Electronics & Electronics Lab

Physics 3310-001 (3 cr.) & 3311-001 (1 cr.) **Fall 2011** **Villanova University**

Lecture:	TR	3:00 – 4:15pm	Mendel 247
Lab:	W	1:30 – 4:20pm	Mendel 284

Instructor:

Dr. Jeremy P. Carlo

Email: jeremy.carlo@villanova.edu

Web: http://homepage.villanova.edu/jeremy.carlo

Office: 365A Mendel Hall

Lab: 364 Mendel Hall

Tel.: (610) 519-3279 (x93279 on campus)

Office Hours: M 3:30-5:00pm, TR 2:00-3:00pm, other times available by appointment.

Content: This is an introductory course covering theory and experiments in electronic circuits. Note that though the lab and the lecture are formally separate courses which will be graded separately, they will follow each other extremely closely. Electronics is a very practical topic, so both the lecture and laboratory components are equally important.

The lectures will cover DC and AC circuits featuring components such as resistors, capacitors, inductors, diodes and transistors, theories of operation and methods of analysis of these circuits, and in the latter portion of the course we will discuss more complex circuits, including amplifiers, switching circuits, integrated circuit devices, and digital electronics.

The lab portion of the course covers the practical aspects of designing and analyzing electronic circuits. This includes the use of common diagnostic equipment such as multimeters and oscilloscopes, learning to translate a printed schematic diagram into a real electronic circuit, and practical skills in constructing and troubleshooting circuits. Although the course is formally structured to have labs on Wednesdays, and lectures on Tuesdays and Thursdays, we may on occasion switch that around.

Ideally, I'd like to cover the course material (that is, the stuff you'll be tested on) within the first 11-12 weeks of the semester. That leaves the last few weeks of lecture for review, and to cover "special topics" of mutual interest, which could include the history and personalities involved in the development of electrical and electronic devices, applications of the course material such as radio transmission/reception, particle detectors and instrument control / data acquisition, or topics of current research interest with important electronics applications (such as magnetoresistance and superconductivity). We can discuss some ideas for "special topics" as the semester progresses. If there is sufficient interest, rather than perform weekly "cookie cutter" lab experiments every week through December, the last few weeks of lab can be used for work on final projects, which would be more open-ended projects over which you would have a great deal of creative input.

Prerequisites: There are no "official" prerequisites for this course. I will, however, assume that you are all majors in physics, astronomy, or a closely related field, and have taken the first two semesters of calculus, and the first two semesters of introductory physics.

Mathematics: I will assume that you have a working knowledge of algebra and trigonometry, and calculus to the extent of conceptually understanding derivatives and integrals, and finding derivatives and integrals of simple functions (mainly sines, cosines and exponentials). We will be algebraically solving simple linear simultaneous equations (i.e. solve for x and y if $3x+y = 5$ and $5x – 7y = -2$) – whether you do this by determinants, addition and subtraction of equations, or substituting one equation into the other is up to you; I will review some techniques to solve simultaneous equations, but leave it to you to become proficient. I will make use of phasors and complex numbers and briefly discuss differential equations in the module on AC circuits, and use binary arithmetic and Boolean logic in the module on digital electronics, but will develop the necessary mathematics in class.

Physics: I will assume that you have paid attention in your mechanics and E&M intro classes (Phy 2410-2413 for most of you), so that you know what electric and magnetic fields and electric potential difference are, and are familiar with the concepts of work, energy and forces. I will delve a bit into solid-state physics when discussing the properties of resistors and of semiconductor devices, and may introduce some rather advanced physics concepts (which you may not see again until grad school!) in the "special topics" lectures, but will develop all that physics as needed.

Some of you may already be electronics hobbyists, which is great, but I will assume you have never wired a circuit before (other than to plug an appliance into the wall, or insert a battery into a portable device!). The lab will cover these skills, which are extremely important in order to translate what you read in textbooks and hear in lectures into practical electronics knowledge (i.e. how to connect a jumble of wires together to get a circuit equivalent to what in printed in a schematic diagram). If you are already knowledgeable about electronics, I hope these labs will not be too boring, and that you'd vote in favor of a final project (which you'd probably find more fulfilling).

Textbooks: I will not be officially following any textbook, although there are several books which closely parallel the material I will present. Therefore, I present a list of "recommended" books.

John O'Malley, *Schaum's Outline of Basic Circuit Analysis*, 2nd ed.
Jimmy J. Cathey, *Schaum's Outline of Electronic Devices and Circuits*, 2nd ed.
Delton T. Horn, *Basic Electronics Theory with Projects and Experiments.*

The first two (which I'd say are "strongly recommended") are from the Schaum's Outline series, and give rather brief overviews of the topics, but have a large number of worked problems. They are available on amazon.com for ~$20 each. The material in the O'Malley book will be covered mostly in the first part of the semester, whereas the Cathey book will be covered (incompletely) in the latter part.

The third (which I'd call "less strongly recommended") is a book by Delton Horn, which makes for (what I consider to be) "pleasure reading," as a good (albeit dated) narrative introduction to most of the material I will cover in the course. Beware of the worked problems, however, as there are a number of typos; if you're looking for problems to work on, steer toward the Schaum's books.

Responsibilities: You are responsible for everything I cover in lecture, unless I say otherwise. There will be lots of things in the "recommended" texts which I will not cover in lecture; you are not responsible for that material but you're welcome to study it as well if you are interested. Conversely, there will be some things I cover in lecture that will not be in any of the texts; I will do my best to distribute hand-outs from other texts, refer you to texts you already have from other courses, or distribute my own lecture notes on these topics, though you are responsible for all material I cover in lecture.

I have divided the course into a half-dozen or so "modules." Since the division is done by topic rather than by week, some of the modules will be longer than others (the shortest will be on the order of 1 week, and the longest about 3 weeks). My plan is to give a homework assignment for each module; it will be assigned around when we complete the module in lecture, and will be due 1-2 weeks later. One topic we can discuss in the first few class sessions is how heavily you would like the homeworks to weigh into your final grade (or whether you'd prefer almost all of the final grade coming from exams).

Exams and Grades: For the lecture, I plan to hold two in-class exams during the semester (one around October 6 (before Fall Break), and one around Nov. 17 (before Thanksgiving Break)), and a final exam at the University-scheduled date and time (though I may be persuaded to substitute this with a final project for the lecture part of the course; we can discuss this as the semester progresses).

For the lab, you will complete weekly experiments, and turn in individual lab reports the following week (although there will be no lab report for the first session on August 24). I will provide more guidance on lab reports in a separate document. These lab reports, as well as my qualitative analysis of your work in the lab itself will factor heavily into your lab grade. Finally, I will give you the option of a "lab exam," or a final lab project to be done in the last few weeks of lab.

Regarding final grades: I don't intend to "kill" anyone with this course, since I know most of you are taking some pretty heavy courses this semester. I want it to be a somewhat relaxed introduction to a fascinating topic, which may evolve over the course of the semester according to our interests. If there are particular topics in which you are interested, please let me know and I will try to tailor the lectures and the labs toward those interests. You're free to take away as much or as little from this course as you want, and I know from experience that some students have much stronger electronics backgrounds than others (particularly regarding the practical/lab aspects). However, if you pay attention in lecture, put forth the effort to perform your lab experiments and consistently turn in your lab reports and homeworks on time, you should expect to receive something in the A or B range.

Academic Integrity and Legalisms: The Villanova University policy on academic integrity will be in effect throughout the semester. I expect that all lab reports, and all exams, are the result of individual effort without outside assistance (unless otherwise authorized). That said, the lab work itself will generally be done in groups, and I encourage you to work in groups on the homework assignments (though what you turn in should represent your own work, even if you work together to solve problems).

If you are a person with a disability please contact me regarding any accommodations you need, and also register with the Learning Support Office at 610-519-5636; the latter is required in order to receive accommodations.

Detailed Overview of Lecture Course Material

This is a tentative list of the topics I'd like to cover. We may cover a bit more than this, or we may cover a bit less, or a slightly different set of topics, as our interests may evolve as the semester progresses.

0. *Introduction* – What is electronics? Why take this course? Orientation & basic skills. (Week 1)
1. *DC Circuits & Resistors* – Current, power and voltage. Theory of electrical resistance / conductance in metals and insulators. Ohm's Law / microscopic Ohm's Law. Types & identification of resistors, resistor color code. Reading schematic diagrams. Series & parallel circuits, equivalent resistances and reducing complex circuits. Kirchhoff's Voltage and Current Laws. Ideal and "practical" DC power supplies. Using a multimeter (voltmeter, ammeter and ohmmeter). Hall effect & charge carriers (?). Overview of network theorems (*e.g.* Thevenin, Norton). Some practical DC circuits (e.g. voltage divider, Wheatstone bridge). (Weeks 1-3)
2. *Capacitors & Inductors* – physical models of capacitors and inductors, definitions of C and L. Review of relevant electromagnetism (e.g. Gauss, Faraday, Ampere). Types & identification of capacitors & inductors. Series and parallel combinations of C & L. RC and RL circuits: charging and discharging curves, time constant, practical RC, RL & RLC circuits. (Weeks 4-5)
3. *AC circuits* - definition of alternating current, comparison of AC and DC. Sinusoidal and other waveforms. Historical overview of AC vs. DC for power distribution. Use of the oscilloscope and function generator. Peak, RMS, average voltages. Transformers. Reactance and impedance. Set up and solution of RLC circuit differential equation. Phasors and complex numbers (*i.e.*, leading and lagging current (ELI the ICE man)). Resonance, Q, and high/low/band-pass filters. A little Fourier analysis. Motors and generators. Household power distribution. (Weeks 5-7)
4. *Diodes* – ideal and practical models of the diode, basic semiconductor physics (*n*-type and p-type doping, band theory, electrons and holes, *pn* junctions, depletion, forward and reverse bias). Types, identification and characterization of diodes. Simple diode circuits - rectifiers, voltage multipliers. Specialty diodes (e.g. Zener, LED). Circuits involving diodes & specialty diodes (*e.g*. LED displays, voltage regulators, voltage multipliers, clippers). (Weeks 8-9)
5. *Transistors* – introduction to switching and amplifying circuits, brief overview of electromechanical relays and vacuum tubes. Historical introduction to transistors. Types & identification of transistors. Bipolar Junction Transistors. Common-emitter, common-base and common-collecter amplifiers. DC load line & biasing. Practical amplifier types. Field effect transistors. Operational amplifiers and analog transistor applications. (Weeks 9-11)
6. *Integrated circuits and digital electronics* - background on integrated circuits. Introduction of digital logic. Boolean algebra, binary arithmetic, de Morgan's laws. Logic Gates, Flip-flops, multivibrators, adders, integrators, differentiators, etc. Building digital components out of transistors. Analog-to-digital conversion (and vice versa). (Weeks 11-12)
7. *Special Topics?* (Weeks 13-14)

Information about Labs and Lab Reports

For most of the semester, we will perform a weekly lab experiment on Wednesday. I will provide you with a handout and a brief overview of what is to be done in the week's lab, and you will perform the experiment (generally working in groups of 2) during the class period.

Then you will write a lab report to be handed in the following week describing the experiment, what you did, and what you found. Following is a list of points to keep in mind:

1. Though the lab experiments themselves are a "group effort" in that you will work with one or more partners, the lab reports are to be *individual* efforts: each of you will submit a lab report which (aside from the data collection itself) represents your own individual work and thoughts.
2. The lab report should be reasonably self-contained, in that it should include an introductory section that describes the motivation for the experiment (i.e. what you are doing and why), and gives a brief overview of the necessary theory or models needed to understand the experiment. This does not need to be (and should not be) an "encyclopedic" introduction to the material, just a brief overview that would explain what you did to someone who is familiar with electronics but not with the particular lab experiment.
3. For sanity's sake, I would recommend dividing the lab report into sections (e.g. Introduction / Background / Overview, Methods / Experiments, Data / Results, Discussion / Conclusions).
4. The introduction should be in your own words (i.e. not a regurgitation of the lab writeup). If (and this is almost always true) there are relevant schematic diagrams, or diagrams of the experimental setup (in most cases the former is the most important, although it may be necessary to include both), you should include them in the Methods section, along with a description of what you are setting up and what you intend to measure.
5. You should discuss your data and results concisely – what did you find? In most cases you will want to determine whether it agrees with "theoretical" expectations (i.e. what you calculate from Ohm's Law or Kirchhoff's Laws, or what you expect from a theoretical model of the behavior of the component under study, which you probably outlined in the Introduction section). This discussion, along with a discussion of sources of error, difficulty or uncertainty which limited your results, can fill the Conclusion section.
6. In some cases your data will be a set of numbers, in which case you should report the values you measured, and state how they compare to the values you expect from calculations. In other cases the most instructive way to present your data is with a graph of some sort (i.e. showing a linear relationship between voltage and current in a resistor, and comparing the slope with the nominal value of the resistance). In these cases the graph (and any relevant fit parameters) are the most important products of the data, and reporting individual values (e.g. in a data table) is unnecessary.
7. In a few cases there will be a "pre-lab" assignment in which you are to calculate certain quantities or read some material before coming to the lab. I don't anticipate this happening regularly, but it will from time to time.