GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-III

Course Title: Medical Sensors and Measurement Techniques
(Course Code: 4330302)

Diploma programme in which this course is offered	Semester in which offered
Bio-Medical Engineering	Third

1. RATIONALE

Students of diploma Bio-medical engineering need to have a thorough understanding of fundamental concepts and principles of medical sensors to measure various biological parameters.Biomedical sensors are the heart of most of the biomedical instruments and patient monitoring systems. The students will be able to test the functioning of different types of transducers (Sensors), and acquisition of different parameters and signals of body using sensors. This is an important prerequisite for studying biomedical engineeringto meet theexpectations of the industry.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Explain functioning and constructional features of different sensors and electrodes used for sensing various parameters of human body.**
- **Select appropriate sensor for different biomedical equipments.**

3. COURSE OUTCOMES (COs)

The practicalexercises, the underpinning knowledgeand the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

a) Explain the block diagram of Man instrumentation system.
b) Describe various transducer for measurement of different physical parameter.
c) Use relevant pressure and flow transducer for measurement of various physiological parameters.
d) Determine appropriate Temperature and level sensors for measurement of various physiological parameters.
e) Identify suitable biopotential electrode for Medical Signal Acquisition.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
4	0	2	5	30	70	25	25	150

(*):Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken

during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) that are thesub-components of the COs.*Some ofthe **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Identify and rearrange the various blocks of man-instrument system.	1	2*
2	Identify various sensors used in biomedical field.	2	2
3	Test the performance of RTD	2	2
4	Use strain gauge type transducer.	2	2*
5	Use LVDT type transducer.	2	2*
6	Test the performance of capacitive type transducer.	2	2
7	Test the performance of thermocouple.	2	2
8	Measure oxygen saturation of the blood using photoelectric transducer.	2	2
9	Use piezoelectric type transducer.	2	2
10	Identify the path used for catheterization method used for blood pressure measurement.	3	2
11	Identify various blood flow meter probes.	3	2
12	Measure blood pressure using digital blood pressure meter.	3	2*
13	Measure blood pressure using sphygmomanometer and stethoscope.	3,4	2
14	Measure body temperature using mercury thermometer.	4	2
15	Measure body temperature using Infrared thermometer.	4	2
16	Test the performance of thermistor.	4	2*
17	Use electrolyte jelly for measuring bio-potentials.	5	2
18	Use different types of ECG electrodes.	5	2*
19	Use different types of EMG electrodes.	5	2*
20	Use different types of EEG electrodes.	5	2
	Total		**40**

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises**of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare of experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specificationsfor the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	RTD Trainer Kit	3
2	Strain gauge with Unbalanced bridge or load cell based Trainer Kit	4
3	LVDT (Linear Variable Differential Transformer) Trainer Kit	5
4	Thermocouple Trainer Kit	7
5	Pulse Oximeter (Measuring range for SPO2: 70-100% and SpO2 measurement accuracy: 91%--100%, ±1%; 70%--89%, ±2%; ≤70%, unspecified.)	8
6	Piezoelectric Trainer Kit	9
7	Automatic Blood Pressure Monitor (Cuff Size - Fits Arm Circumference (22-32Cm), Power Adaptor, Batteries: 4 AAA Batteries, Memory: Last Reading)	12
8	Sphygmomanometer Mercury (Case: Aluminium, I.D. of glass tube: 2.2±0.1, Scale grading: 2mmHg, Cuff: 023 nylon/cotton cuff 51*14cm or 48*147cm, Measurement range: 0-300mmHg, Bladder: Rubber bladder with two tube, Measurement precision:± 3mmHg, Bulb: Rubber bulb with both valves)	13
9	Stethoscope (Comprises a chest piece connected by a double tube to the headgear with earpieces that are placed into the users' ears, Double cup, with two diaphragms for dual-use (adult and paediatric auscultation) chest piece in zinc alloy, Adult diaphragm Ø: 45,5mm; paediatric diaphragm Ø: 31.5mm, Tube made of PVC and is crack resistant, Tube impervious to outside noises, guaranteeing full transmission of sound, good auditive quality, Tube diameter: outer diameter 10mm, inner diameter 4.8mm. Tube length 560mm, Sensitivity from 3.2dB to 26dB in a range from 50 to 1000Hz for cardiology, Sensitivity 8.1dB in a range from 600 Hz to 1,500Hz for pneumology, Arms: brass-steel with a flexible spring, Removable plastic earpiece, Latex-free.)	13
10	Clinical Mercury Thermometer (Type: Mercury Thermometer, Temperature Range: both 35-45 °C & 95-108 °F, Accuracy: 99.9%,	14

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
	Response Time: 1-2 MINUTES)	
11	Infrared Thermometer (Measurement range: Sensible temperature: 35°C~43°C (95°F~109.4°F), Surface temperature: 0°C~60°C (32°F~140°F), Accuracy: ±0.3°C (±32.54°F), Repeatability: 1% of reading or 1°C, Response time: 500 mSec, 95% response, Spectral response: 5-14 um, Emissivity: 0.95 Preset, Working environment: 15°C~40°C (59°F~104°F), Operating Humidity: 10~95%RH non-condensing, Power Supply: 1.5V AAA*2 Batteries, Typical battery life: 12 hrs, Distance to Spot size 2-5cm)	15
12	Thermistor Trainer Kit	16
13	All types of ECG electrodes	18
14	All types of EMG electrodes	19
15	All types of EEG electrodes	20
16	Digital Multimeter (3-1/2 display, max reading 1999m hand held)	3-7, 9, 16

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample***Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using electrical appliances.
c) Practice environmental friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the studentsand teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics

Unit – I Introduction to Biomedical Instrumentation	1a. Explain the block diagram of 'man instrumentation system'. 1b. Define Measurement, Measurand, Transducer, Sensor, Actuator and Electrode. 1c. Compare Transducer, Sensor, Actuator and Electrode. 1d. Define Accuracy, Precision, Resolution, Sensitivity and Errors (Gross, Systemic and Random). 1e. Enlist the problems encountered while measuring a living system and explain in brief.	1.1 'Man-Instrumentation system': 1.1.1 Components and their functions. 1.1.2 Measurement,Measurand, Transducer, Sensor, Actuator and Electrode. 1.1.3 Characteristics of the Measurement System: Accuracy, Precision, Resolution, Sensitivity and Errors (Gross, Systemic and Random). 1.2 Problems encountered in measuring a living system: such as inaccessibility, variability, lack of knowledge, interaction among physiological systems, effect of transducer on measurement, artifacts, energy limitation.
Unit – II Basic transduction principles	2a. Classify transducers. 2b. Describe working principle of piezoelectric type transducers. 2c. Enlist various applications of piezoelectric transducers and explain any one with example. 2d. Explain basic principle of thermocouple based on thermoelectric transduction principle. 2e. Describe working principle of photoelectric transducer. 2f. Describe the working principles of unbonded wire strain gauge type resistive transducer. 2g. Explain RTD type resistive transducer along with neat diagram. 2h. Elucidate the working of Linear variable differential transformer based on electromagnetic induction principle. 2i. Describe Capacitive type transducer along with neat diagram.	2.1 Transducers: 2.1.1 Classification of transducers Active and Passive transducers 2.2 Transduction principles 2.2.1 Active transducers: piezoelectric transducers, thermoelectric transducers, and photoelectric transducers. 2.2.2 Passive Transducers: resistive transducers, inductive transducers, capacitive transducers.

Unit-III Pressure and flow measurement	3a. Define pressure. Enlist various physiological pressures along with their normal measurement range. 3b. Elucidate catheter end type wire strain gauge pressure transducer used for blood pressure measurement. 3c. Explain fiber optic catheter tip type transducer used for blood pressure measurement. 3d. Enlist various transducers used for blood flow measurements. 3e. Describe working principle of electromagnetic blood flow meter. 3f. Describe working principle of ultrasonic blood flow meter 3g. Enlist various respiratory gas flow transducers. 3h. Describe elastoresistive type transducer used for respiratory plethysmography.	3.1.Pressure and flow rate, units of measurement 3.2 Transducers for Blood pressure measurement: 3.2.1 Catheter end type transducers 3.2.2 Fiberoptic tip type transducer 3.3 Transducers for Blood Flow measurement: Electromagnetic blood flow meter, ultrasonic blood flow meter 3.4 Transducers for Respiratory gas flow measurement: Elastoresistive type transducer
Unit – IV Temperature and Level Sensors	4a. Define Systemic and skin surface temperatures with ranges. 4b. Enlist various units of temperatures. 4c. Differentiate between mercury and digital thermometers. 4d. Describe working principle of thermistor sensor used in digital thermometer. 4e. Elucidate working of infrared thermometers with neat diagram. 4f. Describe working of manometer type level sensor along with medical application. 4g. Describe working of ultrasonic type level sensor with one application.	4.1. Systemic and Skin surface temperatures and Units of temperature measurement. 4.2 Thermometers: Mercury, Digital thermometer with thermistorand Infrared. 4.2.1 Mercury thermometers vs Digital thermometers 4.2.2 Working principle of Infrared thermometers 4.3 Level sensors 4.3.1 Basic working principle of Manometer type level sensor 4.3.2 Basic working principle of ultrasonic type level sensor

Unit – V Biopotential Electrodes	5a. Enlist various biopotentials along with their frequencies and amplitudes. 5b. Describe electrode electrolyte interface using neat diagram. 5c. Describe microelectrodes along with their applications. 5d. Describe various needle electrodes used for EMG measurement. 5e. Elucidate various surface electrodes used for ECG measurement. 5f. Elucidate various electrodes used for EEG measurement. 5g. Give advantages of disposable type electrodes. 5h. State the recycling, disposal processes of used or damaged electrodes.	5.1 Biopotentials 5.2Electrode theory: Electrode-electrolyte Interface 5.3 Types of Electrodes 5.3.1 Micro electrodes 5.3.2 Needle Electrodes 5.3.3 Surface Electrodes 5.3.4 Disposable electrodes 5.4 Recycling, disposal of used or damaged electrodes safely for eco-friendly environment.

***Note**:The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A	Total Marks
I	Introduction to Biomedical Instrumentation	7	8	7	0	15
II	Basic transduction principles	10	4	5	6	15
III	Pressure and flow measurement	10	4	5	6	15
IV	Temperature and Level Sensors	8	4	2	4	15
V	Biopotential Electrodes	7	6	4	5	10
Total		**42**	**26**	**23**	**21**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of theUOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may varyslightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and

prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare specification of medical sensors.
b) Give seminar on active and passive transducers and their applications in medical field.
c) Undertake a market survey of different sensors.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessedusing different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Make demonstrable models to compare Transducer, Sensor, Actuator and Electrode.
b) Make demonstrable models for various types of active and passive transducers.
c) Piezoelectric transducer: Use piezoelectric transducer to make simple power generation model by appling pressure.
d) Build a simple digital thermometer.

e) Disposal of used Disposable electrodes – Compile a report on handling recycling and disposal of used Disposable electrodes with figures, tables and comparative charts and strategies used and suggested.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Biomedical Instrumentation and Measurements	Cromwell Leslie, Fred J. Weibell and Erich A. Pfeiffer	Prentice Hall India Learning Private Limited; 2nd edition orlatest edition, ISBN-10: 8120306538
2	Medical Instrumentation Application and Design	Webster John G., Editor	Wiley; 4th edition orlatest edition ISBN-10: 0471676004
3	Biomedical Sensors and Instruments	Tatsuo Togawa,Toshiyo Tamura, P. Ake Oberg	CRC Press; 2nd edition or latest edition, ISBN-10:142009078X

14. SOFTWARE/LEARNING WEBSITES

a. https://nptel.ac.in/
b. https://swayam.gov.in/
c. www.vlab.co.in
d. https://www.electrical4u.com/electrical-engineering-articles/biomedical-instrumentation/
e. www.efymag.com

15. PO-COMPETENCY-CO MAPPING

Semester III	Medical Sensors and Measurement Techniques (Course Code: 3330304)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency • ***Explain functioning and constructional features of different sensors and electrodes used for sensing various parameters of human body.*** • ***Select appropriate sensor for different biomedical equipments.***							
CO a) Explain the block diagram of Man instrumentation system.	2	1	-	-	-	-	1
CO b) Describe various transducer for measurement of different physical parameter.	2	-	-	3	-	-	1

CO c)	Use relevant pressure and flow transducer for measurement of various physiological parameters.	3	2	2	3	2	1	1
CO d)	Determine appropriate Temperature and level sensors for measurement of various physiological parameters.	3	2	2	3	2	1	1
CO e)	Identify suitable biopotential electrode for Medical Signal Acquisition.	3	2	1	2	2	-	1

Legend: '**3'** for high, '**2**' for medium, **'1'** for low or **'-'** for the relevant correlation ofeach competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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