CURRICULUM

July 2023 Admissions Onwards
(as per Senate 41st meeting)

APPROVED BY

DPGC

M.Tech in Control and Instrumentation Engineering

DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING

DR B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY JALANDHAR

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About NITJ

Dr B. R. Ambedkar National Institute of Technology Jalandhar was established in the year 1987 as Regional Engineering College and was given the status of National Institute of Technology (Deemed University) by the Government of India on October 17, 2002 under the aegis of Ministry of Human Resource Development, New Delhi. Now the Ministry of Human Resource Development, Government of India has declared the Institute as ―Institute of National Importance under the act of Parliament-2007.

Institute Vision

To build a rich intellectual potential embedded with interdisciplinary knowledge, human values and professional ethics among the youth, aspirant of becoming engineers and technologists, so that they contribute to society and create a niche for a successful career.

Institute Mission

To become a leading and unique institution of higher learning, offering state-of-the-art education, research and training in engineering and technology to students who are able and eager to become change agents for the industrial and economic progress of the nation. To nurture and sustain an academic ambience conducive to the development and growth of committed professionals for sustainable development of the nation and to accomplish its integration into the global economy.

About the Department

The Department of Instrumentation and Control Engineering commenced its Bachelor of Technology (B. Tech) degree programme in 1990. Initially, the degrees were awarded by Guru Nanak Dev University Amritsar, subsequently, the Institute was affiliated to the newly set-up Punjab Technical University for the period July 1997 through October 2002. The Institute was accorded Deemed University Status w.e.f. October 17, 2002 under the aegis of Ministry of Human Resource Development, New Delhi. Now the Ministry of Human Resource Development, Government of India has declared the Institute as "Institute of National Importance" under the act of Parliament-2007. Instrumentation and Control Engineering is a well-diversified discipline. Many areas of specialization namely Process Instrumentation, Control Systems, Biomedical Engineering, Robotic, Wireless Networking etc. have grown by leaps and bounds and have emerged as full-fledged disciplines in themselves. Training students in all these areas is an uphill and challenging task. Therefore, every effort has been made while developing curricula to ensure full cognizance of all value elements among students. The teaching scheme has been enriched by the valuable inputs of experts of respective fields from prestigious institutions / organizations such as IIT Roorkee and IIT Delhi, R&D organizations like CSIO and leading industries of the region. The Department has commenced M Tech (Full Time) Degree Programme in Control & Instrumentation Engineering w.e.f.

July, 2006 and M Tech (Part-Time) Programme w.e.f. July, 2010. The Department has also started Ph D Programme in 2005 in the areas of Instrumentation and Control Engineering, Biomedical Engineering, Robotics and Wireless Networking etc. The Department is consolidating its efforts to promote industrial research and consultancy in appropriate areas of Instrumentation and Control Engineering. The Department has many IPR's to its credit.

Department Vision

To excel in the field of Instrumentation and Control Engineering education, research and innovation with interdisciplinary approach responsive to the needs of industry and sustainable development of society while emphasizing on human values and professional ethics.

Department Mission

- To create and disseminate knowledge through research, quality education and creative inquiry.
- To orient the education and research towards latest developments through close interaction with industry, other institutions of higher learning and research organizations.
- To train the students in problem solving and soft skills, inculcating leadership and team-work qualities, human values and ethical professionalism.

Preface

With rapidly changing industrial scene and technological advances that have taken place in microelectronics, telecommunications and computer technologies the field of Instrumentation and Control Engineering (ICE) has been revolutionized. This needs upgradation and updating the existing academic programmes, so that trained human resources are competent to meet requirements of today's industries. Accordingly the Department of Instrumentation and Control Engineering has proposed flexible curriculum as per directions of NIT council stipulated under the credit based system. It is really challenging to evolve a common programme for this discipline that meets the need of national and international industries and research establishments. However, with the rich experience of successful experimentation with above idea for over many years, the task of development of a flexible curriculum could be possible. The suggested curriculum is based credit based system in which students will be able to attain minor degree on completing the courses of other departments. The programme has to be forward looking in context of the rapid changing scenario of science and technology which provides a proper balance in teaching of basic sciences, social sciences and management, engineering sciences and technical arts, technologies and their applications. Core subjects have been selected to cover all those, which are essential in training of ICE graduates. The above features have been achieved by offering a number of electives courses both departmental and open in nature. I take this opportunity to express my deep appreciation to members of the Board for their valuable suggestions and critical comments in finalizing the curriculum. It is hoped that the curriculum complied in form of the booklet will be of immense help to the students and the faculty in smooth offering the under graduate programme in Instrumentation and Control Engineering. I thank all the members of curriculum committee and the faculty of ICE Department for help and cooperation rendered in bringing out this booklet in time.

Program Outcomes (POs) of M.Tech Programme

i. Ability to identify, formulate, investigate and synthesize real time engineering problems, and ability to apply holistic approaches towards solving complex engineering problems.
ii. Ability of creative thinking, critical analysis and decision making for conducting the experiments and researches, perform analysis and interpret data for real world engineering problems.
iii. Ability to carry out research and development through collaborative and multidisciplinary engineering approaches to find sustainable and optimal solutions of real world problems.
iv. Ability to professionally and ethically analyze the impact of global and contemporary issues, the role of engineers on society, including, health, safety, legal and cultural issues.

Programme Educational Objectives (PEO)

The Programme Educational Objectives of this Programme are:

i. The graduate is expected to be a good professional by acquiring cognitive knowledge in the principles and practices of Control and Instrumentation Engineering.
ii. The graduate is expected to be equipped with analytical skills to understand real world problems and formulate solutions with professional and social ethics in-line with human values.
iii. The graduate will continue to learn and adapt in the world of emerging technologies to meet the diversified needs of industry, academia and research.

Program Specific Outcomes (PSOs) of MTech Programme

i. Possess sound theoretical and practical knowledge of Control and Instrumentation Engineering.
ii. Devise and deliver efficient solutions to challenging problems in Control and Instrumentation Engineering.

Dr B R Ambedkar National Institute of Technology Jalandhar
Department of Instrumentation and Control Engineering

Proposed Scheme of Teaching and Examination
M. Tech (Control and Instrumentation) for 2023 admissions onwards

Course Code	Subject	Teaching Load			Credit	Exam. Duration	
		L	T	P	C	Theory	Practical
I SEMESTER							
IC-501	Discrete Control Systems	3	0	0	3	3 hrs.	-
IC-503	Process Control and Instrumentation	3	0	0	3	3 hrs.	-
IC-505	Virtual Instrumentation	3	0	0	3	3 hrs.	-
IC-507	Embedded Systems	3	0	0	3	3 hrs.	-
IC-5XX	Elective-I	3	0	0	3	3 hrs.	-
IC-5XX	Elective-II	3	0	0	3	3 hrs.	-
IC-513	Process Control and Instrumentation Laboratory	0	0	3	2	-	3 hrs.
IC-515	Virtual Instrumentation Laboratory	0	0	3	2	-	3 hrs.
		18	**0**	**6**	**22**	**18**	**6**
II SEMESTER							
IC-502	Industrial Automation and Robotics	3	0	0	3	3 hrs.	
IC-504	Medical Instrumentation	3	0	0	3	3 hrs.	
IC-506	Soft Computing Techniques	3	0	0	3	3 hrs.	
IC-508	Robust and Optimal Control	3	0	0	3	3 hrs.	
IC-5XX	Elective-III	3	0	0	3	3 hrs.	
IC-5XX	Elective-IV	3	0	0	3	3 hrs.	
IC-512	Industrial Automation and Robotics Laboratory	0	0	3	2	-	3 hrs.
IC-514	Medical Instrumentation Laboratory	0	0	3	2	-	3 hrs.
		18	**0**	**6**	**22**	**18**	**6**
III SEMESTER							
IC-600	Dissertation (Phase-I)/ Industrial Training (Optional)**	0	0	-	15	-	-
IC-601	Independent Study	0	0	6	3	-	-
		0	**0**	**-**	**18**	**-**	**-**
IV SEMESTER							
IC-600	Dissertation (Phase-II)/ Industrial Training (Optional)**	0	0	-	18	-	-
GRAND TOTAL		**36**	**0**	**18**	**80**	**36**	**12**

* In the allotted slot of the time table, the students will have the option to opt for subjects from other departments, if possible.

** The M. Tech. Students who after completion of 1st year are selected for on campus/off campus internship at some reputed organizations are allowed to carry out their internship subject to the following:

- The cases of students opting for off campus internship will be assessed by the DPGC, based on recommendations of the concerned Supervisor from the Department for granting permission for the same.
- Further, all the M Tech students who are allowed for internship will work under the supervision of the already allotted Supervisor from the department who will collaborate with the Mentor from the industry for the dissertation/project work. The progress of the student will be assessed from time to time by both the Supervisor and the Mentor through presentation of the work.
- The students going for internship in the 3rd semester will undergo mid-term evaluations of the dissertation as well as independent study evaluation as planned by the department. However, they may be allowed by the DPGC to join the evaluation process through online mode.
- End term final dissertation evaluation will be held in the offline mode only.
- In case of any point not covered above, the decision of the DPGC shall be final and binding.
- During the period of internship, Institute's stipend cum assistantship will not be admissible. However, the student will be eligible for the contingency grant as per institute norms.

Research Internships:

The department shall offer sponsored (with stipend) internships of 4-6 months in the research projects through a rigorous selection procedure that shall be defined in the advertisement on the institute website. Number of interns and the amount of stipend will also be displayed on the website.

The internships can be distant internships (from any place) or in-person internships (at NIT Jalandhar).

Foreign Internship/Research Programme at Foreign Institute/University

Any M. Tech. Student from third semester onwards can pursue internship/research programme at any foreign Institute/University within top 200 world ranking Universities (as per QS rankings) for one semester only. The student will be required to apply in advance to the Head of the Department along with the recommendation letter issued by the Foreign Institute/University for approval by the Dean Academic. No Institute stipend shall be claimed for the period of internship.

List of Electives

Sr. No.	Course No.	Course Title
1.	IC-580	Smart Sensors and Sensor Networking
2.	IC-581	Advanced Measurement Systems
3.	IC-582	Robust and Optimal Control
4.	IC-583	Power Electronics and Drives
5.	IC-584	Sensor Data Fusion
6.	IC-585	Data Acquisition and Telemetry
7.	IC-586	Biomedical Signal Analysis
8.	IC-587	Identification and Adaptive Control
9.	IC-588	Physiological Control Systems
10.	IC-589	Industrial Instrumentation
11.	IC-590	Human Computer Interfacing
12.	IC-591	Computer Networks
13.	IC-592	System Modeling and Reliability
14.	IC-593	PLC, DCS & SCADA
15.	IC-594	Analytical Instrumentation
16.	IC-595	Medical Imaging and Processing
17.	IC-596	Power System Operation and Control
18.	IC-597	Power System Planning and Reliability
19.	IC-598	Power System Reliability
20.	IC-599	Deep Learning for Computer Vision
21.	IC-579	Cryogenics Instrumentation and Applications
22.	IC-578	Biomedical Optics and Biophotonics

SEMESTER-I

IC-501 **Discrete Control Systems** **[3 0 0 3]**

Syllabus:

Computer Controlled System: Configuration of the basic digital control scheme, general sampled data system variables, signal classifications, why use digital control system, Advantages, disadvantages, examples of discrete data and digital control systems.

Signal Processing in Digital Control: Sampling process, Frequency domain analysis, ideal samples, Shannon's sampling theorem, generation and solution of process, linear difference equations, data reconstruction process, frequency domain characteristics.

Discrete System Modelling: Determination of the transform, mapping between s and z domains, transform of system equations, open loop Hybrid sampled Data Control Systems, open loop discrete Input Data Control System, closed loop sampled data control system, modified transform method, response between sampling instants, stability on the z-plane and Jury's stability test, steady state error analysis for stable systems.

State Variable Analysis of Digital Control Systems: State descriptions of digital processors, conversion of state variable models to transfer functions, conversion of transfer functions to canonical state variable models, first comparison form, second companion form, Jordon Canonical form, state description of sampled continuous time plants, solution of state difference equations, closed form solution, state transition matrix, Cayley Hamilton Technique, concept of controllability and observability, loss of controllability and observability due to sampling.

Design of Digital Control: Digital PI, PD and PID Controller, Position and velocity forms, state regulator design, design of state observers, dead beat control by state feedback and dead beat

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓	✓	
CO3	✓	✓	✓	
CO4	✓		✓	
CO5		✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Know the theoretical foundations, concepts, and methodologies of digital control.
2. Familiarize with the importance of sampling and discretization of control systems models.
3. Analyze and solve linear control systems models, variation of constants formula, Laplace and z-transform methods.
4. Understand the stability methods for s and z domain in discrete control system
5. Gain practical knowledge in handling and analyzing the state space techniques, controllability, observability to design the digital controller for real time problem.

Text Books

1. Kuo BC, "Digital Control Systems," Oxford University Press
2. Ogata K, "Discrete Control Systems," Prentice Hall

Reference Books

3. Houpis CM and Lamount GB, "Digital Control Systems-Theory, Hardware, Software," McGraw Hill
4. Gopal M, "Digital Control and State Variables Methods," Tata McGraw Hill
5. Deshpande PB and Ash RH, "Computer Process Control," ISA Publication
6. George VI and Kurian CP, "Digital Control Systems," Cengage Learning India
7. Phillips CL and Troy NH, "Digital Control System – Analysis and Design," Prentice Hall

IC-503 **Process Control and Instrumentation** **[3 0 0 3]**

Syllabus:

Review of Process Control Fundamentals: Process control principles, elements of process control system, process modeling, control system parameters, control system evaluation, process and instrumentation symbols and diagrams (P&IDs).

Transducers: Definition and classification of sensors, working principles and salient features of thermal sensor, optical sensors, displacement and location sensors, strain sensor, level sensor, motion sensor, pressure sensor, flow sensor, principles of signal conditioning.

Controller principles: Principles, applications and examples of discontinuous controller modes, continuous three term controller, cascade control, over-ride control, split range control, feed forward control, ratio control, adaptive control, supervisory and direct-digital control, multivariable control system.

PLCs & SCADA: Principles, relative merits over hard-wired logic, relay and programming languages, ladder diagrams, fundamentals of SCADA and applications.

Distributed Control Systems (DCS): Distributed process control, DCS-configurations, Control console equipment, displays, DCS-control unit, Communications between components, DCS-data highways, field buses, multiplexers and remote terminal units, DCS-flow diagrams.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	
CO2	✓		✓	
CO3		✓	✓	
CO4			✓	✓
CO5	✓	✓		✓

Course Outcome:

After completion of this course, the students would be able to:

1. Know the theoretical foundations of process control and analysis.
2. Understand the control schemes for typical processes and it’s P & I Diagram.
3. Familiarize with the importance of suitable transducers and signal conditioning elements as per the requirements.
4. Analyze and implement the various advanced control strategies in process control industries.
5. Apply the PLC, DCS and SCADA control technique in process control.

Text Books

1. Stephanopoulos G, "Chemical process control: an introduction to theory and practice," Prentice Hall
2. Bartelt T, “Process control systems and instrumentation,” Cengage Learning

Reference Books

1. Seborg DE, Edgar TF and Mellichamp DA, "Process dynamics and control," Wiley
2. Smith CA and Corripio AB, "Principles and practice of automatic process control," Wiley
3. Johnson CD, "Process control instrumentation technology," Prentice Hall
4. Liptak GB, “Instrument Engineers' Handbook, vol.2: Process Control and Optimization,” CRC Press

IC-505 **Virtual Instrumentation** **[3 0 0 3]**

Syllabus:

Introduction: Definition, comparison with hard wired instruments, VI architecture, block diagram representation, VI application softwares, salient features and application areas.

LabVIEW basics: Introduction, building front panel and block diagram, tools and palettes, creating subVI, Controlling program flow – Loops, structures, shift registers, local and global variables, data types- Numeric, digital, strings, arrays, clusters, waveform, data presentation elements, graphs and charts.

LabVIEW advance: File input – output, timing and synchronization, mathematical analysis function. Data communication functions, programmatically controlling VIs

Data acquisition basics: Classification of signals, analog I/O and digital I/O signal acquisition, study different types of data acquisition system (USB, PCI, RS-485 network based).

LabVIEW data acquisition and instrument control: Study of various functions, Interfacing DAQ system with LabVIEW, Building VIs for analog I/O and digital I/O, study of VIs, control of instruments and DAQ system using serial, RS-485 and GPIB interface.

Software signal processing and manipulation: Sampling theorem, anti-aliasing filters, time and frequency domain analysis, Windowing, signal generation, spectrum analysis, digital filtering.

Case study: Development of VIs for specific application (simulation, real time)

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	
CO2	✓		✓	✓
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5		✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Familiarize with the importance and explore the concepts of virtual instrumentation technology.
2. Understand the hardware-software components, role and applications areas of the LabVIEW.
3. Develop the LabVIEW programming skills to code virtual instruments for solving different problems.
4. Analyze data acquisition, signal processing -analysis, data visualization and connectivity techniques and methods in the LabVIEW for different applications.
5. To design and develop a VI system with the LabVIEW programming for varied real world measurement, testing, control and automation applications

Text Books

1. Wells LK, “LabVIEW for everyone – Graphical Programming made even easier,” Prentice Hall
2. Gupta S and Joseph J, “Virtual Instrumentation using LabVIEW,” Tata McGraw Hill

Reference Books

1. Johnson GW, “LabVIEW graphical Programming- Practical application in instrumentation and Control,” Tata McGraw-Hill
2. Ritter DJ, “LabVIEW GUI- Essential Techniques,” Tata McGraw-Hill
3. National Instruments, “LabVIEW-User Manual,” National Instruments Corporation

IC-507 **Embedded Systems** **[3 0 0 3]**

Syllabus:

Introduction: Concept of embedded systems; comparison with a general computing system; Classification of embedded systems; Challenges with embedded systems; Application areas and purpose of embedded systems; Characteristics and quality attributes of embedded systems

Elements of an Embedded System: A typical embedded system; Core: General purpose and domain specific processors, ASICs, PLDs, CoTS; Memory; Sensors and actuators; Communication interfaces; Embedded firmware; System components: Reset circuit, Brown-out protection circuit, Oscillator unit, RTC, WDT

Designing Embedded Systems with 8-bit Microcontroller-8051: Factors to be considered for selection of a controller; Why 8051 Microcontroller; Designing with 8051 Microcontroller; The 8052 Microcontroller; 8051/8052 variants

Programming the 8051 Microcontroller: Addressing modes; Data transfer, arithmetic and logical instructions; Bit instructions; Jump, Loop and Call instructions; Time delay using instructions; I/O port programming; Timer/Counter programming; Serial communication and programming; Programming of Interrupts and priority of interrupts

Interfacing to 8051 Microcontroller: Interfacing of 7-segment display, LCD and keyboard; Interfacing of DC motor, stepper motor and relay; Interfacing of ADC, DAC and sensors

Advanced Topics: Issues in Hardware-Software Co-Design; Real time tasks, Real time systems and Real time operating systems; Embedded product development life cycle; Society and Ethics

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	
CO2	✓		✓	
CO3		✓	✓	✓
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Identify the different application areas and purpose of embedded systems.
2. Identify the building blocks and analyse their role in an embedded system.
3. Assess the challenges in the development of an embedded system.
4. Develop microcontroller based systems.
5. Perform ethically towards the societal responsibilities.

Text Books

1. Shibu KV, ‘Introduction to Embedded Systems, McGraw Hill Education
2. Mazidi MA, Mazidi JG and Mchinlay RD, “The 8051 Microcontroller and Embedded Systems using assembly and C,” Pearson Education

Reference Books

1. Morton TD, “Embedded Microcontrollers,” Pearson Education
2. Valvano JW, “Embedded Microcomputers Systems: Real Time Interfacing,” Cengage Learning India
3. Ram B, “Advanced Microprocessors and Interfacing,” Tata McGraw-Hill
4. Rajkamal, “Microcontrollers: Architecture, Programming, Interfacing and System Design,” Pearson Education
5. Ray AK and Bhurchavdi KM, “Advanced Microprocessors and Peripherals: Architecture, Programming and Interfacing,” Tata McGraw-Hill

IC-523 Process Control and Instrumentation Laboratory [0 0 3 2]

Syllabus:

1. To control the level of fluid with the help of ON/OFF control system.
2. To study the control loop of a system of a flow control.
3. To find the differential gap of ON/OFF control system.
4. To rig up an electronic proportional controller unit.
5. To rig up an electronic proportional integrated controller unit.
6. To rig up an electronic PID controller and verify its working.
7. To study the characteristics and controller specifications of different types of control valves and other repair and maintenance.
8. To study and obtain Input/Output relationship of a pneumatic relay.
9. To measure flow using rotameter.
10. To measure temperature using thermocouple, RTD and thermistor.
11. To measure the pH value of given solution.
12. Study of characteristics of various transmitters (electronic/pneumatic/ hydraulic etc.).
13. To study the characteristics of different types of pressure, flow, level gauges.
14. To study hardware and software associated with PLC.
15. To understand Simple Ladder program.
16. To develop a ladder program for DOL starter.
17. To develop a ladder program for Automatic Bottle Filling system.

The list of experiments given above is only suggestive. The Instructor may add new experiments as per the requirement of the course.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	
CO2	✓		✓	
CO3		✓	✓	
CO4			✓	✓
CO5	✓	✓		✓

Course Outcome:

After completion of this course, the students would be able to:

1. Familiarize the practical foundations of process control and Instrumentation systems.
2. Understand the practical knowledge of control schemes for typical processes.
3. Analyse and apply the practical implementation of transducers and signal conditioning elements as per the requirements.
4. Analyze and implement the various advanced control strategies in process control industries.
5. Apply the PLC, DCS and SCADA control technique in process control.

Note:

- **At least 8 experiments are to be performed out of the above list**

IC-525 **Virtual Instrumentation Laboratory** **[0 0 3 2]**

Syllabus:

1. Develop a LabVIEW Virtual Instrument to carry out the arithmetic operations on two numbers fed by user and display the result on the front panel.
2. Develop a LabVIEW VI to generate random number and plot it on the uniform chart .The operation is controlled by the user through the ON/OFF switch.
3. Develop a password window to open the front panel of the VI developed in experiment 1.
4. Build a VI that compares two numbers. If they are equal, LED on the front panel turns ON. If they are not, a message box is displayed indicating, which number is greater.
5. Build a VI that displays the temperature value continuously on the uniform chart in red color after one second of time interval when the acquisition is switched on using build-in temperature simulator.
6. Build a VI that uses formula node to evaluate y = sin(x) and graph the result.
7. Build a VI that that takes the average of the 20 temperature vales and displays the result on temperature indicators. Also store the 20 temperature values in the array.
8. Build a VI to plot temperature reading from two simulators on single uniform chart in different colors.
9. Build a VI to save the data generated in experiment 5 in Excel sheet file with each value stamped with date and time.
10. Build a VI to retrieve data stored in experiment 9 in text and graphic mode.
11. Build a VI to read analog input and write analog output to the respective channels of DAQ system.(PCI based, RS-485 based, USB based)
12. Build a VI to switch ON/OFF the LED from the front panel connected to the digital output channel of DAQ system.
13. Build a VI to monitor the input channels of DAQ card.
14. Build a VI to publish live data from one VI to another.
15. Build a VI to use different type of signal analysis functions.

The list of experiments given above is only suggestive. The Instructor may add new experiments as per the requirement of the course.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		✓
CO2	✓	✓	✓	✓
CO3		✓	✓	✓
CO4	✓	✓	✓	✓
CO5		✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Explore the basic concepts, use, implementation and applications of the virtual instrumentation
2. Gain knowledge and expertise in LABVIEW programming to build virtual instruments for any problem.
3. Use the data acquisition platform to interface analog / digital signals for making a VI system for real time measurement.
4. Use the data acquisition platform to interface analog / digital signals for making a VI system for real time control applications.
5. To implement the real-world problems using the virtual instruments and LABVIEW.

Note:

- **At least 8 experiments are to be performed out of the above list**

SEMESTER-II

IC-502 **Industrial Automation and Robotics** **[3 0 0 3]**

Syllabus:

Industrial Automation: Introduction to automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Automated Flow Lines with Storage Buffers, Automation for Material Handling, Conveyor Systems, Automated Guided Vehicle Systems, Automated Storage/Retrieval Systems.

Computer Based Industrial Control: Introduction & Automatic Process Control, Analog & Digital I/O Modules, SCADA System & RTU. PLC and its applications for automation.

Fundamentals of Robotics: Introduction, classification of Robots, History, Advantages and Disadvantages, components of robots, degree of freedom, joints and coordinates, reference frames, workspace, languages and applications, Introduction to mobile robot, introduction to mobile robot mapping and path planning.

Robotic Kinematics and dynamics: Introduction to Forward and inverse kinematics of robots, Frame mapping, relation between the adjacent links, Denavit-Hertenberg representation of forward kinematics of robot, introduction to mobile robot kinematics, introduction to dynamics of manipulator.

Robotic Actuators: Characteristics of actuating systems, Comparison of actuating systems, components of Hydraulic Actuators, Pneumatic Actuators, Electric Actuators.

Sensors for robotics application: Introduction to various sensors used for robotics and automation application, Position sensors, Velocity sensors, Acceleration sensors, Force and pressure sensors, Torque sensors, Laser and IR sensors, Touch and tactile sensors, Proximity sensors, Introduction to multisensor data fusion.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	✓
CO2		✓	✓	✓
CO3	✓	✓	✓	
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand and analyze the fundamentals of industrial automation for modern production system.
2. Understand various strategies of industrial automation and their design and implementation for industrial automation.
3. Study and analyze the role of PLC, DCS and SCADA system for modern industrial automation.
4. Understand the fundamentals of robotics with kinematic and dynamic analysis.
5. Gain knowledge of identification, analyzing and applying robotic actuators to develop the autonomous system for real time problem.

Text Books

1. Craig JJ, “Introduction to Robotics: Mechanics and Control,” Prentice Hall
2. Spong MW and Vidyasagar M, “Robot Dynamics and Control,” Wiley
3. Richard D. Klafter, “ Robotics Engineering an integrated approach”, Prentice hall of India

Reference Books

4. Mittal RK and Nagrath IJ, “Robotics and Control,” Tata McGraw-Hill
5. Amber GH and Amber PS “Anatomy of Automation,” Prentice Hall
6. Viswanandham, “Performance Modeling of Automated Manufacturing Systems” Prentice Hall

IC-504 **Medical Instrumentation** **[3 0 0 3]**

Syllabus:

Human Body Subsystems: Brief description of neuronal, muscular, cardiovascular and respiratory systems; their electrical, mechanical and chemical activities.

Cardiovascular System: Measurement of blood pressure, blood flow, cardiac output, cardiac rate, heart sounds; Electrocardiograph, Phonocardiograph, Plethysmograph.

Respiratory System: Measurement of gas volume, flow rate, carbon-dioxide and oxygen concentration in exhaled air.

Electrical activity in Neuromuscular System and Brain: Neuron potential, muscle potential, electromyography, brain potentials, electroencephalograph.

Medical Imaging: Fundamentals of imaging, Computed tomography, MRI, Nuclear Medicine, Single-photon emission computed tomography, PET, Ultrasonography, Electrical Impedance, Tomography.

Medical Safety: Electrical Safety, Electrical safety codes and standards; Radiation safety, Chemical safety, Biological safety, Fire and explosive safety, Environmental Safety.

Assisting and Therapeutic Equipments: Pacemakers, Defibrillators, Ventilators, Nerve and Muscle stimulators, Diathermy, Heart-Lung machine, Infant incubators, Audio meters, Dialyzers.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2		✓		✓
CO3	✓		✓	✓
CO4	✓		✓	✓
CO5	✓		✓	✓

Course Outcome:

On successful completion of this course the student will be able to:

1. Understand the principles of human physiological measurements.
2. Learn about the techniques used for measurement of Cardiovascular System, Electrocardiograph, Phonocardiograph, Plethysmograph, and Respiratory System.
3. Analyze the recording of the neuromuscular system, brain and electroencephalograph.
4. Analyze and explore the fundamentals of various techniques used for imaging.
5. Explore the concept of medical safety and therapeutic devices.

Text Books

1. Webster JG (Ed.), “Medical Instrumentation, Application and Design,” Wiley India
2. Carr JJ and Brown JM, “Introduction to Biomedical Equipment Technology,” Pearson Education

Reference Books

3. Waugh A and Grant A, “Ross and Wilson Anatomy and Physiology in Health and Illness,” Elsevier
4. Webster JG (Ed.), “Encyclopedia of Medical Devices and Instrumentation,” Vols. 1-4, Wiley
5. Bronzino JD (Ed.), “The Biomedical Engineering Handbook,” CRC Press

IC-506 **Soft Computing Techniques** **[3 0 0 3]**

Introduction: History of development in neural networks, neural network characteristics, Artificial neural network technology, Model of a neuron, topology, learning, types of learning, supervised, unsupervised and reinforcement learning.

Supervised Learning: Basic hop field model, the perceptron, linear reparability, Basic learning laws, Hebb's rule, Delta rule, Widroff and Huff LMS learning rule, correlation-, In star- and out star- learning rules.

Unsupervised Learning: Unsupervised learning, competitive learning, K mean clustering algorithm, Kolwner's feature maps; Basic learning laws in RBF network, recurrent networks, recurrent back propagation, Real time recurrent learning algorithm.

Advanced Neural Network: Introduction to counter propagation networks, ART networks, associative memories, vector quantization, control, fundamentals of CNN, Architecture of CNN, CNN applications; Introduction, Support Vector classification, Support Vector regression, applications.

Fuzzy Logic: Basic concepts of fuzzy logic, Crisp set, Linguistic variable, Membership functions, Operation of fuzzy set, Variable inference techniques, Defuzzification techniques, Basic fuzzy inference algorithm, Application of fuzzy logic, Fuzzy system design, Implementation of fuzzy system, Useful tools supporting design.

Metaheuristics: Introduction to Optimization and Metaheuristics, NFL Theorem, Popular Metaheuristics: Nature and Non-Nature inspired (Evolutionary Algorithms, Physics-based, Swarm-based and Human based algorithms, etc.; Variable Neighborhood Search, Iterated Local Search, Greedy Adaptive Search Procedure, Simulated Annealing, Iterated Greedy, Tabu Search, etc.), Single Solution and Population based search (Single-Objective, Multi-Objective, Index Tracking, Enhanced Index tracking, Project Selection).

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓		✓
CO3	✓	✓	✓	✓
CO4	✓	✓	✓	✓
CO5		✓	✓	✓

Course Outcome:

On successful completion of this course the student will be able to:
1. Know theoretical foundations, concepts, and algorithms of Neural Network.
2. Familiarize the importance of supervised and unsupervised learning techniques.
3. Understand advance neural network architecture and recurrent neural networks for real-time applications.
4. Explore the fundamentals of Fuzzy logic and design of fuzzy logic controller for real time application.
5. Gain practical knowledge to analyze real time optimization problem using popular metaheuristics Libraries.

Text Books

1. Berkin R and Trubatch, "Fuzzy System Design Principles," Prentice Hall
2. Cristianini N and Taylor JS, "An Introduction to Support Vector Machines (and other Kernel – based learning methods)," Cambridge University Press

Reference Books

3. Kosko B, "Nueral Networks and Fuzzy Logic," Prentice Hall
4. Haykin S, "Neural Networks," Pearson Education
5. Anderson JA, "An Introduction to Neural Networks," Prentice Hall
6. Jang JRS, Sun CT and Mizutani E, "Neuro-Fuzzy and Soft Computing – A Computational Approach to Learning and Machine Intelligence," Pearson Education
7. Sivanandam S and Deepa SN, "Principles of Soft Computing," Wiley India
8. Sean Luke, 2013, Essentials of Metaheuristics, Lulu, second edition, available at http://cs.gmu.edu/~sean/book/metaheuristics/

IC-522 Industrial Automation and Robotics Laboratory [0 0 3 2]

Syllabus:

1. To study the pressure pneumatic trainer kit for Industrial automation
2. To design a ladder logic programme for Seal-in-circuit to switch on a motor using push button for automation application.
3. For automation process operate double acting cylinder using manual Pneumatic Push buttons along with mechanical timer for 5 seconds
4. To design a ladder logic program for the automation process to start a motor for 10 seconds after pressing the push button.
5. Write a PLC program to start a motor after counting 5 objects passing on conveyor belt.
6. To study the Pioneer 3-AT mobile robot.
7. To navigate the mobile robot (Pioneer-3AT) for indoor environment.
8. To study the Hydraulic Piston Cylinder for automation applications.
9. To study the DMC 2143 controller working for manipulator control.
10. To study the characteristics of Laser Range Finder sensor for mobile robot applications.
11. To tele-opetare the Pioneer 3AT mobile robot using RoS software.
12. To find out the direct kinematics of the given manipulator.
13. To study the SLAM for the Pioneer 3AT mobile robot.

The list of experiments given above is only suggestive. The Instructor may add new experiments as per the requirement of the course.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	
CO2	✓	✓	✓	
CO3	✓	✓	✓	
CO4	✓	✓	✓	✓
CO5		✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Explore the basic concepts, use, implementation and applications of the Robotics and Industrial Automation
2. Gain knowledge and expertise in ladder logic programming for automation of modern industrial application.
3. Understand and analyse the PLC program for real time modern industrial automation problem.
4. Familiarize the importance of mobile robot and its kinematics, RoS and SLAM environment.
5. To implement the real-world problems such as control of manipulator and actuator, and Laser Range Finder sensor for mobile robot applications.

Note:

- **At least 8 experiments are to be performed out of the above list.**

IC-524 Medical Instrumentation Laboratory [0 0 3 2]

Syllabus:

1. Record Electroencephalogram and demonstrate alpha waves
2. Concept of ECG system and placement of electrodes
3. Record a 12-lead Electrocardiogram
4. Identify arrhythmias from pre-recorded tapes
5. Measure motion artefact from electrodes and from skin
6. Construct an ECG amplifier from components
7. Measure blood pressure using a cuff or Use of sphygmomanometer for measurement of blood pressure
8. pH measurement of given biological sample
9. Measure volume changes by impedance plethysmography
10. Measure lung volumes using a spirometer
11. Measurement of respiration rate using thermistor
12. Concept of EEG system and placement of electrode
13. Delineate various components of ECG waveform
14. Filtering for removal of artefacts
15. Detection of Dicrotic notch in blood pressure waveform
16. Identification of heart sounds

The list of experiments given above is only suggestive. The Instructor may add new experiments as per the requirement of the course.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓		✓	✓
CO3	✓	✓	✓	✓
CO4		✓	✓	✓
CO5		✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Explore the basic knowledge, use and implementation of the electrode placement for recording the bio-signals and their calibration.
2. Gain knowledge and expertise in recording of EMG, EEG, ECG, Blood pressure, heart sounds, respiration rate and volumes.
3. Understand, analyse and inference of above mentioned bio-signals.
4. Understand and analyse the filters for removal of bio-signal artefacts.
5. Realize the different biomedical devices for real-time monitoring and applications.

Note:

- **At least 8 experiments are to be performed out of the above list.**

ELECTIVES

IC-580 **Smart Sensors and Sensor Networking** **[3 0 0 3]**

Syllabus:
Review of Basic Concepts: Measurement system, transducers, sensors and actuators; signal conditioners; data communications and networking.

Basics of Smart Sensors: Definition and architecture of smart sensor; different levels of integration in small sensors, differences between smart, intelligent and network sensors ;advantages of smart sensors ;smart actuators and transmitters.

Smart Sensor Technologies: IC Technologies: thick film, thin film and monolithic IC technologies; Micro-machining processes: materials for micro-machining, wafer bonding, bulk and surface micromachining, other micro-machining techniques.

Examples of Smart Sensors: Principles, characteristics and constructional details of typical smart sensors for temperature, humidity, pressure and vibrations.

Basics of Sensor and Actuator Networking: Field-level, controller-level and enterprise-level networks; Sensor and actuator network (SAN): Network topologies; seven-layer OSI model of communication system.

Wired Network Protocols: RS-422, RS-485, HART and Foundation Fieldbus protocols, comparison with Ethernet (IEEE – 802.3) protocol.

Wireless Network Protocols: Need and advantages of wireless sensor and actuator network(WSAN); Zigbee (IEEE – 802.15.4) protocol, Merits of Zigbee over WiFi (IEEE – 802.11) and Bluetooth for sensor and actuator networking.

IEEE Standard 1451: Introduction to IEEE Standard 1451: “Smart Transducer Interface for Sensors and Actuators”; highlights of parts 1451.1, 1451.2, 1451.3, 1451.4 and 1451.5 of the Standard.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓		
CO3	✓	✓	✓	✓
CO4	✓	✓	✓	✓
CO5		✓	✓	✓

Course Outcome:
After completion of this course, the students would be able to:

1. Explore the basic fundamentals of smart sensor, intelligent sensor, network sensors, hardware schematics, level of integration, transduction principle, functional capabilities of smart and intelligent transducer.
2. Gain knowledge and expertise IEEE 1451 smart transducer interface for sensor and actuator.
3. Understand the functionality and usage of different types of smart/intelligent sensors.
4. Gain knowledge on the concept of networking of sensors, functions of different layers, wired sensor network protocols, and components
5. Realize the tools to implement the various applications of sensor network.

Text Books
1 Patranabis D, “Sensors and Transducers,” Prentice Hall
2 Frank R, “Understanding Smart Sensors”, Artech House

Reference Books
3 Callaway EH, “Wireless Sensor Networks : Architecture and Protocols,” Auerbach Publications
4 Anand MMS, “Electronic Instruments and Instrumentation Techniques,” Prentice Hall
5 William Stallings, “Data and Computer Communications,” Pearson Education
6 IEEE Standard 1451, “Smart Transducer Interface for Sensor and Actuators”

IC-581 **Advanced Measurement Systems** **[3 0 0 3]**

Syllabus:

Intrinsically Safe Measurement Systems: Pneumatic measurement systems: flapper-nozzle, relay, torque balance transmitters, transmission and data presentation, Intrinsically safe electronic systems: the Zener barrier, energy storage calculations.

Heat transfer effects in measurement systems: Introduction, Dynamic characteristics of thermal sensors, Constant-temperature anemometer system for fluid velocity measurements. Katharometer systems for gas thermal conductivity and composition measurement.

Optical measurement systems: Introduction: types of system, Sources: principles, hot body, LED and LASER sources, Transmission medium: principles, optical fibers, Geometry of coupling of detector to source, Detectors and signal conditioning elements: thermal and photon detectors, measurements systems: intensity and wavelength modulation, interferometers.

Ultrasonic measurement systems: Basic ultrasonic transmission link, piezoelectric ultrasonic transmitters and receivers, Principles of ultrasonic transmission: wave properties, acoustic impedance, attenuation, stationary waves, response, Doppler effect, Examples of ultrasonic measurement systems: pulse reflection, medical imaging, Doppler, cross-correlation and transit time flowmeters.

Gas Chromatography: Principles and basic theory, Typical gas chromatograph, Signal processing and operations sequencing.

Data acquisition and communications systems: Time division multiplexing, Typical data acquisition system, Parallel digital signals, Serial digital signals, Error detection and correction, Frequency shift keying, Communication systems for measurement.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓		✓	
CO3	✓		✓	
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Know the theoretical foundations of advanced measurement system with the viewpoints of measurement principle, sensors and signal processing.
2. Understand and analyze the principles of Heat transfer effects, optical and ultrasonic in measurement systems.
3. Familiarize with the importance of suitable transducers such as flow measurement system for fluid mechanics, and Chromatography.
4. Analyze and implement the logical progression with the up-to-date information on this field of research.
5. Analyze and apply the selected problems to illustrate the different concepts clearly.

Text Books

1. Bentley JP, "Principles of Measurement Systems," Pearson Education
2. Doebelin EO, "Measurement Systems – Application and Design," Tata McGraw-Hill

Reference Books

3. Dally, "Instrumentation for Engineering Measurements," Wiley India
4. Northrop, "Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation", Taylor & Francis
5. Radhakrishnan, "Instrumentation Measurements and Experiments in Fluids", Taylor & Francis

IC-582 **Robust and Optimal Control** **[3 0 0 3]**

Syllabus:

Introduction: Norms for signals & systems, Input-Output Relationships, Internal stability, Asymptotic Tracking, Performance.

Modeling of Uncertain Systems: Structured & unstructured uncertainty, linear fractional transformation.

Robust Design Specifications: Small gain theorem, Robust stabilization, performance consideration, structured singular values.

H_∞ Design: Mixed sensitivity H_∞ optimization, 2-degreee of freedom H_∞ design, H_∞ sub optimal solution, Formula for discrete time cases.

H_∞ Loop Shaping Design: Robust stabilization against normalized co-prime factor perturbation, loop shaping design procedures, Formula for discrete time case.

Design for Robust Performance: Modified problem, spectral factorization, solution of modified problem, design.

Calculation of Variations: Fundamental concepts, minimization of functions, minimization of functionals, functional of a single function, functionals involving several independent functions, Piecewise smooth extremals, constrained extremal, Pontryagins minimum principles, control and state variable inequality constraint.

Optimal Feedback Control: Formulation of optimal control problem, selection of performance criteria for minimum time, minimum energy, Minimum fuel, Principle of optimality, Hamilton –Jacobi- Bellman equation, State regulator, output regulator and tracking problems.

Discrete Linear Regulator Problems: Numerical solution of the Riccati equation. Use of linear state regulator results to solve other linear optimal control problems. Sub optimal linear regulators- continuous and discrete time systems. Minimum time problems, minimum control effort problems.

Dynamic Programming: Multi-stage decision process in discrete time, principle of causality and optimality, Multi stage decision process in continuous time. Numerical solution of two-point boundary value problem, .minimization of functions, the steepest decent method.

<u>CO-PO Mapping</u>

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓	✓	
CO3	✓	✓	✓	
CO4		✓	✓	✓
CO5		✓	✓	✓

Course Outcome:
After completion of this course, the students would be able to:

1. Know the theoretical foundations of robust and optical control systems.
2. Understand and analyze the principles of modeling of uncertain systems and robust design specification.
3. Analyze and implement the H-infinity methods to design robust controllers.
4. Familiarize with the importance of optimal control problem and design the optimal controller.
5. Analyze and apply the linear regulator problems in real time control application problems.

Text Books
1. Kemin Zhou, “Essentials of Robust Control”, Prentice Hall
2. Doyle JC, Francis BA and Tannenbaum AR, “Feedback Control Theory,” Macmillan Publishing Company

Reference Books
1. Kirk DE, “Optimal control theory-An introduction,” Prentice Hall
2. Nagrath J and Gopal M, “Control system Engineering,” Wiley Eastern
3. Naidu DS, “Optimal Control Systems,” CRC Press

IC-583 **Power Electronics and Drives** **[3 0 0 3]**

Syllabus:

Review of Power Semiconductor Devices: Power diodes – Power transistors – Characteristics of SCR, TRIAC, Power MOSFET, IGBT, GTO, MCT, LASCR – Thyristor protection circuits – Thyristor triggering circuits – Commutation – Natural, forced commutation.

Converters: Single phase – Three phase – Half controlled – Full controlled rectifiers – Dual converters – Effect of source and load inductance – Cyclo converters - AC regulators.

Inverters and Choppers: Voltage Source inverters –bridge inverters, Current source inverters – voltage and waveform control of inverters. DC choppers – step up and step down – uninterrupted power supplies.

DC Drives: Basic characteristics of DC motor – Operating modes – quadrant operation of chopper – Closed loop control of DC drives.

AC Drives: Induction motor – Performance characteristics – Stator and rotor voltage control, frequency and voltage control – Current Control – Introduction to synchronous motor, stepper motor, switched reluctance motor drives – Basics of vector control.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2		✓	✓	✓
CO3		✓	✓	✓
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand the fundamentals, working principle and operation of power semiconductor devices.
2. Design and analyse the converters, inverters and choppers for specific applications.
3. Familiarise with the importance of design, working and operation of DC and AC Drives.
4. Understand the control techniques design for DC and AC Drives.
5. Apply the knowledge to solve real world applications using Power Semiconductor Device.

Text Books

1. Rashid MH, “Power Electronics,” Pearson Education
2. Dubey GK, “Power semiconductors and Drives,” Prentice Hall

Reference Books

1. Bose BK , “Modern Power Electronics and AC Drives,” Pearson Education
2. Vithyathil J, “Power Electronics: Principles and Applications,” Tata McGraw-Hill
3. Mohan N, Undeland TM and Robbins WP, “Power Electronics,” Wiley India
4. Subramaniam V, “Thyristor control of Electrical Drives,” Tata McGraw-Hill

IC-584 **Sensor Data Fusion** **[3 0 0 3]**

Syllabus:

Introduction: Sensors and sensor data, Limitations of single sensor, Advantages of multisensor data fusion, Multisensor data fusion applications, Data fusion models, Generic fusion architectures

Algorithms for Data Fusion: Taxonomy of algorithms for multi-sensor data fusion. Learning of fusion models: Learning Bayesian classifier, Rule learning from decision three algorithms.

Estimation: Kalman filtering, practical aspects of Kalman filtering, extended Kalmal filters, partical filter, decision level identify fusion, Knowledge based approaches.

Advanced Filtering: 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, Application of multisensor data fusion for mobile robot mapping and Navigation.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	✓
CO3		✓	✓	✓
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand the benefits and shortcomings of various sensing systems used for automotive applications
2. Apply appropriate data fusion techniques to problems in automotive applications.
3. Analyse the intelligent fusion algorithms for automotive applications.
4. Create fusion models for state estimation and localization for automotive applications.
5. Apply the knowledge to solve real world applications using advanced multi sensor data fusion.

Text Books

1. Das SK, “High-level Data Fusion,” Artech House
2. Hall DL, “Mathematical techniques in Multisensor data fusion,” Artech House

Reference Books

1. Brooks RR and Iyengar SS, “Multi-Sensor Fusion,” Prentice Hall
2. Gelb A, “Applied Optimal Estimation,” MIT Press
3. Candy JV, “Signal Processing,” McGraw-Hill
4. Liggins.II, “Handbook of Multisensor Data Fusion”, Taylor & Francis

IC-585 **Data Acquisition and Telemetry** **[3 0 0 3]**

Syllabus:

Data Acquisition System: Definition and generalized block diagram of data acquisition system (DAQ), Classification of DAQ, working principle block diagram, construction and salient features of the following data acquisition systems: Analog data acquisition system using time division multiplexing, Analog data acquisition system using frequency division multiplexing, Digital data acquisition system with different configurations and Data logger.

Introduction to Telemetry: Meanings and importance of telemetry, signal formation, conversion and transmission, general block diagram of telemetry system, classification of telemetry system, signal transmission media: Wires and cables, Power line carrier communication, terrestrial and satellite radio links, optical fiber communication, Multiplexing – TDM, FDM and WDM.

Analog Communication Techniques: Analog communication techniques: analog modulation of AC carrier; amplitude modulation of AM wave and frequency spectrum, frequency modulation and frequency spectrum of FM wave, Phase modulation and frequency spectrum of PM wave. Analog modulation of pulse carrier; basis of PAM, PFM.

Digital Communication Techniques: Digital modulation of pulse carrier, basis of PCM, DCPM; Digital modulation of AC carrier, ASK, FSK, PSK, error detection and correction methods, error control techniques.

Telemetry Systems: Direct voltage and current telemetry system, AM and FM telemetry system, Multi-channel PAM and PWM telemetry system, single and multi-channel digital telemetry system, modem based telemetry system, short range radio telemetry and satellite telemetry system, fibre optics telemetry system.

<u>CO-PO Mapping</u>

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	✓
CO3		✓	✓	✓
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Understand the functionality of different components and configuration of data acquisition system
2. Understand the working and functionality of the Data Logger
3. Gain knowledge on different telemetry systems working principle, design techniques, signal transmission method, media and salient features
4. Gain knowledge on digital communication techniques and applications of single and multiple channel digital telemetry systems
5. Apply the knowledge to solve real world applications related to data acquisition and telemetry problems.

Text Books
1. Karp HR (Ed.), "Basics of Data Communication," McGraw-Hill
2. Tomasi W, "Fundamentals of Electronic Communication Systems," Prentice Hall

Reference Books
1. Gruenberg EL, "Handbook of Telemetry and Remote Control," McGraw-Hill
2. Ginzberg, Lekhtman and Malov, "Fundamentals of Automation and Remote Control," Mir Publishers
3. Rangan CS, Sharma GR and Mani VSV, "Instrumentation Devices and Systems," Tata McGraw- Hill

IC-586 Biomedical Signal Analysis [3 0 0 3]

Syllabus:

Introduction to Biomedical Signals: Nature of Biomedical Signals, Objectives of Biomedical Signal Analysis, Difficulties in Biomedical Signal Analysis, Computer-aided Diagnosis, ECG, PCG.

Filtering for Removal of Artifacts: Random noise, structured noise, and physiological interference, stationery versus nonstationary processes, Noise in the event-related potentials, High-frequency noise in the ECG, Motion artifact in the ECG, Power-line interference in the ECG signals, Maternal interference in fetal ECG, Muscle-contraction interference in VAG signals, potential solution to the problem. Time-domain Filters, Frequency-domain Filters, The Wiener Filter, Adaptive Filters for Removal of Interference, Filter selection.

Event Detection: Detection of Events and Waves, Correlation Analysis of EEG channels, Cross-spectral Techniques, the Matched Filter, Detection of the P Wave, Homographic Filtering, Applications: ECG Rhythm Analysis, Identification of Heart Sounds, Detection of the Aortic Component of S2

Waveshape and Waveform Complexity: Illustration of the problem with Case-studies, Analysis of Event-related Potentials, Morphological Analysis of ECG Waves, Envelope Extraction and Analysis, Analysis of Activity, Applications: Normal and Ectopic ECG Beats, Analysis of Exercise ECG, Analysis of Respiration.

Frequency-domain Characterization: Illustration of the Problem with Case-studies, Estimation of the Power Spectral Density Function, Measures Derived from PSDs.

Modeling Biomedical Systems: Point Processes, Parametric System Modeling, Autoregressive Modeling, Pole-zero Modeling, Electromechanical Models of Signal Generation, Applications: Heart-rate Variability, Spectral Modeling and Analysis of PCG Signals.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	
CO3	✓		✓	✓
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Understand about different types of biomedical signals.
2. Design different filters for removal of various artifacts present in biomedical signals.
3. Perform biomedical signal analysis for diagnosis of various physiological conditions.
4. Propose and solve real-life problems using transformation and classification techniques.
5. Apply the knowledge to solve real world applications related to Biomedical Signal Analysis problems.

Text Books

1. Rangayyan RM, “Biomedical Signal Analysis,” Wiley India
2. Bronzino JD, (Ed.), “Biomedical Engineering Handbook,” CRC Press

Reference Books

1. Reddy DC, “Modern Biomedical Signal Processing,” Tata McGraw-Hill
2. Akay M, “Biomedical Signal Processing,” Academic Press
3. Tompkins WJ (Ed.), “Biomedical Signal Processing,” Prentice Hall

IC-587 **Identification and Adaptive Control** **[3 0 0 3]**

Syllabus:

Introduction: Problems of identification and control estimation problem and classification, Estimation problems for continuous and Discrete case, Linear and nonlinear estimation problems.

Adaptive Control Problem: Introduction, types of representation, Models and mode classifications, Transfer function and impulse response.

Method of Identification: Impulse response identification methods, Least square identification method, method of maximum likelihood, Recursive identification using Least square methods.

Kalman Filtering: Introduction to smoothing, filtering and prediction, Kalman Filter, Application of Kalman filtering algorithm to identification and adaptive controls.

Advances in Adaptive Control: Adaptive control using model reference techniques, self tunning control and self-tracking control.

Applications: Application of state estimation in electromechanical systems, Maximum likelihood estimation for electromechanical systems. Some case studies.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	
CO3	✓	✓	✓	
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Understand the concept of system identification and adaptive control.
2. Understand various system identification techniques and features of adaptive control like Kalman Filtering, STR and MRAC.
3. Explore the knowledge about batch and recursive identification.
4. Design the concept for adaptive control schemes.
5. Apply the knowledge to solve real time control applications.

Text Books

1. Astrom KJ and Wittenmark B, “Adaptive Control,” Pearson Education
2. Landan ID, “System Identification and Control Design,” Prentice Hall

Reference Books

1. Chalam VV, “Adaptive Control Systems – Techniques and Applications,” CRC Press
2. Nagrath IJ and Gopal M, “Control Systems Engineering,” Anshan Publishers
3. Goodwin GC and Sin KS, “Adaptive Filtering Prediction and Control,” Dover Publications
4. Sanchez M, Juan M and Jose R, ”Adaptive Predictive Control for concept to Plant optimization,” Prentice Hall

IC-588 Physiological Control Systems [3 0 0 3]

Syllabus:

Introduction to Human Anatomy and physiology: Basic human anatomy and physiology of the cardiovascular, nervous, muscular, and respiratory systems and their interactions.

Transport mechanisms: Emphasis on the physical and engineering principles governing the systems, various transport mechanisms of ions and molecules, concept of action potential.

Mathematical Modeling: Generalized system properties, Linear model of physiological systems, transfer function, impulse response and convolution concept, computer analysis and simulation, differences between engineering and physiological control systems.

Static Analysis of Physiological Systems: Open loop vs closed loop systems, steady-state operating point, and regulation of cardiac output.

Time Domain Analysis of Linearized Physiological Systems: Open loop and closed loop – transient responses, Descriptions of impulse and step responses for a generalized second order systems, Transient response, Effect of external disturbances and parameter variations.

Frequency Domain Analysis: Steady state response to sinusoidal inputs, graphical representation of frequency response, frequency response of a model of circulatory system, frequency response of general human body.

Stability Analysis of Physiological Systems: Stability and transient response, various approaches of linear system stability analysis, RH – stability criterion, Root locus plots, Bode plot, Polar plot and Nyquist criterion for stability.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2		✓		✓
CO3	✓		✓	✓
CO4	✓			✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Understand and apply the principles of control theory and system analysis to understand the processes involved in physiological regulation.
2. Explore and develop the lumped and distributed parametric based physiological models.
3. Analyze the time, frequency response and stability analysis with evaluation of different applications of physiological control system.
4. Implement and validation of models on a simulation platform.
5. Apply the gained knowledge to solve real time Physiological control applications problems.

Text Books

1. Khoo MCK, “Physiological Control Systems – Analysis, Simulation and Estimation,” Wiley-Blackwell
2. VanDeGraff KM and Rhees RW, “Schaum's Easy Outline of Human Anatomy and Physiology,” Tata McGraw-Hill

Reference Books

1. Ogata K, “Modern Control Engineering,” Prentice Hall
2. Nagrath IJ and Gopal M, “Control Systems Engineering,” Anshan Publishers
3. Friendland B, “Advanced Control System Design,” Prentice Hall

IC-589 **Industrial Instrumentation** **[3 0 0 3]**

Syllabus:

General Measurement System: Measurement system-purpose, structure and elements, static characteristics of measurement system, accuracy of measurement systems in the steady state.

Characteristics of Measurement System: Transfer function, identification of dynamics, dynamic errors, techniques for dynamic compensation, loading effects and two port networks.

Signals and noise in measurement systems: Introduction, statistical representation of random signals, effects of noise and interference, noise sources and coupling mechanisms, methods of reducing effects of noise and interference, reliability of measurement systems.

Sensing Elements: Resistive, capacitive, inductive, electromagnetic, thermoelectric, elastic, piezoelectric and peizoresistive and electrochemical sensing elements.

Signal Conditioning Elements: Deflection bridges, amplifiers, A.C. carrier systems, Current transmitters, oscillators and resonators.

Signal Processing and Data Presentation: ADC, microcomputer system, signal processing calculations, steady state compensation, dynamic digital compensation and filtering, data presentation elements.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓		✓
CO3	✓	✓	✓	
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Understand and apply the fundamentals of measurement and instrumentation systems.
2. Explore the characteristic, error compensation and identification of dynamics of measurement system.
3. Analyze the functioning of sensing elements.
4. Implement the application of signal conditioning elements.
5. To explore and apply the Signal Processing and Data Presentation systems to real time applications.

Text Books

1. Bentley JP, “Principles of Measurement Systems,” Pearson Education
2. Doebelin EO, “Measurement Systems – Application and Design,” Tata McGraw-Hill

Reference Books

1. Dally, “Instrumentation for Engineering Measurements,” Wiley India
2. Northrop, “Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation”, Taylor & Francis
3. Radhakrishnan, “Instrumentation Measurements and Experiments in Fluids”, Taylor & Francis

IC-590 **Human Computer Interfacing** **[3 0 0 3]**

Syllabus:

An Introduction to Human Computer Interfacing: Introduction to Human-computer Interaction, The nature of human-computer interaction. Methodology for Designing User-computer Interfaces:-conceptual, semantic, syntactic, and lexical levels of the design of an interactive system.

Interaction Tasks, Techniques, and Devices: Design of novel interaction techniques, Modes of human-computer communication, Voice, Gesture and Eye movement. P300 based communication, Thought Translation device (TTD), Graz-HCI research, μ-rhythm synchronization and de-synchronization.

BCI Techniques: General Signal processing and machine learning tool for HCI analysis, Spectral filtering, spatial filtering, PCA, ICA, AR modeling, CWT, DWT Classification Techniques: Bayesian Analysis, LDA (Linear Discriminant Analysis) SVM (Support Vector Machine) ANN (Artificial Neural Network)

User Interface Software: Languages and tools for specifying and interfaces, Dialogue independence, UIMS (user interface management system) approach .BCI2000: A general purpose software platform for HCI research.

Applications of HCI: HCI for Communication and motor control, combining HCI and Virtual reality: Scouting Virtual worlds.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓		✓
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the basic concepts of human-computer interaction, modes of communication, implementation and its application.
2. Interface various physiological signals with the external world and the signal processing techniques associated with them.
3. Analyze and implement the various BCI classification techniques to real-world problems
4. Learn different applications of human computer interface.
5. Familiarize with associated research directions and can use it for real-world problems

Text Books

1. Dornhege G, Millan JDR, Hinterberger T, Mcfarland DJ and Muller KR, “Toward Brain-Computer interfacing,” MIT Press
2. Rangayyan RM, “Biomedical Signal Analysis: a case study Approach,” Wiley India

Reference Books

1. Tompkins WJ (Ed.), “Biomedical signal Processing,” Prentice Hall
2. Berger TW, Chapin JK et.al., “Brain-Computer Interfaces-An International Assessment of Research and Development trends,” Springer Science
3. Bronzino JD (Ed.), “The Biomedical Engineering Handbook,” CRC Press

IC-591 **Computer Networks** **[3 0 0 3]**

Syllabus:

Introduction: Uses of Computer Networks, Network Hardware and Software, OSI, TCP/IP Reference Models, Networking Terminology, Internet Evolution**.**
Ethernet Technology: IEEE Standard, Switched Ethernet, fast Ethernet, Gigabit Ethernet, Logical link control Retrospectives on Ethernet.

ATM Networks: Introduction, Reference Model, Routing and Addressing, ATM Signalling, ATM Switching Overview, ATM Traffic Management & Congestion, SS7.

Wireless Networks: Introduction, Wireless LANs, IEEE 802.11 Standard, Physical Layer, MAC sub Layer, 802.11 Frame Structure and Services, ad-hoc networks: Introduction, Proactive and Reactive protocols-AODV, DSR and TORA, performance issues- Quality of Service (QoS).

Bluetooth Technology, Bluetooth Architecture and Applications, Protocol Stack, Radio layer, Baseband Layer, L2CAP Layer, Frame Structure.

Broad Band Wireless Networks: IEEE 802.16 Standard, Comparison of 802.11 with 802.16, 802.16 Protocol Stack, 802.16 Physical Layer, 802.16 MAC sub Layer Protocol, 802.16 Frame Structure and Services.

Sensor Networks: Introduction, topology and Applications.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓		
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the basic concepts, terminologies and technologies used in modern day's data communication and computer networking.
2. Familiarize the basics of wired technologies used in computer networking.
3. Analyze and implement the concepts and basics of various wireless technologies used in modern days computer networking
4. Understand different protocols and network components
5. Familiarize with associated research directions and can use it for real-world problems

Text Books

1. Tananbum AS, "Computer Networks," Pearson Education
2. Forouzan BA, "Data Communication and Networking," Tata McGraw Hill

Reference Books

1. Peterson LN and Davie BS, "Computer Networks: A system approach," Elsevier
2. Walrand J and Varaiya P, "High Performance Communication Networks," Morgan Kauffman
3. Vasseure JP, Picavet M and Demeester P, "Network Recovery Protection and Restoration of Optical, SONET-SDH, IP and MPLS," Elsevier
4. Stalling William, "Wireless communication and networks," Pearson Education

IC-592 System Modeling and Reliability [3 0 0 3]

Syllabus:

System Models and Studies: Concept of a system, system Environment, stochastic Activities, continuous and discrete systems, systems modeling, types of models, Principles used in Modeling, system Analysis & design.

System Representation: Introduction, Block diagram presentation, Standard Block – Diagram, Signal flow graphs, Determination of overall system response using Block diagram and Signal flow for the various inputs.

System Equations: Introduction, Electric circuits and components, Basic linear algebra, state concept, Mechanical Translation system, analogous circuits, Mechanical rotational system.

Probability concepts in simulation: Stochastic variables, discrete probability functions, continuous probability functions, Measures of probability. Functions, numerical evaluation of continuous probability functions, Estimation of mean variances, and Correlation, Random number generator and Properties of Random Numbers.

System Simulation: Step in simulation study, techniques of simulation, comparison of simulation and analytical methods, Experimental Nature of simulation, types of system simulation, Numerical computation Technique for continuous models, Numerical computation technique for Discrete models, Distributed lag models, Real Time Simulation, Selection of Simulation Software, Simulation Packages, Trends in simulation software.

Introduction to system Reliability: Reliability, MTTF, MTBF, failure data analysis, hazard rate, System reliability using: - series configuration, parallel configuration, mixed configuration, Markov model, fault tree analysis. Reliability improvement and maintainability.

Case Studies: Illustrations of problems and case studies using soft computing algorithm.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓		
CO3	✓	✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the needs and applications of computer simulation.
2. Familiarize the basics concepts of mathematical modelling and its representation.
3. Analyze and implement the concepts and basics of mathematical modelling and its representation.
4. Understand the importance of reliability, maintainability and safety aspects.
5. Familiarize with associated research directions and can use it for real-world problems.

Text Books

1. Nagrath IJ and Gopal M, "System Modeling and Analysis," Tata McGraw-Hill
2. Srinath LS, "Reliability Engineering," East West Press

Reference Books

1. Gorden G, "System Simulation," Prentice Hall
2. Law AM and Kelton WD, "Simulation Modeling and Analysis," Tata McGraw-Hill
3. Banks J, Carson JS, Nelson BL and Nicol DM, "Discrete Event System Simulation," Prentice Hall

IC-593 **PLC, DCS and SCADA** **[3 0 0 3]**

Syllabus:

Computer Based Control: Implementing control system using computer or microprocessor; computer based controller: hardware configuration and software requirements.

Distributed Control System: Meaning & necessity of distributed control; hardware components of DCS; DCS S/W.

Introduction to Programmable Logic Controller (PLC): Introduction, PLC vs. microprocessor / microcontroller / computer, advantages & disadvantages of PLC, architecture & physical forms of PLC.

Basic PLC functions: Registers: holding, input & output registers; Timers & timer functions; counters & counter functions

Intermediate PLC functions: Arithmetic functions: addition, subtraction, multiplication, division and other arithmetic functions; Number comparison and conversion.

Data Handling Functions of PLC: Skip function and applications; master control relay function and applications; jump with non-return and return; data table, register and other move functions.

Bit Functions of PLC: Digital bit functions and applications; sequencer functions and applications.

Advanced Functions of PLC: Analog input and output functions, analog input and output modules, analog signal processing in PLC; PID control function, network communication function.

PLC programming: PLC programming languages, ladder programming, mnemonic programming and high level language programming.

SCADA: Supervisory control Vs. distributed control; Layout and parts of SCADA system, detailed block schematic of SCADA system; Functions of SCADA system: data acquisition, monitoring, control, data collection and storage, data processing and calculation, report generation; MTU: functions, single and dual computer configurations of MTU; RTU: functions, architecture / layout; MTU-RTU communication and RTU-field device communication.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓	✓	
CO3		✓	✓	✓
CO4		✓	✓	✓
CO5	✓		✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals of computer based control systems.
2. Familiarize the basics, programming and functioning of PLC and its application in computer based control systems.
3. Analyze and implement the functioning of relay, and PID Control and Ladder logic of PLC.
4. Understand the importance of application of PLC, DCS and SCADA in Distributed computer Control Systems.
5. Familiarize with the Layout, functioning details of SCADA.

Text Books

1. Johnson CD, “Process Control Instrumentation Technology,” Prentice Hall
2. Chemsmond CJ, “Basic Control System Technology,” Viva Books

Reference Books

1. Webb JW and Reis RA, “Programmable Logic Controllers,” Prentice Hall
2. Hackworth JR and Hackworth FD, “Programmable Logic Controllers,” Pearson Edition
3. Boyer SA, “Supervisory Control and Data Acquisition (SCADA),” International Society of Automation

IC-594 **Analytical Instrumentation** **[3 0 0 3]**

Syllabus:

Introduction: Difference between analytical and other instruments, sampling, sampling system for liquids and gases, sampling components, automatic and faithful sampling.

Gas Analysis: Gas Chromatography – principles & components, Thermal conductivity gas analyzers, Heat of reaction method, Estimation of Oxygen, Hydrogen, Methane, CO_2, Carbon monoxide etc. in binary or complex gas mixtures, paramagnetic oxygen analyzer, Electro chemical reaction method, Polarography, Density measurement.

Humidity and Moisture Measurements: Humidity measurement: definitions – absolute, specific, relative humidity and dew point, Dry and wet bulb psychrometer, Hair hygrometer, dew point meter. Moisture Measurement: definitions, electrical methods, NMR method, IR method.

Chemical Composition Measurements: Newtonian and Non Newtonian flow, Measurement of viscosity and consistency, Laboratory and on line methods, Measurement of pH:- definition and methods, redox potential, electrical conductivity, conductivity cell and applications, density measurement: solids, liquids, gages.

Spectrochemical Analysis: Classification of techniques, Principles and components, emission spectrometery:- flame emission, atomic absorption type, Dispersive techniques, scheme for UV, IR and near IR analysis, comparison of methods, X-ray analyzers NMR spectrometry, ESR spectroscopy, Mass spectrometery.

Analytical Electron Microscope: An overview

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓	✓	
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓		✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals of Liquid and gas sampling systems.
2. Familiarize the principle and working of gas analysis instruments.
3. Analyze and implement the principle and working of humidity and moisture measuring instruments.
4. Understand the principle, working and importance of chemical composition measuring instruments.
5. Familiarize with the Principle and working of spectro-chemical analytical instruments.

Text Books
1. Patranbis D, "Principles of Industrial Instrumentation" , Tata McGraw-Hill
2. Jones EB, "Instrument Technology, Vol II", Butterworths Scientific

Reference Books
1. Khare RP, "Analytical Instrumentation an Introduction," CBS Publication
2. Khandpur RS, "Handbook of Analytical Instruments,", Tata McGraw-Hill
3. McMillan GK and Considine D, "Process/Industrial Instruments and Controls Handbook", Tata McGraw-Hill

IC-595 Medical Imaging and Processing [3 0 0 3]

Syllabus:

Introduction: Medical imaging technology, systems, and modalities. Brief history; importance; applications; trends; challenges.

Medical Image Formation Principles: X-Ray physics; X-Ray generation, attenuation, scattering; dose. Basic principles of CT; reconstruction methods; artifacts; CT hardware. Mathematics of MR; spin physics; NMR spectroscopy; imaging principles and hardware; image artifacts. Nuclear Imaging: Imaging methods; mathematical principles; resolution; noise effect; 3D imaging; positron emission tomography; single photon emission tomography; ultrasound imaging; applications.

Medical Image Enhancement: Compensation for nonlinear characteristics of display or print media, intensity scaling, histogram equalization, edge enhancement, denoising, spatial domain and frequency domain methods, adaptive image filtering.

Image Segmentation: Histogram-based methods; region growing and watersheds; Markov random field models; active contours; model-based segmentation. Multi-scale segmentation; semi-automated methods; clustering-based methods; classification-based methods; multi-model segmentation.

Medical Image Analysis: Shape quantification; texture quantification, importance of texture in medical images, geometrical tools for analysis, Gabor filters, gradient based analysis.
Image Registration: Intensity-based methods; feature-based methods; transformation models; spatial domain and frequency domain methods; single modality and multimodality methods; automatic and interactive methods; similarity measures.

Visualization: Fundamentals of visualization; surface and volume rendering/visualization; animation; interaction.

Medical Image Archive, Retrieval and Communication: Picture archiving and communication system (PACS), Radiology Information Systems (RIS) and Hospital Information Systems (HIS); systems and formats: DICOM, teleradiology and telemedicine.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓	✓	
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals principles of important medical imaging modalities: Conventional X-ray, computed tomography, positron emission tomography, magnetic resonance imaging, ultrasound.
2. Familiarize the concepts about characteristics quality of medical images and mathematical techniques for image acquisition and reconstruction.
3. Analyze and implement the important concepts in medical image analysis (including image registration, segmentation, function detection / extraction, filtering).
4. Recognize and interpret characteristic image artifacts in medical images.
5. Critically reflect on and discuss the role of the medical image in healthcare and medical research.

Text Books

1. Webb S, “The Physics of Medical Imaging,” Taylor & Francis
2. Bankman IN, “Handbook of Medical Image Processing and Analysis,” Academic Press

Reference Books

1. Dougherty G, “Digital Image Processing for Medical Applications,” Cambridge University Press
2. Sinha GR, Patel BC, “Medical Image Processing: Concepts and Applications,” Prentice Hall
3. Gonzalez RC, “Digital Image Processing,” Pearson Education
4. Jain AK, “Fundamentals of Digital Image Processing,” Prentice Hall

IC-596 **Power System Operation and Control** **[3 0 0 3]**

Syllabus:

Introduction: Operating States, Preventive and Emergency control, Indian Electricity Grid Code, Co-ordination between different agencies in India.

Load Frequency Control: Introduction, Types of speed governing system and modeling, Mechanical, Electro-hydraulic, Digital electro-hydraulic governing system, Turbine modeling, Generator-load modeling, Steady-state and dynamic response of ALFC loop, the secondary ALFC loop, Integral control.

Multi-control-Area System: Introduction, Pool operation, Two-area system, Modelling the tie line, Static and dynamic response of two area system, Tie-line bias control, State space representation of two-area system, Generation allocation, Modern implementation of AGC scheme, Effect of GRC and speed governor dead-based on AGC.

Excitation System: Introduction, Elements of an excitation system, Types of excitation system, Digital excitation system, modeling.

Optimum Operating Strategies: Introduction, Generation mix, Characteristic of steam and Hydro- electric units, Optimum economic dispatch - neglecting Loss and with transmission loss, Computational steps, Derivation of loss formula, Calculation from Jacobian matrix equation, Economic dispatch for Hydro-thermal plants, Short-term Hydro-thermal scheduling, Hydrothermal co-ordination, Reactive power scheduling.

Unit Commitment: Introduction, Constraints in unit commitment, Thermal unit constraints, Hydro- constraints, Unit commitment solution method - Priority list method, Dynamic programming solution.

Power System Restructuring: Introduction, Regulation vs. Deregulation, Competitive Market for Generation, Advantages of Competitive Generation, Electric Supply Industry Structure under Deregulation in India, Restructuring Models.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	
CO2	✓	✓	✓	
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals of load frequency control and multicontrol area system.
2. Familiarize the concepts about the optimum operating strategies including hydrothermal scheduling techniques, maintenance scheduling and unit commitment.
3. Recognize and interpret the characteristic excitation system.
4. Analyze and implement the concept of power system restructuring.
5. Critically reflect on and discuss the role of the Power System Operation and Control research.

Recommended Text/Reference Books:

1. Elgerd OI, “Electric Energy Systems Theory an Introduction,” McGraw-Hill Book Company
2. Wood, AJ and Wollenberg BF, “Power Generation Operation and Control,” Wiley India
3. Kothari, DP and Dhillon, JS, “Power System Optimization,” PHI Learning Pvt Ltd
4. Kundur P, “Power System Stability and Control,” Tata McGraw-Hill Book Company

IC-597 **Power System Planning and Reliability** **[3 0 0 3]**

Syllabus:

Introduction : Hierarchy of modern power system planning, Brief description about short term and long term planning, Introduction to Reliability Engineering: Definition of reliability, Probabilistic reliability, Repairable and non-repairable items, the pattern of failures with time (non-repairable and repairable items).

Generation expansion planning: fundamentals, Economic analysis, planning including maintenance scheduling.

Network expansion planning: Introduction, Heuristic methods, Mathematical optimization methods. **Reliability**

Mathematics : The general reliability function, The exponential distribution, Mean time to failure and repair, series and parallel systems, Markov processes, System reliability using network and state space method.

Static Generating Capacity Reliability Evaluation: Introduction, Capacity outage probability tables, Loss of load probability (LOLP) method, Loss of energy probability (LOLE) method, Frequency and duration approach.

Spinning Generating Capacity Reliability Evaluation: Introduction, Spinning capacity evaluation, Derated capacity levels.

Transmission System Reliability Evaluation: Average interruption rate method, the frequency and duration approach, Stormy and normal weather effects, The Markov processes approach, System studies.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓		
CO3		✓	✓	✓
CO4	✓	✓	✓	
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals of modern power system planning and reliability.
2. Familiarize the concepts about the static and spinning generating capacity reliability evaluation.
3. Recognize and interpret the basic concepts of Expansion planning and transmission system reliability evaluation.
4. Develop the critical thinking for the mathematical foundation for Power System Planning and Reliability
5. Critically reflect on and discuss the role of the Power System Planning and Reliability.

Recommended Text/Reference Books:

1. Billinton R, “Power System Reliability Evaluations,” Gordon and Breach Science Publishers, New York
2. Wang X and McDonald JR, “Modern Power System Planning,” McGraw-Hill Book Company
3. Endrenyi J, “Reliability Modeling in Electric Power Systems,” John Wiley & Sons, New York
4. Patrick D.T. O'Connor, “Practical Reliability Engineering,” John Wiley & Sons, (Asia) Pvt. Ltd., Singapore
5. Ryabinin I, “Reliability of Engineering Systems - Principles and Analysis,” MIR Publishers, Moscow

IC-598 **Power System Reliability** **[3 0 0 3]**

Syllabus:

Introduction to Reliability Engineering: Definition of reliability, Probabilistic reliability, Repairable and non-repairable items, the pattern of failures with time (non-repairable and repairable items).

Reliability Mathematics: The general reliability function, The exponential distribution, Mean time to failure and repair, series and parallel systems, Markov processes, System reliability using network and state space method.

Static Generating Capacity Reliability Evaluation: Introduction, Capacity outage probability tables, Loss of load probability (LOLP) method, Loss of energy probability (LOLE) method, Frequency and duration approach.

Spinning Generating Capacity Reliability Evaluation: Introduction, Spinning capacity evaluation, Derated capacity levels.

Transmission System Reliability Evaluation: Average interruption rate method, the frequency and duration approach, Stormy and normal weather effects, The Markov processes approach, System studies.

Composite System Reliability Evaluation Considering Interconnection: Service quality criterion, Conditional probability approach, Two-plant single load and two load systems. The probability array for two interconnected systems, Loss of load approach, Interconnection benefits.

Direct Current Transmission System Reliability Evaluation: System models of failure, Loss of load approach, Frequency and duration approach, Spare-valve assessment, multiple bridge equivalents.

<u>CO-PO Mapping</u>

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2	✓	✓	✓	
CO3	✓	✓	✓	
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Explore the fundamentals principles and different methods in power system reliability analysis.
2. Develop the critical thinking for the mathematical foundation for Power System Reliability.
3. Familiarize the concepts about the composite system reliability considering inter-connection and its evaluation.
4. Recognize and interpret the basic concepts of direct current transmission system reliability and its evaluation.
5. Critically reflect on and discuss the role of the Power System Reliability.

Recommended Text/Reference Books:

1. Billinton R, “Power System Reliability Evaluations,” Gordon and Breach Science Publishers, New York
2. Endrenyi J, “Reliability Modeling in Electric Power Systems,” John Wiley & Sons, New York
3. Wang X and McDonald JR, “Modern Power System Planning,” McGraw-Hill Book Company
4. Patrick D.T. O'Connor, “Practical Reliability Engineering,” John Wiley & Sons, (Asia) Pvt. Ltd., Singapore
5. Ryabinin I, “Reliability of Engineering Systems- Principles and Analysis,” MIR Publishers, Moscow

IC-599 **Deep Learning for Computer Vision** **[3 0 0 3]**

Syllabus:

Introduction to Computer Vision: Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution; Visual Features and Representations: Edge, Blobs, Corner Detection; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc.; Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow

Foundation of Deep Learning: Introduction to deep learning, logical computations with neurons, single and multi-layer perceptron, Training a network: different activation functions, softmax, cross entropy loss functions, back propagation and variants of gradient descent.

Deep Networks and Dimensionality Reduction: Fine-tuning neural network hyper-parameters, regularization, batch normalization, VC Dimension and Neural Nets-Deep Vs Shallow Networks, Convolutional Neural Networks, Generative Adversarial Networks (GAN), Semi-supervised Learning, Linear (PCA, LDA) and manifolds, metric learning, Auto encoders and dimensionality reduction in networks.

Deep Learning Architecture: Convolutional layer, Filters, Stacking, pooling layer, Popular Architecture: AlexNet, VGG, Inception, ResNet, C3D, GoogLeNet, EfficientNet, Training a Convnet: weights initialization, Custom Deep Neural Networks, Transfer Learning, vanishing/exploding gradient issues, reusing pre-trained layers, optimizers.

Recurrent neural networks (RNNs): Recurrent neurons networks and Long-Short Term Memory (LSTM) architectures, unrolling, input and output sequences, training RNNs, Deep RNNs, LSTM, GRU cell, Deep Reinforcement Learning.

Introduction to popular Deep Learning Libraries: TensorFlow, PyTorch, Theano, fast.ai, Lasagne, Distributed Keras, Apache MXNet and their implementation on Keras.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓		✓	✓
CO2	✓	✓	✓	
CO3	✓	✓	✓	✓
CO4	✓	✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand the fundamentals of Computer Vision and its real time problem application.
2. Explore and understand the concepts of Deep Neural Network.
3. Familiarise with the importance of dimensionality reduction techniques.
4. Understand deep learning architecture and recurrent neural networks to support real-time applications.
5. Apply the knowledge to solve real world applications using popular Deep Learning Libraries.

Text/Reference Books

1. Geron A., Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems: Using Problem Solving Approach, O'Reilly Media, Second Edition, 2019.
2. Goodfellow I., Bengio, Y., COurville, A., Deep Learning, MIT press, 2017
3. Chollet F., Deep Learning with Python, Manning Publication, First Edition, 2018
4. Atienza R., Advanced Deep Learning with Keras, Packt Publishing, First edition 2018

IC-579 **Cryogenics Instrumentation and Applications** **[3 0 0 3]**

Syllabus:

Basic Theory: Gas kinetic theory, pressure, conductance, gas flow regimes, vapor pressure, pumping speed, throughput. Gas surface interactions: physisorption, chemisorption, condensation.

Vacuum Pumps: Mechanical, diffusion, molecular drag, turbo molecular, cryopumps, ion pumps - general working principles, operating regimes.

Vacuum Instrumentation: Vacuum gauges (Mechanical phenomena gauges –Transport phenomena gauges – Ionization phenomena gauges), gas regulators, flow meters, residual gas analyzers. Problem Solving: Leak detection and detectors, gas signatures.

Vacuum Applications: Freeze drying, packaging, vacuum coating, microelectronics, particle accelerators, distillation, metallurgical processes, television and X-ray tubes, cryogenic insulation, space simulation.

Low temperature – Basic ideas: Low Temperature properties of Engineering Materials, Mechanical properties-Thermal properties- Electric and magnetic properties – Cryogenic fluids and their properties.

Production of low temperature: Liquefaction systems ideal system, Joule Thomson expansion, Adiabatic expansion, Linde Hampson Cycle, Magnetic Cooling.

Cryogenic instrumentation: Pressure, flow-level, and temperature measurements.

Cryogenic fluid storage and transfer systems: Cryogenic Storage vessels

Applications of Cryogenics: Applications in space, Food Processing, superconductivity, Electrical Power, Biology, Medicine, Electronics and Cutting Tool Industry.

Experimental learning modules: Case studies for real time applications problems.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	
CO3	✓	✓	✓	
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand and interpret the concepts of vacuum, classify different orders of vacuum and various units of Pressure.
2. Explore and illustrate the principles of kinetic theory of gases, pressure, particle collisions, velocity and free trajectory, viscous and molecular flow.
3. Familiarise the various types of vacuum pumps, operating principles, designs and limitations in operating at various pressure ranges.
4. Understand and explore the principles of vacuum measurement, some basic vacuum gauges, and their operating principles, designs and their limitations in operating at various pressure ranges.
5. Apply the knowledge to solve the cryogenics related real world applications.

Text Books/References:

1. Harris, Nigel S. Modern vacuum practice. 2007.
2. Roth, A. Vacuum Technology, North-Holland. 1990.
3. Rao, V. V., T. B. Gosh, and K. L. Chopra. Vacuum science and Technology. Vol. 1. Allied Publishers, 1998.
4. R. B. Scott, Cryogenic Engineering, Van Nostrand Co., 1959
5. Randal F. Barron, Cryogenic systems, McGraw Hill, 1986

IC-578 **Biomedical Optics and Biophotonics** **[3 0 0 3]**

Syllabus:

Introduction to biological tissues: Cells as therapeutic agents, cell differentiation, cell division, cell death/apoptosis, Types of tissues and their functions, Light-tissue and biological cell interactions and light induced effects in biological systems.

Conventional biomedical instrumentation: Basic principles of optical imaging systems, Principles of standard optical microscopy (Transmission microscopy, Phase contrast Microscopy, Fluorescence Microscopy, Multiphoton Microscopy, Optical Coherence Tomorgaphy), endoscopy and instrumentation, absorption and fluorescence spectroscopy (Fluorescence spectroscopy, Raman Spectroscopy, SERS, diffuse reflectance spectroscopy)-Instrumentation and applications.

Advanced tomography and nanoscopic techniques: Optical coherence tomography (OCT): Physics, Technology, Imaging Concepts and Applications. Photo-acoustic Tomography (PAT): Principles, Technology, Imaging Concepts and Applications. Optical Tweezers and it's applications in biology, Near field Scanning Optical Microscopy, SIM AND Nanoscopy.

Optical Bio-nano sensors: Principles of optical biosensing, Fiber-optic biosensors, Interferometric biosensors, Surface Plasmon Resonance biosensors.

CO-PO Mapping

CO-PO Mapping	PO1	PO2	PO3	PO4
CO1	✓	✓		
CO2		✓	✓	
CO3	✓	✓	✓	
CO4		✓	✓	✓
CO5	✓	✓	✓	✓

Course Outcome:

After completion of this course, the students would be able to:

1. Understand and interpret the comprehensive concepts of light and biological tissue interaction.
2. Understand and explore the basic and advanced applications of photonics for biomedical diagnosis and therapy.
3. Familiarize the designing, fabrication and standardization of different bio-photonic instruments for research and clinical purposes.
4. Recognize and interpret the basic concepts of tomography, nano-scopic techniques and optical bio nano-sensors.
5. Bride the gap between biomedical researcher, clinicians, and optical instrumentation engineers for advanced interdisciplinary work.

Text Books

1. Valery V. Tuchin, Handbook of Optical Biomedical Diagnostics, Kluwer Academic Publishers, 2004, ISBN: 1402075766
2. Paras N Prasad, Introduction to Biophotonics, John Wiley and Sons, 2003, ISBN: 9780471287704.

Reference Books:

1. R.W. Waynant, Lasers in Medicine, CRC Press, 2002, ISBN: 0- 8493-1146-2.
2. Bernhard O. Palsson, Tissue Engineering, CRC Press 2003.

M.Tech Laboratories

1. Analytical Instrumentation Laboratory
2. Biomedical Instrumentation Laboratory
3. Control Engineering Laboratory
4. Electrical Machines Laboratory
5. Fabrication Unit and Transducers Laboratory
6. Measurement and Circuit Laboratory
7. Microprocessor based Instrumentation Laboratory
8. Computing Laboratory
9. Process Control Instrumentation Laboratory
10. Robotics Laboratory
11. Signal Processing Laboratory
12. Virtual Instrumentation Laboratory

Research Laboratories

1. Human Machine Interface Laboratory
2. Wireless Networks Laboratory
3. Computer Vision Laboratory

ANNEXURE-V

Ph.D Entrance Examination Syllabus based on GATE latest Syllabus 2023

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, consistency and rank, Eigenvalue and Eigenvectors.

Calculus: Mean value theorems, theorems of integral calculus, partial derivatives, maxima and minima, multiple integrals, Fourier series, vector identities, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential Equations: First order equation (linear and nonlinear), second order linear differential equations with constant coefficients, method of variation of parameters, Cauchy's and Euler's equations, initial and boundary value problems, solution of partial differential equations: variable separable method.

Analysis of Complex Variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem, solution of integrals.

Probability and Statistics: Sampling theorems, conditional probability, mean, median, mode, standard deviation and variance; random variables: discrete and continuous distributions: normal, Poisson and binomial distributions.

Numerical Methods: Matrix inversion, solutions of non-linear algebraic equations, iterative methods for solving differential equations, numerical integration, regression and correlation analysis.

Section 2: Electricity and Magnetism

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Section 3: Electrical Circuits and Machines

Voltage and current sources: independent, dependent, ideal and practical; v-i relationships of resistor, inductor, mutual inductance and capacitor; transient analysis of RLC circuits with dc excitation. Kirchoff's laws, mesh and nodal analysis, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems. Peak-, average- and rms values of ac quantities; apparent-, active- and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, locus diagrams, realization of basic filters with R, L and C elements. transient analysis of RLC circuits with ac excitation. One-port and two-port networks, driving point impedance and admittance, open-, and short circuit parameters.

Single phase transformer: equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three phase induction motors: principle of operation, types, performance, torque-speed characteristics, no-load and blocked rotor tests, equivalent circuit, starting and speed control; Types of losses and efficiency calculations of electric machines.

Section 4: Signals and Systems

Periodic, aperiodic and impulse signals; Laplace, Fourier and z-transforms; transfer function, frequency response of first and second order linear time invariant systems, impulse response of systems; convolution, correlation. Discrete time system: impulse response, frequency response, pulse transfer function; DFT and FFT; basics of IIR and FIR filters.

Section 5: Control Systems

Feedback principles, signal flow graphs, transient response, steady-state-errors, Bode plot, phase and gain margins, Routh and Nyquist criteria, root loci, design of lead, lag and lead-lag compensators, state-space representation of systems; time-delay systems; mechanical, hydraulic and pneumatic system components, synchro pair, servo and stepper motors, servo valves; on-off, P, PI, PID, cascade, feedforward, and ratio controllers, tuning of PID controllers and sizing of control valves.

Section 6: Analog Electronics

Characteristics and applications of diode, Zener diode, BJT and MOSFET; small signal analysis of transistor circuits, feedback amplifiers. Characteristics of ideal and practical operational amplifiers; applications of opamps: adder, subtractor, integrator, differentiator, difference amplifier, instrumentation amplifier, precision rectifier, active filters, oscillators, signal generators, voltage controlled oscillators and phase locked loop, sources and effects of noise and interference in electronic circuits.

Section 7: Digital Electronics

Combinational logic circuits, minimization of Boolean functions. IC families: TTL and CMOS. Arithmetic circuits, comparators, Schmitt trigger, multi-vibrators, sequential circuits, flipflops, shift registers, timers and counters; sample-and-hold circuit, multiplexer, analog-to-digital (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (weighted R, R2R ladder and current steering logic). Characteristics of ADC and DAC (resolution, quantization, significant bits, conversion/settling time); basics of number systems, Embedded Systems: Microprocessor and microcontroller applications, memory and input-output interfacing; basics of data acquisition systems, basics of distributed control systems (DCS) and programmable logic controllers.

Section 8: Measurements

SI units, standards (R,L,C, voltage, current and frequency), systematic and random errors in measurement, expression of uncertainty - accuracy and precision, propagation of errors, linear and weighted regression. Bridges: Wheatstone, Kelvin, Megohm, Maxwell, Anderson, Schering and Wien for measurement of R, L, C and frequency, Q-meter. Measurement of voltage, current and power in single and three phase circuits; ac and dc current probes; true rms meters, voltage and current scaling, instrument transformers, timer/counter, time, phase and frequency measurements, digital voltmeter, digital multimeter; oscilloscope, shielding and grounding.

Section 9: Sensors and Industrial Instrumentation

Resistive-, capacitive-, inductive-, piezoelectric-, Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation: displacement (linear and angular), velocity, acceleration, force, torque, vibration, shock, pressure (including low pressure), flow (variable head, variable area, electromagnetic, ultrasonic, turbine and open channel flow meters) temperature (thermocouple, bolometer, RTD (3/4 wire), thermistor, pyrometer and semiconductor); liquid level, pH, conductivity and viscosity measurement. 4-20 mA two-wire transmitter.

Section 10: Communication and Optical Instrumentation

Amplitude- and frequency modulation and demodulation; Shannon's sampling theorem, pulse code modulation; frequency and time division multiplexing, amplitude-, phase-, frequency-, quadrature amplitude, pulse shift keying for digital modulation; optical sources and detectors: LED, laser, photo-diode, light dependent resistor, square law detectors and their characteristics; interferometer: applications in metrology; basics of fiber optic sensing. UV-VIS Spectrophotometers, Mass spectrometer.