GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3150504

Semester – V
Subject Name: Instrumentation and Process Control

Type of course: Professional Core Corse

Prerequisite: Material and Energy Balance Calculations, Basics of differential equations.

Rationale: The course is designed to introduce the fundamentals of process control along with instrumentation and its applications. The course will teach the students about mathematical models based on transfer function approach for single loop systems, how to obtain dynamic response of open loop and closed loop systems, stability analysis in transient and frequency domains, and controller tuning methods. The course introduces P, PI, and PID controllers and their applications. The course would end with more advanced concepts like feed-forward control, ratio control, model-predictive control, dead-time compensation, etc. The instrumentation for process control is also focused along with hands-on practical experience. Principles of operation of different measuring devices for temperature, level, pressure, flow, pH, humidity, density, and viscosity. Students will be introduced to transmitters, transducers, converters, control valves, digital and analog components related to PLC, DCS, and SCADA systems.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	2	5	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**Introduction of Process Control:** Need for control and automation, Steady state and dynamic system, control logic, servo and regulatory, control, block diagrams, control structures (feedback vs. feedforward)	3
2	**Laplace Transforms:** Definition, Transforms of simple functions, Ramp functions, Sine functions, Solutions of differential equations. Inversions of transform function by partial fractions, qualitative nature of solutions, Final value and initial value theorems, Translation of transforms, Transforms of unit impulse functions, Transforms of integral.	4
3	**Response of First Order Systems:** Mercury thermometer, Transient response of step functions, Sinusoidal input, Impulse functions. Physical Examples of First Order Systems: Liquid level, Mixing process, linearization. First Order System in Series: Non-interacting system of liquid level, Generalization of several non-interacting systems in series, Interacting systems.	5
4	**Second Order Systems:** Development of transfer functions, Damped vibrator, Liquid manometer, Thermometer in thermo-pocket, Step response & impulse response,	4

	Overshoot, Decay ratio, Rise time, Response time, Period of oscillation, Natural period of oscillation, Sinusoidal response, Transportation lag.	
5	**The Control Systems:** Block diagram, Standard block diagram symbols, Negative and positive feedback, Servo problem v/s regulator problems, Development of block diagrams, Process measuring element, Controller, Final control element. Closed Loop Transfer Functions: Block diagram reduction, Overall transfer function for single loop system, Overall transfer function for change in load, Overall transfer function for multi loop control system, process and instrumentation diagrams , parts of control system.	**4**
6	**Controllers and Final Control Elements:** Actual v/s Ideal controller, Pneumatic controller mechanism of proportional control, Proportional integral (PI) control, Proportional derivative (PD) control, Proportional integral derivative (PID) control. Control valve, Control valve characteristics. Transfer functions of P, On-off, PI, PD, and PID control, Motivation for addition of integral and derivative modes, Block diagram of chemical reactor control system.	**4**
7	**Transient Response of Simple Control Systems:** Proportional control for Set point change (Servo Problem), Proportional control for load change (Regulator Problem), Proportional integral control for load change, Proportional Integral control for set point change, Proportional control for system with measurement lag.	**3**
8	**Stability:** Concept of stability, Definition of stability (linear system), Stability criterion, Characteristic equation, Routh test for stability, Routh array, Method of Root Locus for stability analysis, Nyquist stability criterion.	**5**
9	**Frequency Response analysis:** Fortunate circumstances, Transportation lag, First order system, First order system in series, Bode diagrams, Bode stability criterion, Graphical rules for Bode diagrams. Transient response phase margin, magnitude ratio, phase shift, open loop bode diagrams of various controllers.	**5**
10	**Controller tuning and advance controllers:** Ziegler-Nichols method, Cohen-Coon method, introduction to cascade control, feed forward control, ratio control, Smith-predictor, IMC, MPC, dead-time compensation, digital control.	**5**
11	**Introduction of Process Measurement:** Elements of instruments, Parts of instruments, Static and dynamic characteristics.	**2**
12	**Temperature Measurement:** Scales, Expansion thermometers like constant volume gas, Mercury in glass, Bimetallic, Filled system thermometer like pressure spring thermometer, Static accuracy of thermometer, Dip effect in thermometer, Errors in thermometer of liquid and gas filled type like cross ambient effect, Head effect, Methods of compensation, Thermoelectric temperature measurement: Thermo couples, Pyrometers: Radiation pyrometer, Photo electric pyrometers, Optical pyrometers, Errors in optical pyrometers.	**4**
13	**Pressure Measurement:** Liquid column manometer, Enlarged leg manometer, Inclined tube manometer, Ring manometer, Tilting U tube manometer, Bourdon gauge, Bellows, Bellows differential pressure gauge, Vacuum Measurement: Ionization gauge, Pirani vacuum gauge, Thermocouple vacuum gauge, McLeod gauge	**3**
14	**Liquid Level Measurement:** Direct measurement, Float and tap, Float and shaft, Hydraulic remote transmission, Bubbler system, Diaphragm & air trap system, Differential pressure manometer, Float and spring pneumatic balance, Displacement float, Magnetic float gauge.	**2**

15	**Flow Measurement:** Head flow meter, Orifice plate, Flow nozzle, Venturi tube, Pitot tube, Differential pressure meter, Electric type head flow meter, Bellows type meter, Rota meter, Piston type area meter and Positive displacement meter, Flow control actuators: different types of valves.	**3**
16	**Humidity measurement & pH Measurement:** Psychometer method, wet bulb and dry bulb thermometer, hygrometer method, dead point method, electrolytic water analyzer. Electrode for pH measurement, calomel reference electrode, measuring circuits.	**2**
17	**Density & Viscosity Measurement:** Liquid level method, displacement meters, hydrometer. Viscosity meter, continuous viscosity meters, capillary type viscometers, rotating bowl type viscometer.	**2**
18	Introduction to advance topics like Electrical and pneumatic signal conditioning and transmission, Computer process control, PLC, DCS, and SCADA.	**4**

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	15	10	10	**5**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Coughanowr, D. R., LeBlanc, S. "Process Systems Analysis and Control", 3rd edition,McGraw-Hill (2008).
2. Stephanopoulos, G. "Chemical Process Control: An Introduction to Theory and Practice", Pearson Education (1984)
3. Seborg, D.E., Edgar, T.F., Mellichamp, D.A. "Process Dynamics and Control", 2nd edition, John Wiley (2003)
4. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, Mc-GrawHill (2005).
5. S.K. Singh, Industrial Instrumentation and Control, 3rd edition, McGraw-Hill (2008).
6. R. P. Vyas, "Process Control and Instrumentation", Denett & Co.
7. Donald .P. Eckman, "Industrial Instrumentation", John Wiley & Sons Inc, New York.

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

Sr. No.	CO statement	Marks % weightage
CO-1	understand concepts of open and close loop control system	10
CO-2	construct mathematical models of chemical process with its transfer function	25
CO-3	evaluate the performance of control system with controllers and control strategies along with instrumentation	25
CO-4	design control loop with appropriate controllers and control valve	20
CO-5	apply appropriate instruments for various application in chemical plant	20

List of Open Source Software/learning website:

Scilab Xcos open source software can e used for process control modelling and analysis.

Students can refer to video lectures available on the websites including NPTEL

Students can refer website of "*The International Federation of Automatic Control (IFAC)*" https://www.ifac-control.org/ for international conference proceedings.

List of Experiments: (Minimum 10 experiments to be performed)

1. Response of first order system: thermometer
2. Response of first order liquid level system
3. Response of mixing process
4. Reponses of second order system: U-tube manometer or damped vibrator
5. Response of Interacting tanks
6. Response of Non-interacting tanks
7. Calibration of thermos couple test rig
8. Characteristics of flow control valves
9. Temperature and pressure measuring devices
10. Level measuring devices (Bubble system)
11. Viscosity and pH measuring devices (pH Control trainer)
12. Transmitters and transducers
13. Open loop systems: lagged thermometer
14. Temperature, level, flow, and pressure control trainers
15. Flow-level cascade control