GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Diploma

Branch: Biomedical Engineering

Course / Subject Code: DI03003011

Course/Subject Name: Medical Transducers & Actuators

w. e. f. Academic Year:	2024-25
Semester:	3rd
Category of the Course:	ESC

Prerequisite:	Basic Knowledge of Fundamental of Biomedical Engineering
Rationale:	This course introduces students to the principles, characteristics, and applications of transducers and actuators used in medical systems. It equips learners with knowledge to understand, select, and apply appropriate sensors and actuators in diagnostics and therapeutic devices, focusing on accuracy, safety, and innovation in biomedical engineering applications.

Course Outcome:

After Completion of the Course, Student will be able to:

No	Course Outcomes	RBT Level
CO-1	Explain the basic principles, classification, and selection criteria of medical transducers and actuators.	R
CO-2	Describe and analyze different types of actuators and their use in biomedical applications.	U, A
CO-3	Demonstrate understanding of transducers for pressure and flow measurement in medical diagnostics.	U, A
CO-4	Analyze various optical and chemical transducers used in biomedical sensing.	U, A
CO-5	Understand the structure and applications of micro and nano transducers in modern biomedical technologies.	U, A

**Revised Bloom's Taxonomy (RBT)*

GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Diploma

Branch: Biomedical Engineering

Course / Subject Code: DI03003011

Course/Subject Name: Medical Transducers & Actuators

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE (V)	
2	0	2	3	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Fundamentals of Transducers and Actuators**	06	20
	1.1 Introduction to transducers: 1.1.1 Definitions (Measurement, Measurand, Transducer, Sensor, Actuator and Electrode), 1.1.2 Classification: Active vs. passive, analog vs. digital, 1.1.3 Characteristics (static and dynamic): Accuracy, Sensitivity, Linearity, Hysteresis, Drift and Response Time. 1.1.4 Artifacts and Errors (Gross, Systemic and Random) 1.2 Types of actuators: electric, pneumatic, hydraulic, and piezoelectric 1.3 Biomedical application areas for transducers and actuators 1.4 Selection criteria for medical transducers and actuators		
2.	**Medical Actuators and Applications**	06	20
	2.1 Introduction to motors: Servo motors, stepper motors, DC and brushless DC motors 2.2 Linear actuators in medical devices 2.3 Actuators in prosthetics, surgical robots, and infusion pumps 2.4 Pneumatic and hydraulic actuators in rehabilitation devices 2.5 Wireless and remote-controlled actuators 2.6 Safety standards and control mechanisms in medical actuators		
3	**Pressure and Flow Measurement Transducers**	06	20
	3.1 Blood Pressure Measurement Transducers: 3.1.1 Catheter end type transducers 3.1.2 Fiberoptic tip type transducer		

	3.2 Blood Flow Measurement Transducers: 3.2.1 Electromagnetic blood flow meter 3.2.2 Ultrasonic blood flow meter 3.3 Respiratory Flow Measurement Sensors: Elastoresistive transducers for respiratory gas flow measurement		
4.	**Optical and Chemical Transducers**	06	20
	4.1 Optical Transducers: 4.1.1 Photodiodes, 4.1.2 Photomultiplier tubes, 4.1.3 Fiber optic sensors in medical instrumentation 4.2 Chemical and Biosensors: 4.2.1 pH sensors, 4.2.2 Blood gas sensors, 4.2.3 Ion-selective electrodes, 4.2.4 Glucose biosensors and wearable chemical sensors 4.3 Biomedical imaging sensors (basic overview): CCD, CMOS		
5.	**Micro and Nano Transducers**	06	20
	5.1 MEMS-based transducers: 5.1.1 Design, 5.1.2 Working Principles, 5.1.3 Fabrication, 5.1.4 Piezoelectric MEMS, 5.1.5 Capacitive MEMS and 5.1.6 Biomedical Applications 5.2 Nanotechnology in Bio-sensing: Quantum Dots, Nano-Shells, and Nanowires 5.3 Advantages of micro/nano sensors in implantable devices 5.4 Application in lab-on-chip and minimally invasive diagnostics		
	Total	**30 Hrs.**	**100 %**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
40 %	**40 %**	**20 %**	--	--	--

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. R.S. Khandpur – Handbook of Biomedical Instrumentation, McGraw Hill
2. John G. Webster – Medical Instrumentation: Application and Design, Wiley
3. M. Bhattacharya – Transducers and Instrumentation, Oxford University Press
4. M. Gad-el-Hak – MEMS: Introduction and Fundamentals, CRC Press
5. E.O. Doebelin – Measurement Systems: Application and Design, McGraw Hill
6. S. Saliterman – Fundamentals of BioMEMS and Medical Microdevices, Wiley-Interscience

(b) Open-source software and website:

1. LTSpice / PSpice (Circuit Simulation)
2. Scilab (Signal Processing)
3. Arduino IDE (Embedded Actuator Control)
4. Fritzing (Hardware Prototyping)
5. Proteus (Sensor simulations)
6. www.nibib.nih.gov – Biomedical imaging and bioengineering
7. www.ncbi.nlm.nih.gov – Biomedical publications
8. www.arduino.cc – Open-source hardware/software
9. www.allaboutcircuits.com – Sensor basics
10. www.medicaldesignbriefs.com – Design innovations

Suggested Course Practical List: If any

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. hours required.
1	Study and classification of medical transducers and actuators.	1	2
2	Study Static and dynamic characteristic analysis of transducers.	1	2
3	Study and analysis of signal drift and hysteresis in sensors	1	2
4	Test DC motor interfacing with Arduino for actuator control.	2	2
5	Test Servo motor interfacing with Arduino for actuator control.	2	2
6	Test Stepper motor programming for linear motion in medical application.	2	2
7	Demonstrate pneumatic actuator working and safety analysis.	2	2

8	Study application of actuators in prosthetics, surgical robots, and infusion pumps.	2	2
9	Study application of Pneumatic and hydraulic actuators in rehabilitation.	2	2
10	Identify the path used for catheterization method used for blood pressure measurement.	3	2
11	Measure blood pressure using digital blood pressure meter.	3	2
12	Study Ultrasonic blood flow meter.	3	2
13	Study Electromagnetic blood flow meter.	3	2
14	Identify various blood flow meter probes.	3	2
15	Light intensity variation with photodiode and phototransistor	4	2
16	Demonstration of pH and ion-selective electrodes.	4	2
17	Measure glucose using glucose biosensor.	4	2
18	Study Applications of MEMS in medical.	5	2
19	Study Applications of Nano biosensors in medical.	5	2
20	Study about Lab-on-chip applications.	5	2

List of Laboratory/Learning Resources Required:

A. Instruments, Sensors & Actuators

Resource	Purpose/Linked Practicals
Various Medical Transducers (temperature, pressure, force, displacement)	Practicals 1, 2, 3
DC Motor with Motor Driver Module (e.g., L298N)	Practical 4
Servo Motor (SG90 or MG995)	Practical 5
Stepper Motor with Driver (e.g., ULN2003/DRV8825)	Practical 6
Pneumatic Actuator with Manual/Air Pump Demo Kit	Practical 7
Hydraulic actuator demo setup	Practical 9
Digital Blood Pressure Monitor	Practical 11
Catheter BP Transducer Demo Kit (or images/videos if physical model	Practical 10

unavailable)	
Ultrasonic Blood Flow Meter Kit	Practical 12
Electromagnetic Flow Meter Simulation Setup or Virtual Demo	Practical 13
Various Flow Meter Probes (Ultrasonic/EM/Clamp-on types – real/simulated)	Practical 14
Photodiode, Phototransistor, LDR Modules	Practical 15
pH Sensor Module (e.g., SEN0161)	Practical 16
Ion-selective Electrode Set	Practical 16
Glucose Biosensor Kit (or commercial glucometer with test strips)	Practical 17
MEMS Sensors: Accelerometer, Gyroscope (e.g., MPU6050)	Practical 18
Nano Sensor Simulation/Models (Quantum dots, nano-shells – image-based or software simulation)	Practical 19
Lab-on-Chip Demo Model or Video Simulation	Practical 20

B. Microcontrollers and Kits

Resource	Purpose
Arduino UNO/Nano boards (minimum 5 units)	Interfacing motors, sensors (Practicals 4, 5, 6, 15, 17)
Jumper Wires, Breadboards, Power Supply Modules (5V/12V)	Circuit connections
Multimeter	Electrical measurements
Oscilloscope (DSO)	To observe sensor signals and waveform

C. Software Tools (Open Source / Free)

Software	Usage
Arduino IDE	Programming for motor/sensor control
Tinkercad / Fritzing	Circuit simulation and documentation
Scilab / Python (with matplotlib)	Signal plotting and data analysis
Proteus / LTSpice (Optional)	Circuit simulation
COMSOL / NanoHUB (optional)	MEMS/Nano simulation for advanced projects

D. Additional Learning Materials

Item	Purpose
Posters/Charts of Biomedical Sensors and Actuators	For visual learning (Practicals 1, 8, 9, 10)
Component Datasheets (print/digital)	For understanding specifications and interfacing
Safety manuals for actuators and motors	For safe usage in Practicals 4–7
Instructional Videos / Demo Animations (for MEMS, nano, catheterization, etc.)	Practicals 10, 18, 19, 20

Suggested Project List:

The projects serve as practical learning experiences for students in the field of Biomedical Engineering. These projects integrate theoretical knowledge with hands-on application, fostering competency development across various Course Outcomes (COs). Below are guidelines for designing and executing projects:

- **Project Types:**
  - It can be industry-based, internet-based, workshop-based, laboratory-based, or field-based.
  - Each project should align with specific COs and address real-world challenges.
- **CO Integration:**
  - It should encompass two or more COs.
  - Integration involves aligning Program Outcomes (PrOs), Unit Outcomes (UOs), and Assessment and Design Outcomes (ADOs).
- **Project Duration:**
  - Students are encouraged to maintain a dated work diary to document their individual contributions and sufficient engagement time for each project should be allocated by faculty during the course.
- **Seminar Presentation:**
  - Before submission, students must give a seminar presentation on their project.
  - The presentation should highlight the project's objectives, methodology, results, and relevance to industry-oriented COs.

Following are suggestive projects, and additional ones can be tailored to specific course objectives. Encourage students to explore innovative solutions and apply their engineering skills effectively.

- Smart wearable for temperature monitoring
- Arduino-based syringe pump with flow control
- Wireless heart rate and SpO_2 monitoring band
- Smart infusion system with flow alert
- Fall detection MEMS-based wearable
- IoT-based glucose sensor with alert system
- Portable respiratory gas flow monitor
- Actuated prosthetic arm prototype
- Smart chair with pressure sensors for posture tracking
- Real-time blood pressure alerting system

Suggested Activities for Students: If any

In addition to classroom and laboratory learning, students are encouraged to engage in co-curricular activities that enhance their understanding and practical skills. These activities can be conducted in groups and should be documented in 5-page reports. Collecting physical evidence of their work will also contribute to their portfolio, which can be valuable during placement interviews.

- Case study: Failures due to sensor malfunctions in medical devices
- Industrial visit: Medical device manufacturing facility
- Poster Presentation: Latest sensor technologies in diagnostics
- Group Discussion: Ethics in sensor-based patient monitoring
- MOOC/NPTEL: Short course on Biomedical Instrumentation
- Mini Hackathon: Build a biosensing device with Arduino
- Technical Quiz: Based on types and applications of sensors/actuators
- Seminar: Role of MEMS in modern healthcare

* * * * * * *