

# Free-Fall Acceleration

In the laboratory, you can use a recording timer to determine the velocity and acceleration of bodies moving in one dimension. A recording timer measures the time it takes an object to move a short distance by making marks at regular time intervals on a strip of paper attached to the moving object. As the paper tape is pulled through the timer, the distance between two dots on the tape is the distance the tape moved during one back-and-forth vibration of the clapper. The time required for one back-and-forth motion of the clapper is called the *period* of the timer.

In this experiment, you will first calibrate a recording timer by determining an average value for its period. You will then use the recording timer to determine the average velocity and average acceleration of falling bodies of different masses.

## OBJECTIVES

**Measure** motion in terms of the change in distance during the period of a recording timer.

**Compare** the speed and acceleration of different falling masses at different stages of free fall.

**Compare** the experimental value for the average acceleration to the accepted value for free-fall acceleration.

## MATERIALS LIST

- C-clamp
- masking tape
- meterstick
- recording timer and paper tape
- ring stand
- set of hooked masses
- stopwatch

## SAFETY



- Tie back long hair, secure loose clothing, and remove loose jewelry to prevent their getting caught in moving or rotating parts. Put on goggles.
- Attach masses securely. Falling or dropped masses can cause serious injury.

## Procedure

### PREPARATION

1. Read the entire lab procedure, and plan the steps you will take.

**Free-Fall Acceleration *continued***

2. Record the data for your distance calculations in Data Table 1 below.

**DATA TABLE 1**

Trial	Mass (kg)	Distance (m) A-B	Distance (m) C-D	Distance (m) E-F	Distance (m) G-H
1					
2					
3					
4					

3. Record your calibrations in Data Table 2 below.

**DATA TABLE 2**

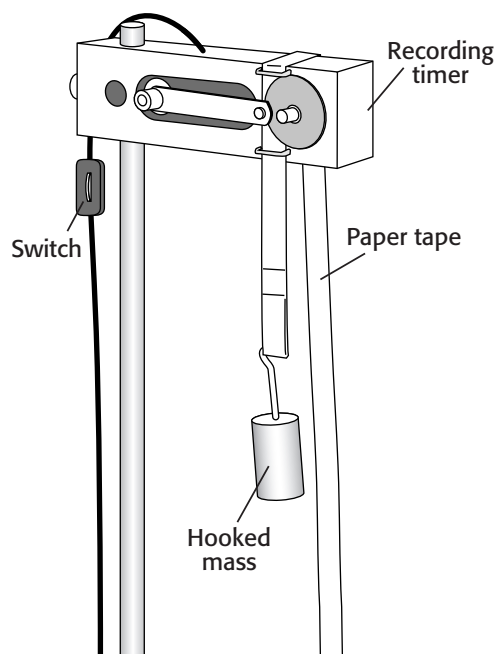
Trial	Time (s)	Number of Dots
1		
2		
3		
4		

4. Clamp the recording timer to the ring stand to hold the timer in place. Choose a location that will allow you to pull a long section of paper tape through the timer in a straight line without hitting any obstacles. ***Do not plug in the timer until your teacher approves your setup.***
5. Insert a strip of paper tape about 2.0 m long into the timer so that the paper can move freely and will be marked as it moves. Lay the tape flat behind the timer. One student should hold the end of the tape in front of the timer.
6. When your teacher approves your setup, plug the timer into the wall socket.
7. One student should start the timer and the stopwatch at the same time that the other student holding the free end of the tape begins pulling the tape through the timer at a steady pace by walking away from the timer.
  - a. After exactly 3.0 s, the first student should turn off the timer and stop the watch, just as the second student with the tape stops walking. Mark the first and last dots on the tape. Tear or cut the dotted strip of tape from the roll and label it with the trial number and the time interval as measured by the stopwatch.
  - b. Repeat this procedure three more times. Label all tapes.
8. Count the number of dots for each trial, starting with the second dot. Record this number in Data Table 2.

**Free-Fall Acceleration** *continued*

**a.** Compute the period of the timer for each trial by dividing the 3.0 s time interval by the number of dots recorded in the table.

**b.** Find the average value for the period of the recording timer. Use this value for all your calculations.



**Figure 1**

**SPEED AND ACCELERATION OF A FALLING OBJECT**

- 9.** Set up the apparatus as shown in **Figure 1**. If the timer cannot be mounted on the stand, clamp the timer to the edge of the table.
- 10.** Cut a length of paper tape that is at least 20 cm longer than the distance between the timer and the floor. Thread the end of the tape through the timer.
- 11.** Fold the end of the paper tape and fasten it with masking tape to make a loop. Hook a 200 g mass through the looped end of the paper tape, as shown.
- 12.** Position the mass at a convenient level near the timer, as shown. Hold the mass in place by holding the tape behind the timer. Make sure the area is clear of people and objects. Simultaneously, start the timer and release the tape so the mass falls to the floor. Stop the timer when the mass hits the floor.
- 13.** Label the tape with the mass used. Label the second and third dots *A* and *B*, respectively. Count four dots from *B* and label the seventh and eighth dots *C* and *D*, respectively. Label the twelfth and thirteenth dots *E* and *F*, and label the seventeenth and eighteenth dots *G* and *H*.
- 14.** Repeat this procedure using different, larger masses, such as 300 g and 400 g masses. Drop each mass from the same level in each trial. Label all tapes, and record all data.
- 15.** On each tape, measure the distance between *A* and *B*, between *C* and *D*, and so on. Record the distance in meters in Data Table 1.
- 16.** Clean up your work area. Put equipment away safely so that it is ready to be used again.

**Free-Fall Acceleration *continued***

**Analysis**

**1. Organizing Data** For each trial with the falling mass, find the magnitude of the average velocity,  $v_{avg}$ . Divide the distance  $A-B$  by the average period of the timer. Repeat this calculation for the other marked distances for each trial.

**2. Organizing Data** Using the results from item 1, calculate the average acceleration. Find the change of speed between the distance  $A-B$  and the distance  $C-D$ , between the distance  $C-D$  and the distance  $E-F$ , and so on. (Hint: Remember to use the total time interval for each calculation. For example, for the first calculation, use the time interval from  $A$  to  $D$ .)

**3. Constructing Graphs** Use your data to plot the following graphs for each trial. On each graph, label the axes and indicate the trial number. Use a graphing calculator, computer, or graph paper.

**a.** position versus time



**b.** velocity versus time



**Free-Fall Acceleration** *continued*

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c. acceleration versus time



**4. Organizing Data** Use the values for the average acceleration for all four trials to find the average value.

**5. Evaluating Results** Use the accepted value for the free-fall acceleration given in the text and the average of your results from item 4.

a. Determine the absolute error of your results using the following equation:

$$\text{absolute error} = | \text{experimental} - \text{accepted} |$$

b. Determine the relative error of your results using the following equation:

$$\text{relative error} = \frac{(\text{experimental} - \text{accepted})}{\text{accepted}}$$

**Free-Fall Acceleration** *continued*

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## Conclusions

**6. Making Predictions** Based on your results, how long would it take a 1000 kg mass to reach the floor if it were dropped from the same height as the masses in this experiment?

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**7. Analyzing Graphs** Calculate the slope of each velocity-time graph from item 3b.

**8. Evaluating Results** Find the average value for the slope of the velocity-time graphs. What is the relationship between this value and the values you found for the average accelerations of the masses?

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## Extension

**9. Designing Experiments** Devise a plan to perform this experiment to study the motion of an object thrown straight up into the air. Make sure you take into account any special safety requirements or equipment you might need to use. If there is time and your teacher approves your plan, perform the experiment. Use your data to plot graphs of the position, velocity, and acceleration versus time.