Engineering Faculty Document No. 46-19
October 9, 2019

TO: The Faculty of the College of Engineering

FROM: The Faculty of the School of Biomedical Engineering

RE: Change to Undergraduate-Level Course BME 30500 requisites

The faculty of the School of Biomedical Engineering has approved the change in requisites of the course listed below. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM: **BME 30500 Bioinstrumentation Circuit and Measurement Principles**
Term offered: Fall, Lecture 1, Lab 3, Cr. 3
Restriction: Must be enrolled in the School of Biomedical Engineering
Prerequisites: PHYS 24100 or PHYS 27200 or equivalents, and MA 26600 or MA 26200 or MA 36600 or equivalents

Description: Introduction of laboratory instruments used to measure physiological events. Stimulation and conduction of electric signals within the nervous system and other excitable tissues are demonstrated. Fundamental circuit elements and concepts include resistance, capacitance, inductance, op-amps, impedance, voltage, current, power, and frequency. Fundamental analog measurement concepts include adequate bandwidth and amplitude and phase linearity. An integrative two-week design project addresses the practical aspects of quantitative physiological measurements.

TO: **BME 30500 Bioinstrumentation Circuit and Measurement Principles**
Term offered: Fall, Lecture 1, Lab 3, Cr. 3
Restriction: Must be enrolled in the School of Biomedical Engineering
Prerequisites: PHYS 24100 or PHYS 27200 or equivalents, and MA 26600 or MA 26200 or MA 36600 or equivalents, and BME 20600
Concurrent prerequisite: BME 30100

Description: Introduction of laboratory instruments used to measure physiological events. Stimulation and conduction of electric signals within the nervous system and other excitable tissues are demonstrated. Fundamental circuit elements and concepts include resistance, capacitance, inductance, op-amps, impedance, voltage, current, power, and frequency. Fundamental analog measurement concepts include adequate bandwidth and amplitude and phase linearity. An integrative two-week design project addresses the practical aspects of quantitative physiological measurements.

REASON: Skills acquired in BME 20600 and 30100 are needed for successful completion of BME 30500.

George R. Wodicka

George Wodicka
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

Course Syllabus
BME 305: Bioinstrumentation, Circuit, and Measurement Principles
CRN: 54265

Course Instructor:	Dr. Joseph V. Rispoli Email: jrispoli@purdue.edu Phone: 765.494.6178	Office: MJIS 3035 Office Hours: by appointment via https://calendly.com/jrispoli/bme305
Lab Coordinator:	Mr. Asem F. Aboelzahab Email: aboelzahab@purdue.edu	Office: MJIS 1055 Office Hours: Open-door
Course TAs:	Ms. Katherine Leyba Email: leybak@purdue.edu Mr. Xin (Jack) Li Email: li2543@purdue.edu Mr. Michael MacLean Email: mmaclea@purdue.edu Ms. Mandira Marambe Email: mmarambe@purdue.edu	Office: MJIS 1061 Office Hours: T/R 6:00 - 8:00 pm

Lecture Location: MJIS 1097
Meeting Time: Monday 9:30 - 10:45 am

Lab Location: MJIS 1061
Meeting Time:

Wednesday:	8:30 am - 12:20 pm	or
Wednesday:	1:30 pm - 5:20 pm	or
Thursday:	1:30 pm - 5:20 pm	or
Friday:	8:30 am - 12:20 pm	or
Friday:	1:30 pm - 5:20 pm	

Course Credit Hours: 3

Pre-requisites:

PHYS 241	Electricity and Optics
MA 266	Differential Equations
BME 206	Biomechanics & Biomaterial Lab

Co-requisites: BME 301 Bioelectricity

Course Description: Introduction of laboratory instruments used to measure physiological events. Stimulation and conduction of electric signals within the mammalian nervous system and other excitable tissues are demonstrated. Fundamental circuit elements and concepts include resistance, capacitance, inductance, op-amps, impedance, voltage, current, power, and frequency. Fundamental analog measurement concepts include adequate bandwidth and amplitude and phase linearity. Integrative design project emphasizes the practical aspects of quantitative physiological measurements.

Learning Outcomes: Upon completion of the course each student will be able to:

1. Appraise the validity of established bioelectricity hypotheses and circuit models based on quantitative physiological measurements.
2. Document procedures, measurements, and subsequent data analysis in clear and cohesive laboratory reports.
3. Design an analog bioinstrumentation measurement system meeting prescribed specifications to accurately record a physiological event.

Course Web Page: https://mycourses.purdue.edu; Course Name: Fall-2019-BME-30500

Required Text: Hayt, Kemmerly, Phillips, & Durbin. *Engineering Circuit Analysis* (9th ed.). McGraw-Hill, 2019. ISBN-13: 9780073545516 / 9781259989452 / 9781259989513.

Required Materials:
1. Paper or printable electronic notebook (e.g., Microsoft Word)
2. One component kit per lab group (Available for purchase at https://www.elexp.com/purdue_bme305/; Part no. 32PRDBME305)

Topics Covered:

1. Fundamentals of electrical measurements and properties, Ohm's law (1 lecture, 1 lab)
2. Resistive models of biological systems (1 lecture, 1 lab)
    a. KCL, KVL, nodal analysis, conductivity of physiological solutions
3. Generation and measurement of bioelectric signals (1 lecture, 1 lab)
    a. Linearity, Thevenin equivalent, practical circuit models of voltage sources and voltmeters
4. Time varying bioelectric signals (1 lecture, 1 lab)
    a. Capacitors, step response of RC circuits
5. Bioelectric amplifiers (1 lecture, 1 lab)
    a. Operational amplifiers
6. Sinusoidal response of linear circuits (1 lecture)
    a. Lead/lag networks, phasor notation
7. Frequency response of RC models & frequency content of physiological signals (1 lecture, 2 labs)
    a. Phasor analysis of RC circuits, Fourier series
8. RLC model of the cochlea (1 lecture, 1 lab)
    a. 2nd order linear systems, step response, frequency response
9. Recording and stimulating electrodes (1 lecture, 1 lab)
    a. electrodes, circuit models of electrodes, Wheatstone bridge circuit
10. Stimulation of nervous system (1 lecture, 1 lab)
    a. Impulse function, convolution in time domain
11. Action potential propagation in nervous and muscle tissue (1 lecture, 1 lab)
    a. Convolution in frequency domain, high pass and low pass filtering
12. Recording of physiological signals (1 lecture, 1 lab)
13. Differential and Instrumentation amplifiers, common mode rejection ratio
14. Instrumentation design (2 lectures, 2 labs)
15. Adequate magnitude and phase linearity and bandwidth, signal distortion, filtering

Course Procedures:

During a typical week there will be one lecture and one laboratory. The *lecture* will introduce and cover the circuit analysis techniques to be utilized in one or more of the accompanying laboratories. The *laboratories* have been designed to provide a hands-on learning environment to explore and relate the circuit analysis concepts to bioelectricity (BME 301) and measurement of physiological events. As such, an attempt was made to create lab activities that contain either a wet lab experiment or a measurement of a physiological event on a living subject. Students successfully completing this course will obtain understanding of the criteria required to faithfully reproduce a physiological event as well as the ability to design, construct, and test simple measurement circuits.

Format of lecture period: The lecture period is devoted to covering the week's topics through traditional lecture and active learning activities. At the end of some lecture periods a short (10-minute) quiz may be administered.

Format of laboratory period: The pre-lab assignments are due online before coming to lab. There will be a brief introduction (5 – 15 minutes) to the lab provided by the Teaching Assistants at which time a brief quiz may be given. Students then execute the lab.

- *Laboratory Attire:* Safety regulations require that you wear long pants (or equivalent) and closed-toe shoes while working in the laboratory.
- *Lab Group Composition:* At the start of the lab, students will be paired into lab groups. Most lab groups will contain two students. No lab group will contain more than 3 students. The instructor of the course reserves the right to reassign lab partners at any point during the semester.

Format of office hours: Lab office hours will be held in MJIS 1061. In addition to using office hours to obtain further understanding of laboratory concepts, students may also use these hours to work on BME 305 homework, to complete laboratory procedures not finished in lab, to practice for the mid-term lab practical, and to work on the design project. If you are unable to attend the assigned office hours, please consult with a TA to set up alternative arrangements. Instructor office hours are made by appointment through the URL on the first page of the syllabus.

Class Attendance: Completion of every lab is required to pass. In the case class is missed due to extenuating circumstances (e.g., death in family), the course instructor should be contacted immediately and written documentation will be required. Make-up work will be considered and assigned on a case-by-case basis. **To receive credit for the lab, a student must be in the lab on time, no more than 15 minutes late. A student who is more than 15 minutes late and who does not have an excused reason may receive a zero on the lab.**

Academic Conduct: Incidents of academic misconduct in this course will be addressed by the course instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result minimally in a failing or zero grade for that particular assignment, and at the instructor's discretion may result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered.

Grading:

Laboratories (11)	50 %
Design laboratory	8 %
Lab practical (1)	7 %
Exam I (Midterm)	17.5 %
Exam II (Final)	17.5 %
Total	**100%**

Breakdown of Standard Laboratory Grading

Pre-lab & homework problems (individual)	40 %
Notebook (group)*	10 %
Post-Lab Analysis (individual)	50 %

Breakdown of Design Laboratory Grading#

See Design Lab supplementary material

* *All assignments are collected, but only select sets (randomly selected) are graded.*
# *TA/Peer Review (individual) can drop grade by as much as 15 % of the group grade.*

Note: Late pre-labs and notebooks will not be accepted. For other assignments, a 20% penalty will be incurred for each day that an assignment is late.

Online Course Evaluations: To receive credit for the design project laboratories (8% of your grade), you must complete all online course evaluations for this class **AND** submit to the lab coordinator evidence of survey completion via Blackboard.

Grade Scale: The following grading scale is guaranteed; however, based upon student performance, final grades may be curved by the instructor.

Letter Grade	Percentage	GPA score
A+	≥ 100	4.0
A	≥ 94	4.0
A-	≥ 90	3.7
B+	≥ 87	3.3
B	≥ 83	3.0
B-	≥ 80	2.7
C+	≥ 77	2.3
C	≥ 73	2.0
C-	≥ 70	1.7
D+	≥ 67	1.3
D	≥ 63	1.0
D-	≥ 60	0.7
F	< 60	0

Assignment Details:

For each lab, you will be required to complete a pre-lab assignment and either a post-lab assignment or a formal lab report. In addition, you are expected to maintain a laboratory notebook throughout the course of the semester. Following is a description of what is expected for each.

- **Pre-lab:** Prior to each laboratory session, students are expected to read over the laboratory material and the assigned textbook reading. Pre-labs can be found on Blackboard but will require students to refer to their lab manual/text for more information. **Pre-lab exercises are to be completed and submitted online by noon the day before coming to lab.** By completing this assignment, you will better understand the lab and lecture concepts and form expectations for the lab activities. Please note that although pre-labs are completed online, you should keep a notebook showing your work for all calculations. **IMPORTANT:** Students who do not turn in a Pre-lab assignment will be awarded a zero for that assignment.

- **Pre-lab Quizzes:** To ensure students come prepared to class, there may be a pre-lab quiz at the beginning of laboratories. The quizzes will be in the format of short answer, true/false, and multiple-choice questions. The intent of the quiz is to encourage students to come prepared for that day's laboratory exercise. The score achieved on the quiz will be factored into the pre-lab grade associated with that laboratory.

- **Notebook:** During the laboratory exercises, each team will be expected to keep a notebook, either electronic or handwritten. The entries should follow the standard notebook layout with a brief statement of the **Objective** of the activity, the **Procedure** followed, and any **Results** obtained. **Conclusions** must also be provided for each part of the lab activity. The procedure must include a record of all circuits constructed. The results section should include all relevant observations and data. These observations/thoughts may be important in the post-lab analysis. Calculations and numerical information used or obtained in the experiment must be written down in the notebook. All entries in the lab notebook are to be written in ink. If you make a mistake, simply cross out the mistake by making an X through the area and make the correction next to it. It is expected that all work is well organized. For an example of a well-kept lab page, see Figure 1. The notebook entries will be graded for their organization and content. **Notebook entries will be submitted with the post-lab assignment.**

- **Post-Lab Analysis:** Post-lab analyses will **always** include the analysis and interpretation of the data obtained during the laboratory exercises. A few textbook problems that cover the lecture topics may be assigned. In addition, you will be expected to answer questions posed involving application and integration of the relevant concepts covered in that lab. *All post-lab assignments may be typed or handwritten (as long as you print clearly); the post-lab should* ***not*** *be embedded within your in-lab notebook observations and data.* Please note that you must show work for all calculations and **circle or box your final solution**. Each person in the class is to complete and turn in his/her own post-lab assignment for grading. **IMPORTANT:** If the post-lab analysis is not turned in within the first 15 minutes of lab, it will be considered late, and the assignment will be automatically assigned a 20% grade deduction.

- **Lab practical:** This is a closed-book exam to be conducted **individually** within the laboratory. Each member of the lab group will be allotted 70 minutes of the typical laboratory period to complete the assignment. No assistance will be provided during the laboratory; it is expected that the students will complete the activity on their own and will demonstrate the working circuits and measurements to the laboratory instructor before the end of the allotted time. The exact lab practical exercises are provided to you in the laboratory manual (lab 6). You are encouraged to practice the exam as often as you wish.

- **Exam:** There will be two closed book exams that will take place around mid-semester and at the end of the semester. These exams will cover all topics addressed in the lecture and may include laboratory topics.

- **Re-grade Policy:** Students have the right to contest any grades throughout the semester. In the event that a student feels an assignment has been inappropriately graded, the student must submit one typed page indicating the source of the problem and an explanation for the re-grade submission. Along with this document, the original assignment must be returned. Students have one week after the return of a graded assignment to protest a grade; after this time, grade disputes will not be accepted. Papers submitted for a re-grade will be completely re-evaluated (i.e., the entire paper will be re-graded, not only the portion under protest), which means that students may lose additional points for mistakes missed during the first grading process.

Campus Emergency Policy: In the event of a major campus emergency, course requirements, deadlines, and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. If an emergency should occur, check Blackboard and your Purdue email accounts to learn about modifications to the course.

Students with Disabilities: Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765.494.1247.

Nondiscrimination Statement: Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue's nondiscrimination policy can be found at http://www.purdue.edu/purdue/ea_eou_statement.html.

Class Schedule

WEEK OF	WEEK	LAB ACTIVITY	SUPPORTING LECTURE TOPICS	ASSIGNED TEXT READING
8/19	1	***No Lab***	Basic concepts, Ohm's Law, KCL, KVL, linearity, equivalent	Ch. 2-3
8/26	2	Fundamentals of electrical measurements and properties	Equivalent resistance, nodal analysis, mesh analysis	Ch. 4
9/2	3	Resistive models of biological systems	***Labor Day – No Lecture***	
9/9	4	Generation and measurement of bioelectric signals	Superposition, source transformation, Thévenin and Norton equivalents	Ch. 5.1-5.4
9/16	5	Time varying bioelectric signals and response times of measurement devices	Capacitors, RC circuits	Ch. 7.1, 8.1-8.2, 8.4-8.6, 8.8
9/23	6	Bioelectric Amplifiers	Operational amplifiers	Ch. 6 & 7.5
9/30	7	Frequency response of RC models of biological systems	Sinusoids and sinusoidal steady-state response, phasors	Ch. 10
		Exam I: Tuesday, October 1, 8:00-9:00 pm in PHYS 114		
10/7	8	Frequency content of physiological signals and bandwidth	***October Break – No Lecture***	Ch. 15
10/14	9	**Lab Practical**	Basic filter design	
10/21	10	The RLC Model of the cochlea	Inductors, RLC circuits, electrode RC models	Ch. 7.2-7.3, 8.3, 8.7 & Ch. 9
10/28	11	Recording and stimulating electrodes	Nerve stimulation	Article on Blackboard
11/4	12	Stimulation of nervous tissue	Advanced op-amp circuits & criteria for faithful reproduction of physiological signals	Ch. 7.4, 7.6-7.7
11/11	13	Action potential propagation in nervous and muscle tissue	Laplace transform	Ch. 14.1-14.3
11/18	14	Design project	Circuit analysis in s-domain & convolution	Ch. 14.4-14.12
11/25	15	***Thanksgiving Break – No Lab***	Two-port networks & impedance parameters	Ch. 16.1, 16.4
12/2	16	Design project (wrap-up)	***No Lecture***	
12/9	17	***Finals Week – No Lab***	**Exam II: Friday, December 13, 10:30-12:30 pm in MJIS 1097**	