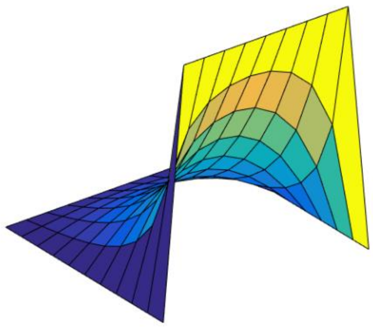
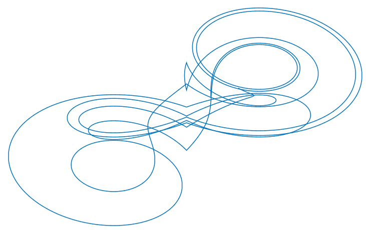
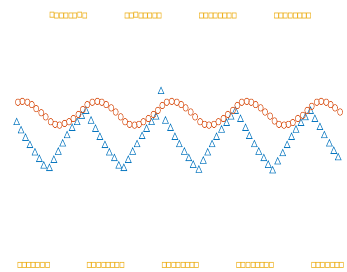
PHYS 222: Fundamentals of Engineering Design

Broadly applicable mathematical, computational, and experimental skills strategically selected to be mutually reinforcing with a small but diverse set of engineering topics.







"When I am working on a problem, I never think about beauty but when I have finished, if the solution is not beautiful, I know it is wrong." – R. Buckminster Fuller

Engineering is vast. Even a single engineering discipline, such as electrical engineering, is vast, a subject for a lifetime of study. **This course is a "super fun pack" of four engineering skills and three engineering topics.** The skills and topics were not selected at random. Instead, the chosen skills and topics are mutually reinforcing, like the stones in an archway. **All four skills will be illustrated through all three topics:**

- We will use **Fourier series** to analytically solve problems in **heat conduction**, **circuit analysis**, and **semiconductor physics**.
- We will use **Laplace transforms** to analytically solve problems in **heat conduction**, **circuit analysis**, and **semiconductor physics**.
- We will use **finite difference approximations** to numerically solve problems in **heat conduction**, **circuit analysis**, and **semiconductor physics**.
- We will use the **Arduino microcontroller** to do experiments in **heat conduction**, **circuit analysis**, and **semiconductor physics**.

Fourier series, **Laplace transforms**, **finite difference approximations**, and proficiency with the **Arduino microcontroller** are broadly applicable skills. Problems in heat conduction, circuit analysis, and semiconductor physics are just a small sampling of the problems that can be solved using the skills that you'll learn in this course. By the end of the course, I think you'll be amazed at your ability to solve problems analytically, computationally, and experimentally.

The course is divided into three units:

1. **Design of Heat Fins**: Heat conduction, Fourier series, and finite difference approximations.
2. **Design of Amplifiers**: Op amps, circuit analysis, and Laplace transforms.
3. **Design of Solar Cells**: Semiconductor physics and further applications of Fourier series, Laplace transforms, finite difference approximations, and Arduino!

Texts:

For your convenience, I provide 88 pages of typed lecture notes. The primary references are also ebooks that you can access for free:

- Chapters 2, 4, and 5 from Lienhard and Lienhard, *A Heat Transfer Textbook*, 4^{th} ed., 2012. Free ebook: http://web.mit.edu/lienhard/www/ahttv202.pdf.
- Chapters 10, 11, 13, 15, 16, and 18 from Santiago, *Circuit Analysis for Dummies*, 2013. Ebook accessible through Emory libraries.
- Chapters 3 and 4 from Honsberg and Bowden, *PVCDROM*. Free ebook: http://pveducation.org/pvcdrom.

I think the material is sufficiently complicated that you'll benefit from both attending the lectures and reading the typed lecture notes (maybe skim them before the lecture, and review afterward).

Grading:

- 15% Test 1 (heat transfer)
- 15% Test 2 (circuit analysis)
- 15% Test 3 (semiconductor physics)
- 30% Lab reports (5% $\times$ 6 reports)
- 25% Final project (5% oral presentation, 10% written report, 10% degree of difficulty)

Lab (and final project) reports:

Clearly, correctly, and thoroughly explain what your data means and how you got it. Lab assignments may be submitted jointly by lab partners. Electronic submissions are welcome.

Problem sets: Ungraded but recommended as preparation for tests. Solutions are provided.

Final project:

Imitation is a great way to learn, so you can replicate a project you find online, as long as you cite your sources, and you thoroughly explain how it works. You can elevate the degree of difficulty by one or more of the following:

- Pick a project that requires advanced mathematical or computational skill.
- Pick a project that requires laborious construction or troubleshooting in the lab.
- Pick a project that you partially or entirely design yourself (not imitating someone else's).

	Topic	Lab activity	Problem Set	Due
Jan 10	Fourier's law	Smith Ch. 1	1	
Jan 12	1D heat equation	Smith Ch. 2	3	
Jan 17	Lumped capacity	Smith Ch. 5.1, 5.2	2	
Jan 19	Heat fin	Lab 1	4	
Jan 24	T(x,t): Fourier series	Lab 1	5	
Jan 26	$T_{steady}(x) + T_{transient}(x,t)$	Lab 1	6	
Jan 31	Finite difference approx.	Lab 2	7	**Lab 1**
Feb 2	T(r)	Lab 2	8	
Feb 7	T(x,y)		9	**Lab 2**
Feb 9	**Test 1**			
Feb 14	Op amps	Lab 3	10	
Feb 16	RC circuits	Lab 3	15	
Feb 21	Frequency response (gain)	Lab 4	11	**Lab 3**
Feb 23	Laplace transforms	Lab 4	12	
Feb 28	Transfer functions	Lab 4	13	
Mar 2	Shortcut to T(s)	Lab 4	14	
Mar 14	Chaos in electronics		16	**Lab 4**
Mar 16	**Test 2**			
Mar 21	Semiconductors	Lab 5	17	
Mar 23	Generation, recombination	Lab 5	18	
Mar 28	Diffusion equation	Lab 6	19	**Lab 5**
Mar 30	Nonhomogeneous dif. eqs.	Lab 6	20	
Apr 4	Surface recombination	Final project	21	**Lab 6**
Apr 6	p-n junction	Final project	22	
Apr 11	Solar cells	Final project	23	
Apr 13	**Test 3**			
Apr 18		Final project		
Apr 20	Project presentations			
Apr 28				**Final project**