Oscillations and Waves in *Mathematica*

Preliminary Syllabus

Latest version at brianhill.github.io/oscillations-and-waves

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Course Short Name: **Oscillations and Waves**
Academic Year 2024-2025, Spring Semester (Terms 4 & 5)

Prerequisites

Very good high school math *Accessible* <===|=+=|===> *Hard*

AP math helpful but most definitely not required. The mathematical level will be similar to the Fall 2024 Bayesian Statistics course.

Materials

- *Tentatively*, Stephen Wolfram, *An Elementary Introduction to the Wolfram Language, 3rd Edition*, 2023, but I am still looking at similar introductions

- *Tentatively,* Steven Tan, *Introduction to Oscillatory Motion with Mathematica, First Edition Revised*, 2018, and I may draw from this myself but not require you to have a copy

- *Mathematica* license: Desktop and Cloud is $75/year for a student. There is also a semester (six-month) plan for $50, and even a monthly plan, for $10/month, which would work fine and save you another $10 if you only used it for the four months from early-January to early-May (see also **Computing Resources!** section below)

Computing Resources!

You need a laptop on which you can install your own copy of *Mathematica*. Disk space is critical: 18 GB is required if you install the local documentation. 9 GB is tight but doable without local documentation.

The nice thing about installing the local documentation, is that you don't have to have internet access just to look up how all the *Mathematica* features work, but if you don't quite have 18 GB free, then you will be ok without it.

Context and Overview

The First Course within the Course

In order to do mathematical modeling, we need to learn a serious programming language, and nowadays I prefer *Mathematica* for a wide variety of purposes. *Mathematica* is a program that you interact with using the "Wolfram Language." We will learn the language by studying the first half of *An Elementary Introduction to the Wolfram Language, 3rd Edition*, by Stephen Wolfram himself.

The printed edition is over 300 pages divided into 48 sections. If we do 2-3 sections a class we can do most of the material up to Section 40 during Term 4, at which point you will be in an extremely good position to apply *Mathematica* to any problem that interests you. In parallel with learning the language we will be learning oscillatory motion and then waves.

The Second Course within the Course

What we will do with *Mathematica* in this course is fundamental physics that all theoretical physicists know very well: oscillations and waves. We will begin with simple oscillations involving a single particle. The classic is a mass on an idealized spring. There is a significant increase in complexity when you next put the mass on the end of a pendulum rod.

The next level of complexity is to step it up to two particles. If the two particles are connected, even weakly connected, this leads to all sorts of complex behavior that was not present for either particle separately. The most common example is known as the coupled pendulum. Since Kel asked about chaos, I will see if we can code up some chaotic motion using the compound pendulum (which is not the same as the coupled pendulum).

The next level of complexity is to step it up to N particles. ***After that, we take the limit that N goes to infinity!*** Waves appear! They appear completely naturally from laws governing a finite but ever larger number of ever more closely spaced and ever smaller particles.

Waves first show up in a single dimension, such as waves on a string. But then we can step up the complexity yet again and consider waves in two dimensions, such as waves on a drumhead. Finally the highest level of complexity we can hope to get to in a one-semester course, starting with no significant prerequisites, is a taste of what quantum-mechanical waves look like in three dimensions.