I. Before you come to lab:

- Read through this handout and the supplemental
- Read section 12-7 in Kesten and Tauck on The Damped Oscillator

II. Learning Objectives

1. Learn how to quantitatively model a real harmonic oscillator
2. Learn how damping affects simple harmonic motion

III. Materials

- 3 springs:
    - Type A, long (thin)
    - Type A, short (thin)
    - Type B, short (thick)

- Mass stand and masses

The mass stand is a hook with a tray at the bottom for putting masses on it. The stand itself has a mass of 50 grams, and the CD attached to it has a mass of 20 grams. There are also masses ranging from 100 g to 500 g in the set.

- Lab jack
- Sonar motion detector

The sonar motion detector is a sensor that detects the position of objects using sonar ranging. The **minimum distance** away from the sonar detector that objects can be "seen" is 15 cm (about 6 inches). The resolution of the detector is 0.3 mm (that is, an object has to move by at least 0.3 mm in order for the sonar detector to read a different position measurement for it). The sampling frequency of this motion detector is about 30Hz.

- 600 mL plastic beaker
- 25 mL graduated cylinder
- Plastic water bottle
- Karo corn syrup (consult a TF before using)
- Stirring rod
- Forceps
- Plastic tray
- Ruler
- Computer with Logger Pro
- Balance

IV. Warm up

Describe how you can measure the spring constant of a spring using an object of known mass and a ruler. Discuss with your TF.

A:

Measure the spring constant of a **type A, long** spring using your procedure above. **What is this spring constant?**

Spring constant =

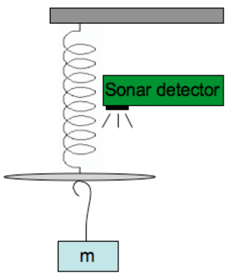
What do you think will be the spring constant of a type A, short spring (it is half the length of the type A, long)**?**

A:

Measure the spring constant of a **type A, short** spring using your procedure above. **What is this spring constant? How does this compare to your prediction?**
Spring constant =
A:

V. Procedure

Part 1: (Nearly) Undamped oscillations
In this part of the lab, you will determine the angular frequency of a 70-g mass (50 g for the stand + 20 g for the CD) oscillating on a long (not very stiff) spring. Hang the mass-spring system high over your lab bench and place the sonar detector above it. The CD on the hanging mass is so that the detector can "see" the motion of the hanging mass.



Remember, the sonar detector can only detect objects a *minimum distance of 15 cm away*. Also, use only small amplitudes of oscillation; this will significantly decrease the chances of having the mass fall off the stand and break something and it gives cleaner data.

Zero the motion sensor, then pull the mass down and let go. Record data for the motion of the hanging mass for several periods, but **only a few seconds** (about 5 cycles). Try to get everything lined up vertically and minimize side-to-side motion.

After you have taken some data, use it to estimate the period of the oscillation by inspecting the position vs. time graph. **What is the period of oscillation (with uncertainty)?**
Period=

Calculate the angular frequency from the period that you measured (don't forget uncertainty).
ω =

Try fitting a sinusoidal curve to the position vs. time graph. Under "General Equation," scroll down to the option near the bottom called "Undamped." The general equation for un-damped motion is position = A*cos(C*t+D)+E.
Which parameter in the fit corresponds to angular frequency?
A:

What do the other parameters correspond to?
A:

Before clicking "OK", choose "Manual" (rather than "Automatic") from the top right. Manually change the value of the parameter D by clicking the up or down arrow button (and holding it). **What does this do to the fit?**
A:

What is the angular frequency from the fit (don't forget uncertainty)?
ω =

How does this compare to the angular frequency from estimating the period (don't forget uncertainties)?
A:

Which method for determining the angular frequency is more accurate? Why?
A:

Paste a copy of the position vs. time graph, including the sinusoidal fit, below:
Graph:

From your data and the sinusoidal fit, calculate the spring constant of the spring (don't forget units and uncertainty):
k =

Qualitatively, how will ω change if you have a larger mass than 70 g oscillating on the same spring?
A:

Add some extra mass to the mass stand, pull down, and let go. **What is the angular frequency of the resulting motion (don't forget uncertainties)?**
ω =

How does this measured value compare to your prediction above?
A:

Pull down on the mass stand again, with larger amplitude than before, and let go. **What is the angular frequency of the resulting motion (with uncertainty)? Is it the same, larger, or smaller than the angular frequency of the motion with smaller amplitude?**
ω =
A:

Now hang the mass stand with the extra mass to the stiffer spring. **Qualitatively, how will the angular frequency change compared to the case where you had a spring that was not as stiff?**
A:

Pull down on the mass stand and let go. **What is the angular frequency of the resulting motion (with uncertainty)? How does this value compare with your prediction in the previous question?**
ω =
A:

Part 2: Damping due to air drag
For this part of lab, you will use a total mass of about 70 g and a type A, long spring oscillating with amplitude of a few centimeters. Pull down on the mass, let go, and observe the motion of the mass for **two minutes.** (Change the data collection settings before taking data, if you need to. Instructions on how to do this are in the Logger Pro help file.) **Describe what you observe.**
A:

Is the motion under-damped or over-damped?
A:

Fit the data to a curve based on your observation of the motion. **Paste a copy of your position vs. time graph, including the fit parameters, here:**
Graph:

What is the angular frequency of the oscillatory motion?
ω =

What is the time constant for the motion?
τ =

Looking at the graph, compare the amplitude of the motion at the beginning, and at a time B seconds later. **What factor do they differ by?**
A:

What would happen to the time constant τ (or fit parameter B) as you change the amount of damping?
A:

Part 3: Damping due to viscous drag
In this part of the lab, you will explore damping due to viscous drag by observing the motion of an oscillating mass that has been submerged in corn syrup. Please refer to the supplemental material for notes on setting up the experiment. The main question you will be answering is: **At what dilution of water-syrup is the system critically damped?** You will begin with a 0mL of water dilution (100% corn syrup). Then you will add 25mL of water at a time, take data of the motion of the hanging mass, and extract some parameters from your data (which you will use to fill the table below). This isn't exactly a titration, so you don't need to be as careful as you would in a chemistry lab.

Dilution (mL)	Time constant (s)	Time to zero (s)	Angular Frequency (rad/s)
0			
25			
50			
75			
100			

NOTES: Corn syrup is very viscous. You have to be patient and careful with things moving in corn syrup. Diluting water in corn syrup takes time (see previous note). Be careful and make sure you don't lose any fluid and that the water and syrup are well mixed before taking more data. Hot water works better than cold or warm water.

Set up the experiment as described in the supplemental material. Start with only corn syrup in the beaker. While collecting data, and without touching the spring directly, pull the mass up so that the top of the mass is level with the top of the syrup and then release it. After it has come to a complete stop, you can stop the data collection. **Describe what you observe.**
A:

How does this relate to what you know about damped harmonic motion? Is the motion over-damped or under-damped?
A:

Fit the data to a curve based on your observation. **What is the time constant of the motion?**
τ =

Add y-error bars to your graph (see Logger Pro help file). You may need to zoom in to see the tiny error bars. From visually inspecting the graph, estimate when the mass reaches a position within one error bar of its final equilibrium position. Subtract the starting time (the time when you released the mass) to get the time elapsed until the mass reached equilibrium. **What is this time?**
Time to equilibrium =

Save your data run by pressing command+L.
On page 2 of the Logger Pro file you will see a data table like the one above. Enter your time constant in the top row, in the column labeled τ. Enter your time to equilibrium in the last column, labeled "Time to zero." The third column (angular frequency) for this case will be empty. **Why?**
A:

Remove the mass from the corn syrup without changing the height of the jack. Add 25 mL of water, mix well, and repeat the experiment to determine the time to equilibrium and the angular frequency (if applicable). Take data for dilutions of 0 mL, 25 mL, 50 mL, 75 mL, and 100 mL of water, being sure to mix thoroughly for each dilution. Make sure you save each run (command+L) and fill the table above and on page 2 of the Logger Pro file.

Describe your observations as you dilute the corn syrup:
A:

What does τ represent if the system is under-damped?
A:

For under-damped motion, "time to zero" can refer to the time it takes the system to come to equilibrium, or to the time when the system first crosses the equilibrium point. Both definitions are OK; you just have to make sure you are consistent. **Which definition did you choose and why?**
A:

Critical damping is the threshold behavior between over-and under-damped motion. From your data on page 2, **which dilution comes closest to critical damping?**
A:

What was the time constant when the system was closest to critical damping?
τ =

What was the time to zero for the system closest to critical damping?
Time to zero =

Paste a copy of the position vs. time graph for the system when it was closest to critical damping:
Graph:

Create a graph showing both τ and Time to zero vs. dilution and paste it here. If you are having trouble finding the right variables, check out the supplemental for tips.
Graph:

In words, what conclusions can you draw from this graph regarding the relationship among τ, Time to zero, and the regimes of damping?
A:

Look at the values of ω that you observed for the under-damped systems. **How do they compare to the ω you got for the same system damped only by air drag? For under-damped systems, does ω increase, decrease, or stay the same as the amount of damping goes up?**
A:

When you have finished, clean up anything in your work area that has corn syrup all over it (the beaker, mass stand, masses, stirring rod, forceps if you used them, and anything else which was in the splash radius of your corn syrup) by taking it to the sink and rinsing it out thoroughly with warm water. Leave everything to dry on the tray **at your station** (not at the sink).

VI. Conclusion

What quantities affect the angular frequency of simple (un-damped) harmonic motion?
A:

What is the most important thing you learned in lab today?
A: