E12 Linear Physical Systems Analysis

Spring 2026, Swarthmore College

What is E12 about?

E12 is titled Linear Physical Systems Analysis. This might be a somewhat puzzling or inscrutable title for you. The title of this course has been set by engineering professors who already know what 'linear physical systems' are and why their 'analysis' is important. You, as a student who has not yet taken this course, may not necessarily be on board with the whole idea. The purpose of this section of the syllabus is to give you some background and motivation for why this course is important. First, let's look at each word in the course title in turn.

1. Linear

When we use the word 'linear', we are referring to a mathematical property of equations. As you know by now, equations are at the heart of engineering, but this course is specifically about *linear* equations. Whether you know it or not, you are already aware of what linearity is, but in this course, you will dive deeper into what makes some phenomena 'linear', and — perhaps more importantly — why linear-ness is very useful for engineers.

2. Physical

This course is about physical things, i.e., things that you can see, touch and feel. But what kinds of physics? In this course, you will see that many different kinds of things are governed by suspiciously similar equations, whether you are describing a car's suspension system, a motherboard's power module, a gear train or a steam turbine. The two kinds of physics that we will focus on are: (classical) **mechanics** and (classical) **electromagnetism**. By 'classical', we mean to exclude quantum or relativistic effects, which you should be (at least vaguely) aware of but which you will not encounter in this class. This is not a physics class, however, but an engineering class, which brings us to:

3. Systems

This course is about systems, especially mechanical and electromagnetic systems. For the purpose of this course, you should think of a system as a set of processes that relates inputs to outputs. Given a certain kind of input, what kinds of outputs are predicted by the governing equations? In a physics class, you would dive deep into the why and the how of mechanics and electromagnetism.

In this engineering class, we will take the physics equations as given, and we will learn to view physical phenomena — both natural and engineered ones — as (linear) systems in which outputs are related to inputs in predictable ways.

4. Analysis

This class has a laboratory and a lecture component, but both are geared towards *analysis* rather than *design*. This is not to say that design is not important in E12; often, you will be asked to choose parameters that fit certain engineering specifications, i.e., you will be asked to design systems. But this course is primarily about the analysis of relatively simple systems, which is a prerequisite for being able to design more complex ones. The word 'analysis' does *not* have the meaning that it does in the math department. The meaning of the word 'analysis' as used in this course's title is something like "resolution into simpler elements by analysing (opp. synthesis)". If you want to read 10,000 words about what 'analysis' really means, here you go! (You can thank me later)

History of the course

E12 is numbered sequentially after E11, and you should see these two classes as a two-semester sophomore-level sequence. These two courses follow each other both logically and chronologically, and used to be named something like 'Linear Physical Systems 1 & 2'. Over time, E11 became specialized toward electrical linear physical systems and E12 toward mechanical linear physical systems, but in E12 you will deal with both electrical and mechanical systems.

To the instructor's knowledge, it appears that E12 has been taught at Swarthmore College since at least 1977. The ideas that you will learn about have an even longer history, and have been 'canon' for engineers, scientists, and applied mathematicians for a long time. These ideas are covered in the engineering curriculum at most institutions, but Swarthmore College is fairly unique in teaching a course with the specific title 'Linear Physical Systems Analysis'.

You may find it interesting that a longtime instructor of E12, Prof. Erik Cheever, who is presently Edward Hicks Magill Professor Emeritus of Mathematics and Natural Sciences at Swarthmore College, maintains a website devoted to an earlier version of this course. The present instructor will not make use of this website directly, but due to its somewhat legendary reputation, he thinks it's best that you be aware of it.

Course at a glance

Field	Info
Course Number	ENGR 012
Course title	Linear Physical Systems Analysis
Type	Core ENGR course
Lab	Meets biweekly
Enrollment	60+
Prerequisites	ENGR 6, ENGR 11
Lecture Instructor	Prof. Emad Masroor

Field	Info
Lab Instructor	Prof. Will Johnson
Meeting times	TR 8:30 to 9:45
Location	SCI 199
Required Textbook	*System Dynamics*, Palm. 3rd or 4th ed.
Optional Textbook	*Modeling and Analysis of Dynamic Systems*, Close, Frederick Newell.

Catalog Description

This course (including the lab) will provide you with an introduction to time-domain and frequency-domain approaches involving the measurement of, modeling, solution to and analysis of linear dynamical systems that occur in many engineering disciplines. The course is designed to enable you to gain experience in closed-form and numerical solutions of ordinary differential equations governing the behavior of single- and multiple-dimensional systems. You will have an opportunity to explore system responses due to impulse, step, sinusoidal, and general inputs. System response characteristics such as superposition, stability, resonance, amplification, and attenuation will be considered.

Brief schedule of topics

Week	Topic	Due
1	Math preliminaries	HW 0
2	First-order systems in time domain	HW 1
3	Frequency domain; Laplace Transform	HW 2
4	Block diagrams & Simulink	HW 3
5	Second-order systems with no damping	HW 4
6	State-variable approach	HW 5
7	Mechanical modeling	HW 6
Spring break		
8	Second-order systems with damping	Midterm
9	Damping ratio, settling time, etc.	HW 7
10	Second-order systems with Laplace	HW 8
11	Bode plots	HW 9
12	Introduction to Fourier Series	HW 10
13	Vibrations; modes; normal modes	HW 11
14	Further second-order models	HW 12

Learning Objectives

After completing this course successfully, you should be able to …

- Mathematically model mechanical and electrical systems using linear differential equations derived from Newton's Laws and Kirchhoff's Laws respectively.

- Distinguish between *linearity* and *nonlinearity* in physical systems, and approximate the latter with the former in appropriate circumstances.
- Solve linear constant-coefficient ordinary differential equations of first and second order, as relevant to mechanical and electrical lumped-parameter models.
- Use the Laplace Transform to transform equations from the time domain to the frequency domain and thereby replace differential equations with algebraic ones.
- Cast linear physical systems into 'input-output' form and quantify the relationship between the input of a system and its output, particularly using the Transfer Function
- Numerically solve the governing equations using software packages in MATLAB, Python, or similar.
- Use block diagrams to model linear physical systems, and become familiar with MATLAB's Simulink package to numerically model these systems with block diagrams.

Teaching Team

Name	Role
Emad Masroor	Lecture Instructor
Will Johnson	Laboratory Instructor
Kenny Relovsky	Course Wizard
Madeline Mountcastle	Course Wizard
Bella Thoen	Course Wizard
Ian Forehand	Lab Wizard
Nick Fettig	Lab Wizard
Aubree Daugherty	Grader
Ryder Maston	Grader
Owen Hoffman	Grader
Howard Wang	Grader
Julian Courtney-Bacher	Grader

Grades

In this course, it is possible for you to calculate your overall numerical score by using the following table of weights. Your final score in the course is a weighted average of the components. Each homework assignment will be weighted equally.

Components of Grade

Component	Grade
Participation	5%
Labs	20%
HW	25%
Midterm	20%
Final	30%

Grade Thresholds

This class uses an absolute threshold for grades. Your grade in E12 is not explicitly compared against your peers' grades, but is instead compared against an absolute standard set by the instructor. Numerical threhsolds will be used to convert numeric scores to letter grades according to the Swarthmore College grade definitions.

> **Definitions of Letter Grades**
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> From the Swarthmore College catalog: A means excellent work; B, good work; C, satisfactory work; D, passing but below the average required for graduation; and NC (no credit), uncompleted or unsatisfactory work.

The instructor will assign +/- qualifiers to the letter grades, approximately equally spaced across the corresponding letter grades, i.e., 83 is the minimum for a B and 87 the minimum for a B+.

> **Adjustment of thresholds**
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> The numeric thresholds set out in this document may be adjusted downward in your favor (i.e., by making it easier to get a certain letter grade) and will not be adjusted upward. Should the instructor choose to make such a change, this will translate *all* thresholds downward by the same numeric amount. Such changes are made to bring letter grades in alignment with the College's definitions.

A+ grades are reserved for truly exceptional mastery of linear physical systems' analysis.

Letter	Numerical score
A range	90-100
B range	80-90
C range	70-80
D range	60-70
NC	Below 60

Policies

Electronic Communication and Website

This course will make use of three main electronic channels of communication between you and the teaching team (i.e., instructors, wizards, and graders). These are:

1. Moodle
2. Gradescope
3. Course Website

Lectures

This course will be conducted in the form of in-person lectures during the regularly-scheduled meeting time. Lectures will not be recorded and remote participation is not possible. Students are expected to attend every lecture, and to take their own notes. Although the instructor will post lecture slides from class to the website, these do not replace the need for students to actively engage with the material, ideally by taking their own notes. In addition, you are expected to abide by the following norms:

- Please be respectful of everyone else's time by being punctual.
- Cell phone use is not permitted in class. If you have an urgent matter to attend to that requires you to use your phone, you may leave the room discreetly and return when you are able to.
- Bring writing implements and a calculator to class.
- In general, electronics are not allowed in class. The only exception to this is tablets or tablet-like devices that you use to take electronic notes with a stylus. Laptops, even for the purpose of taking notes, are a distraction to others and to yourself, and they should not be open unless the instructor has announced otherwise.

Homework

- Late work will automatically incur a penalty of 20% per day, i.e., if the assignment is worth 100 points, 20 points will be deducted from your score if submitted 0-24 hours late, 40 points will be deducted if submitted 24-48 hours late, and so on. You do not need permission to submit late work.
- Exceptions may be granted for extenuating circumstances, such as medical procedures, family emergencies, and other circumstances beyond one's control. These exceptions will be at the discretion of the instructor.
- Each student can request one extension during the semester, of one week's duration, with no penalty. This is a no-questions-asked extension and will be deemed automatically granted when you request before the deadline.
- Homework extensions of all kinds are to be requested using the Google Form located at this URL.

Exams

There will be one midterm exam covering the first half of the semester and a final exam that will be cumulative. The midterm will be held during an evening during the week listed in the syllabus on a precise date to be announced. Both exams will be in-person and will require the use of writing implements and a calculator. If you miss an exam without prior notice, it will not be rescheduled and you will get a zero on that exam, barring extenuating medical emergencies.

Evening midterms have been scheduled outside of usual class times. This step is necessary to ensure that midterm exams can happen without undue pressure of completing them in 75 minutes. It is expected that students will resolve any foreseeable scheduling conflicts well in advance.