GUJARAT TECHNOLOGICAL UNIVERSITY

BIO-MEDICAL ENGINEERING (03)
MODELLING & SIMULATION OF PHYSIOLOGICAL SYSTEMS
SUBJECT CODE: 2150305
B.E. 5th SEMESTER

Type of course: Core

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 & behaviour.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		PA (V)		PA (I)	
					PA	ALA	ESE	OEP		
3	0	2	5	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1.	**Basic Concepts Of Physiological System:** Introduction to physiological system and mathematical modelling of physiological system, classification of model – grey box & black box, parametric & non parametric, lumped & distributed models, linear & non-linear, characteristics of models. Purpose of physiological modelling and signal analysis, linearization of nonlinear models. Engineering system and physiological system, System variables & properties- Resistance, Compliance & their analogy.	6	15%
2.	**Linear Model:** respiratory mechanics & muscle mechanics. Voltage clamp experiment - Hodgkin and Huxley's model of action potential, model for strength-duration curve, model of the whole neuron.	5	10%
3.	**Cardio-Pulmonary Modelling:** Cardiovascular system and pulmonary mechanics modelling and simulation, Model of Cardiovascular Variability, Model of Circadian Rhythms.	7	12%
4.	**Time-Domain Analysis of Linear Control Systems:** Time domain analysis – Introduction to first order and second order model -Respiratory mechanics – open loop and closed loop model of lung mechanics – First order model – impulse and step response – Second order model – Impulse response – undamped, under damped, critically damped, and over damped behaviour – Method of obtaining step response from impulse response – Transient response descriptors – Model of neuromuscular reflex motion – Transient response analysis using MATLAB.	6	10%
5.	**Steady State Analysis Of Physiological System:** Close loop verses 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. Case study: Stability Analysis of the Pupillary Light Reflex, Model of Cheyne-Stokes Breathing	10	20%
6.	**Frequency Domain Analysis:** Frequency response analysis of linearized lung mechanics, circulatory control system, glucose insulin regulation by MATLAB tool	5	25%
7.	**Eye Movement Model:** Types of Eye movement, Eye movement system and Wetheimer's saccade eye model. Robinson's Model, Oculomotor muscle model, Linear Reciprocal Innervations Oculomotor Model.	6	8%
	TOTAL HOURS	45	100%

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15%	**30%**	**30%**	**15%**	**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.

Course Outcome:

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

1. Build on a basic understanding of physiology (from pre-requisites) to develop a more indepth level of understanding that will enable engineering analysis of selected physiological systems.
2. Be able to translate the understanding of physiological function into an engineering model based on block-diagram analysis of a dynamic system whose function is based on a differential equation.
3. Develop skill in applying a high-level engineering tool for block diagram modeling (SIMULINK).
4. Be able to apply engineering models of physiological systems to answer questions relevant to the design of biomedical engineering devices or processes.
5. Be able to apply basic principles of steady-state and dynamic negative feedback control to physiological systems.
6. Be able to recognize the difference between the roles of variables and parameters in a model.
7. Be able to break down a complex physiological system into the function of its component subsystems, and then build an engineering model based on subsystems.

List of Experiments: (Outlines)

1. Design Lumped and Distributed SIMULINK model for simple lung mechanism.
2. Design a SIMULINK model for steady-state analysis of muscle stretch reflex.
3. Design a SIMULINK model for steady-state respiratory control.
4. Design a SIMULINK model of neuromuscular reflex model.
5. Design a SIMULINK model to compute frequency response of linearized lung mechanics model.
6. Design a SIMULINK model to compute frequency response of glucose-insulin regulation (Stolwijk and Hardy model).
7. Design a SIMULINK model for respiratory sinus arrhythmia (Saul model).
8. Design a SIMULINK model of simplified and linearized version of Hodgkin-Huxley model.
9. Design a SIMULINK model for cardiovascular variability. (stroke volume constant)
10. Design a SIMULINK model for cardiovascular variability. (stroke volume variable)
11. 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 Equipment: MATLAB and SIMULINK.

Active Learning Assignments: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.