Conservation of Mechanical Energy
Fall 2017

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 super 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 the axes are labeled and clearly distinguish each of the three energies. Briefly explain what your graph shows.

Theory

Mechanical energy is the sum of the potential energy and the kinetic energy. 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 \( PE = mgy \).
   Recall for a ball in free fall that \( y = y_i + v_{iy}t + \frac{1}{2}a_yt^2 \), where \( a_y = -g = -980 \text{ cm/s}^2 \).
2. The kinetic energy of the ball is \( KE = \frac{1}{2}mv^2 \).
3. If the mechanical energy is conserved this sum, \( E = KE + PE \), 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’ll 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 report; 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 curser to click on the bottom side of the upper piece of tape and drag your curser 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.
5. 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 \( \frac{1}{60} \) 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 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.

6. 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.

7. Now you will set the frame rate for the video: click the Options menu, select “Movie Options”, put a check next to “Override frame rate to:”, and then type 60 in the space next to “fps” (frames per second). Click OK when finished.

Analysis

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

1. Shrink the video window (drag the lower right corner) so that the graphs can be seen.
2. 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.
3. Calculate the % difference between \( a_y \) and the accepted acceleration, \( g = 980 \text{ cm/s}^2 \). If your difference is greater than 5%, you should check the scale (step 4 above), or measure the points again.
4. Consider the second graph for the Energy as a function of time.
   a. How does this graph compare to the one you drew for your prediction? Be sure to refer to the Potential Energy, the Kinetic Energy, and the 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 actually measured – just discuss the differences!
   b. You will next perform a sample calculation of the potential energy, the kinetic energy and the total energy for that time from the point closest to \( t = 0.2 \text{ s} \) in your table. These calculations will confirm the values that appear in the table; check your calculations if your answers don’t match, keeping the same number of sig figs. Use \( g = 9.80 \text{ m/s}^2 \) and assume that the mass of the ball is 1.0 kg.
   c. Calculate the change in kinetic energy and the change in potential energy from start to finish using your first and last data points.
   d. 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.
   e. Record the mean, max and min 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) in order to see how flat your energy curve is.
   f. Print your graphs and data to include with your report as follows:
      i. Resize the data table to show all of the data. It’s ok if the table covers the video window.
      ii. 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.
iii. 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 member in your group.

iv. Highlight point #13 in the data table on the printout.

Discussion

- Report the results and % differences of the expected and calculated values for $a_y$, as well as the total energy comparison from step 4e.
- What are the primary sources of error in this experiment?
- Consider your value for the 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 4c). 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?