BME-511 **PHYSIOLOGICAL CONTROL SYSTEMS** **Fall 2021**

Instructors: Dr Michael Khoo khoo@usc.edu Off Hrs & Loc: **Tu 5-6 pm, W 11-12pm**
Dr Nathan Cho chonatha@usc.edu Off Hrs & Loc: **Tu 3-5 pm**
Teaching Asst: Colin Cess cess@usc.edu Off Hr & Loc: **Th 4-5 pm**

Class Meetings: Lectures **M & W 3:30–5:20p (OHE-132)** Discussion **M 2:00-2:50pm (OHE-100D)**

Course Goals: To highlight the basic analytical techniques employed in control theory, systems analysis and model identification, and to demonstrate how these quantitative principles can be applied to obtain an improved understanding of the dynamic processes involved in physiological regulation.

Preparation: Knowledge of Ordinary Differential Equations, Laplace Transforms, and Matlab programming

Learning Objectives: Upon successful completion of this course, the student should be able to:

- Develop simple mathematical models of physiological control systems
- Apply the basic analytical techniques in control theory to determine the dynamic characteristics of linear closed-loop systems
- Apply basic system identification methods to estimate the parameters of physiological models
- Analyze and simulate the dynamics of simple nonlinear oscillators, neuronal models and closed-loop nonlinear systems with delayed feedback
- Use MATLAB and SIMULINK software to analyze and simulate models of physiological systems

LECTURE SCHEDULE: *(Superscripts refer to chapters in the textbook for assigned reading)*

Color code for Lecturer: Dr. Khoo / Dr. Cho / Both / Dr. Leonardo Nava-Guerra (Medtronic Diabetes)

Aug.	23 & 25	Intro to Physiological Control Systems[K1], Review of Linear Systems ***(HW#0 assigned 8/25)***
	30 & 1	Modeling dynamic systems[K2] ***(HW#1A assigned 8/30)***
Sep.	6 & 8	***LABOR DAY (Sep.6)***; Dynamic models: examples of analog conversions[K2]
	13 & 15	Static Analysis of Closed-Loop Systems[K3] ***(HW#1B assigned, HW#1A due 9/13)***
	20 & 22	Time-domain analysis[K4]; Frequency-domain analysis [K5] ***(HW#2A assigned 9/20)***
	27 & 29	Review/Discussion ***(HW#1B due 9/27)***; **Quiz #1 (9/29)**
Oct.	4 & 6	Computational modeling and simulation of physiological systems[K4] ***(Project A assigned)***
	11 & 13	Stability Analysis of Linear Systems-I [K6] ***(HW#2A due 10/11, HW#2B assigned)***
	18 & 20	Stability analysis-II; Frequency Response & Stability – worked examples
	25 & 27	Review/Discussion ***(HW#2B due 10/25)***; **Quiz #2 (10/27)**
Nov.	1 & 3	Nonlinear Analysis: Phase Plane [K10]; Nonlinear oscillators[K10] ***(HW#3 assigned 11/1)***
	8 & 10	Describing functions[K10]; System identification - I [K8] ***(Project B assigned 11/10)***
	15 & 17	Continuous Glucose Monitoring and Current Developments in Diabetes Therapeutics
	22 & 24	System Identification – II[K8]; ***THANKSGIVING Break (Nov.24)***
	29 & 1	Review/Discussion ***(HW#3 due 11/29)***; **Quiz #3 (12/1)**
Dec.	13 (Mon)	***Reports for Projects A&B due @ 5 pm***

GRADING SCHEME:

Homework (1A,1B,2A,2B,&3):	10%
Quizzes #1, #2 & #3:	lowest 15%; middle 25%; highest 30%*
Projects A&B:	20%

(* The lowest quiz score is weighted 15%, the highest 30% and the one in between is weighted 25%)

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DISCUSSION SCHEDULE: (Every Monday 2:00 – 2:50 pm, starting Aug. 30)

Aug. 30	HW#0 (Linear systems review)	Oct. 18	Questions: Freq resp & Stability analysis
Sep. 6	No class (Labor Day)	Oct. 25	HW#2B
Sep. 13	HW#1A	Nov. 1	Review of Quiz #2
Sep. 20	Questions: dynamic models, static analysis	Nov. 8	Questions: nonlinear analysis
Sep. 27	HW#1B	Nov. 15	No class
Oct. 4	Review of Quiz #1	Nov. 22	Questions on HW#3
Oct. 11	HW#2A	Nov. 29	HW# 3

EXAM/QUIZ DATES: **(All dates are Wednesdays)**

Quiz #1: Sep. 29; Quiz #2: Oct. 27; Quiz #3: Dec. 1

Recommended Reading and Supplementary Materials

The primary textbook used for this course is:

Khoo: Physiological Control Systems – Analysis, Simulation and Estimation 2nd Ed., Wiley/IEEE Press, 2018 (ISBN: 978-1-119-05533-4).

Other useful references include:

Dorf and Bishop: Modern Control Systems, 13th Ed., Pearson Education Pub., 2016.

Lathi and Green: Linear Systems and Signals, 3rd Ed., Oxford University Press, 2017.

Description and Assessment of Assignments

Homework: The homework assignments each consists of quantitative problems related to the topics covered in the lectures, and are aimed at solidifying the student's understanding of the concepts introduced in the lectures. Students are allowed to discuss and work on these assignments in collaboration with their peers. Homework "groups" can consist of 1 to 3 people.

Projects: To provide a stronger appreciation and "hands on" experience of how the concepts and methodologies covered in this course can be applied to solve problems in physiology, the student will work on 2 projects. These projects may be considered additional homework assignments that are more open-ended and require solution employing Matlab/Simulink programming. Submission of project reports will be done through the same "groups" established for homework assignments (see "Homework" above).

Exams: There will be 3 quizzes throughout the semester, spaced roughly a month apart. These will be open-book tests consisting of quantitative problems and short essay questions (duration of each quiz = 75 mins). Students who are not able to take any of these quizzes due to medical or other emergency must notify one of the instructors before the exam via email (**khoo@usc.edu or chonatha@usc.edu**). Make-up quizzes may be administered in cases where a valid excuse (e.g., medical/emergency) is given.

Discussion sessions

A 50-min discussion section is held every week on Monday (except 8/23, 9/6 and 11/15), led by the TA, to answer questions related to the assigned homework and the lecture contents presented the week before. This session is meant to be interactive, and students are encouraged to ask questions that would help enhance their understanding of the class material.

Technological Proficiency and Hardware/Software Required

All students have real time access to the course lectures (slides and video recordings) through the DEN website (https://courses.uscden.net). A key objective of this course is for students to learn how to develop computational models of physiological regulation using MATLAB/Simulink. To accomplish this objective, in addition to material covered in the lectures, hands-on exploration sessions focused on physiological modeling will be held during the latter part of some of the lecture periods. Students are expected to have had previous experience using MATLAB/Simulink, but the Discussion sessions can be used to help those who are not so familiar with MATLAB/Simulink programming to reacquaint themselves with the basics. MATLAB/Simulink is available to students from the university without charge:
https://www.mathworks.com/academia/tah-portal/university-of-southern-california-623588.html

Online resources for Matlab/Simulink include the following sites:

Matlab tutorials:

1. https://www.mathworks.com/support/learn-with-matlab-tutorials.html
2. https://matlabacademy.mathworks.com/

Simulink tutorials:

1. https://www.mathworks.com/academia/student_center/tutorials/sltutorial_launchpad.html?s_tid=ac_sim_tut_til
2. https://www.mathworks.com/products/simulink.html?s_tid=hp_products_simulink

NOTES:

(1) The quizzes are all open-book, open-notes. A table of Laplace transforms will be provided if there are questions that require analyses that use transforms.

(2) The Homework sets and Projects are done on a group basis, but you can opt to form a "group" consisting of only yourself – or you can form a group consisting of up to 3 people (including yourself). All members in the group will receive the same grade, so you should all participate equally.

(3) Homework solutions and Project reports should be submitted on time (**by the time noted on the date due – homework solutions are generally due by Monday @ noon**). Late homework submissions will be penalized at the rate of **50% per day** and will not be graded >1 day late. Late Project Reports will **NOT** be graded. Each group will need to submit only **one** set of homework solutions as a PDF file. Similarly, each group will need to submit only one project report. Project reports should be submitted in the form of a Zip folder, containing the PDF report and any Matlab/Simulink code or data files used.

(4) Cheating/plagiarism will not be tolerated under any circumstances. Please refer to the following links for further information regarding academic integrity:
https://sjacs.usc.edu/students/academic-integrity/
https://policy.usc.edu/student/scampus/

Disability Statement:

Students requesting academic accommodations based on a disability are required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP when adequate documentation is filed. Please be sure the letter is delivered to me within the first few weeks of the semester. For more information, please go to http://dsp.usc.edu.