

## Conservation of Mechanical Energy

### Fall 2023

### Introduction

The purpose of this experiment is to determine whether mechanical energy is conserved in a free fall experiment. You will determine the kinetic energy and the potential energy as a function of time as a ball is dropped.

### Predictions

Scenario: A ball is dropped from height  $h$  and falls through space. Draw a single graph where you sketch the following:

1. the potential energy as a function of time (draw using dashes).
2. the kinetic energy as a function of time (draw using dots).
3. the total energy as a function of time (draw using a solid line).

Make sure that you clearly label each of the three energies, as well as the axes. Briefly explain what your graph shows.

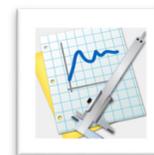
### Theory

Mechanical energy is the sum of the potential energy,  $U_g$  and kinetic energy,  $K$ . It is conserved when only conservative forces (such as gravity) are acting.

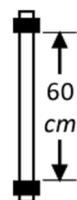
1. In this case there is only gravitational potential energy. The potential energy of the ball is  $U_g = mgy$ . Recall that for a ball in free fall  $y = y_i + v_{iy}t + \frac{1}{2}a_y t^2$ , where  $a_y = -g = -980 \text{ cm/s}^2$ .
2. The kinetic energy of the ball is  $K = \frac{1}{2}mv^2$ .
3. If the mechanical energy is conserved this sum,  $E = K + U_g$ , should be constant over time.

### Experiment

You will extract your data from a video of a super ball falling through the air. Start *Logger Pro* (icon at right) and open the file "Conservation of energy" from the PHYS103 folder on the T: drive. You will see a video, axes for two graphs and a data table.



1. Drag the lower right corner of the video to make the video as large as possible (it's ok if the graphs are covered). Keep the video large until you're finished collecting your data.
2. Play the video by clicking on the play button at the bottom of the video; you can play it more than once if you like. **Be sure to reset the video to the beginning!** Draw a sketch of the experiment in your journal; you'll only measure the falling motion of the ball, not the position when the ball bounces upward.
3. Before extracting data, the video needs to be scaled; Logger Pro needs to know how long a centimeter is on the video. There are a set of tools on the right-hand side of the video. Select the horizontal yellow ruler tool ("Set Scale", icon at right), which is the fourth from the top.
4. There is a vertical meter stick with black tape on the top and bottom on the right side of the video. The inner distance between these tape strips is 60 cm. Use the cursor to click on the *bottom* side of the upper piece of tape and drag your cursor down to the *top* side of the bottom piece of tape, as shown at right. When you are prompted to indicate the distance, type in **60** for the number and **cm** for the units.



- You will now set the frame rate for the video: click the **Options** menu, select “Movie Options” and put a check next to “Override frame rate to:”. Type **60** in the space next to “fps” (frames per second) and then click **OK** when finished.
- The data to be measured is the position of the ball as it falls downward as a function of time. The video frames give the time because each frame is separated by  $1/60^{\text{s}}$ . Select the “Add Point” tool  (right), which is the second from the top and has a red dot in the center. You will use this tool to mark the location of the ball in each frame.  
  
Move the mouse to position the cursor at the bottom edge of the ball and click the mouse button. This will place a blue dot on the screen where you clicked, and it will advance the video one frame (the ball may not seem to move very far at first!) *If you don't like where you clicked, you must immediately choose “Undo” under the **Edit** menu.*
- Continue to click on the bottom edge of the ball in each frame until the ball disappears from the video.
- IMPORTANT!** Click the “Select Point” tool (right) before proceeding; this will ensure that you don't add an erroneous point if you accidentally click the video. 

## Analysis

You will see two graphs on the right-hand side of your screen. The top graph is the vertical position of the super ball,  $y$ , as a function of time. Since the ball is in free fall, the expected relationship is  $y = y_i + v_{iy}t + \frac{1}{2}a_yt^2$  (as seen in the second experiment this semester.) Now you will compare the curve fit of your data to this equation.

- Shrink the video window (drag the lower right corner) so that the graphs can be seen.
- Click the graph of the vertical position to select it. Under the **Analyze** menu choose “Curve Fit”. Select the curve fit that has the same form as the expected relationship, click the “Try Fit” button, and then click **OK**.
- Determine the value of  $a_y$  from the curve fit; you can ignore the  $\pm$  (*uncertainty*) value. (*Hint: how did you calculate the acceleration from the Excel graph in “The Motion of Free Fall” and “Motion with Constant Acceleration” experiments?*)
- Calculate the % difference between  $a_y$  and the accepted acceleration,  $g = 980 \text{ cm/s}^2$ . You should redo the scale (steps 3 and 4 above) if your difference is more than 10% or measure the points again.
- Consider the second graph for Energy as a function of time.
  - How does this graph compare to the one you drew for your prediction? Be sure to refer to Potential Energy, Kinetic Energy, and Total Energy in your discussion. What are the similarities and differences? *You don't need to change your prediction graph if it doesn't match what you measured – just discuss the differences!*
  - You will next perform a sample calculation of the potential energy, the kinetic energy and the total energy for that time using the point closest to  $t = 0.2 \text{ s}$  in your table. These calculations will confirm the values that appear in the table; keep the same number of significant figures as appear in the data sheet and check your calculations if your answers don't match exactly. Use  $g = 9.80 \text{ m/s}^2$  and assume that the mass of the ball is  $1.0 \text{ kg}$ .
  - Calculate the change in kinetic energy and the change in potential energy from start to finish using your first and last data points.
  - Logger Pro has a tool that will allow you to find the average total energy. Select the Energy graph, and under the **Analyze** menu choose “Statistics”. In the next window that appears, select “Video Analysis: Total Energy”, and click OK. A box with these statistics will appear on the Energy graph.
  - Record the mean, maximum and minimum energy. Calculate the percent difference between the average Total energy and either the minimum or maximum (choose the one with the larger difference from the average) to see how flat your energy curve is.

- f. Print your graphs and data to include with your journal as follows:
  - i. Resize the data table to show all the data. It's ok if the table covers the video window.
  - ii. Move the statistics boxes around so they don't cover any of the curves.
  - iii. Click an empty area in Logger Pro so that no windows are selected. From the **File** menu, choose "Page Setup". Choose the correct printer, and click the "Landscape" button, then OK.
  - iv. From the **File** menu, choose "Print Preview" – you'll see the video, data, and graph windows. Click the **Printing Options** button, and then click the box next to "Print Footer", type your name and your partner's name(s), then click **OK** and then **Print**. Print a copy for each person in your group.
  - v. Finally, circle the point you used for your calculations (*step 5b*) in the data table on the printout.

## Discussion

- Record the results and % differences of the expected and calculated values for  $a_y$ , as well as the total energy comparison from step 5e.
- What are the primary sources of error in this experiment?
- Consider your value for vertical acceleration. Is it greater than, less than or equal to  $g$ ? What could cause a discrepancy between your value for acceleration and the accepted value? Don't forget to consider whether your value is larger or smaller than  $g$ .
- Comment on your calculation of the change in kinetic and potential energies (step 5c). How do they compare? What does the sign of each tell you?
- What can you conclude about conservation of mechanical energy? Justify your answer using the data from your experiment. Are there any significant forces acting other than gravity?