Prof. Raghuveer Parthasarathy
University of Oregon; Fall 2007

Physics 351 Project: *Coupled Oscillators*

Synopsis

Design and build a coupled oscillator system. Observe and analyze the motions of the oscillators and write a report describing your results, due Nov. 26. You are encouraged to work in groups of two, but each individual should hand in a report.

Introduction

To more deeply understand the workings of coupled oscillators, to practice designing experiments, and to gain experience in scientific writing, you will design, build, analyze, and describe one or two coupled oscillator systems. You have three options:

(i) <u>Create two distinct systems with two normal modes each</u>;
(ii) <u>Create one system with at least three normal modes</u>;
(iii) <u>Create one system with two modes in which the coupling can be adjusted</u>.

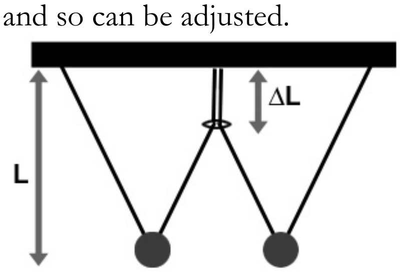
You are free to create whatever sort of systems you like (see "Design," below.) You may work in groups of two, or alone. In either case, each individual must turn in a report. The report is worth 10% of your course grade (as mentioned in the Syllabus) and are due before class (10 am) on **Monday, November 26, 2007**.

In addition to the goals listed above, I hope you have fun, explore, and "play" with the things you put together!

Design

Some possible coupled oscillator systems are:

- Pendulums coupled by rods. Pendulums whose strings are glued to a connecting rod will influence each other due to the torque they exert via the rod (see pages 127-128 of French).
- Pendulums coupled by springs, as demonstrated (for N=2) in class.
- Pendulums coupled by suspended masses (e.g. French, Figure 5-6) or other connections between the wires. In the example below, the coupling is provided by tying two of the pendulum wires together a distance ΔL below the support. The coupling will depend on ΔL, and so can be adjusted.



- A mass suspended by (or on) springs (e.g. French, Figure 5-7).
- A linear system of masses and springs (as discussed in class, and as illustrated, though with non-identical springs, in Exercise 5-7 in French). A system of 2 masses and 3 springs will have only 2 normal modes if the motions are confined to the line of the system, but 2 more if one includes motions perpendicular to the line. (Can you think, using symmetry considerations, of what they are?) Recall that you examined the modes of the "1 mass, 2 spring" case in Problem Set 4.

There are, of course, possibilities beyond this list (oscillating circuits, hydrodynamic systems, etc.)! I recommend building systems for which the normal modes are evident from symmetry considerations, but this is not a requirement.

Designing an experimental system is often enjoyable, sometimes frustrating, and rarely straightforward. Often, things don't work as expected or are more difficult than planned. Keep this in mind, start early, and expect to discard designs that don't work. Calculate the properties of your system whenever you can and use these as a guide – if you make a pendulum with a length of 5mm, for example, can you really expect to measure its period? Also, measure if possible the properties (oscillation frequencies) of each "uncoupled" component of your coupled oscillator(s). For springs, this may involve measuring extensions, given known masses, to get spring constants.

In your report, clearly describe the devices you construct. Either include photographs, or bring the system(s) in so that I can see them (see also "Report," below).

Observation and Analysis

Describe the normal modes of oscillation – the motions of the oscillators, whether the individual oscillators move "together" or oppositely, etc. Measure the normal mode oscillation frequencies, using a watch with a second hand or a timer. I've often used a simple Windows "freeware" timer program called TimeLeft (*http://www.timeleft.info/*). Note that you can most accurately measure the period of an oscillation by measuring the time it takes to complete several cycles, then dividing by the number of cycles. Can you observe "beats" – i.e. transfers of amplitude from one oscillator to another? (E.g. Eqns. 5-7 in the text, or as discussed in class.)

Analyze the behavior of your coupled system. This analysis can take various forms, for example:

(*i*) Given the components of your coupled system (and the frequencies of the uncoupled oscillators) calculate the theoretically expected normal mode frequencies, and compare with the values you measured.

(*ii*) If your system has couplings of "unknown" strength (e.g. related to the torsion of a rod, in the first "Design" example, or related to ΔL in example 3), use your observations plus theory to determine the strength of the coupling (perhaps expressed as an oscillation frequency). If the coupling is adjustable, determine the relation between the normal mode frequencies and the adjustable parameter.

You can ignore damping in your analysis, though it will probably be significant. Roughly describe the strength of damping (e.g. "the oscillations died out after about ten cycles..."), and give a rough estimate of Q.

Include a brief note of your experimental precision in measuring things like time, length, etc. You needn't do a full "error analysis" or worry about error propagation. (These are important, but beyond the scope of this project.)

If things don't work as expected, still provide a clear description of both experiment and theory, plus possible sources of error. Note alternative experimental approaches that you tried.

Materials

Use common materials to build your oscillator system. Use your imagination! You may want to purchase a few small items like rubber bands, super glue, toothpicks, straws, candy bars (as objects of known mass), etc. I can provide some potentially useful items: **twine, springs, bungee cord and hooks**. (I don't have many springs, so plan your design soon if you want some.)

Report

Each person must hand in a report. The report must be typed, though equations and figures can be hand-written. In addition to scientific content, I will also grade on grammar and clarity. As mentioned earlier, good communication skills are vital for any practicing scientist or engineer. Be sure to look over PS4 #7 (your own grade, and the posted "Solution"); note, however, that I was more lenient on issues of grammar and clarity than I will be for this report. Always ask yourself while writing: would this be comprehensible to another student who has *not* taken this course?

I believe there is some sort of drop-in writing center at the library, which may be of use. If you are unaware of it or can't find it, please see me, and I'll see what I can unearth.

The report should begin with a one-paragraph **abstract**, summarizing the system(s) and results. The body of the report should include an **introduction**, a discussion of the **experimental design & methods**, **observations**, **analysis**, and a **conclusion**. You needn't include derivations of formulas derived in class or in the text, but you should clearly state the meaning of all symbols used. There is no page requirement; use as many pages as necessary, but be as concise as possible.

I would like to see what you have built, so either bring your system(s) in to my office hours (or some other arranged time), or include a photograph with your report. If both of these options are very difficult, please see me, and we'll try to arrange something. If you bring your construction in, you can do so anytime through Friday, Dec. 1.

Misc

This "freeform" project probably has little in common with your other coursework (unfortunately). But it does have a lot in common with what preceded it – learning by playing with toys when you were young – and what follows – dealing with the perplexing unknowns of scientific or technological research. In "real life," no problem worth answering has a well-defined solution!

Despite (or perhaps because of) its vagueness, I hope you enjoy this project. Try to have fun with it. Meet your classmates over coffee and chat about what you might build.

Please see me if you have any questions!