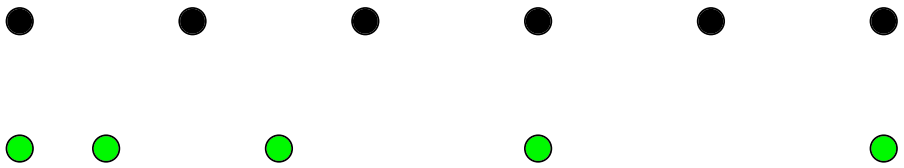
Physics

Free Fall Lab

Purpose & Hypotheses

This lab measures the acceleration of the Earth's gravitational field. Before beginning the lab, consider the following two pictures. Each is a **multiple-exposure** image showing the position of a ball every 1/60 of a second. How much time passes from start to finish in each picture? Which ball is accelerating and which is moving with a constant velocity? How could you determine the ball's velocity in each picture?



Procedure

1. Remove your timer from the box and use your clamp to attach it to your table in a position where you bring one of the two staples as **close as possible to the table edge** while **keeping the staple and the edge of the table parallel**. Make sure there is a clear line through both staples to the edge of the table that the clamp doesn't interfere with.
2. **Make sure the timer is turned off**, then plug the cord into the closest electric outlet. If the cord doesn't reach, you may have to repeat **Step #1**. Ask your instructor for help if necessary.
3. Locate the black plastic feeler gauge, which you'll use to adjust the length of the timer's striker screw. Insert the feeler gauge between the screw and the metal disk below it. If it doesn't fit easily through the staples, you can just stick it in from the side.
4. Adjust the wing nuts so that the bottom of the screw barely touches the feeler gauge **without raising the arm**, but try to keep the screw pointed at **the center of the metal disk** (under the feeler gauge). Tighten the wing nuts to hold the screw to the arm in this position. The screw should still be barely touching the feeler gauge (or close to it). If so, **remove the feeler gauge**. Otherwise, loosen the wing nuts and try again.
5. Remove one carbon disk from the envelope and return the others to the envelope exactly as you found them (though you may discard one paper spacer).
6. Fit the carbon disk over the black pin, **carbon side up**.
7. **Carefully** pull off about 1 meter of paper ribbon from the roll without unraveling the whole thing. Put a piece of tape on the end of the roll to hold it together.
8. Attach your bolt to one end of the paper ribbon with some tape. The bolt needs to hang freely from the ribbon, so attach it well.
9. Thread the other end through the two staples on the timer, **over the carbon**.
10. Pull the ribbon through the staples until your bolt is hanging freely near the top of the table. Hold the ribbon taught by the weight of the bolt on one side and one finger holding down the ribbon on the **other side** of the timer. Make sure the ribbon slack beyond your finger is straight and free to run through the timer without binding up. Also make sure that your electrical cord won't interfere with the bolt and ribbon as it falls.
11. Release your finger and verify that the bolt falls to the floor without causing the ribbon to twist or bind at all. Make adjustments as necessary.
12. Repeat **Step #10**, turn on your timer, and then quickly release your finger from the ribbon. **Stop the timer as soon as possible** after the bolt hits the floor as the noise is pretty obnoxious and the striker wears out the carbon disk.

13. Examine your paper ribbon to ensure that it has a section of 21 marks that demonstrate constant acceleration – it's probably a good idea to avoid both the marks closest to the bolt and the jumbled mess made when the bolt hits the floor. **Without covering up either mark**, draw a **circle around the 1st** of the 21 marks you chose (the one closest to the bolt), and a **square around the 21st** mark. **Count them again carefully to make sure you didn't make a mistake**.
14. As precisely as possible, measure and record the distance between the 1st (circled) mark and the 3rd one (i.e., skip one mark). Measure and record the distance between the 3rd and the 5th marks. Measure and record the distance between the 5th and the 7th marks. Continue this process until you've recorded **10 distances**, the last of which should be the distance between the 19th mark and 21st (squared) mark.
15. Make certain that each person in your group has a copy of this data before continuing.
16. **Carefully** remove the bolt from the paper ribbon (**don't discard the ribbon** – someone should keep it in case you realize you made measurement errors!)
17. Return your carbon disk to the envelope, and place the envelope, paper roll, and plastic feeler gauge in the bottom of the timer box, and return all of your equipment to your instructor.

Analysis & Conclusions

There is a great deal of mathematical analysis and careful graphing in this lab, so plan to devote an **enormous** amount of time and effort to it. **Don't put this work off until later** - you won't have a prayer of completing it properly!

A1. The timer makes 60 marks on the ribbon every second. How much time passes between each mark on your ribbon? How much time passes between each pair of marks for which you measured the distance? Would the time be the same for every pair?

A2. Construct a table to record the following items that you will calculate carefully for each pair of marks that you measured. The table is very wide, so turn your paper sideways to give enough room horizontally for all of the **columns** (a-g below). There should be 10 **rows** (vertically), since you have 10 pairs of marks for which you measured the distance:

a) **Total time** (from the 1st mark – needs to be calculated)

b) **Total displacement** (from the 1st mark – needs to be calculated)

c) **Displacement** (the distance you measured between the two marks)

d) **Change in time** (the time that passed between the two marks)

e) **Average velocity** (while time was passing between the two marks)

f) **Change in velocity** (increase from the previous average velocity)

g) **Acceleration** (the acceleration while time was passing between the two marks)

A3. Come up with formulas for calculating the values in each column of your table.

A4. Use your formulas to fill out all the columns and rows of your table.

Note: Leave the **change in velocity** and **acceleration** blank in the **very first** row (for your first pair of marks), since they both depend on the previous velocity, which you're ignoring.

A5. Estimate the acceleration of gravity by taking the average of the 9 **acceleration** values you calculated (from the last 9 rows of your table).

A6. Calculate the percentage error between your estimate and the accepted acceleration of gravity (the one we learned in class that has 2 significant digits of precision).

A7. Use your table to draw three graphs: **total displacement** vs. **total time**, **average velocity** vs. **total time**, and **acceleration** vs. **total time**. The total time should be on the x-axis, since it's the independent variable. Make sure that you **carefully** and **clearly** label both axes of each graph with regular tick marks, units, etc.