# GUJARAT TECHNOLOGICAL UNIVERSITY

**Bachelor of Engineering**
**Subject Code: 3140311**
**Semester – IV**
**Subject Name: Fundamentals of Biopotentials**

**Type of course:** Professional Core Course

**Prerequisite:** Human anatomy and physiology, basic physics

**Rationale:** The bioelectric signals such as ECG, EMG, EEG etc. are vital signs considered for primary diagnostic tools for the patient. This course describes the generation of these bioelectric signals which occur because of movement of sodium, potassium, calcium ions across the cell membrane. The course also covers the core physics associated with this movement, the properties of electrodes used to record these bioelectric signals and electrical safety associated with the patient.

**Teaching and Examination Scheme:**

| Teaching Scheme | | | Credits | Examination Marks | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|
| L | T | P | C | Theory Marks | | Practical Marks | | |
| | | | | ESE (E) | PA (M) | ESE (V) | PA (I) | |
| 3 | 0 | 2 | 4 | 70 | 30 | 30 | 20 | 150 |

**Content:**

| Sr. No. | Content | Total Hrs | % Weightage |
|---|---|---|---|
| **1** | Introduction to Physiological systems of the body, The Origins of Biopotentials, Medical Instrumentation System, Electrical activity of excitable cells- Resting states, Nernst equation, G-H-K equation, Active states, Network equivalent circuit of nerve/ skeletal fiber, properties of action potentials, propagation of the action potential | **08** | **15** |
| **2** | Review of biopotentials, Electrode as a bioelectric transducer, The electrode-electrolyte interface, Polarizable and nonpolarizable electrodes, Half-cell potential, Electrode behavior and circuit models, The electrode-skin interface and Motion artifact, Body-surface recording electrodes, Internal electrodes, Electrode arrays, Microelectrodes | **10** | **25** |
| **3** | Generation of ECG, Electrocardiography, The ECG waveform & Wigger's diagram, The standard ECG lead system, Characteristics of Electroencephalogram (EEG), EEG electrodes and the 10-20 system, Physiology of Electromyogram (EMG), EMG electrodes, Electroneurogram (ENG), Electroretinogram (ERG) | **08** | **15** |
| **4** | Introduction to ion distributions, $Na^+$ and $K^+$ distributions, $Cl^-$ distributions, $Ca^{2+}$ distribution, Exchange and pumping, (Na-K) ATPase Pump, Diffusion and diffusion coefficient, Permeability coefficient, Circuit analysis for cell membrane, | **08** | **25** |

| | | | |
|---|---|---|---|
| | Estimation of $P_K$ from Flux Measurements, Estimation of the $P_{Na}/P_K$ from membrane potential measurements, Calculations of $P_{Na}$ from $P_K$ and $P_{Na}/P_K$ | | |
| **5** | Physiological effects of electricity, Important susceptibility parameters, distribution of electric power, Macroshock and Microshock hazards, Capacitive and Inductive crosstalk, EM coupling and interference, grounding considerations, shielding theory and techniques, Mechanisms for Cooling, Mechanisms for Cooling, Design of Heat Sink Selection, Input Guarding, Electrical- Safety codes and standards, Basic approaches to protection against shock | **08** | **20** |

**Suggested Specification table with Marks (Theory):**

| **Distribution of Theory Marks** | | | | | |
|---|---|---|---|---|---|
| R Level | U Level | A Level | N Level | E Level | C Level |
| **15%** | **20%** | **15%** | **15%** | **20%** | **15%** |

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

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

**Reference Books:**

1. J.G. Webster (ed.): **Medical Instrumentation: Application and Design**, 4th ed., John Wiley & Sons, Inc., 2010
2. N. Sperelakis: **Electrogenesis of Biopotentials: In the Cardiovascular System**, Springer Science+ Business Media, LLC, 1995
3. R.D. Barr & R.L. Plonsey : **Bioelectricity: A Quantitative Approach**, Academic Press, N.Y., 1988.
4. E.R. Kandel & J. Schwartz (ed.): **Principles of Neural Science**, 3rd ed., 1991.
5. J.J.Carr & J.M.Brown: **Introduction to biomedical equipment technology**, 4th edition, Pearson Publications,
6. R. S. Khandpur: **Bio-medical instrumentation: Technology and Applications**, 2nd edition, Mcgraw Hill, 2003

**Course Outcomes:**

| **Sr. No.** | **CO statement** | **Marks % weightage** |
|---|---|---|
| CO-1 | To understand the origin of the biopotential signal and its propagation | 25 |

| | | |
|---|---|---|
| CO-2 | To evaluate the properties of electrodes used for recording and stimulating purpose | 20 |
| CO-3 | To analyze and understand the bioelectric signals such as ECG, EMG, EEG, etc. | 20 |
| CO-4 | To evaluate the ion distributions and ion pumps across the cell membrane | 20 |
| CO-5 | To understand the electrical safety and physiological effects of electric current and shock hazards. | 15 |

**List of Experiments:**

1. To analyze the circuit for the cell membrane.
2. To simulate the generate of an action potential using MATLAB.
3. To understand the different electrodes used in biopotentials measurements.
4. To study the generation and measurement of Electrocardiogram.
5. To understand the generation and measurement of Electromyogram.
6. To understand the generation and measurement of Electroencephalogram.
7. To determine the permeability coefficient for sodium and potassium channel.

**Major Equipment:**

Computers, simulation software (MATLAB), ECG measurement system, EMG acquisition system, EEG with 10-20 lead system

**List of Open Source Software/learning website:**

https://nptel.ac.in/courses/102104062/16
http://vlab.amrita.edu/index.php
https://www.egr.msu.edu/classes/ece445/mason/Files/