# GUJARAT TECHNOLOGICAL UNIVERSITY

**Bachelor of Engineering**
**Subject Code: 3160314**
**Semester – VI**
**Physiological Systems Modeling**

**Type of course:** Professional Elective Course - II

**Prerequisite:** Human anatomy and physiology, Control system & analysis, Physics, Higher Engineering Mathematics

**Rationale:** The purpose of this course is to acquaint each student with the knowledge of modelling a physiological system and enable them to and thereby enable them to understand its interactions with various other system, and dependency on various conditions affecting its stability & behavior.

**Teaching and Examination Scheme:**

| Teaching Scheme | | | Credits | Examination Marks | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|
| | | | | Theory Marks | | Practical Marks | | |
| L | T | P | C | 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. | **Basic Concepts of Physiological System:** System Analysis: Fundamental Concept, Example of Physiological Control System Analysis: Muscle stretch reflex, Contribution to interrelated system, Adaptive Characteristic; Engineering system and physiological system, Science of Modeling, Classification of Models. Mathematical Modeling, Generalized System variables & Properties, Compliance and their analogy. Lumped and Distributed Parameter models, Linear Systems and the Superposition Principle. | 6 | 15 |
| 2. | **Steady State Analysis of Physiological System:** Close loop versus open loop system, Steady state analysis of Muscle stretch reflex using SIMULINK. Regulation of Cardiac output, Regulation of Glucose – Insulin regulation, Chemical regulation of Ventilation. | 10 | 18 |
| 3. | **Time & Frequency Domain Analysis of Linear Control Systems:** Time domain analysis of Respiratory mechanics, open loop and closed loop model of lung mechanics, Descriptors of Impulse and Step Responses, Transient response analysis using MATLAB, Model of neuromuscular reflex motion, Analysis of linearized lung mechanics model, Analysis of Model of Circulatory Control system, Analysis of Glucose-Insulin Regulation. | 11 | 25 |

| | | | |
|---|---|---|---|
| 4. | **Stability Analysis - Linear approach:** Stability and transient response, Routh- Hurwitz stability criterion, Root Locus Plots, Bode Plots, Nyquist criterion for stability, Stability analysis of pupillary light reflex, Model of cheyne-stokes breathing model and its stability analysis. | 5 | 15 |
| 5. | **Models of Neuronal Dynamics:** Hodgkin and Huxley's model of generation of action potential, The Bonhoeffer-van der Pol Model.<br><br>**Complex Dynamics in Physiological Control Systems:** Concept of Spontaneous Variability, Model of cardiovascular variability, Coupled Nonlinear Oscillators – Model of Circadian Rhythm. Closed loop systems for Sleep Apnea Model.<br><br>**Eye Movement Model:** Types of Eye movement, Various indices & characteristics of saccadic eye movement, Wetheimer's Saccadic Eye Movement Model, Robinson's Model, Oculomotor muscle model. | 13 | 27 |
| | **TOTAL HOURS** | **45** | 100% |

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

| Distribution of Theory | | | | | |
|---|---|---|---|---|---|
| **R Level** | **U Level** | **A Level** | **N Level** | **E Level** | **C Level** |
| 15 % | 20 % | 25 % | 30 % | 10 % | - |

**Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels**

**(Revised Bloom's Taxonomy)**

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

**Reference Books:**

1. Michel C Khoo, Physiological Control Systems -Analysis, simulation and estimation, Prentice Hall of India, 2001.
2. Joseph D, Bronzino, "The Biomedical Engineering Handbook", CRC Press, 3rdedition, 2006.
3. Christof Koch, "Biophysics of Computation", Oxford University Press, 28-Oct-2004.
4. Modeling and Simulation in Medicine and the Life Sciences (2nd Edition), by F.C. Hoppensteadt and C.S.Peskin, Springer (2002) ISBN: 0-387-95072-9.
5. John D. Enderle, "Model of Horizontal eye movements: Early models of saccades and smooth pursuit", Morgan & Claypool Publishers, 2010.

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**Course Outcome:**

After learning the course, the students should be able to do:

| Sr.No. | CO Statements | Marks Weightage % |
|---|---|---|
| CO-1 | Understand the roles and relationship of components, variables, parameters and characteristics of physiological system with respect to engineering control system. | 15 |
| CO-2 | Analyze various physiological systems in context of open-close loop and steady state analysis. | 18 |
| CO-3 | Translate the understanding of physiological function into a mathematical model in time and frequency domain | 25 |
| CO-4 | Apply the knowledge of characteristics of physiological systems for the stability analysis. | 15 |
| CO-5 | Illustrate the application of modelling on various complex physiological control systems | 27 |

**List of Experiments: (Outlines)**

1. Design Lumped and Distributed SIMULINK model for simple lung mechanism (for various abnormality).
2. Design a SIMULINK model for steady-state analysis of muscle stretch reflex.
3. Design a SIMULINK model for steady-state model of chemical regulation of ventilation.
4. Design a SIMULINK model of neuromuscular reflex model.
5. Design a SIMULINK model for compute time & frequency response of respiratory sinus arrhythmia (Saul model).
6. Design a SIMULINK model to compute time & frequency response of glucose-insulin regulation (Stolwijk and Hardy model).
7. Design a SIMULINK model of simplified and linearized version of Hodgkin-Huxley model.
8. Design a SIMULINK model of the Bonhoeffer-van der Pol Model.
9. Design a SIMULINK model for cardiovascular variability.
10. Design a SIMULINK model for Kronauer circadian rhythms model.

**Design based Problems (DP)/Open Ended Problem:** Physiological system design for various parameter variations as per stable and unstable conditions.

**Major Tools:** MATLAB and SIMULINK.