PHYSICS 133 EXPERIMENT NO. 3
ACCELERATION

Introduction

In this experiment we determine the gravitational acceleration constant *g* by measuring the position of a freely-falling ruler as a function of time.

Equipment

- 1 Computer set
- 1 Photogate
- 1 Interface box
- 1 Plastic ruler and masking tape

Method

By dropping a ruler through a photogate (an "electric eye") we can determine the rate at which a freely-falling object will accelerate due to the earth's gravitational force. The clear, plastic ruler will be marked at regular intervals with strips of masking tape that will block and unblock an infra-red light beam in the photogate at certain time intervals. These times will be measured and recorded in the computer and displayed on the monitor. If supplied with the distance between successive pieces of masking tape, the computer can perform the calculation of the average velocity of the ruler in these time intervals during its descent. The results can be displayed graphically on the monitor in various ways.

Procedure

1. Preparing the ruler: Lay a piece of masking tape across the ruler so that it lines up as precisely as possible with the 0 cm marker line. Then lay down the next piece tightly against the first one. Repeat the procedure until the tape covers the entire length of the ruler. Starting with the second piece, peel off every other piece of tape so that the ruler looks like a blunt "picket fence." See Fig. 1. Lay the peeled off tapes directly over the ones on the ruler so that you end up with a double thickness. This insures that the tape blocks the light efficiently. Trim off any excess tape.
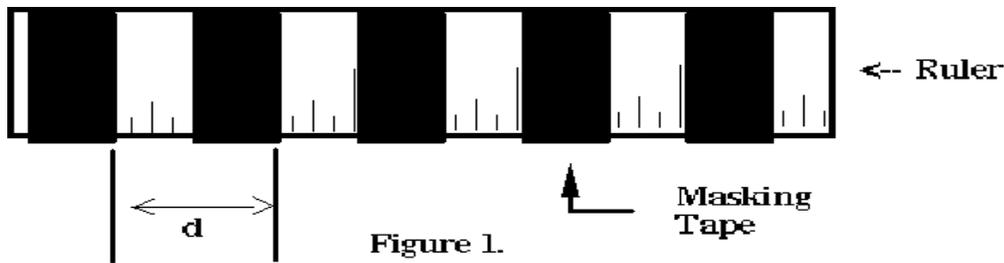
Figure 1.

2. Interval Measurement: Measure the interval *d* between the two successive leading edges of the tape pieces, i.e., one piece of tape and one blank spot (see Figure 1). To do it more accurately measure the distance from the first leading edge to the last one and divide it by the number of intervals between them.

Q1. Why is this more accurate?

3. Connect the photogate output to the interface box by plugging its cable into the first socket of the interface box.

4. Turn on the computer and check the system. Find the MS-DOS icon on the computer's "Desktop", and double click on it. Press M or use the cursor keys to highlight "Motion Timer" on the screen. Then push "ENTER".

5. Now we are ready to take data. Push the "SET" button on the interface box to permit the flow of data to the computer. Hold the ruler just above the photogate and drop it between the arms of the photogate so that the tape that was carefully applied to the ruler interrupts the light path. The computer will give a high-pitched whistle while the measurement is in progress. Push the "ENTER" key on the keyboard after the ruler has fallen.

6. A table of the time intervals will appear on the screen. By following the choices for graphing the data, plots of displacement vs. time, velocity vs. time and acceleration vs. time can be seen.

Q2. What can you say about the shape of the arrangement of points in each kind of plot?
Q3. Could you easily fit a straight line through the data in each of these plots?

7. Write down a table of values of velocities from the computer monitor in your lab book, and plot velocity vs. time by hand. The velocities are put on the y or vertical axis and the times on the x or horizontal axis. By eye, fit a straight line through these points. Calculate the slope of this line to determine the gravitational acceleration constant *g* which is the average rate of change of the velocity of the ruler as it falls. Next, fit a line that would have a larger slope and one with a smaller slope than the first one. (The lines should still fit the data reasonably.) These two additional lines should give an indication of the uncertainty in the slope of the first line. Calculate the slopes of the lines and determine the uncertainty in your measured value of *g*.

Q4. Are error bars appropriate on this plot?
Q5. How would you determine them?

8. The computer program has the facility to determine the slope of the line in the "Statistics" section. It will give the slope and uncertainty in the slope. Record its result in your lab book for this run. Compare the values with the ones you have determined in your lab book from the procedure 7. Repeat the experiment four more times to determine four more *g* values in this way. We do not need to record the individual velocities in these additional runs! For each run just write down the *g* value and its uncertainty from the computer. From these values, calculate the average experimental value of *g* and its associated uncertainty.

Q6. How does this value compare with the textbook value? Does the book value fall within your
    experimental uncertainty?
Q7. If there is discrepancy, what can be the possible sources for it?

9. Try dropping the ruler from above the photogate to give it an initial velocity before breaking the beam.

Q8. What effect does this have on the acceleration, or the straightness of the line?

10. Another way of measuring *g* is to simply drop an object from a known height and measure the time it takes to fall. To do this, return to the first menu of the computer program and select Mode K-Keyboard Timing Modes. At the prompts, select the "Simple Stopwatch" and "Large Display" options. The computer is now ready to operate as a stopwatch, with the spacebar starting and stopping the timing.

11. Hold the ruler vertically with its bottom edge 1.00 meters above the floor. Release the ruler and at the same time click the space bar. The instant the ruler hits the floor, click the space bar again. The display will report the time between clicks. Practice this procedure a few times until you become confident in your technique.

12. Measure the fall times for 25 drops of the ruler and record your results. Make a histogram of your results.

Q9. What is the mean time it takes the ruler to fall, according to your data?
Q10. What is the standard deviation?
Q11. What value of g do you get by this method?
Q12. Comment on your results and compare them with those obtained using the photogate.

Background Reading

Read Chapter 2 and Sections 3-1 and 3-2 of *University Physics*. You should review the text before coming to lab. Be sure you understand instantaneous and average velocity. It makes comprehending the lab a lot easier if you do the reading first.