	2	PCC
9.	CH5291	Seminar - II	0	0	2	1	PCC
		TOTAL	**20**	**2**	**6**	**23**	

M. Tech. II - Year I - Semester

S No	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1	CH6242	Comprehensive Viva-voce	2	PCC
2	CH6249	Dissertation Part–A	9	PCC
		Total	11	

M. Tech. II - Year II - Semester

S No	Course Code	Course Title	Credits	Cat. Code
1	Ch6299	Dissertation Part B	18	PCC
		Total	18	

List of Electives

I Year I Semester

CH5211	Industrial Instrumentation
CH5212	Optimization Techniques
CH5213	System Identification
CH5214	Instrumentation for Environmental Analysis
CH5215	Internet for Measurement and Control
CH5216	Optimal and Adaptive Control
CH5217	Tuning of PID Controllers
CH5218	Statistical Process Control
CH5219	Probability and Random Processes
CH5111	Process Modelling & Analysis

I Year II Semester

CH5261	Nonlinear Dynamics and Control
CH5262	Soft-computing Techniques
CH5263	Distillation Control
CH5264	Bioprocess and Biomedical Instrumentation
CH5265	Multi Sensor Data Fusion
CH5266	Robust Control
CH5267	Control Loop Performance Assessment
CH5268	State Estimation Techniques
CH5269	Real-time and Embedded System
CH5270	Industrial Automation
CH5161	Data Analytics
CH5162	Process Scheduling & Utility Integration

Note: In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable.

DETAILED SYLLABUS

CH5201	**SYSTEMS & CONTROL ENGINEERING**	**PCC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Understand the benefits of mathematical modeling of dynamic systems.
CO2	Select the controlled and manipulated variables for a system.
CO3	Describe controllers for systems.
CO4	Use time and frequency domain tools for control and stability.
CO5	Understand discrete domain.

Mapping of course outcomes with program outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	3	3	-	1
CO2	1	-	3	3	-	1
CO3	3	-	3	3	-	1
CO4	3	-	3	3	-	1
CO5	1	-	3	3	-	1

Detailed syllabus:

Introduction to control; open loop vs. closed loop.

Introduction to the purpose, uses and benefits of system modelling; physical equations of systems; first and second order system models. Selection of controlled and manipulated variables. time domain solutions. System linearization; state space and transfer function models.

Applications to cruise control, DC motors, suspension system, inverted pendulum, aircraft, distillation column, heat exchangers, boilers, IC engines, photo voltaic power generation systems.

PID Control and methods for design of PID controllers: Ziegler–Nichols, Cohen-Coon Methods. Advantages and disadvantages. Model based design methods – direct synthesis and IMC methods for different types and orders of processes. Model reduction. Frequency domain based design methods.

Stability - Routh's stability criterion, Bode plots. Nyquist stability criterion. Gain margin, phase margin.

Sampling concepts. Analysis of sampling and relationship to z-transforms. Frequency and time-domain analyses of sampled-data systems. Introduction to PLC and DCS.

Reading:

1. Dorf R. C. and Bishop R. H., Modern Control Systems, 9th Edition, Prentice Hall, 2001.
2. Close C. M.; Frederick D. K and Newell J. C., Modeling and analysis of dynamic systems, 3rd Edition, John Wiley & Sons, 2002.
3. Hung V. V. and Esfandiari R. S., Dynamic Systems: Modeling and Analysis, McGraw-Hill, 1998.
4. Lathi, B.P, Linear Systems and Signals, 2nd Edition, Oxford University Press, 2010.
5. Coughnour, D. R., LeBlanc S. E., Process Dynamics and Control, 3rd Edition, McGraw-Hill, 2009.
6. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 3rd Edition, Wiley, 2014.

CH5202	MODERN CONTROL THEORY	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand state-space models and their representations.
CO2	Solve the state equations.
CO3	Design control systems using state-space models.
CO4	Estimate the states using Kalman filter.

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	2	-	1
CO2	1	-	3	3	-	1
CO3	3	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus:

State-Space Representation: The State-Space, Linear Transformation of State-Space Representations, System Characteristics from State-Space Representation, Special State-Space Representations: The Canonical Forms.
Solving the State-Equations: Solution of the Linear Time Invariant State Equations, Calculation of the State-Transition Matrix, Understanding the Stability Criteria through the State-Transition Matrix. Numerical Solution of Linear Time-Invariant State-Equations. Numerical Solution of Linear Time-Varying State-Equations. Numerical Solution of Nonlinear State-Equations.
Control System Design in State-Space: Design: Classical vs. Modern. Controllability and observability, Pole-Placement Design Using Full-State Feedback, Pole-placement regulator design.
Optimal control and optimal observers: Hamilton-Jacobi-Bellman equation, Linear Quadratic Regulator Problem,
Kalman Filter: Importance, Analytical form, limitations and extensions.

Reading:

1. Ogata, K, Modern Control Engineering, 5th Edition, Prentice-Hall, 2010.
2. Ashish Tewari, Modern Control Design - with MATLAB & SIMULINK, Wiley & Sons, 2002.
3. K.J. Astrom and B. Wittenmark, Computer Controlled Systems: Theory and Design, Prentice-Hall, 2000.
4. Brogan W. L, Modern Control Theory, 3rd Edition, Prentice Hall, 1991.

5. Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Prentice Hall, 1991.
6. M. Gopal, Modern Control Systems Theory, 3^{rd} Edition, New Age International, 2014.

CH5103	COMPUTATIONAL TECHNIQUES	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply linear algebra to solve engineering problems
CO2	Solve ordinary differential equations (ODEs) and partial differential equations (PDEs)
CO3	Analyze engineering problems using graph theory
CO4	Apply Statistical techniques to solve engineering problems

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	-	-	1
CO2	2	-	3	-	-	1
CO3	2	-	3	-	-	1
CO4	2	-	3	-	-	1

Detailed syllabus:
Linear Algebra: Linear spaces, Vector spaces, Function spaces, Linear operator theory, self-adjoint operators, Eigenvalues and eigenvectors-eigenfunctions, Cayley-Hamilton theorem, Polynomials and functions defined on matrices, Similarity transformations, Jordan forms, quadratic forms, Strum-Liouville equations and solution of boundary value problems, Finite difference equations, Difference operators.
Review of Linear Ordinary Differential Equations Solution Methods. Nonlinear Ordinary Differential Equations: Autonomous/ nonautonomous systems of odes, Phase plane analysis, Limit cycle and bifurcation, regular and singular perturbation techniques, Chaos, Differential-Algebraic equations.
Partial Differential Equations: Partial differential operators, First order partial differential equations, Method of characteristics, Classification of the second order partial differential equations and boundary conditions, Method of separation of variables, Similarity solutions, Greens functions, Laplace and Fourier transforms.
Graph theory: Classification of graphs, matrix representation of graphs, Analysis of trees, directed graphs and networks.
Reading:

1. Gilbert Strang, Introduction to Applied Mathematics, Wellesley Cambridge Press. 2009.
2. Gilbert Strang, Linear Algebra and Its Applications, 4^{th} Edition, Wellesley Cambridge Press, 2009.
3. Gourdin, A. and M Boumhrat; Applied Numerical Methods. Prentice Hall India, 2000.

4. Gupta, S. K.; Numerical Methods for Engineers. New Age International, 3rd Edition, 2015.
5. Singiresu S. Rao, “Applied Numerical Methods for Engineers and Scientists” Prentice Hall, 2001.

CH5203	**PROCESS CONTROL LABORATORY - I**	**PCC**	**0 – 1 – 2**	**2 Credits**

Pre-requisites: None

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

CO1	Apply the identification concepts for systems.
CO2	Design controllers for non-interacting systems.
CO3	Identify and control nonlinear processes.
CO4	Design controllers for time delay processes.
CO5	Design controllers for cascade processes.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	1	1
CO2	2	1	3	3	1	1
CO3	2	1	3	3	1	1
CO4	2	1	3	3	1	1
CO5	2	1	3	3	1	1

Detailed syllabus

In this lab, experiments are given to the students like mini projects. Students need to apply the concepts in a systematic manner in order to perform these experiments. The experiment need to be performed with the given operating conditions in the respective session.

1. Identification and control of liquid level in non-interacting cylindrical tank systems.
2. Identification and control of level in cylindrical tanks operated in interacting mode
3. Design of cascade control system for level/flow process.
4. Identification and control of level in a spherical tank process.
5. Data acquisition using standard add-on cards/remote I-O modules.
6. Identification and control of level in an SISO conical tank process
7. Feed forward control for temperature process.

Reading:

Lab Manuals.

CH5104	COMPUTATIONAL LABORATORY	PCC	0 – 1 – 2	2 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply numerical methods for solving engineering problems using MATLAB
CO2	Apply statistical methods for data analysis using MATLAB
CO3	Simulate process dynamics using SIMULINK
CO4	Analyze data using Design Expert

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	1	3	1
CO2	2	1	3	1	3	1
CO3	2	1	3	1	3	1
CO4	2	1	3	1	3	1

Detailed syllabus:
The student will carry out simulation studies using MATLAB/SIMULINK/DESIGN EXPERT. The list of case studies include

1. Solution of linear initial value ODEs
2. Solution of linear boundary value ODEs
3. Solution of non-linear initial value ODEs
4. Solution of non-linear boundary value ODEs
5. Solution of Elliptic PDEs
6. Solution of Parabolic PDEs
7. Solution of Hyperbolic PDEs
8. Linear Regression and Non-linear Regression Methods
9. Statistical analysis of data – mean, variance, distribution characteristics
10. Dynamic analysis of first and second order processes
11. Design Expert based data analysis
12. Analysis using Pipeline Studio

Out of 12 experiments, 10 experiments are offered.

Reading:

Lab Manuals.

CH5241	SEMINAR	PCC	0 – 0 – 2	1 Credit

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Communicate with group of people on different topics
CO2	Prepare a seminar report that includes consolidated information on a topic

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1	-	3	3
CO2	2	3	1	-	1	3

Detailed syllabus:

Any topic of relevance to systems and control engineering.

CH5251	ADVANCED PROCESS CONTROL	PCC	3 – 0 – 0	3 Credits

Pre-requisites: Knowledge in engineering mathematics and control
Course Outcomes: At the end of the course, the student will be able to:

CO1	Develop parametric and non-parametric models for LTI systems.
CO2	Design PID controller for a given process
CO3	Analyze the controlled and manipulated variables in multivariable processes.
CO4	Apply model predictive control.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	3	3	-	1
CO3	2	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus

Review of basics, advanced regulatory control schemes - Cascade control, feed-forward control, ratio control, split-range control, time delay compensator, inverse response compensator, combinations of cascade and feed-forward control schemes.
Multivariable control - Challenges; Control pairing; Interactions in closed-loop systems; Relative Gain Array (RGA) and variants. Introduction to decentralized, decoupled control schemes.
Models of Discrete-Time LTI Systems - Sampling and Hold operations, Convolution theorem, Difference equations, Transfer functions, State-space models
Identification of Non-parametric models - impulse response, step response and frequency response models. Identification of Parametric models - ARX, ARMAX, OE and BJ.
Model Predictive Control (MPC) - Concepts; Theory and implementation; Relation with LQ-control. Implementation of MPC: Step response model; State update and model prediction. Receding Horizon implementation; Issues and Challenges.

Reading:

1. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 3rd Edition, Wiley, 2014.
2. Kannan Moudgalya, Digitial Control, Wiley, 2007.

3. Liuping Wang, Model Predictive Control System Design and Implementation using MATLAB, Springer, 2009.
4. Arun K. Tangirala, Principles of System Identification: Theory and Practice, CRC Press, 2014
5. E. F. Camacho and Carlos Bordons, Model Predictive Control, Springer, 1999.
6. B. Roffel and B. Betlem, Process Dynamics and Control, Wiley, 2006.

CH5252	COMPUTER CONTROL OF PROCESSES	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand Z transforms.
CO2	Analyze stability for discrete time processes.
CO3	Design controllers for discrete time processes.
CO4	Understand discrete state space models.
CO5	Design state feedback controllers.

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	3	2	-	1
CO2	1	-	3	2	-	1
CO3	1	-	3	2	-	1
CO4	1	-	3	2	-	1
CO5	1	-	3	2	-	1

Detailed syllabus:
Introduction - Discrete time system representation, Mathematical modeling of sampling process, Data reconstruction, modeling discrete-time systems by pulse transfer function.
Z-transform, Mapping of s-plane to z-plane, Pulse transfer function, Pulse transfer function of closed loop system.
Stability analysis of discrete time systems - Jury stability test, Stability analysis using bi-linear transformation. Time response of discrete systems - transient and steady state responses, Time response parameters of a prototype second order system and analysis.
Design of sampled data control systems - Root locus method, Controller design using root locus, Nyquist stability criteria, Bode plot.
Deadbeat controller design, Dalhin controller design, Vogel-Edgar control algorithm, Discrete IMC controller design.
Discrete state space model - Introduction to state variable model, various canonical forms, state transition matrix, Solution to discrete state equation.
Controllability, observability and Lyapunov stability of discrete state space models with examples. State feedback design - Pole placement by state feedback.

Reading:

1. B. C. Kuo, Digital Control Systems, Oxford University Press, 2nd Edition, 2012.
2. K. Ogata, Discrete Time Control Systems, Prentice Hall, 2nd Edition, 1995.
3. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 2nd Edition, 2003.
4. G. F. Franklin, J. D. Powell and M. L. Workman, Digital Control of Dynamic Systems, 3rd Edition, Addison-Wesley Press, 2000.
5. K. J. Astrom and B. Wittenmark, Computer Controlled Systems - Theory and Design, Prentice Hall, 3rd Edition, 1998.

CH5253	LOGIC AND DISTRIBUTED CONTROL SYSTEMS	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand process automation technologies.
CO2	Design PLC programming for processes.
CO3	Apply distributed control systems (DCS) for processes.
CO4	Understand security design approaches.

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	3	3	-	1
CO3	2	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus:
Review of computers in process control: Data loggers, Data Acquisition Systems (DAS), Direct Digital Control (DDC). Supervisory Control and Data Acquisition Systems (SCADA), sampling considerations. Functional block diagram of computer control systems. alarms, interrupts. Characteristics of digital data, controller software, linearization.
Programmable logic controller (PLC) basics: Definition, overview of PLC systems, input/output modules, power supplies, isolators. General PLC programming procedures, Auxiliary commands and functions: PLC Basic Functions: Register basics, timer functions, counter functions.
PLC intermediate functions: Arithmetic functions, number comparison functions, Skip and MCR functions, data move systems. PLC Advanced intermediate functions: Utilizing digital bits, sequencer functions, matrix functions.
PLC Advanced functions: Alternate programming languages, analog PLC operation, PLC-PID functions, design of interlocks and alarms using PLC. Creating ladder diagrams from process control descriptions. Structured text programming.
Interface and backplane bus standards for instrumentation systems. Field bus: Introduction to smart sensor, industrial field bus, concept. HART protocol: Method of operation, structure, operating conditions and applications.
Distributed control systems (DCS): Definition, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

Reading:

1. John. W.Webb Ronald A Reis Programmable Logic Controllers - Principles and Applications, 3rd Edition, Prentice Hall, 1995.
2. E. A. Parr, Programmable Controllers, 3rd Edition, Newnes, 2003.
3. Curtis D. Johnson, Process Control Instrumentation Technology, 4th Edition, Prentice Hall of India, 1999.
4. Chidambaram, M. Computer Control of Processes, Narosa Publishers, 2002.

CH5254	**PROCESS CONTROL LABORATORY - II**	**PCC**	**0 – 1 – 2**	**2 Credits**

Pre-requisites: None

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

CO1	Apply the identification concepts for different systems.
CO2	Design controllers for interacting systems
CO3	Identify and control nonlinear processes
CO4	Design controllers for MIMO processes
CO5	Design controllers for unstable processes

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	2	2
CO2	3	1	3	3	2	2
CO3	3	1	3	3	2	2
CO4	3	1	3	3	2	2
CO5	3	1	3	3	2	2

Detailed syllabus

In this lab, experiments are given to the students like mini projects. Students need to apply the concepts in a systematic manner in order to perform these experiments. The experiment need to be performed with the given operating conditions in the respective session.

1. Interaction analysis in a MIMO four tank system.
2. Identification and control of level in a coupled four tank system.
3. Programmable logic controller implementation on (i) bottle filling unit (ii) conveyer belt system (iii) level control
4. Ratio control in a flow system.
5. Identification and control of unstable inverted pendulum system.
6. LQR application to a coupled four tank system
7. Identification and control of level in an MIMO conical tank process

Reading:

Lab Manuals.

CH5255	PROCESS CONTROL SIMULATION LABORATORY	PCC	0 – 1 – 2	2 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Develop mathematical models using step and pulse tests
CO2	Apply discrete control tools for processes
CO3	Design controllers and simulate its performance on MIMO systems.
CO4	Apply model predictive control for SISO and MIMO systems.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	1	2
CO2	2	1	3	3	1	2
CO3	2	1	3	3	1	2
CO4	2	1	3	3	1	2

Detailed syllabus
The student will carry out simulation studies using appropriate programming tools (MATLAB/SIMULINK/Python/Simens-TIA. The list of case studies include

1. Development of step response models (MATLAB)
2. Development of impulse response models (MATLAB)
3. Linearization of nonlinear models (MATLAB)
4. MIMO closed loop control (MATLAB/LabView/Python)
5. Discrete controller design an analysis (MATLAB/Python)
6. Identification of ARX, ARMAX and FIR models
7. State estimation using Kalman filter
8. Model predictive control of SISO processes (MATLAB/Python)
9. Model predictive control of MIMO processes (MATLAB/Python)
10. PLC programming (Simens-TIA)

Reading:

Lab manuals.

CH5291	**SEMINAR**	**PCC**	**0 – 0 – 2**	**1 Credits**

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Communicate with group of people on different topics
CO2	Prepare a seminar report that includes consolidated information on a topic

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1	-	3	3
CO2	2	3	1	-	1	3

Detailed syllabus:

Any topic of relevance to systems and control engineering.

CH6242	COMPREHENSIVE VIVA-VOCE	PCC	0 – 0 – 0	2 Credits

Pre-requisites: None

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

CO1	Demonstrate an understanding of advanced topics.
CO2	Explain the principles, phenomena and their applications.

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	2	1
CO2	1	1	1	1	2	1

Detailed syllabus:

Process Control courses of I year.

CH6249	DISSERTATION PART-A		0 – 0 – 0	9 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to

CO1	Identify the problem based on literature survey
CO2	Formulate the problem
CO3	Identify the methods or techniques required for the solution
CO4	Develop the solution methodology
CO5	Demonstrate the progress of dissertation work

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	1	2
CO2	3	3	3	3	1	2
CO3	3	3	3	3	1	2
CO4	3	3	3	3	1	2
CO5	3	3	3	3	1	2

CH6299	**DISSERTATION PART-B**		**0 – 0 – 0**	**18 Credits**

Pre-requisites: CH6149 Dissertation Part-A

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

CO1	Implement the methods/techniques identified in dissertation part-A
CO2	Analyze and interpret the results obtained
CO3	Compare the results obtained with literature.
CO4	Demonstrate the outcomes of dissertation work

Mapping of course outcomes with program outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	1	1
CO2	3	3	3	3	1	1
CO3	3	3	3	2	1	1
CO4	3	3	3	3	1	1

CH5211	INDUSTRIAL INSTRUMENTATION	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand techniques for measurement of level, pressure.
CO2	Measure temperature using contact / non-contact techniques.
CO3	Analyze methods for torque and velocity.
CO4	Select methods for acceleration, vibration and density measurement.
CO5	Identify a suitable technique for flow measurement.

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	1	-	-	1
CO2	2	-	1	-	-	1
CO3	2	-	1	-	-	1
CO4	2	-	1	-	-	1
CO5	2	-	1	-	-	1

Detailed syllabus:

Level measurement: Gauge glass technique coupled with photo electric readout system, float type level indication, different schemes, measurement using displacer and torque tube – bubbler system. Differential pressure method. Electrical types of level gauges using resistance, capacitance, nuclear radiation and ultrasonic sensors.

Pressure measurement: Manometers, pressure gauges – Bourde type bellows, diaphragms. Electrical methods – elastic elements with LVDT and strain gauges. Capacitive type pressure gauges. Measurement of vacuum – McLeod gauge – thermal conductivity gauges – Ionization gauge cold cathode and hot cathode types – testing and calibration.

Temperature measurement: Thermometers, different types of filled in system thermometer, bimetallic thermometers. Electrical methods, signal conditioning of industrial RTDs and their characteristics –3 lead and 4 lead RTDs. Thermocouples and pyrometers.

Measurement of force torque, velocity: Electric balance – different types of load cells – magnets – elastics load cell-strain gauge load cell. Different methods of torque measurement, strain gauge, relative regular twist-speed measurementrevaluation counter- capacitive tacho-drag up type tacho D.C and A.C tacho generators – stroboscope.

Measurement of acceleration, vibration and density: Accelerometers – LVDT, piezo-electric, strain gauge and variable reluctance type accelerometers, calibration of vibration pickups, Baume scale API scale – pressure head type densitometer – float type densitometer.

Flow measurement: Volumetric flow measurement through electromagnetic, ultrasonic and vortex techniques. Mass flow measurement through Coriolis principle. Basics of analyzers - single and multiple components through chromatography. Control valves – different types, characteristics and smart valves.

Reading:

1. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, McGraw-Hill, 2005.
2. R. K. Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1999.
3. E. L. Upp, Paul J. LaNasa, Fluid Flow Measurement, 2nd Edition, Gulf Professional Publishers, 2002.
4. Bela G. Liptak, Instruments Engineers Handbook, 4th Edition, CRC Press, 2003.
5. D. Patranabis, Principles of Industrial Instrumentation, Tata McGraw Hill, 1999.

CH5212	**OPTIMIZATION TECHNIQUES**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

Pre-requisites: None Course Outcomes: At the end of the course, the student will be able to:

CO1	Formulate objective function for a given problem
CO2	Understand unconstrained single variable optimization and unconstrained multi variable optimization
CO3	Understand linear programming and nonlinear programming techniques
CO4	Use dynamic programming and semi definite programming for optimization

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	-	2	-	-	1
CO2	3	-	2	-	-	1
CO3	3	-	2	-	-	1
CO4	3	-	2	-	-	1

Detailed syllabus

The Nature and Organization of Optimization Problems: What Optimization is all about, Why Optimize?, Scope and Hierarchy of Optimization, Examples of applications of Optimization, The Essential Features of Optimization Problems, General Procedure for Solving Optimization Problems, Obstacles to Optimization.

Basic Concepts of Optimization: Continuity of Functions, Unimodal vs multimodal functions, Convex and concave functions, convex region, Necessary and Sufficient Conditions for an Extremum of an Unconstrained Function, Interpretation of the Objective Function in terms of its Quadratic Approximation.

Optimization of Unconstrained Functions: One Dimensional search Numerical Methods for Optimizing a Function of One Variable, Scanning and Bracketing Procedures, Newton and Quasi-Newton Methods of Unidimensional Search, Polynomial approximation methods, How One-Dimensional Search is applied in a Multidimensional Problem, Evaluation of Unidimensional Search Methods.

Unconstrained Multivariable Optimization: Direct methods, Indirect methods – first order, Indirect methods – second order.

Linear Programming and Applications: Basic concepts in linear programming, Degenerate LP's – Graphical Solution, Natural occurrence of Linear constraints, The Simplex methods of solving linear programming problems, standard LP form, Obtaining a first feasible solution, Sensitivity analysis, Duality in linear programming.

Nonlinear programming with constraints The Lagrange multiplier method, Necessary and sufficient conditions for a local minimum, introduction to quadratic programming.

Optimization of Stage and Discrete Processes: Dynamic programming, Introduction to integer and mixed integer programming.

Applications to different processes.

Reading:

1. Edgar T.F. and D. M. Himmelblau, 'Optimization of Chemical Processes', 2nd Edition, McGraw Hill, 2001.
2. Stoecker W. F., Design of Thermal Systems, McGraw-Hill, 3rd Edition, 2011.
3. Singiresu S Rao, 'Engineering Optimization: Theory and Practice', 4th Edition, John Wiley & Sons, 2009.
4. Mohan C. Joshi and Kannan M. Moudgalya, 'Optimization: Theory and Practice', Alpha Science International, 2004.
5. Stephen Boyd, Lieven Vandenberghe, Convex optimization, Cambridge University Press, 2004.
6. P. Venkataraman, Applied Optimization with MATLAB Programming, 2nd Edition, Wiley, 2009.

CH5213	SYSTEM IDENTIFICATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand system identification concepts
CO2	Identify Parametric, Non-parametric and disturbance models
CO3	Estimate parameters using regression analysis
CO4	Design inputs for identification

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	-	-	1
CO2	2	-	3	-	-	1
CO3	2	-	3	-	-	1
CO4	2	-	3	-	-	1

Detailed syllabus:

System Identification - Motivation and Overview. Models of Discrete-Time LTI Systems – Convolution equation. Difference equations, Transfer functions, State-space models, Discretization, Sampling and Hold operations, Sampling theorem.

Non-parametric models - impulse response, step response and frequency response models.

Disturbance models - random processes, representation of stationary processes, white-noise process, auto-covariance function (ACF), ARMA models. Parametric model structures - ARX, ARMAX, OE, BJ and PEM – structures and their applicability in real-time.

Linear Regression - Least Squares estimates, Statistical properties of LS Estimates. Weighted Least Squares, Recursive Least Squares, Maximum Likelihood Estimation and properties.

Estimation of non-parametric models - impulse / step response coefficients, frequency response models.

Estimation of parametric models - notions of prediction and simulation, predictors for parametric models, prediction-error methods, Instrumental Variable method.

Model Structure Selection and Diagnostics -estimation of delay and order, residual checks, properties of parameter estimates, model comparison and selection, model validation.

Reading:

1. Arun K. Tangirala. System Identification: Theory and Practice, CRC Press,

2014.
2. Karel J. Keesman, System Identification – An Introduction, Springer, 2011.
3. Nelles, O. Nonlinear System Identification, Springer-Verlag, Berlin, 2001.
4. Zhu, Y. Multivariable System Identification for Process Control, Pergamon, 2001.
5. Ljung, L. System Identification: Theory for the User, 2nd Edition, Prentice-Hall, 1999.
6. B. Roffel and B. Betlem, Process Dynamics and Control, Wiley, 2006.
7. Rolf Johansson, System Modeling and Identification, Prentice Hall, 1993.

CH5214	INSTRUMENTATION FOR ENVIRONMENTAL ANALYSIS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand electromagnetic radiation measuring devices
CO2	Assess the water quality by measuring water quality parameters
CO3	Estimate pollution levels in air by measuring the particulate matter in air
CO4	Analyze noise pollution and soil pollution by employing suitable measuring technique

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	3	3	-	1
CO3	2	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus:

Electromagnetic radiation, Characteristics - Interaction of e.m. radiation with matter - Spectral methods of analysis - absorption spectroscopy - Beer's law - radiation sources - monochromators and filters - diffraction grating - ultraviolet spectrometer - single beam and double beam instruments, difference between single beam and double beam instruments.

Particles emitted in radioactive decay - nuclear radiation detectors - injection chamber - Geiger - Muller counter - proportional counter - scintillation counter - Semiconductor detectors.

Measurement techniques for water quality parameters –thermal conductivity detectors, Opacity monitors, pH analyzers, conductivity analyzers, turbidity measurement.

Measurement techniques for chemical pollutants - chloride - sulphides - nitrates and nitrites - phosphates - fluoride - phenolic compounds and analysis.

Measurement techniques for particulate matter in air. Measurement of different oxides sulphur, oxides of nitrogen unburnt hydrocarbons, carbon-monoxide, dust mist and fog and analysis.

Noise pollution – measurement of sound, tolerable levels of sound. Measurement of sound level and analysis. Different measurement techniques for soil pollution with examples.

Reading:

1. Rajvaidya N., D. K. Markandey, Environmental Analysis and Instrumentation, APH Publishing Corporation, 2005.
2. Randy D. Down, Jay H. Lehr, Environmental Instrumentation and Analysis Handbook, John Wiley & Sons, 2004.
3. Dardo Oscar Guaraglia, Jorge Lorenzo Pousa, Introduction to Modern Instrumentation, De Gruter, 2014.
4. G. N. Pandey and G.C. Carney, “Environmental Engineering”, Tata McGraw-Hill, 2004.
5. Walt Boyes, Instrumentation Reference Book, 4th Edition, Elsevier, 2010.

CH5215	INTERNET FOR MEASUREMENT AND CONTROL	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the serial communication and parallel communication standards
CO2	Understand the protocols used with internet
CO3	Understand routers, modems and cryptography for communicating the measured data
CO4	Understand the web based calibration and data acquisition
CO5	Know the control of plants using virtual laboratories, wireless sensors and internet based tuning of the controllers

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	3	-	1
CO2	2	-	2	3	-	1
CO3	2	-	2	3	-	1
CO4	2	-	2	3	-	1
CO5	2	-	2	3	-	1

Detailed syllabus:

Industrial communication systems: Interface - Introduction, Principles of interface, serial interface and its standards. Parallel interfaces and buses

Introduction to Internet: Origin of Internet – Overview of TCP / IP layers – IP addressing – DNS – Packet switching – Routing – SMTP, POP, MIME, NNTP, ftp, Telnet, HTML, HTTP, URL, SNMP, RFCs, FYIs – STDs.

Physical Layer Aspects: Backbone network – Trunks, Routers, Bridges – Access network – MODEMs, WILL, ISDN, XDSL, VSAT.

Network Layer Aspects and Network Security: IPVG, Mobile IP – IPSEC – IPSO – Public key cryptography – digital signature standard – firewall – Secure socket Layer SSL – Secure Data Network System SDNS – Network layer security Protocol NLSP – Point to point Tunneling Protocol PPTP – SHTTP.

Measurements through Internet: Web based data acquisition – Monitoring of plant parameters through Internet – Calibration of measuring instruments through Internet.

Internet based Control: Virtual laboratory – Web based Control – Tuning of controllers through Internet. Wireless sensors for measurement and feedback control.

Internet of Things (IoT) – communication and feedback control

Demonstration using appropriate tools in the laboratory.

Reading:

1. Shuang-Hua Yang, Internet Based Control Systems, Springer, 2011.
2. Douglas E. Camer, Internet Working with TCP/IP, 3rd Edition, Prentice Hall, 1999.
3. Richard Stevens, TCP/IP Illustrated, Addison Wesley, 1999.
4. Richard E. Smith, Internet Cryptography, Addison Wesley, 1999.

CH5216	OPTIMAL AND ADAPTIVE CONTROL SYSTEMS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Formulate an optimal control problem
CO2	Determine optimal trajectories
CO3	Identify the suitable adaptive control scheme
CO4	Design self-tuning regulators for real-time applications

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	3	3	-	1
CO3	2	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus:

Problem formulation – Performance measure Optimal control problem.

Dynamic Programming – Optimal control law – Principle of optimality. An optimal control system. A recurrence relation of dynamic programming – computational procedure. Characteristics of dynamic programming solution.

Variational approach to optimal control problems – Necessary conditions for optimal control – Linear regulator problems. Linear tracking problems. Pontryagin's minimum principle and state inequality constraints.

Introduction to Adaptive Control. Adaptive Control Versus Conventional Feedback Control. Fundamental Hypothesis in Adaptive Control. Basic Adaptive Control Schemes - Open-Loop Adaptive Control, Direct Adaptive Control, Indirect Adaptive Control.

Deterministic self-tuning regulators (STR) – pole placement design, indirect self-tuning regulators, continuous time self-tuners, direct self-tuning regulators, disturbances with known characteristics. Application of STRs to different case studies.

Model reference adaptive schemes (MRAS) – the MIT rule, determination of adaptation gain, Lyapunov theory, relationship between MRAS and STR. Auto tuning – PID control, transient response methods, Gain scheduling – the principle, design of gain scheduling controllers, nonlinear transformations, applications of gain scheduling.

Reading:

1. Frank L. Lewis, Draguna Vrabie, Vassilis L. Syrmos, Optimal Control, John Wiley & Sons, 2012.
2. Astrom .K. J., Wittenmark B., Adaptive Control, 2nd Edition, Pearson Education, 2008.
3. Donald E. Kirk, Optimal Control Theory: An Introduction, Dover Publications, 2004.
4. D. Subbaram Naidu, Optimal Control Systems, CRC Press, 2002.
5. Loan Doré Landau, Rogelio Lozano, Mohammed M'Saad, Alireza Karimi, Adaptive Control: Algorithms, Analysis and Application. 2nd Edition, Springer, 2011.
6. Chang C. Hong, Tong H. Lee and Weng K. Ho, Adaptive Control, ISA Press, 1993.

CH5217	TUNING OF PID CONTROLLERS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Design PID controllers using different methods
CO2	Use right tuning method for tuning the PID controller
CO3	Design PID controllers for MIMO systems
CO4	Automate the control at plant level
CO5	Design PID controllers for nonlinear processes

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	2
CO2	2	-	3	3	-	2
CO3	2	-	3	3	-	2
CO4	2	-	3	3	-	2
CO5	2	-	3	3	-	2

Detailed syllabus:
Introduction to design of PID controllers. Classifications of PID design methods. Open loop and closed loop tuning methods.
Ziegler–Nichols, Cohen-Coon Methods. Advantages and disadvantages. Model based design methods – direct synthesis and IMC methods for different types and orders of processes. Model reduction. Frequency domain based design methods. Design for desired robustness levels using sensitivity analysis.
Multivariable Systems – Poles and zeros, directionality, Decentralized, decoupled and centralized PID controllers design – advantages and disadvantages of each method.
Relay based tuning of PID controllers. Feedback - Experimental Design, Approximate Transfer Functions: Frequency-domain Modeling - Simple Approach, Improved Algorithm, Parameter Estimation. Approximate Transfer Functions: Time-domain Modeling. Shape of Relay, Improved Relay Feedback.
Auto tuning for Plant wide Control Systems - Recycle Plant, Control Structure Design, Unbalanced Schemes, Balanced Scheme, Controllability, Operability, Controller Tuning for Entire Plant. Guidelines for Auto tune Procedure. Applications to case studies.
Introduction to nonlinear PID controller design.

Reading:

1. Cheng-Ching Yu, Autotuning of PID controllers: Relay feedback approach, 2nd edition, Springer, 2006
2. Alfaro, Victor M., Vilanova, Ramon, Model-Reference Robust Tuning of PID Controllers, Springer, 2016.
3. S. W. Sung, Jietae Lee, In-Beum Lee, Process Identification and PID Control, Wiley, 2009.
4. Michael A. Johnson, Mohammad H. Moradi, PID Control: New Identification and Design Methods, Springer, 2005.
5. Ramon Vilanova, A. Visioli, PID Controller Design in The Third Millennium: Lessons Learned and New Approaches, Springer, 2013.
6. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 3rd Edition, Wiley, 2014.

CH5218	STATISTICAL PROCESS CONTROL	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to

CO1	Apply statistical methods for process control
CO2	Use univariate charts and cumulative sum charts
CO3	Control the processes with attribute based charts
CO4	Use multivariate statistical process control methods
CO5	Use process monitoring charts

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	2	2	-	1
CO3	2	-	3	3	-	1
CO4	2	-	2	2	-	1
CO5	2	-	2	2	-	1

Detailed syllabus:
Introduction to statistical process control. Basic statistical concepts and methods – population and population distribution, continuous and discrete distributions, parametric and non-parametric statistical inferences.
Univariate Shewhart charts for numerical and categorical variables. Process capability analysis. Univariate CUSUM charts – monitoring the mean and variance of a normal process, self-starting and adaptive CUSUM charts.
Univariate EWMA charts – monitoring the mean and variance of a normal process, self-starting and adaptive EWMA charts.
Process control by attributes: Underlying concepts, np-charts for number of defectives or non-conforming units, p-charts for proportion defective or non-conforming units, c-charts for number of defects/non-conformities, u-charts for number of defects/non-conformities per unit, Attribute data in non-manufacturing.
Cumulative sum (CUSUM) charts: Introduction, Interpretation of simple cusum charts, Product screening and pre-selection, Cusum decision procedures.
Multivariate statistical process control (MSPC) – overview of conventional methods, Independent component analysis, Principal Component Analysis, Partial Least Squares, Factor Analysis, Independent Component Analysis, Kernal Principal Component Analysis.
Process monitoring charts, Fault detection, Scatter diagrams, Non-negative quadratic monitoring statistics, Fault isolation and identification, Contribution charts, Residual-based tests, Variable reconstruction, Geometry of variable

projections, Linear dependency of projection residuals, Geometric analysis of variable reconstruction. Examples.

Reading:

1. Peihua Qiu, Introduction to Statistical Process Control, CRC Press, 2014.
2. John Oakland, Statistical Process Control, 6th Edition, Elsevier, B-H Publications, 2008.
3. Zhiqiang Ge, Zhihuan Song, Multivariate Statistical Process Control, Springer, 2013.
4. Uwe Kruger, LessiXie, Statistical Monitoring of Complex Multivariate Processes, Wiley, 2012.

CH5219	PROBABILITY AND RANDOM PROCESSES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Describe a random event in terms of procedure, observation, and probability
CO2	Characterize probability models for discrete and continuous random variables
CO3	Understand the convergence of random variables
CO4	Characterize stochastic processes with an emphasis on random processes

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	2	-	1
CO2	1	-	2	2	-	1
CO3	1	-	2	2	-	1
CO4	1	-	2	2	-	1

Detailed syllabus:

Introduction to Probability: Definitions, scope and history; limitation of classical and relative-frequency-based definitions. Sets, fields, sample space and events; axiomatic definition of probability. Combinatorics: Probability on finite sample spaces. Joint and conditional probabilities, independence, total probability; Bayes' rule and applications.

Continuous and discrete random variables, cumulative distribution function (cdf); probability mass function (pmf); probability density functions (pdf) and properties. Jointly distributed random variables, conditional and joint density and distribution functions, independence. Expectation: mean, variance and moments of a random variable. Joint moments, conditional expectation; covariance and correlation; independent, uncorrelated and orthogonal random variables. Random vector: mean vector, covariance matrix and properties. Special distributions. Vector-space representation, linear independence, inner product, Schwarz Inequality. Estimation theory and orthogonality principle.

Sequence of random variables and convergence: Almost sure (a.s.) convergence and strong law of large numbers; convergence in mean square sense from parameter estimation; convergence in probability; convergence in distribution. Central limit theorem and its significance.

Random process: realizations, sample paths, discrete and continuous time processes, examples. Probabilistic structure. Stationarity: strict-sense stationary (SSS) and wide-sense stationary (WSS) processes. Ergodicity and its importance. Power spectral density, properties; cross-power spectral density, auto-correlation. LTI system with a WSS process as an input: stationarity of the output, auto-correlation and power-spectral density of the output.

Reading:

1. Steven M. Kay, Intuitive Probability and Random Processes using MATLAB, Springer, 2006.
2. Athanasios Papoulis, S. Unnikrishna Pillai, Probability, Random Variables and Stochastic Processes, 4th Edition, Tata Mc-Graw Hill, 2002.
3. G. P. Beaumont, Probability and Radom Variables, Woodhead Publishers, 2005.
4. Stirzaker D., Probability and Random Variables: A Beginner's Guide, Cambridge University Press, 2003.
5. Robert G. Brown, Patrick Y. C. Hwang, Introduction to Random Signals and Applied Kalman Filtering, John Wiley & Sons, 1997.

CH5111	**PROCESS MODELING & ANALYSIS**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Understand model building techniques
CO2	Develop first principles, grey box and empirical models for systems.
CO3	Develop mathematical models for engineering processes
CO4	Model discrete time systems

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	-	1
CO2	2	-	3	2	-	1
CO3	2	-	3	2	-	1
CO4	2	-	3	2	-	1

Detailed syllabus:

Introduction to modeling, a systematic approach to model building, classification of models.

Development of steady state and dynamic lumped and distributed parameter models based on conservation principles. The transport phenomena models: Momentum, energy and mass transport models. Analysis of ill-conditioned systems.

Classification of systems, system's abstraction and modeling, types of systems and examples, system variables, input-output system description, system response, analysis of system behavior, linear system, superposition principle, linearization, non-linear system analysis, system performance and performance targets.

Development of grey box models. Empirical model building. Statistical model calibration and validation. Population balance models. Examples.

Mathematical model development for electromagnetic forces in high field magnet coils, free and forced vibration of an automobile, cantilever beam subjected to an end load. Mathematical model development for different chemical engineering processes – distillation columns, reactors, heat exchangers.

Discrete systems: difference equations, state-transition diagrams, cohort simulation of Markov models, random processes, descriptive statistics, hypothesis testing, probabilistic distributions, pseudo-random numbers, Monte Carlo methods, numerical simulation of continuous-time dynamics, discrete-event systems, cellular automata, Moore machines, real-world system examples: Mechanical, Electrical, Electro-Mechanical, Chemical Systems.

Reading:

1. Ashok Kumar Verma, Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, 2014.
2. Amiya K. Jana, Chemical Process Modeling and Computer Simulation, 2nd Edition, Prentice Hall, 2011.
3. Jim Caldwell, Douglas K. S. Ng, Mathematical Modeling: Case Studies, Kluwer Academic Publishers, 2004.
4. Said S. E. H. Elnashaie, Parag Garhyan, Conservation Equations and Modeling of Chemical and Biochemical Processes, Marcel Dekker Publishers, 2003.
5. K. M. Hangos and I. T. Cameron, "Process Modelling and Model Analysis", Academic Press, 2001.
6. John Ingham, Irving J. Dunn, Elmar Heinzle, J. E. Prenosil, Jonathan B. Snape, Chemical Engineering Dynamics, Wiley, 2007.

CH5261	**NONLINEAR DYNAMICS & CONTROL**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Understand nonlinear systems and their dynamics
CO2	Apply realization theory to linear systems and stability concepts
CO3	Understand nonlinear control and the concepts of controllability and observability
CO4	Apply Lyapunov method for stability of linear and nonlinear systems

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	1
CO2	2	-	3	3	-	1
CO3	2	-	3	3	-	1
CO4	2	-	3	3	-	1

Detailed syllabus:

Introduction to nonlinear systems, Phase plane analysis – generalization of phase plane behavior. Limit cycle behavior of nonlinear systems.

Nonlinear dynamics –Bifurcation and orbit diagrams. Stability of fixed point solutions. Cascade of period doublings. Bifurcation behavior of single ODE systems. Bifurcation behavior of two state systems – limit cycle behavior, Hopf bifurcation.

Realization theory – Realization of LTI systems, realization of bilinear systems, examples. Stability and the Lyapunov method – local stability, Lyapunov theory.

Introduction to nonlinear control – importance. Singular perturbation theory, Properties of ODE systems with small parameters, Nonstandard singularly perturbed systems with two time scales, Singularly perturbed systems with three or more time scales.

Controllability and Observability: controllability and Observability of LTI Systems, local Controllability and Observability of Nonlinear Systems.

Stability and The Lyapunov Method: Stability Notions, BIBO (Bounded-input-bounded-output)Stability Conditions for LTI Systems, L_2-gain of Linear and Nonlinear Systems, the Small-gain Theorem, Asymptotic or Internal Stability of Nonlinear Systems.

Lyapunov Function, Lyapunov Theorem for LTI Systems. Feedback and Input-output Linearization of Nonlinear Systems - Relative Degree, Exact Linearization via State Feedback, Nonlinear Coordinates Transformation and State Feedback, The State-space Exact Linearization Problem for SISO Systems. Exact and Input-output Linearization. Exact Linearization via State Feedback.

Reading:

1. K.M. Hangos, J. Bokor, G. Szederkényi, Analysis and Control of Nonlinear Process Systems, Springer, 2004.
2. Jean-Jacques E Slotine, Weiping Li, Applied Nonlinear Control, Prentice-hall, 1991.
3. Daizhan Cheng Xiaoming Hu Tielong Shen, Analysis and Design of Nonlinear Control Systems, Springer, 2010.
4. Michael Baldea, Prodromos Daoutidis, Dynamics and Nonlinear Control of Integrated Process Systems, Cambridge University Press, 2012.
5. H. K. Khalil, Nonlinear Systems, 3rd Edition, Englewood Cliffs, NJ: Prentice Hall, 2001.
6. B. Wayne Bequette, Process Dynamics: Modeling, Analysis and Simulation, Prentice Hall, 1998.

CH5262	**SOFT-COMPUTING TECHNIQUES**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Understand the concept of neural networks
CO2	Use neural networks to control the process plants
CO3	Develop fuzzy logic based controllers for different processes
CO4	Combine fuzzy logic with neural networks for plant control
CO5	Design controllers using genetic algorithms

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	3	-	1
CO2	1	-	2	3	-	1
CO3	2	-	2	3	-	1
CO4	2	-	2	3	-	1
CO5	3	-	3	3	-	1

Detailed syllabus:

Introduction to Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, Feed forward networks. Computational complexity of ANNs.

Neural Networks Based Control: ANN based control: Introduction: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control: Examples – Inferential estimation of viscosity an chemical process, Auto – turning feedback control, industrial distillation tower.

Introduction to Fuzzy Logic: Fuzzy Controllers: Preliminaries – Fuzzy sets and Basic notions – Fuzzy relation calculations – Fuzzy members – Indices of Fuzziness – comparison of Fuzzy quantities – Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy Controllers: Preliminaries – Fuzzy sets in commercial products – basic construction of fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies – fuzzy control for smart cars.

Neuro – Fuzzy and Fuzzy – Neural Controllers: Neuro – fuzzy systems: A unified approximate reasoning approach – Construction of role bases by self-learning: System structure and learning.

Introduction to Genetic algorithms. Controller design using genetic algorithms.

Reading:

1. Bose and Liang, Artificial Neural Networks, Tata McGraw Hill, 1996.
2. Huaguang Zhang, Derong Liu, Fuzzy Modeling and Fuzzy Control, Birkhauser Publishers, 2006.
3. Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, New Delhi, 1992.
4. Lakshmi C. Jain, N. M. Martin, Fusion of Neural Networks, Fuzzy Systems and Genetic Algorithms: Industrial Applications, CRC Press, 1998.
5. Muhammet Ünal, AyçaAk, VedatTopuz, Hasan Erdal, Optimization of PID Controllers using Ant colony and Genetic Algorithms, Springer, 2013.
6. S. N. Sivanandam and S. N. Deepa, Principles of Soft Computing, John Wiley & Sons, 2007.

CH5263	**DISTILLATION CONTROL**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

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

CO1	Understand distillation operations
CO2	Choose control scheme for distillation control
CO3	Design control schemes for control of pressure, temperature, flow and level in the column
CO4	Design control schemes in the presence of process interactions
CO5	Design control schemes for different types of distillation processes

Mapping of course outcomes with program outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	-	1	2	-	1
CO2	1	-	1	3	-	1
CO3	3	-	3	3	-	1
CO4	3	-	3	3	-	1
CO5	3	-	3	3	-	1

Detailed syllabus:

Introduction to distillation operations - Binary separation concepts - McCabe - Thiele diagram - other parameters in binary distillation - Introduction to multi component separation - Minimum reflux - Number of plates calculations. Formulation of the Control Problem, Tower Internals, Flooding, Tray Hydraulics, Inverse Response in Bottoms Level, Composition Dynamics.

Steady state calculations for control structure selection – control structure alternatives, feed composition sensitivity analysis, temperature control tray selection.

Classification of control schemes for distillation - Control of composition, choice of temperature measurement to infer composition. Distillate Composition Control - Constant Boil up, Constant Bottoms Flow, Operating Lines, Temperature Profiles, Feed Composition Disturbances, Bottoms Composition Control, Propagation of Variance in Level Control Configurations, Level Control in Direct Material Balance Configurations

Pressure control and condensers. Feed forward control - feed flow and composition, internal reflux control, extreme feed forward, feed forward for bottoms level and column pressure, product specifications.

Dynamic modeling and simulation. Pairing and Interaction in distillation - Proper pairing in single and dual composition control. Double-End Composition Control: Defining the Problem, Options for Composition Control, Relative Gain, Relative Gains from Open Loop Sensitivities, Relative Gains for Other Configurations, Ratios for Manipulated Variables, Effect of Operating Objectives, Model predictive control.

Control of extractive distillation process, columns with partial condensers, heat-integrated distillation columns, azeotropic columns and reactive distillation process.

Reading:

1. Cecil L. Smith, Distillation Control: An Engineering Perspective", Wiley, 2012.
2. William L. Luyben, Distillation Design and Control using ASPEN Simulation, 2nd Edition, Wiley, 2013.
3. Lanny Robins, Distillation Control, Optimization and Tuning, CRC Press, 2011.
4. W.L. MaCabe, J.C.Smith and P. Harriott, "Operations of Chemical Engineering", 5th Edition, McGraw Hill, 1993.
5. Urmila Diwekar, Batch Distillation: Simulation, Optimal Design, and Control, 2nd Edition, CRC Press, 2012.

CH5264	BIOPROCESS & BIOMEDICAL INSTRUMENTATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the techniques to handle biomass and monitor bio-processes
CO2	Understand on-line sensors for measuring bio-process parameters
CO3	Understand bio signals; their generation and processing
CO4	Apply different instrumentation techniques in medical field

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	1	-	1
CO2	1	-	1	1	-	1
CO3	1	-	1	2	-	1
CO4	2	-	2	2	-	1

Detailed syllabus

Introduction to bioprocesses. Bio-process Monitoring Requirements: Standard Techniques for Biomass, Substrates, Products, Intermediates and Effectors.

On-Line Sensing Devices: In Situ Instruments for Temperature, pH, Pressure, Oxygen, Carbon Dioxide, Culture Fluorescence, Redox Potential, Biomass, Comparability of Sensors, Optical Density.

Sampling: Sampling of Culture Fluid Containing Cells, Sampling of Culture Supernatant Without Cells, Interfaces, Flow Injection Analysis (FIA), Chromatography such as GC, HPLC. Mass Spectrometry (MS). Biosensors, Electrochemical Biosensors, Fiber Optic Sensors, Calorimetric Sensors, Acoustic/Mechanical Sensors.

Nature and complexities of biomedical measurements, Medical equipment standards- organization, classification and regulation. Biocompatibility - Human and Equipment safety – Physiological effects of electricity, Micro and macro shocks, and thermal effects.

Modeling and simulation in biomedical instrumentation – Difference in modeling engineering systems and physiological systems – Model based analysis of Action Potentials - cardiac output – respiratory mechanism - Blood glucose regulation and neuromuscular function.

Types and Classification of biological signals – Signal transactions – Noise and artifacts and their management - Biopotential electrodes- types and characteristics - Origin, recording schemes and analysis of biomedical signals with typical examples of Electrocardiography(ECG), Electroencephalography(EEG), and Electromyography (EMG)– Processing and transformation of signals-applications of wavelet transforms in signal compression and denoising.

Reading:

1. J. F. Van impe, P. A. Vanrolleghem, D. M. Iserentant, Advanced Instrumentation, Data Interpretation and Control of Biotechnological Processes, Springer, 2010.
2. T. K. Ghose, Process Computations in Biotechnology, Tata McGraw Hill, 1994.
3. John G. Webster, Bioinstrumentation, John Wiley & Sons, 2005.
4. Cromwell l., Biomedical Instrumentation and Measurements, Prentice Hall of India, 1995.
5. Rangaraj M. Rangayan, Biomedical Signal Analysis, John Wiley & Sons, 2nd Edition, 2015.
6. Kayvan Najarian and Robert Splinter, Biomedical Signal and Image Processing, CRC Press, 2005.

CH5265	MULTI SENSOR DATA FUSION		3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Infer the data collected from multiple sensors
CO2	Understand the models and architectures used for data fusion
CO3	Develop mathematical models and algorithms for multi sensor data fusion
CO4	Understand the variety of methods available for data fusion and sensor fusion
CO5	Use data structures for implementing data fusion systems

Mapping of course outcomes with program outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	1	-	1
CO2	1	-	1	1	-	1
CO3	1	-	3	3	-	1
CO4	1	-	1	1	-	1
CO5	1	-	1	1	-	1

Detailed syllabus:

Multi sensor data fusion: Introduction, sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data.

Models of the Data Fusion Process and Architectures: Data Fusion Models - Joint Directors of Laboratories Model, Modified Waterfall Fusion Model, Intelligence Cycle–Based Model, Boyd Model, Omnibus Model. Fusion Architectures - Centralized Fusion, Distributed Fusion, Hybrid Fusion

Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta – heuristics. Taxonomy of algorithms for multi sensor data fusion. Data association. Identity declaration.

Unified Estimation Fusion Models and Other Methods: Definition of the Estimation Fusion Process, Unified Fusion Models Methodology, Unified Optimal Fusion Rules, Kalman Filter Technique as a Data Fuser. Bayesian and Dempster–Shafer Fusion Methods - Bayesian Method, Bayesian Method for Fusion of Data from Two Sensors, Dempster–Shafer Method, Comparison of the Bayesian Inference Method and the Dempster–Shafer Method.

Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

High performance data structures: Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems within dependability bounds. Implementing data fusion system.

Reading:

1. H. B. Mitchell, Multi Sensor Data Fusion Springer, 2007.
2. Jitendra R. Raol, Multi Sensor Data Fusion with MATLAB, CRC Press, 2009.
3. Lawrence A. Klein, Sensor and Data Fusion, 2nd Edition, SPIE Press, 2012.
4. David L. Hall, Mathematical Techniques in Multi Sensor Data Fusion, Artech House, Boston, 1992.
5. J. Manyika, H.F. Durrant-Whyte: Data Fusion and Sensor Management: An Information-Theoretic Approach, Prentice Hall, 1994.
6. Martin Liggins, David Hall, James Llinas, Handbook of Multi Sensor Data Fusion: Theory and Practice, 2nd Edition, CRC Press, 2008.

CH5266	ROBUST CONTROL	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the concept of norm, stability of systems and modeling of uncertain systems
CO2	Design robust control systems
CO3	Understand limited horizon and infinite horizon control
CO4	Apply the designed controllers to processes

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	3	-	1
CO2	3	-	3	3	-	1
CO3	1	-	1	3	-	1
CO4	3	-	3	3	-	1

Detailed syllabus
Elements of linear system theory: System descriptions, State controllability and state observability, Stability, Poles, Zeros, More on poles and zeros, Internal stability of feedback systems, Stabilizing controllers, Stability analysis in the frequency domain. Limitations on performance in SISO and MIMO systems.
Modeling of Uncertain Systems: Unstructured Uncertainties, Parametric Uncertainties, Linear Fractional Transformations, Structured Uncertainties.
Robust Design Specifications: Small-Gain Theorem – nominal stability, nominal performance, robust stability, robust performance. Structured Singular Values.
Kharitonov Approach: Introduction, preliminary Theorems, Kharitonov Theorem, Control Design Using Kharitonov Theorem.
H_∞ and H_2 Control: Introduction, Function Space, Computation of H_2 and H_∞ Norms. Robust Control Problem as H_2 and H_∞ Control. H_2/H_∞ Control Synthesis. μ-Analysis and Synthesis: Consideration of Robust Performance, μ-Synthesis: D–K Iteration Method, μ–K Iteration Method.
Robust model predictive control for multivariable dead-time processes. Applications to processes.

Reading:

1. Sigurd Skogestad, Ian Postlethwaite, Multivariable Feedback Control: Analysis and Design, John Wiley & Sons, 2nd Edition, 2007.

2. Da-Wei Gu, Petko H. Petkov, Mihail M. Konstantinov, Robust Control Design using MATLAB, 2nd Edition, Springer, 2013.

3. Philippe Feyel, Loop-shaping Robust Control, Wiley, 2013.
4. Feng Lin, Robust Control Design: an Optimal Control Approach, John Wiley & Sons, 2007.
5. B. Roffel, B.H.L. Betlem, “Advanced Practical Process Control” Springer, 2004.
6. J. E. Normey-Rico, E. F. Camacho, Control of dead-time processes, Springer, 2007.

CH5267	PERFORMANCE ASSESSMENT & PLANT WIDE CONTROL	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand minimum variance bench mark
CO2	Estimate and use interactor matrices
CO3	Apply unified approach for performance assessment
CO4	Carry out degrees of freedom
CO5	Understand plant wide control

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	-	2
CO2	2	-	3	3	-	2
CO3	2	-	3	3	-	2
CO4	2	-	3	3	-	2
CO5	2	-	3	3	-	2

Detailed syllabus

Introduction. Unitary Interactor Matrices and Minimum Variance Control - Weighted unitary interactor matrices and singular LQ control. Estimation of the Unitary Interactor Matrices, Determination of the order of interactor matrices, Factorization of unitary interactor matrices. Estimation of the interactor matrix under closed-loop conditions, Numerical rank.

Feedback Controller Performance Assessment - Simple Interactor. Multivariable performance index. Feedback Controller Performance Assessment - Diagonal Interactor, effect of non-minimum phase zeros. Performance assessment with both stochastic and deterministic disturbances. Performance assessment with pure deterministic disturbances.

Plant wide Control Fundamentals – Introduction, Integrated Processes - Material Recycle, Energy Integration. Effects of Recycle. Time Constants in Recycle Systems, Steady-State Design. Dynamic Controllability.

Degrees of freedom, Design, steady operation and control DOF, DOFs for Economic optimum design, Steady economic process operation, Economic CVs for self-optimizing control Economic tradeoffs in plant design and steady operation Process Dynamics, PI(D) Control, Controller Tuning and Pairings.

Optimum design and operation of complete plants, Steady state economic optimum design, Steady state optimum operating policy. The bottom-up pairing approach, Systematic top-down plant wide control design procedure, Simple control structure design examples.

Reading:

1. Biao Huang and Sirish L. Shah, Performance Assessment of Control Loops: Theory and Applications, Springer-Verlag, 1999.
2. Andrzej Ordys, Damien Uduehi, Michael A Johnson, Process Control Performance Assessment: From Theory to Implementation, Springer, 2007.
3. Mohieddine Jelali, Control Performance Management in Industrial Automation, Springer, 2013.
4. Biao Huang, Ramesh Kadali, Dynamic Modeling, Predictive Control and Performance Monitoring, Springer, 2008.
5. William L. Luyben, Bjorn D. Tyreus, Michael L. Luyben, Plantwide Process Control, McGraw Hill, 1998.
6. G.P. Rangaiah, Vinay Kariwala, Plantwide Control: Recent Developments and Applications, Wiley, 2012.

CH5268	STATE ESTIMATION TECHNIQUES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Estimate the states using statistical and fundamental theories
CO2	Develop Kalman filter algorithms for state estimation
CO3	Use particle filters for state estimation
CO4	Apply optimization techniques for state estimation

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	1	-	1
CO2	2	-	3	3	-	1
CO3	1	-	2	2	-	1
CO4	1	-	2	2	-	1

Detailed syllabus

Introduction to State Estimation – Introduction to statistical theory. Introduction to state and parameter estimation - Steady-state perspective, State-space model formulation from fundamental theories. Continues and discrete state space model and relationships.
Development of Kalman Filter - Predictor-Corrector form, Analysis of Kalman Filter from various view-points, Kalman Filter algorithms - Orthogonality Principle, Divergence Problems, Suboptimal Error Analysis, Reduced-Order Sub-optimality.
Extended and Unscented Kalman Filters – Extensions to handle Non-Linearity and Non-Gaussianity in processes. Predictor-Corrector form. Unscented Kalman Filter - Concept of unscented sampling, Predictor-Corrector form, estimation of the states with examples. Smoothing – Fixed point smoother, Fixed lag smoother, Fixed interval smoother. Performance of estimators – bias and covariance.
Introduction to Particle Filters - State Estimation, Enhancements to handle Delayed or infrequent measurements. Differential Algebraic Equation systems. Difficulties to use particle filters.
Optimization based approaches to State Estimation – Extensions to handle Non-Linearity and Constraints. Moving Horizon Estimator - Problem formulation, Connections to Kalman Filter. Receding Horizon Kalman Filter - Problem formulation, Connections to Kalman Filter.

Reading:

1. Dan Simon, Optimal State Estimation, John Wiley & sons, 2006.

2. Mohinder S. Grewal and Angus P. Andrews, Kalman Filtering: Theory and Practice Using MATLAB, 3rd Edition, John Wiley & sons, 2008.
3. F. Vander Heijden, R.P.W. Duin, D. de Ridder, D.M.J. Tax, Classification, Parameter Estimation and State Estimation: An Engineering Approach Using MATLAB, John Wiley & Sons, 2004.
4. Robert G. Brown and P.Y.C. Hwang, Introduction to Random Signals and Applied Kalman Filtering, 4th Edition, John Wiley & Sons, 2012.
5. Bruce P. Gibbs, Advanced Kalman Filtering, Least-Squares and Modeling, Wiley, 2011.

CH5269	REAL TIME AND EMBEDDED SYSTEMS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand microprocessors, microcontrollers and digital signal processors
CO2	Understand the pc based data acquisition; analog to digital signal conversion and vice versa
CO3	Understand the digital logic circuits used with embedded systems
CO4	Design embedded systems
CO5	Use real time operating systems

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	1	-	1
CO2	1	-	1	1	-	1
CO3	1	-	1	1	-	1
CO4	2	-	3	3	-	1
CO5	1	-	1	1	-	1

Detailed syllabus

System Design: Definitions, Classifications and brief overview of micro-controllers, microprocessors and DSPs. Embedded processor architectural definitions. Typical application scenario of embedded systems.
Data acquisition basics: Introduction to data acquisition on PC, Sampling fundamentals, Input/Output techniques and buses. ADC, DAC, Digital I/O, counters and timers, DMA, Software and hardware installation, Calibration, Resolution, Data acquisition interface requirements.
Interface Issues Related to Embedded Systems: A/D, D/A converters, timers, actuators, power, FPGA, ASIC, diagnostic port.
Techniques for Embedded Systems: State Machine and state tables in embedded design, Simulation and Emulation of embedded systems. High-level language descriptions of S/W for embedded system, Java embedded system design.
Real time Models, Language and Operating Systems: Event based, process based and graph based models, Petrinet models – Real time languages – The real time kernel, OS tasks, task state4s, task scheduling, interrupt processing, clocking communication and synchronization, control blocks, memory requirements and control, kernel services.

Case Studies: Discussion of specific examples of complete embedded systems using mc68 HC11, mc8051, ADSP2181, PIC series of microcontroller.

Reading:

1. Ball S.R, Embedded Microprocessor Systems – Real World Design, Prentice Hall, 1996.
2. Herma K, Real Time Systems – Design for Distributed Embedded Applications, Kluwer Academic, 1997.
3. Gassle J, Art of Programming Embedded Systems, Academic Press, 1992.
4. Gajski D.D, Vahid F, Narayan S, Specification and Design of Embedded Systems, PRT Prentice Hall, 1994.
5. C.M. Krishna, Kang G. Shin, Real Time Systems, McGraw Hill, 1997.
6. Raymond J.A. Buhr, Donald L. Bailey, An Introduction to Real Time Systems, Prentice Hall, 1999.

CH5270	INDUSTRIAL AUTOMATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Draw block diagram of industrial automation and control system
CO2	List basic devices used in automated systems
CO3	Use programmable logic controllers for industrial automation
CO4	Integrate SCADA with PLC systems
CO5	Use Internet of Things for industrial automation

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	1	1	-	1
CO2	1	-	1	1	-	1
CO3	1	-	1	1	-	1
CO4	2	-	3	3	-	1
CO5	1	-	1	1	-	1

Detailed syllabus

Introduction: Automation overview, Requirement of automation systems, Architecture of Industrial Automation system, Introduction of PLC and supervisory control and data acquisition (SCADA). Industrial bus systems: modbus & profibus

Automation components: Sensors for temperature, pressure, force, displacement, speed, flow, level, humidity and pH measurement. Actuators, process control valves, power electronics devices DIAC, TRIAC, power MOSFET and IGBT. Introduction of DC and AC servo drives for motion control

Computer aided measurement and control systems: Role of computers in measurement and control, Elements of computer aided measurement and control, man-machine interface, computer aided process control hardware, process related interfaces, Communication and networking, Industrial communication systems, Data transfer techniques, Computer aided process control software, Computer based data acquisition system, Internet of things (IoT) for plant automation

Programmable logic controllers: Programmable controllers, Programmable logic controllers, Analog digital input and output modules, PLC programming, Ladder diagram, Sequential flow chart, PLC Communication and networking, PLC selection, PLC Installation, Advantage of using PLC for Industrial automation, Application of PLC to process control industries. Distributed Control System: Overview of DCS, DCS software configuration, DCS communication, DCS Supervisory Computer Tasks, DCS integration with PLC and Computers, Features of DCS, Advantages of DCS.

Reading:

1. Singh, S, Industrial Instrumentation and Control, McGrawhill, 3rd Edition, Prentice Hall, 2008.
2. Johnson, C D., Process Control Instrumentation Technology, Pearson, 8th Edition, 2014.
3. Dunning, G. A., Introduction to Programmable logic controller, Cengage Learning, 2005.
4. Jamkar, R. G., Industrial Automation using PLC, SCADA and DCS, Global press, 2018.

CH5161	DATA ANALYTICS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Demonstrate proficiency with statistical analysis of data.
CO2	Use inferential statistics for decision making
CO3	Apply supervised learning for classification and regression problems
CO4	Apply unsupervised learning for clustering

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**-**	**2**	**2**	**-**	**1**
CO2	**3**	**-**	**2**	**2**	**-**	**1**
CO3	**3**	**-**	**2**	**2**	**-**	**1**
CO4	**3**	**-**	**2**	**2**	**-**	**1**

Detailed Syllabus:

Introduction

Data Quality and Preprocessing: Distance measures, Dimensionality reduction, Principal Component analysis (PCA)

Descriptive Statistics: Frequency tables, graphs - bar graph, relative frequency tables and graphs), grouped data, histograms, Ogives, Stem and leaf plots, Box plots, Pareto diagram, dot diagram

Measures of Central Tendency and Dispersion - Arithmetic Mean, Median and Mode; Variance, Standard deviation, quartlies, range, mean absolute deviation, Z scores, coefficient of variation. Normal Distribution

Confidence Interval Estimation

Inferential Statistics: Hypothesis Testing, Analysis of Variance (ANOVA)

Machine Learning:

Supervised learning: Least squares regression, Ridge regression, logistic regression, k-Nearest Neighbours Algorithm, Bias – Variance Dichotomy, Linear Discriminant analysis, Classification and Regression Trees, Support Vector Machines, Neural networks, Deep learning.

Unsupervised learning: Cluster Analysis – K-Means, Hierarchical, DBSCAN

Reading:

1. Douglas C. Montgomery, George C. Runger, Applied Statistics and Probability for Engineers, Third Edition, John Wiley & Sons Inc., 2003.
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009.
3. Tomáš Horváth, André C. P. L. F. de Carvalho, João Mendes Moreira, A General Introduction to Data Analytics, Wiley, 2019.
4. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, Second Edition, Pearson, 2019.
5. Ethem Alpaydın, Introduction to Machine Learning, Third Edition, MIT Press, 2014

CH5162	PROCESS SCHEDULING AND UTILITY INTEGRATION	DEC	3 – 0 – 0	3 Credits

Prerequisites: Computational Techniques.

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

CO1	Identify the objectives of scheduling problem
CO2	Develop a model for batch process scheduling
CO3	Integrate process scheduling and resource conservation
CO4	Design and synthesize batch plants

Mapping of the Course Outcomes with Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	-	1	1
CO2	2	-	3	-	1	1
CO3	2	-	3	-	1	2
CO4	2	-	3	-	1	1

Detailed Syllabus:

Introduction to Batch Chemical Processes: Definition of a batch process, Operational philosophies, Types of batch plants, Recipe representations, Batch chemical process integration.

Short-Term Scheduling: Effective technique for scheduling of multipurpose and multi-product batch plants, Different storage policies for intermediate and final products, Evolution of multiple time grid models in batch process scheduling, Short-term scheduling of multipurpose pipeless plants, Planning and scheduling in biopharmaceutical industry.

Resource Conservation: Integration of batch process schedules and water allocation network, Water conservation in fixed scheduled batch processes, Wastewater minimization in multiproduct batch plants: single contaminants, Storage design for maximum wastewater reuse in batch plants, Wastewater minimization in multipurpose batch plants: multiple contaminants, Wastewater minimization using multiple storage vessels, Wastewater minimization using inherent storage, Zero effluent methodologies.

Heat integration in multipurpose batch plants: direct and indirect heat integration, Simultaneous optimization of energy and water use in multipurpose batch plants, Flexibility analyses and their applications in solar-driven membrane distillation desalination system designs, Automated targeting model for batch process integration.

Design and Synthesis: Design and synthesis of multipurpose batch plants, Process synthesis approaches for enhancing sustainability of batch process plants, Scheduling and design of multipurpose batch facilities: Periodic versus non periodic operation mode through a multi objective approach, Mixed-integer linear programming model for optimal synthesis of polygeneration systems with material and energy storage for cyclic loads.

Reading:

1. Thokozani Majozi, Esmael Reshid Seid, Jui-Yuan Lee "Synthesis, Design, and Resource Optimization in Batch Chemical Plants", CRC Press Taylor & Francis, 2015.
2. Thokozani Majozi "Batch Chemical Process Integration - Analysis, Synthesis and Optimization", Spinger, 2010.
3. Gintaras V. Reklaitis, Aydin K. Sunol, David W. T. Rippin, Oner Hortacsu "Batch Processing Systems Engineering", Spinger, 1996.
4. Mariano Martin Martin, Introduction to Software for Chemical Engineers, CRC Press, 2015.