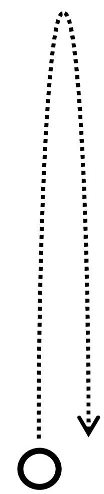
Experiment: Free Fall

Objectives:

1. Record and analyze a ball in free fall motion
2. Model the free-fall motion
3. Study the kinematic equations of the accelerated motion
4. Determine the acceleration due to gravity.

Equipment:

- Windows-based computer
- LoggerPro software
- Free-fall motion movie



Introduction:

Objects tossed up or down accelerate, in the absence of air resistance, at a constant rate. This rate is called the free-fall acceleration or acceleration due to gravity, and its magnitude is represented by "g". This value (in the absence of air resistance) does not depend on the object's mass or shape → it is constant for all objects.

For objects traveling at relatively low speed, air resistance is not significant so it will be considered zero in this experiment. During this experiment you will record and analyze the motion of an object in free fall. This experiment will allow you to better understand the concept of acceleration and the kinematic equations.

Preliminary Questions

1. For an object tossed vertically upward with an initial velocity of 2m/s, sketch the predicted velocity vs. time graph. What is the significance of the slope of this graph, in the absence of air resistance?

2. For the same object, what is the value of the acceleration at the beginning of the motion? At the top of the path?

3. For the same object, predict the shape of the distance vs. time graph.

4. At the top of the path, what is the value of instantaneous velocity? What about instantaneous acceleration?

Procedure:

A. Preliminary measurements, Video Recording and Analysis

1. Open the LoggerPro software
2. Click on "Insert"→ "Movie" then select the movie as directed by the instructor.
3. Toggling through the movie, observe and <u>describe</u> the flight of the ball (do this before performing video analysis)

4. Use LoggerPro, to analyze the flight of the ball
   a. Enable the video analysis toolbar by clicking on the button in the lower right hand corner of the movie window.
   b. From the vertical toolbar, click on the ruler shaped button to set the movie scale. On the screen, click on the bottom end of the meter stick and drag to the top end. In the dialog box, enter the length of the meter stick.
   c. You are now ready to analyze the movie. From the vertical toolbar, click on the icon to select the pointer. Click on the ball in the first frame where the ball is moving. The movie will advance by one frame. Click on the ball on each frame, until the last frame of the movie.

      It is important to use the same point on the ball for each frame.
   d. Click on the icon again to de-activate your pointer. Minimize the movie, so you can observe see the graphs.
5. Cut and paste the following graphs into Microsoft Word {this will make printing out the graphs more efficient}:
   a. (vertical) position vs time
   b. (vertical) velocity vs time
6. Print out a copy the motion graphs on a single page (one copy per each person in the group).
7. Describe shape of the vertical position vs time graph.

8. Describe shape of the velocity vs time graph.

Question: How can the velocity of the ball be zero at the top of its trajectory while its acceleration remains non-zero constant?

B. Graphical Analysis

9. Select the region of the position-time graph that represents the "in air" motion of the ball. Click on the <Curve Fit> icon in LoggerPro then "fit" the graph section to an appropriate model function. *Apply the simplest model that best fits the graph.*
10. Observe the selected curve fit generated by the software. If the model does not adequately fit the region of the graph you selected then adjust the highlighted area and repeat this operation. You may need to select a more appropriate fit equation.
11. Record the fit equation and corresponding coefficients in Table 1.

Table 1: Position vs Time Graph

	Fit Coefficient(s)					
Fit Equation (Experimental)	**A**	**B**	**C**	**D**	**Expected Fit Equation**	**Agree?** (yes or no)

12. Referring to your textbook, does your selected fit equation correspond to the expected "kinematic" equation for a free fall body? Record the expected equation in Table 1.

Question: Assuming the experimental and expected fit equations are in agreement, what is the physical significance of each the coefficients (A, B, etc…) in your experimental fit equation?

13. Observing the velocity-time graph and repeat steps 10-13 for this graph. Record values in Table 2.

Table 2: Velocity vs Time Graph

	Fit Coefficient(s)					
Fit Equation (Experimental)	**A**	**B**	**C**	**D**	**Expected Fit Equation**	**Agree?** (yes or no)

Question: Assuming the experimental and expected fit equations for Table 2 are in agreement, what is the physical significance of each the coefficients (A, B, etc…) in your experimental fit equation?

C. Summary Questions

1. Explain why there is a portion of positive velocity and then negative velocity on the graph.

2. Is there a point where the vertical velocity is zero?
   a. If so, where is this point?

   b. Is the acceleration zero at this point?

   c. Do these results match your prediction in the Preliminary Question?

3. Is there a relationship between the slope of the velocity graph and the fit coefficient A position-time graph? Explain why this might or might not be expected.

4. Using the velocity-time graph, determine the vertical acceleration for the ball.

5. Referring to your graphs, where does the ball slow down? Where does it speed up?

6. Is the acceleration zero at the top of the path?

7. Do your data demonstrate that the free fall acceleration is constant? Explain how does your data support or contradict this.

8. Do your experimental results match your predictions in the Preliminary Questions?

9. The acceleration due to gravity, g, has an accepted magnitude of 9.8 m/s^2. How does this value compare to the acceleration determined from your experimental data? *Calculate the % Error between the experimental and accepted values for free fall acceleration.*