Physics 2010 – Spring 2006
Laboratory 2: Acceleration from gravity

NAME _____
Section Day (circle): M Tu W Th F
Section Time: 8a 10a 12p 2p 4p

In this lab you will do two separate experiments exploring how gravity makes things accelerate: one exploring a simple pendulum, the other measuring the motion of a freely-falling object.

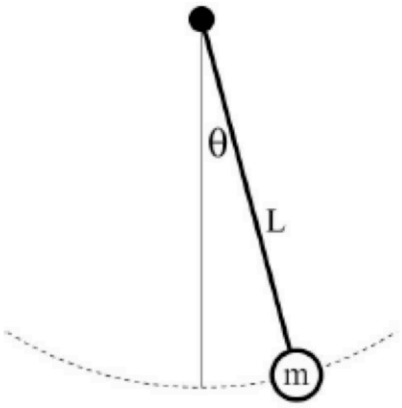
Instructions

- **Your first priority in any lab is safety.** The good news is that there are relatively few ways to hurt yourself or others in this lab. Still, pay attention at all times to what you and your lab mates are doing.
- Your next priority is to treat the equipment safely and respectfully. They are cool instruments, but they are sensitive and easily broken. Don't swing the pendulums wildly or let them go from a huge angle, or knock the ball-drop device or rulers.
- **DO NOT BRING FOOD OR DRINK TO THE LAB.**
- Work the prelab problems *before* the lab. Failure to turn in the prelab before the lab will result in a 2-point penalty for the lab. You are encouraged to make a copy of your prelab responses, so you can refer to them in the lab.
- Use the space provided for short answers, and attach extra pages to record your data. BRING EXTRA PAPER to record your data on - one or two sheets should do.
- All plots should have axes drawn neatly, with scales and units clearly labeled.
- A measurement is *wrong* if it has units and they are not specified.
- Measurements made with real equipment are not infinitely precise. It is important to report enough figures of a result so that all the real information from the measurement is conveyed. However, it's equally wrong – and more misleading – to report more digits than are significant!

Prelab Questions

A simple pendulum consists of a weight attached to a wire or string, hanging from a point where the string is attached – see the figure. The end of the string cannot leave its attachment point.

1. If you are not touching it, the pendulum hangs straight down. What forces act on the weight at the bottom? Which direction (if any) is the total force?
2. Now imagine moving the weight a small amount to one side and holding it still with your hand. What forces are acting on the weight now? Which direction (if any) is the total force?
3. Now imagine letting go. In the split second after you let go, what forces are acting on the weight? Which direction (if any) is the total force?
4. What kind of motion do you expect from the pendulum after you let go?



5. Our other experiment involves timing how long it takes a ball to fall from a certain height. Given the time t it takes a ball to fall a distance y, starting from rest and feeling only the force of gravity, how can you calculate gravity's acceleration?

1 Setting Up the Pendulum (10 min.)

First, get acquainted with the pendulum equipment.

- Examine the apparatus. A string hangs from a point. To the hook on the end of the string, one can attach a number of different "bobs," with different masses.
- You will also have measuring equipment: a protractor to measure the angle of the string, a two-meter stick to measure the length of the pendulum, and a scale to measure the mass of the bobs.
- Get some practice with the equipment, as follows. You don't have to write anything down.
    1. Take a bob and use the scale to find its mass. Then place it on the hook at the end of the string.
    2. Adjust the string to a height you pick: there are two knobs on top of the apparatus to do this. Now measure the length of the pendulum with the meter stick: start the measurement at the point the string is fixed on top, and end it in the *middle* of the weight. (We would like to measure to the "center of mass" of the bob, and the middle should be a good approximation to this.)
    3. Have one person hold the protractor at the top of the string, while another person takes the bob and GENTLY moves it a SMALL amount to the left or the right. The person with the protractor should then measure the angle that the pendulum is making (where straight up-and-down is zero degrees).
    4. Pick an angle less than five degrees, and release the pendulum. Observe the motion as it swings back and forth. Do NOT give the pendulum a push – just open your hand and let it go. Do NOT let it go from more than five degrees. The point of the lab is to observe smooth, steady, controlled motion.

5. The next section involves doing this procedure over and over, so make sure you understand how to measure the mass, length and angle, and how to start the pendulum motion. Ask your TA if you have any questions.

2 Measuring the period of the pendulum (50 min)

The goal is to take data measuring a single quantity, the *period* of the motion of the pendulum, while varying the experimental conditions: you will change the mass of the bob, the length of the pendulum, and the release angle of the pendulum, and measure the period in each case.

What does the period mean? You will have noticed that the pendulum swings back and forth, executing the same motion over and over. Anything that does the same motion over and over is said to *oscillate*. When that happens, one of our first questions is, "How long does it take to come back to the place it started?"

The answer is the period of the motion: the period is the amount of time it takes an oscillating body to complete the motion once before it starts doing it again. So for the pendulum, it is the time it takes the pendulum to go from its furthest point right, to its furthest point left, and back to its furthest point right again.

You could also measure the period starting at any other point in the motion, as long as you end the measurement with the pendulum at the same point and moving in the same direction as you started. Be careful not to measure half a period by mistake! If you start measuring with the pendulum straight up and down and moving left, you must stop measuring when it is next straight up and down and moving left - if you measure it when it is moving right you will get the wrong answer.

A NOTE ABOUT TAKING DATA: The most important experimental technique (besides safety) is accurately and honestly reporting the data you take. Even if you think you know what answer you should get, don't try to fudge the data to get that answer. You are being graded on good experimental technique, not on having perfect data!

For the following three sections, it is recommended that you record your data first on scratch paper. Then neatly record it on extra pages that you will attach to the lab.

2.1 Varying length

1. Pick a bob and determine its mass. Put the length of the string to something that you pick, and measure it. Put the bob on the string and displace the pendulum to an angle you pick, five degrees or less. Let the pendulum go and measure the period.

2. Make sure you have written down the experimental conditions – the mass, length and start angle – as well as your measured value for the period. All your numbers should accurately represent what you think the accuracy of the measurements are.

3. Now do it five more times without changing anything – mass, length or start angle. You know have six estimates for the period. *Average* them together by adding them all and dividing by six, to obtain your best estimate for the period with those experimental conditions.

4. Now do it again, but with a different length for the pendulum. It is vitally important that you keep the mass and start angle the same! We are only varying length. Measure the new length – try to make it different from the first one. Do six trials to obtain six estimates for the period, and average them together.

5. Now do it with a third and a fourth different length of the string. Try to have a nice range of lengths - from 10 or 20 cm up to more than a meter.

6. Make sure all this data is recorded neatly. You should have four sets of mass, length and angle (though mass and angle will be the same), and six estimates of the period and the average for each.

7. You now have four measurements of the period for four different lengths of the pendulum. Try to draw a conclusion: does the value of the period depend on the length?

2.2 Varying mass

- Repeat the steps from the previous section, but this time pick four different bobs with four different masses, while keeping the length of the pendulum and the starting angle fixed. (You may use any one of the measurements from the previous section as one of the four, and then make sure to use that same length for the other three. If you do, indicate which measurement you are reusing.) Record the data.

- You now have four measurements of the period for four different masses. Try to draw a conclusion: does the value of the period depend on the mass?

2.3 Varying angle

- Repeat the steps from the previous section, but this time pick four different starting angles, while keeping the length of the pendulum and the mass of the bob fixed. THE STARTING ANGLES SHOULD ALL BE FIVE DEGREES OR LESS. Again, you may use any one of the measurements from one of the previous sections as one of the four, and then make sure to use that same length and mass for the other three; if you do this indicate which measurement you are reusing. Record the data.

- You now have four measurements of the period for four different angles. Try to draw a conclusion: does the value of the period depend on the angle?

3 Finding the acceleration of gravity with the pendulum (10 min)

Once you are done with the previous section, ask the TA and he or she will tell you the correct formula for the period as it depends on length, mass and/or angle. Write it here.

- How does the formula compare to your conclusions from last section? Did you correctly determine what the period depends on? (Be honest – you will not be penalized for getting it wrong as long as you showed good technique.)

- Use three of your measured values of the period, along with the other variables, to determine g, the acceleration of gravity, from this formula. Average the three estimates together to get your final prediction. How does it compare with the correct value?

4 Dropping the Ball (20 min)

The final section of the lab uses a different apparatus to measure the acceleration of gravity. Here, we drop a ball from three different heights, and measure the time it takes to fall.

The setup is simple – an electromagnet holds the ball in place at the top. Pushing a button causes the ball to be released, and then a photogate below records the time the ball took to drop.

- Pick a height for the ball to drop from and measure it. Be sure to measure the correct length – think about what part of the ball the photogate sees first.

- Do four trials from that height – let the ball drop and record the time. Average the four trials together by adding the results for the time and dividing by four. Record the data.

- Choose two more heights and repeat these steps. Try to get a nice spread in possible heights. Record the data.

1. Plot the time versus height, and also the (time)^2 versus height (two separate plots). Is one of them linear?

2. Use the slope of the linear plot to calculate the acceleration of gravity.

3. Use the numerical data (not the plot) to calculate the acceleration of gravity using the formula from the prelab.

REMEMBER TO ATTACH YOUR DATA TO THE LAB.