BIOE3210 Bioelectricity (Section 02), Spring 2019

(Last updated on **Jan. 21, 2019**)

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Course Time: Tuesday/Friday 1:35-3:15 PM | Hurtig Hall 224 | Jan. 08 – Apr. 26 2019
Office Hours: Monday 3:00-5:00PM, ISEC 223, (additional office hours by appointment)
TA Office Hours: Tuesday 3:30-4:30 PM, ISEC 232 (TA: Xin Sun sun.xin1@husky.neu.edu)
Section 01 Office Hours: (Prof. Yaseen) Friday 3:30-5:30, ISEC 201, (TA): Wed. 4-5PM, ISEC 201

Recommended Textbooks (not required)

- *Electric Circuits, 10rd or 11th Edition* - by Nilsson & Riedel, Pearson, 2015/2019
- *Medical Instrumentation: Application and Design (4th Edition)* - by John G. Webster (for ECG)

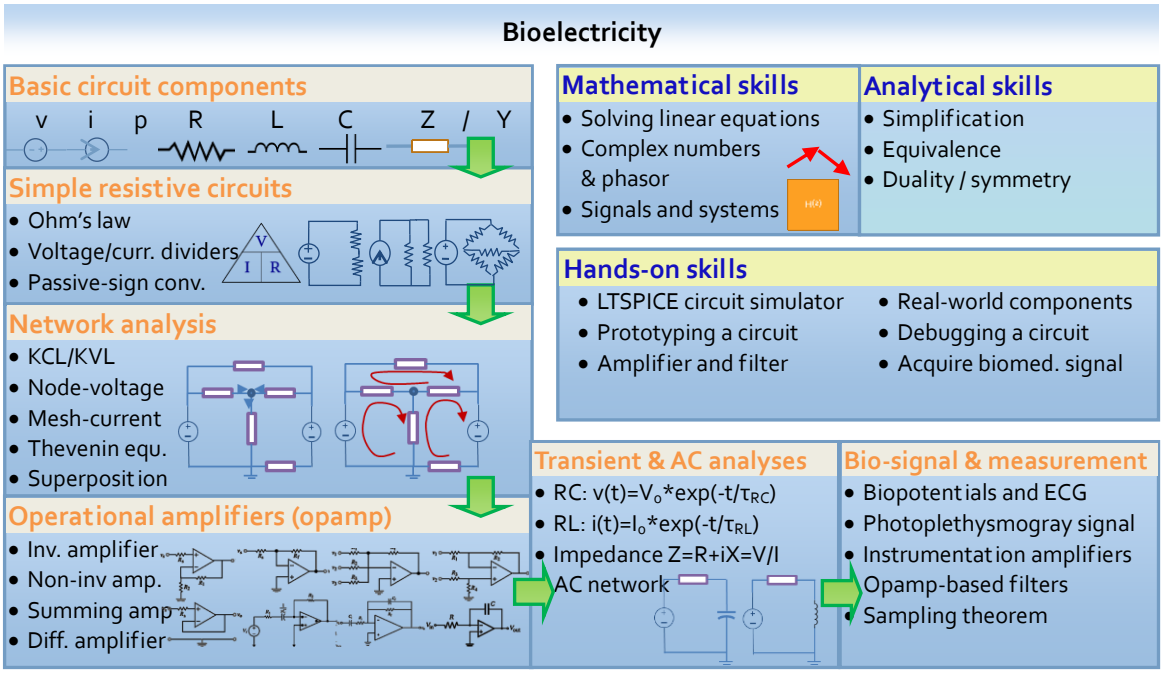
Required purchase (for online learning service)

- *Pearson MyLab & Mastering Engineering (with or without eText)*

Textbook options	*Include eText*	*Access Length*	*Cost*
Mastering Engineering	no	2 years	$61.00 **(recommended)**
Mastering Engineering	yes	2 years	$111.00(not-recommend.*)

* While purchasing the eText is not recommended, you are expected to use the abundant online tutorials, videos and ebooks to enhance your in-class learning in order to smoothly complete all homework assignments and exams.

Visual Syllabus



As a bioengineering student, understanding biological processes by directly measuring those using instruments, whether designed by yourself or available off-the-shelf, is an essential skill, no matter

what concentration you have chosen. At the heart of those instruments, you can inevitably find circuits that make these measurements possible. This course prepares you for the future explorations of complex biological systems and instrument development by **teaching you the key skills to understand, analyze and build functional circuits for biomedical applications**. You will find that mastering such skill will likely help you in your next co-op project or, if you are a senior student, capstone design project.

While the materials we cover may resemble those from a circuit course from ECE, you will find that the course had **added emphases to biomedical/biological applications**. Particularly, we have 3 dedicated units (Units 8-10) to discuss biophotentials, electricalcardiography (ECG), neural imaging with electroencephlography (EEG), plethysmography (PPG) and data acquisition methods in medical devices. Ending the course with these topics allows you to connect the general circuit analysis and design methodologies to bio-related applications.

We understand that most students do not have previous experience in circuit analysis or amplifier/filter design. Therefore, the course is designed to build your skills from the ground-up and walks you through various types of circuits, starting from simple ones and preparing you for more advanced circuits towards the end. Throughout this course, you will learn to analyze, build and test 4 different types of circuits: **#1) direct-current (DC) circuits** made of resistors, **#2) time-varying (transient) circuits** using combinations of resistors, capacitors and inductors, **#3) alternating-current (AC) circuits**, and **#4)** circuits based on **operational-amplifiers (opamps)**. To cover these topics, we split the course materials into **10 different units**. Units 1-5 (before mid-term exam) focus on DC resistive circuits (#1) and resistor-only opamp circuits (#4); Units 6-10 extend the methodology to the analyses of transient circuits (#2), AC circuits (#3) and amplifier/filter designs using opamps (#4) and apply these techniques to the acquisition of biological signals (ECG, PPG).

In addition to teaching you circuit theories, we also placed a great emphasis on **developing hands-on skills** in this course and designed 9 in-class labs to enhanced your learning, typically 1 lab per unit. Every two of you will form a group, and will be given a National Instrument (NI) **myDAQ device** and a set of components to build, test and verify the circuits you learned in the lectures. With the installed NI ELVISmx software on your laptop (**Mac requires Bootcamp**, see instructions), the myDAQ device can turn your laptop into a multimeter, an oscilloscope, a power supply and a function generator (for time-varying signals) or a combination of those. You will also receive a breadboard (for circuit prototyping) and components (such as resistors, capacitors, LEDs) and build simple circuits, test their properties and learn how to debug them in this process.

Course summary

The course materials are divided into 10 units - each contains 1-2 lectures followed by an in-class lab.

- **Opening** [*Assignment 0*]
- **Unit 1.** Circuit variables and circuit components [*Lab 1, Assignment 1*]
- **Unit 2.** Kirchoff's laws and circuit simplification [*Lab 2, Assignment 2*]
- **Unit 3.** Node-voltage and mesh-current methods [*Lab 3*,Assignment 3*]
- **Unit 4.** Thevenin equivalent circuits [*Lab 4*,Assignment 4*]
- **Unit 5.** Opamps with resistors [*Mid-term covers 1-5]* [*Lab 5, Assignment 5*]
- **Unit 6.** Transient response with RC and RL circuits [*Lab 6*,Assignment 6*]
- **Unit 7.** AC circuit analysis [*Lab 7, Assignment 7*]
- **Unit 8.** ECG and biopotential amplifiers [*Lab 8, Assignment 8*]
- **Unit 9.** Neuroimaging with EEG and fNIRS [*no assignment*]
- **Unit 10.** Data acquisition and digitization [*Lab 9, Assignment 9*]
- **Final Review** [*Final exam focuses on Units 6-10 but may also involve methods from earlier units*]

Labs marked with a "*" (Labs 3,4,6) are software-based labs and need to be completed using a free circuit

simulator (LTSPICE, you need to bring your laptop and pre-install the software). The remaining labs require myDAQ (will be distributed at the beginning of the lab, and return at the end of the lab; checking out a myDAQ to work offline can be arranged with TA) and a laptop. A written report is required for each lab, but one should only report the key results via screen captures, photos, measured values with simple but sufficient explanations. A full report including background and detailed derivation is not necessary. Although two students form a group to complete the lab together, one should write their own report.

All homework assignments (9 total) are given via the Mastering Engineering (ME) website, with a typical due date 1 week after the lecture is given. At the end of each lecture, we will try to provide students with **step-by-step problem solving examples** (as many as we can fit) to prepare you from solving the homework problems, but one should keep in mind that you may encounter questions that require combinations of methods used in the sample problems. You may need to review the lecture slides, textbook chapters or use additional online tutorials to smoothly complete the homework assignments. **To ensure we have enough time to give in-class examples, you are required to review the lecture slides before the lecture time.**

There will be two close-book exams – the **mid-term exam will cover Units 1 through 5** (resistive circuits and opamps with resistors), and the **final-exam will focus on Units 6 to 10** (transient and AC response, opamp filters and ECG), however, it may also involve important concepts from the earlier units. Two **0-credit assignments will be available** on Mastering Engineering (midterm practices and final practices) to give you more practice opportunities before exams. In addition, we allocated two class slots (**problem-solving hackathon I and II**) for going through previous exams or student submitted questions.

Calendar and Course Outline (changes will be announced by emails)

WEEK	TOPICS	NOTES
1	**Opening**: Overview and fundamentals – overview of the course structure, logistics, expectations, and necessary preparations. 01/08	**Objectives**: Understand the overall structure of the course, review basic math skills: linear equations, complex numbers, puzzle solving and transfer functions.
	Unit 1-1: Circuits, circuit variables – voltage, current, power, charges, resisters and Ohm's law, passive sign convention 01/11	**Objectives**: Understand voltage, current, power, charges, and their relationships & units; know Ohm's law, understand voltage/current sources, switches, LEDs and their properties.
2	**Unit 1-2**: Circuit terminologies – circuit terminologies, dependent and independent sources, LED, switch, SI units 01/15 (Homework 0)	**Objectives**: Understand nodes, essential nodes, loops, meshes, branches, ground, recognize dependent/independent sources, switches and LEDs.
	Lab 1: Circuit variables, Ohm's law –Overview and build simple resistor circuits 01/18	**Objectives**: Learn how to use breadboard and myDAQ to build simple resistor circuits and test.
3	**Unit 2**: Kirchoff's laws and simplifications – Kirchoff current and voltage laws, resistor in parallel, voltage/current divider, circuit simplification and analyses. 01/22 (Homework 1)	**Objectives**: Know how to combine resistors/sources in parallel and in series; know how to define KCL and KVL equations, recognize voltage/current dividers.
	Lab 2: Resistive circuit and Kirchoff's law – Building circuits with multiple resistors, and verify KCL/KVL 01/25 (Lab 1)	**Objectives:** Test and measure resistors in parallel and series, test Kirchoff's current and voltage laws.

4	**Unit 3-1**: Node-voltage and mesh current – Analyzing a complex network using the node-voltage and mesh current methods. 01/29 (Homework 2)	**Objectives:** Understand the general techniques to analyze a network made of resistors and independent sources.
	Unit 3-2: Node-voltage and mesh current II – Supermesh and supernode, practice, practice and practice 02/01 (Lab 2)	**Objectives:** Study methods to analyze networks with dependent sources. Doing more in-class practices.
5	**Lab 3**: Network analysis using LTSPICE - Using circuit simulator LTSPICE to virtually build circuits and verify the network analysis outcomes. 02/05 (Quiz for Units 1-2)	**Objectives:** Understand how to use LTSPICE to create complex DC circuits and network of resistors, know how to apply sources and measure voltage and currents in LTSPICE.
	Unit 4: Thevenin equivalent circuits – Thevenin theorem and Norton theorem, maximum power transfer theorem, superposition analysis 02/08 (Homework 3)	**Objectives:** Know how to convert a two-terminal network into an equivalent voltage-source using Thevenin theorem or equivalent current-source via the Norton theorem.
6	**Lab 4**: Equivalent circuit with LTSPICE – Verify Thevenin theorem and Norton theorem using LTSPICE 02/12 (Lab 3)	**Objectives**: Build circuits and their equivalent circuits and verify their properties using simulator.
	Unit 5: Opamps with resisters – Properties of opamps, inverting and non-inverting amplifiers, summing amplifier and buffer 02/15 (Homework 4)	**Objectives**: Understand the two basic rules in analyzing opamp circuits; recognize the basic circuits made of opamps and their properties; apply network analysis to opamp circuits
7	**Lab 5:** Opamp circuits – Build opamp-based amplifiers 02/19 (Quiz for Units 3-4, Lab 4)	**Objectives**: Build amplifier, adder, comparator circuits using opamps and breadboard.
	Problem-solving hackathon I – We collect student-submitted questions and explain them step-by-step in class. 02/22 (Homework 5)	**Objectives**: Helping students on specific questions and prepare everyone for the mid-term exam.
8	**Middle-term exam**: A half-sail check-up 02/26	**Objectives**: Verify our learning goals are met for Units 1-5.
	Unit 6: Capacitors and inductors – Properties of capacitors and inductors, step and natural response of RC/RL circuits 03/01 (Lab 5)	**Objectives**: Understand the dynamic properties of capacitors and inductors, understand the natural and step responses of RC and RL circuits.
9	03/05	No-class (Spring Break)
	03/08	No-class (Spring Break)
10	**Lab 6**: Capacitors and inductors – Create simple capacitor and inductor circuits in lab exercise 03/12 (Homework 6)	**Objectives**: LTSPICE–based lab to understand natural and step response with RC circuit, RC low-pass filter
	Unit 7: AC, phasors, networks and opamp 2 – AC sources, phasor analysis and impedance, generalize network analysis	**Objectives**: Understand AC power sources, and know how to convert R/L/C into impedance and perform KCL, KVL,

	(KCL/KVL, node-voltage, mesh-current) to AC circuits 03/15	node-voltage/mesh-current analysis using phasors, analyze opamp circuits with capacitors/inductors.
11	**Lab 7:** Opamp filters – Create opamp-based low-pass and high-pass filters in class. 03/19 (Quiz for Units 5-6, Lab 6)	**Objectives**: Understand how to build opamp-filters using breadboard and components; test the AC signal and measure the response.
	Unit 8: ECG and biopotential amplifiers – action potential, neural and muscle cells biophotentials and how to measure 03/22 (Homework 7)	**Objectives**: Understand action potential in nervous and muscle cells, understand the principle of ECG/EKG and amplifiers for measurements.
12	**Lab 8**: Biopotential amplifier – Create an instrumentation amplifier to measure biopotentials 03/26 (Lab 7)	**Objectives**: Create instrumentation amplifier using quad-opamp and build a circuit to measure biophotentials.
	Unit 9: Neuroimaging with EEG and fNIRS – brain anatomy, measuring brain activities using EEG and fNIRS 03/29 (Homework 8)	**Objectives**: Understand the main parts of human brains, and major neuroimaging methods, understand how EEG, MEG and fNIRS work.
13	**Lab 9**: Building an ECG and PPG detector – Create a circuit to measure ECG as well and PPG 04/02 (Quiz for Units 7-8, Lab 8)	**Objectives**: Know how to design key parameters for an opamp based amplifier +filter circuit to process ECG and PPG signals.
	Lab 9 - 2: Building an ECG/PPG detector – Complete the circuit and measure your own ECG and PPG 04/05	**Objectives**: Complete the lab exercise with the measurement of your own ECG and PPG, know how to debug and adjust circuit to measure bio-signals.
14	**Unit 10**: Data acquisition and digitization – Signal sampling, data communication protocols (serial, I^2C, SPI), quantization of analog signals. 04/09 (Homework 9)	**Objectives**: Know how different devices talk to each other; understand how signals are sampled and stored in digital computers and how to convert between analog and digital signals.
	Closing: Final review – A review of the entire class materials 04/12 (Lab 9)	**Objectives**: A final review of the course.
15	**Problem-solving hackathon II** – We collect student-submitted questions and explain them step-by-step in class. 04/16 (Quiz for Units 9-10)	**Objectives**: Helping students on specific questions and prepare everyone for the final exam.
	Final Exam (TBD) 04/19 – 04/26	Final exam focuses on the second-half of the course (Units 6-10) but will also involve methods taught in Units 1-5.
16	Final exam week (additional office hour will be arranged)	

Notes: All homeworks will be assigned and completed via **Mastering Engineering** in Blackboard. For homework questions, multiple submissions are typically allowed (which means if you keep learning and trying the tests again, your score will get better). All lab reports should be submitted in Blackboard in the form of a single **PDF and Word** (doc, docx, …) file. Additional files (such as circuit layout files) can be submitted as attachments. Typically, homework will be assigned on the day the lecture, and you have one full week to complete. I will drop your worst quiz if 95% of the students complete the **TRACE survey** before its deadline.

Condensed Course Calendar Map (16 weeks, 32 slots)

Jan 08 Open	Unit 1.1	Unit1.2	Lab 1	Unit 2	Lab 2	Unit 3.1	Unit3.2	*Weeks 1-4*
Feb 05 Lab 3	Unit 4	Lab 4	Unit 5	Lab 5	Prep 1	Middle	Unit 6	*Weeks 5-8*
Mar 05		Lab 6	Unit 7	Lab 7	Unit 8	Lab 8	Unit 9	*Weeks 9-12*
Apr. 02 Lab 9	Lab 9-2	Unit 10	Review	Prep 2	Final			*Weeks 13-16*

Legend: each cell in the above chart represents a class time slot; two slots per week. Color code: - Regular Lecture; - In-class labs; - sample problem-solving sessions; - Exams; Empty – No class.

Course Policies

Grading

Assignments in this course are divided into these general categories with their respective weights

Homework	15%
Quizzes	10%
Midterm Exam	20%
Lab Reports	25%
Final Exam	30%

Homework Assignments on Pearson Mastering Engineering (15%)

Regular homework will be assigned, approximately one per week. Doing the homework regularly and diligently is essential for students to succeed in the class. These will be available online through the Blackboard System (Pearson Mastering Engineering). Questions are correct / incorrect, **you will be given multiple attempts** up until the homework deadline. Therefore, it is anticipated that if you spend time, your assignment score will be close to 100%. There are also a number of guided learning activities and videos related to the textbook that are optional, but encouraged.

Please be aware that **completing the homework problems on Mastering Engineering (ME) is an integral part of the learning**. You should expect to encounter problems of different level of difficulties – some can be solved directly using the methods discussed in the lectures, others may require combinations or minor extensions of those techniques. Reading additional materials, such as the guided learning activities in ME or relevant online tutorials, has been shown to be important tools for one to efficiently solve those questions.

Labs (25%)

As described in the syllabus, there are a series of 9 planned "in-class labs". All of the in-class labs will be performed in the regular classroom. All students **should review the lab instructions before the actual lab, and complete the pre-lab questions**. These questions are very important in understanding the lab and ensure that you have sufficient time to complete it in-class. Failure to complete the pre-lab questions may result in additional works outside of the class. One should use a

bound notebook to keep good notes of your lab results to facilitate report writing and future review.

Lab reports will be due as indicated in the syllabus, but can be uploaded to Blackboard sooner. Late penalty for lab write-ups is 10% of total per day. While two students work together in a lab, **each one should write their own report.** The NI ELVISmx software 18.0 (to use myDAQ) only supports old versions of Mac OS (before OSX 10.9). If you use a Mac, please follow this instruction to install Windows via Bootcamp in order to run ELVISmx, **or find a lab partner who has a Windows laptop**.

Quizzes (10%)

A total of 5 quizzes are planned (1 quiz for every two units) as indicated in the tentative Calendar above, normally given after the homework is completed and discussed. These are intended to provide students and instructor with regular feedback on understanding of the course material, to help students stay current in the course, and to provide evidence that students have mastered the course material. For each quiz I will report the average class score and standard deviation. Occasionally there will be a quiz with a low class average. This is not cause for concern, since it is actually helpful in knowing which concepts should be reviewed.

There are no makeup quizzes. If you are absent for a quiz without a valid reason (illness with doctor's note, family emergency, etc.) a grade of zero will be assigned. If you have a valid excuse, the quiz will be "dropped" from your average. At the end of the semester I will drop your lowest quiz score in calculating your final average.

Midterm (20%) and Final Exams (30%)

There will be two close-book exams – the **mid-term exam will cover Units 1 through 5** (resistive circuits and opamps with resistors), and the **final-exam will focus on Units 6 to 10** (transient and AC response, opamp filters and ECG), however, it may also involve important concepts from the earlier units. Two **0-credit assignments will be available** on Mastering Engineering (midterm practices and final practices) to give you more practice opportunities before exams. In addition, we allocated two class slots (**problem-solving hackathon I and II**) for going through previous exams or student submitted questions.

To better prepare you for the exams, sample mid-term and final exams, along with the solutions, from previous semesters are available on Blackboard throughout the semester. We will explain some of the problems during the problem-solving hackathon sessions, but feel free to ask questions during any of the office hours.

Receiving Grades & Instructor Feedback

Assignment grades and feedback are provided generally ***1 week*** after the assignment is due and always before an assignment of the same type is due. Unless otherwise stated, grades and feedback will be available via the ***Grades*** area of the online course site.

Accepting Late Work

Late work may be accepted for extenuating circumstances. These include family emergencies, sickness, and various other unforeseen circumstances. All work must be submitted by the last day of the course; no extensions or late work will be accepted beyond that date. Please plan ahead.

Communication

Feel free to ask questions by phone, email, or scheduling meetings in my office (during office hours or another scheduled time), or by video conferences (skype). I will try to respond to your question within a day or two.

Minimum Technical Skills

Students should have basic understandings to college-level mathematics, including, but not limited to, **complex number algebra, solving simultaneous equations, trigonometric functions, integration** and **differentiation** etc.

Students are expected to be comfortable accessing the online course site and downloading files such as Microsoft Office documents, YouTube videos, and PDFs. In addition, students should be able to use Microsoft Office to compose written documents, spreadsheets, and PowerPoint presentations.

A **basic knowledge of MATLAB** is required.

Academic Integrity

The University views academic dishonesty as one of the most serious offenses that a student can commit while in college and imposes appropriate punitive sanctions on violators. The Student Handbook contains more information on what is considered academic dishonesty and is available here. A first offense will result in a grade of zero on the assignment. A second offense will result in a failing grade for this course and disciplinary action through Northeastern University's student judicial committee.

University Policies

Students with Disabilities

Students needing disability accommodations should visit the Northeastern University Disability Resource Center (DRC).

Student Privacy (FERPA)

The Family Educational Rights and Privacy Act (FERPA) affords students certain rights with respect to their education records. For information about these rights, visit the Northeastern University Office of the Registrar.

Diversity

Northeastern University is committed to providing equal opportunity to its students and employees, and to eliminating discrimination when it occurs. For more information, including grievance procedures, please visit the Northeastern University Office of Institutional Diversity and Inclusion.