Biomedical Engineering 301 – Analysis of Physiological Systems - Fall 2019

Lectures: **10:35 am - 11:50 am Tuesday and Thursday, 101 Chambers Building**

Computer Lab - 116 Chemical and Biomedical Engineering (CBE) Building:

Section 1	**Monday**	**3:35-5:30 pm**
Section 2	**Tuesday**	**3:35-5:30 pm**
Section 4	**Monday**	**1:25-3:20 pm**

Instructor
Raj Kothapalli, PhD
Assistant Professor
Department of Biomedical Engineering
Office: 325 CBE Building
Email: szk416@psu.edu
Phone: 814-865-0459 (office)

Office Hours in 109 CBEB: Tuesday 6 - 7 pm (and by appointment if cannot be resolved with TAs and graders or in class).

Teaching Assistants:

Name	Email	Office Hours	Location
Sumit Agrawal	sua347@psu.edu	Wednesday 4:00 – 6:00 pm	109 CBEB
Thomas Radford	tir14@psu.edu	Wednesday: 1 pm - 2:30 pm	116 CBEB
Ling Yang	lby5034@psu.edu	Thursday: 3 pm – 5 pm	116 CBEB
Hayreddin Said	hxu5007@psu.edu	Friday 12 noon – 1:30 pm	107 CBEB

Grading Assistants:

Name	Email	Office Hours	Location
Erica Vasti	exv16@psu.edu	Monday 5.30 pm to 6.30 pm	109 CBEB
Alexander Kutz	awk5571@psu.edu	Monday 5.30 pm to 6.30 pm	109 CBEB

Text Book: Circuits, Signals and Systems for Bioengineers: a MATLAB-Based Introduction, 3rd edition, by John Semmlow, **eBook ISBN:** 9780128096260; **Paperback ISBN:** 9780128093955 © 2017; *2nd edition is also fine if 3rd edition is not available to you, as there are only minor changes between the two.*

Supplemental Reference Materials: (Handouts posted on Canvas)

Quick tutorial on Matlab.pdf
MatLab for engg students.pdf

Prerequisites: **BIOL 141 or BIOL 240W, PHYS 212, MATH 250 or MATH 251, CMPSC 200**

Course Catalog Description: Linear systems analysis applied to electrical networks and lumped parameter models of physiological control systems.

Course Objectives: BME 301 is a core bioengineering course designed to introduce students to the fundamentals of signals and systems and provide tools for analyzing them in both the time and

frequency domains. While this course has some topics in common with standard introduction to signals and systems courses, emphasis will be placed on the application of signals and systems tools to biological signals such as ECG and biomedical devices. Students will learn to analyze signals and systems by solving regular homework problems and active participation during lectures and in-class examples.
In addition, a two period computer laboratory supplements material given in the lectures. Three sections of laboratory will be held. Each laboratory session will provide hands on Matlab programming of assignments, and serve as a recitation period for review of homework. Each laboratory section will be taught by a TA. The course instructor, Dr. Kothapalli, will monitor each session, as needed, and develop the course materials. Each 2 hour session will consist of: (1) Introductory overview of goals, objectives and methods of the lab, (2) hands-on solution of Matlab/Simulink problems using the workstations in 116 CBEB, and (3) review of solutions to previous week's homework assignments given in the lectures.

Laboratory Assignments: A total of six laboratory assignments will be given throughout the course. All assignments should be submitted by posting to the **Canvas** of the section for which you are registered. Laboratory grades will be posted Canvas corresponding to your section. Grading of each section will be performed by the TA in charge of that section. The TA will enter grades into the section site and they will be transferred to the master BME 301 grade book at the end of the semester.

Course Outline: A tentative class schedule and outline of topics to be covered this semester is given in the following table. Slides presented in class are grouped in modules as indicated in this table, and will be posted to Canvas.

Tentative Class Schedule:

BME 301 Schedule Fall 2019 — **Revised date 08/24/2019**

	Date M/D	Class #	Reading Chapter	HW Assign	HW Due	Topics	Labs	Lecture* Module
week 1	8/27	1	1.1 - 1.3			Overview of course. Introduction to biological systems and signals. Continuous/Analog signals; discrete signals; sampling; time domain vs spatial domain. A/D conversion. Noise: Thermal noise, shot noise.	Lab 1 Intro to Matlab and Analysis of Noisy Signals	1
	8/29	2	2.1-2.2			Signal representation: Decibels; sound pressure level, SNR. Basic measurements: Mean, Variance, RMS, normal distribution, basic Measurements in Matlab. Ensemble averaging.		1
week 2	9/03	3	Slides	#1		Cardiac cycle-EKG-review; setup signal averaging of microvacular press-flows;slicing+quantization errors		1
	9/05	4	2.3			Basic Concepts: Signals and Systems Basic signals: sine wave, sine wave arithmetic, review complex #'s; Eulers Identity.		2
week 3	9/10	5	2.4			Signal comparisons and transformations;: correlation, cross-correlation, autocorrelation, covariiance, auto-covariance.		2
	9/12	6	2.3, 3.1-3.3	#2	#1	Introduction to Fourier Analysis. Time and Freq domain representations, probe for sinusoids;properties sinusoids		3
week 4	9/17	7	3.3			Fourier Series;polar+rect forms;complex representation;using MATLAB to calculate coefficientsFourier series (con't): Frequency representation,	Lab 2 Random Processes Noise and Simulation	3
	9/19	8	3.3-3.4			the continuous Fourier transform,DFT,FFT. Fourier series (con't): Frequency representation, complex number representation, the continuous fourier series representation.		3
week 5	9/24	9	3.3-3.4		#2	Fourier transform,DFT,FFT. Properties of the FFT. Speed of the algorithm vs direct series computation.		3
	9/26	10				**- Exam #1 - In Class - -**		3

week 6	10/01	11	4.1-4.6	#3		Fourier tranform: Applications. Data sampling, Quantitization, Spectral Spectral Averaging, and Time-Frequency Analsys, Signal Bandwidth, Power, Parseval's Thm, Power Spectrum analysis:	Lab 3 Frequency Spectrum Analysis	4
	10/03	12	1.4, 5.2, 6.2			LTI systems,Classic Feedback Equations.		5
week 7	10/08	13	6.3-6.7			Linear Systems Analysis in the Frequency Domain: The transfer function. Phasor Analysis, Transfer Function, The Bode Plot		5
	10/10	14	6.3-6.7	#4	#3	Bode Primitivs, Combining Multiple Elements, The Transfer Function and the Fourier Transform. Feedback Pathways, TF(jω)		5
week 8	10/15	15	6.3-6.7, 7.2			TF in freq domain, Mag vs freq plots, static and dynamic cal press xducer, Exam Q#14; BeginThe Laplace Transform	Lab 4 Physiological Modeling & Digital Simulation Introduction to Simulink	6
	10/17	16	7.2-7.3			L(s) for step, impulse, derivative, integral; characteristic eq first and second order systems, Laplace Xform Table, partial frac exp.		6
week 9	10/22	17	7.2-7.3			First and second order systems in the Laplace domain. Real and imaginary roots of second order systems. Partial fraction expansions.		6
	10/24	18	7.4-7.6		#4	Xfer fncts, first and second order, Intial and Final Value theorems, Impulse response and transfer function in Laplace and Fourier domains;		6
week 10	10/29	19	5.3-5.6			Extracting time domain response by convolution. Indicator dilution and Mean Transit Time by convolution.		7
	10/31	20				-- **Exam #2 In Class** --		8
week 11	11/05	21	12.2-12.7			Circuit elements & variables: Resistance, capacitance, inductance in the time & Laplace domain continued	Lab 5 Cardiovascular Systems Simulation - Windkessel	8
	11/07	22	13.1-13.3	#5		Continue circuit elements. Application to electrical networks. Network Analysis of the circulation.		8
week 12	11/12	23	12.8-12.9			Mechanical elements and their representation in the Laplace and frequency domains.		9
	11/14	24	13.4-13.5			Mechancial Analogs Mechanical Analogs cont'd. Introduction to Physiological Modeling: Oxygen Delivery to Tissue		9
week 13	11/19	25	Slides	#6	#5	Oxygen Delivery to Tissue cont'd Overview of Simulink GS Model. Overview of microcirculation.	Lab 6 Oxygen Transport to Tissue	10
	11/21	26	Slides			Linearity of the PORH response. O_2 delivery in context of a linear system. Intro to Control Systems; The PID Controller and relation to model of O2 transport.		10
Thxgiving	11/26	***Thanksgiving Break***						-
	11/28	***Thanksgiving Break***						-
week 14	12/03	27	Slides			Glucose Homeostasis. Pancreas-insulin-glucose. First model by Bolie implmtd in Simulink. Damiano dual hormonal control.	Lab 6 Cont'd	10
	12/05	28	Slides		#6	Modeling continued. Application of standard linear solid to describing cell deformation in response to step shear stress.		10
week 15	12/10	29	Slides			First Order Filters. Wrap up and Review for Final Exam		10
	12/12	30				-- **Exam #3 (Final) In Class** --		-

***Lecture modules correspond to the PowerPoint slides used in class and posted to CANVAS**

Homework (HW) Assignments: Homework assignments will be uploaded to Canvas, or assigned in class (usually on Thursdays) and will be due one week later. Homework will be collected at the beginning of class on the assignment due date listed on each homework handout. Late homework will not be graded (homeworks turned in at the end of class are considered late). DO NOT submit your homework solutions by email. It will be difficult to respond with complex answers to questions about homework by email, ask questions in or after class, or during the lab recitation period. Students may also seek help during regular office hours held by the TAs.

Solutions to homework assignments given in the lectures should be submitted as paper copies. Please indicate your *name and section number* on all BME 301 homework. These assignments will involve analytical problem solving as well as Matlab exercises.

Exams: There will be three exams (held during the regular class period) given during the semester. Depending on the overall class performance in the first two exams, the third exam might be replaced by a final comprehensive exam held during final exam week. Exams will be based on reading assignments (i.e. entire chapters) from the textbook and supplemental materials, homeworks, textbook problems and in-class lectures. Everything is fair game!

Grading:		
	Homework (≈6 assignments)	20%
	Exams (3 total; 2 midterms and final)	15+15+20% = 50%
	In-class quizzes (conducted on HW due dates)	5%
	Laboratory Exercises	20%
	Lab quizzes (conducted on Lab due dates)	5%

Exam 1: Thursday, Sept 26, 2019
Exam 2: Thursday, October 31, 2019
Exam 3: December 12, 2019

Exams will be held during the regularly scheduled class period and will consists of a mix of multiple choice questions and theoretical questions. There will **not** be any quizzes or exams held separately for the laboratory section. At the end of the semester, each student will receive a cumulative score and the grading scale will be curved at that point to reflect difficulties of exams and groupings of performance, but the degree of the grade curve will not be known until the end of the semester. Midterm scores will be calculated but no grade will be assigned at that point. Questions on this will result in a recitation of this paragraph, so it's better to focus on your performance than the details of the grading scheme.

Grading Scale: A final numerical grade will be determined by computing the weighted averages for homework, exams, clickers and labs. A letter grade will be assigned according to the following scale. Instructor will consider curving if the entire class performance is below average, for example due to some difficult problems.

Letter Grade	Range
A	90 - 100
A-	88 - 89
B+	86 - 87
B	75 - 85
B-	73 - 74
C+	71 - 72
C	51 - 70
D	40 - 50
F	< 40
Please note this course you need C or better; D and F are considered as fail and you need to repeat the course.	

Grade Disputes: Grade disputes on homework assignments and exams will be settled at the Instructor's discretion. In both cases, the problem in question will be RE-GRADED, making it possible for you to receive a lower score. To dispute an exam grade, you must explain your dispute IN WRITING AND STAPLE this to the front of your exam. The Instructor will then re-grade your exam. **There is a one week time period from the return of exams or homework to dispute the grade; after this period, the grade is final.**

Computer Accounts for BME 301: For students enrolled in BME 301 computer accounts are created for each student and access is granted using your PSU ID card for the BME computer laboratory located in 116 CBE Building. For facility details and policies go to: **http://bme.psu.edu/computerlabs.html**

For computer related (e.g. Canvas/computer lab/printing) problems, please see:

Mr. Gary Meyers
Room 124 CBEB
gmeyers@engr.psu.edu
865-6730
Hours: 8am-5pm

Attendance Policy for BME 301: The Penn State Class Attendance Policy can be found at www.psu.edu/ufs/policies/**.** Students are **expected to attend each lecture for BME 301 and their lab section.** If you need to schedule a conflict exam for a legitimate evaluative event, you need to contact the instructor two weeks before the scheduled exam. ***Due to a limited number of workstations, students must attend only the lab section for which they are registered.***

A Statement on Plagiarism and Academic Dishonesty

You are required to read the following site: http://tlt.psu.edu/plagiarism/
What is Plagiarism?
Plagiarism is the act of stating or implying that another person's work is your own. You commit plagiarism if you:

Submit a paper you have not written to be graded or reviewed.
Copy answers or text from another classmate and submit it as your own.
Quote or paraphrase from another paper without crediting the original author.
Cite data without crediting the original source.
Propose another author's idea as if it were your own.
Creating references or using incorrect references.

This is not a definitive list - any action in which misleadingly imply someone else's work is not your own can constitute plagiarism.

BME 301 Statement on Academic Integrity

1. You are required to read the web sites listed above regarding the Academic Integrity. If you have any questions, please see me.
2. Exams and quizzes are **closed book**. Exams are based on information and equations from the text book along with lecture material and handouts. You may be given permission to use an equation sheet for some exams. This policy will be addressed prior to each exam.
3. You can consult each other regarding homework solutions however each assignment must be **your own solution**. Verbatim, plagiarism or duplicates assignments, regardless of the semester, will be regarded as cheating.
4. If a student is caught plagiarizing, they will be turned over to the College of Engineering for disciplinary action.

NOTE: The class schedule (including lectures, HW's, exam dates) is tentative and **subject to change** throughout the semester. Changes will be indicated at the lectures only, and may not be necessary

posted on the Canvas web site. It is YOUR responsibility to attend lectures ON-TIME to obtain any updated information.

Accreditation Board for Engineering and Technology (ABET):

Biomedical Engineering at Penn State is accredited by ABET. ABET is a non- governmental organization that accredits post-secondary education programs in "applied science, computing, engineering, and engineering technology. To fulfill accreditation requirements, each academic program must specify a set of educational outcomes specific for that course that state learning expectations. The particular outcomes for BME 301 are summarized as follows:

ABET Bioe Program Outcomes and Specific Course Outcomes Addressed by BME 301:

Outcome 1: An ability to apply knowledge of advanced mathematics, science, and engineering to solve problems at the interface of engineering and biology.

- Given a system (differential equation or electrical/mechanical model), students will be able to correctly obtain the transfer function.
- Given a frequency response of a system and a sinusoidal input, predict the output magnitude and phase.

Outcome 2: An ability to design a system, component, or process to meet desired needs within realistic constraints.

- Students will be able to quantitate interactions between stimulus and response of physiological systems using techniques of cross-correlation and convolution.
- Students will be able to implement design methods that overcome noise limitations

Outcome 3: An ability to identify, formulate, and solve engineering problems

- Be able to apply Kirchoff laws to accurately determine voltages and currents in a passive circuit using phasor analysis
- Students will be able to derive and analyze the input/output relationship for typical 2nd order systems (RLC circuit; mass-spring-damper) in the frequency domain to determine time-domain behavior.

Outcome 4: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- Students will be able to determine the Fourier Series representation of signals and utilize Matlab to plot an arbitrary number of harmonics of the signal
- Given the Fourier or Laplace transform of a system or system block, students will be able to obtain an accurate Bode plot and use it to determine its response as a function of frequency

Outcome 5: An understanding of physics, chemistry, and of physiology at molecular, cellular and organ levels

- Using Laplace transforms and a model of a the circulatory system, students will be able to understand the response of the system to sinusoidal and stepwise variations in flow
- Utilize signals and systems fundamentals to accurately simulate and analyze blood flow and regulation of oxygen delivery to tissues, regulation of blood volume and control of blood glucose levels.

Students with Disabilities: Penn State welcomes students with disabilities into the University's educational programs. If you have a disability-related need for reasonable academic adjustments in this course, contact the Office for Disability Services (ODS) at 814-863-1807 (V/TTY). For further information regarding ODS, please visit the Office for Disability Services Web site at http://equity.psu.edu/ods/. In order to receive consideration for course accommodations, you must contact ODS and provide documentation (see the documentation guidelines at http://equity.psu.edu/ods/guidelines/documentation- guidelines). If the documentation supports the need for academic adjustments, ODS will provide a letter identifying appropriate academic adjustments. Please share this letter and discuss the adjustments with your instructor as early in the course as possible. You must contact ODS and request academic adjustment letters at the beginning of each semester."