

Conservation of Energy- Video Analysis (10/2022) (approx. 60 min)

Introduction

The Work-Energy theorem tells us that changes in kinetic energy, $K = \frac{1}{2} mv^2$, are caused by work done by forces. A conservative force is one for which the work done when traveling between any two points is independent of the path taken between the initial and final point. An example of this is the force of gravity (weight): work by gravity is always equal to $-mg$ times the change in height, Δh . The amount of work done does not depend on how the object in question gets from one height to another, only on the final change in height. Furthermore, if the object returns to its initial height all of the energy lost to work against gravity can be recovered. We can think of the negative work done against gravity as potential energy that is being stored up and which can be recovered and converted back to kinetic energy by allowing gravity to do positive work. We define the change in potential energy, U , as $U = -\text{work by a conservative force}$. If there are no non-conservative forces (such as loss of energy due to heat) the total mechanical energy, E , defined as $E = K + U$, is a constant. We say energy is conserved when the total mechanical energy of a physical system remains constant/ For the gravitational force, the potential energy is given by: U_{gravity} where mg is the weight (force due to gravity) and Δh is the change in height. Note that $= mg\Delta y$ potential energy can be negative In this lab we will investigate the conservation of energy for a bouncing ball. This investigation will use the video analysis feature within PASCO Capstone to track the location (x, y) and Velocity components (V_x, V_y) of a basketball or any object you collect via digital video. The data collected via video analysis will be used to calculate the kinetic, potential, and total mechanical energy of an object within a system.

Equipment

PASCO Capstone Software (students can download this software for use on personal computers)
Video file: [Bouncing Ball](#) located at

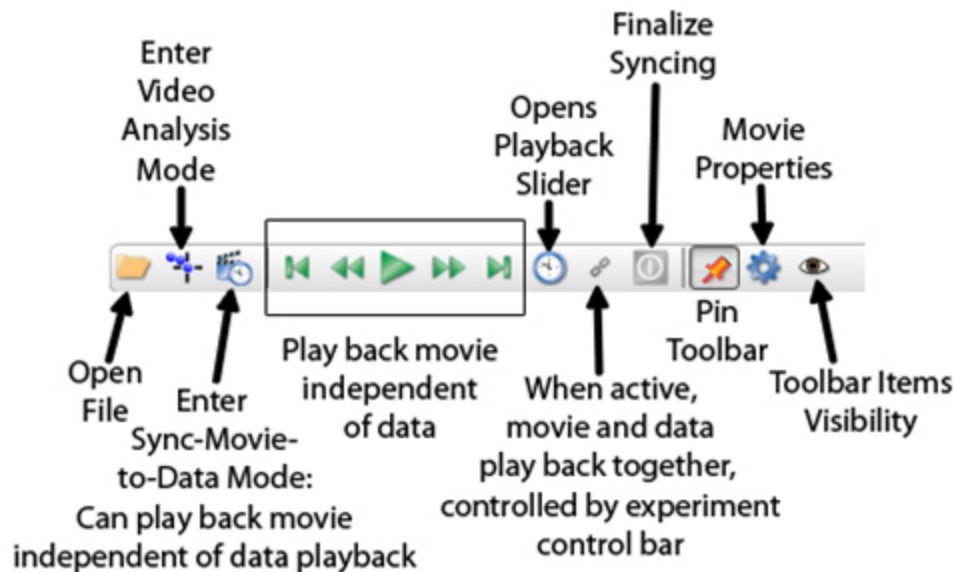
https://drive.google.com/file/d/1pQgOPGDFL9WstPcS85cIHSO-NXD_WIqz/view?usp=sharing

Meter stick or another object of known length for video reference

Procedure

- 1)Download the Bouncing Ball (or another video file) to the local computer.
- 2)Launch the PASCO Capstone software from the desktop.
- 3)Drag and drop the movie Icon from the display palette (on the right).
- 4)Click “Open Movie File”.
- 5)Select the appropriate movie file from your computer (Downloads, Bouncing Ball)

6)The downloaded movie demonstrates a basketball being thrown, freefalling, and experiencing several bounces. Push the green play button in the movie toolbar to play the movie. Below is an explanation of the items on the movie toolbar.



Enter Analysis Mode

Enter Analysis Mode by clicking on the **Enter Video Analysis Mode** button. Note that the toolbar changes (see below for an explanation of the new tools). New objects are automatically created as soon as you click in the movie to make it active, the next click you make will be the first track mark for the object. (Note: Steps 1 and 2 below are not necessary for a regular 30 frames/second movie.)

1)Before you start clicking, we need to tell it the proper number of frames per second (30 fps).

Open the properties by clicking on the **gear icon** on the right end of the toolbar. Under "**Movie Playback**", type in 30 for "Playback Frame Rate".

2)In the properties, under "Overlay", change the "Frame Increment" to 2. This will mean that the movie will advance 2 frames each time you click on a point (and, thus, your points will be 1/15th of a second apart).

3)You can also rename "Tracked Object 1" to "Ball". To do this, make sure you are in the Video Analysis Mode and open the Properties and under "Tracked Object", change the name to "Ball".

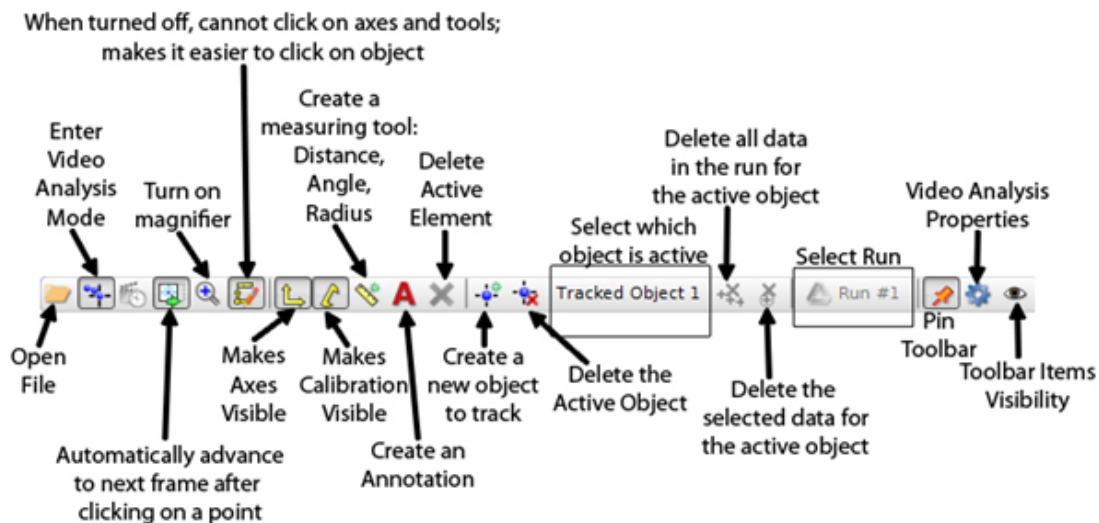
4)Drag and drop a graph from the display palette toolbar (on right). Once users track objects (ball) the graph will automatically plot data points.

5)When clicking Select Measurement you will be able to select a variety of quantities associated with the tracked object (ball).

6)Using the playback tools on the Experiment Control bar at the bottom of the page, advance the movie to the frame where the ball is leaving the person's hands in the video.

7) Click on the movie to make it active and then start clicking on the ball to track it. Try the magnifier to find the positions more accurately. Below is an explanation of the tools on the Video Analysis toolbar. In the event of a mistake when tracking (clicking on) the ball, use the undo button or hit Control Z to undo actions.

8) After tracking the ball through several (3) bounces if you play back the movie you may want to decrease the playback speed on the Experiment Control bar to 1/8 speed.

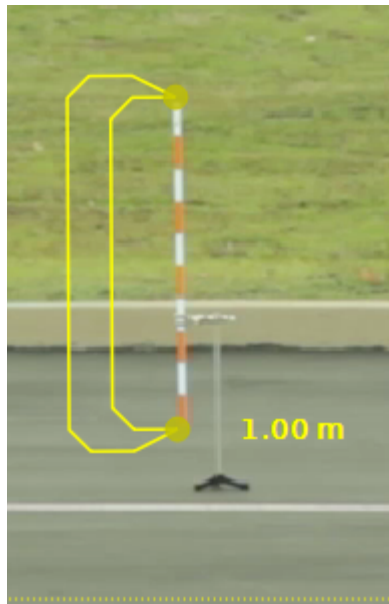


Changing Track Points

If you decide you want to change one or more of the points that you have already made, use the playback controls on the Experiment Control bar to return to the frame of the point you want to change. The point will have a circle around it. Then click where you want the point to be. The point will be moved to the new location. Then you can use the playback controls to advance frames or you can continue to relocate points by clicking on each frame as it advances.

Calibration can be done (or re-done) at any time.

Click on the Calibration Tool and move the yellow dots on the tool to the edges of the orange and white meterstick (oriented vertically) in the video. The length of the meter stick is 1.0 meters. Open the Properties and under "Calibration Tool", set the "Real World Length" to 1.0 meters. The calibration tool establishes a scale for quantitative measurements such as curve fits.



Track a Second Object (if needed)

- 1) Now we want to track the cart. Push the "Create New Object" button. You can rename this "Tracked Object 2" to "Ball2" in the same manner as you did for the ball.
- 2) Use the playback tools on the Experiment Control bar at the bottom of the page, and advance the movie to the frame where the ball is coming out of the ballistic cart launcher, exactly on the same first point for the ball.

Adjusting the Axes: The axes can be moved or rotated at any time.

- 1) Click on the yellow dot near the end of the x-axis and drag it to rotate the axes until the x-axis is aligned with the “horizontal”. Note that your graphs will change also.
- 2) In the movie analysis, click on the origin of the axes and drag the origin to the first analysis point for the ball.



Data Analysis

After tracking points, Capstone allows for displaying of additional data by dragging and dropping additional graphs. Users have the ability to change the quantities displayed by clicking on the variable labels on the axes. After completing the tracking users can display the horizontal position (x), vertical position (y), horizontal velocity (Vx), and vertical velocity (Vy).

The creation of calculated columns within Capstone allows for the analysis and comparisons of potential, kinetic, and total mechanical energies of this physical system.

Instructions for the Creation of Calculated Columns (PE, KE, and TE)

- 1) Tabulated data from object tracking can be displayed by dragging and dropping a table from the display palette (on right).
- 2) By clicking select measurement, users can choose any of the quantities from the tracking data (ball, or object).
- 3) The potential energy can be plotted as a function of time through the creation of a calculated column.
- 4) To create a calculated column (within the Table), click on the Create a new calculation button- this is the third button from the left along the top of the table.
- 5) When users click the calculated column button, a new row appears allowing the entry of a formula. The formula for $PE = m g (y)$. The mass of regulation basketballs is 0.625 kg, the acceleration due to gravity is 9.8 m/s/s, and lastly, the vertical position (y) of the ball can be

retrieved by pressing the open bracket “ [“ key. When the open bracket key is depressed, Capstone opens a drop-down tab allowing the user to select any quantity; you will select the (y) values from the ball/object data.

6) Lastly, users can rename the calculated column by clicking on the column label and selecting rename. This column should be titled PE with units of Joules.

7) Calculating the kinetic energy requires finding the vector sum (V_r) of V_x and V_y . Remember $V_r^2 = V_x^2 + V_y^2$. Therefore $KE = \frac{1}{2} m V_r^2 = \frac{1}{2} m (V_x^2 + V_y^2)$.

8) Perform an additional Calculated Column for the total energy ($TE = PE + KE$)

Displaying Energy Graphs

1) Drag and drop a graph.

2) Users can display multiple variables (PE, KE, TE) by clicking the add a new y-axis to active

plot button ( on graphs).

Conclusions

1) Sketch or perform screenshots of the x, y, V_x , and V_y data as a function of time.

2) Compare and contrast horizontal and vertical velocities and accelerations. Be sure to cite empirical (experimental) evidence.

3) What is the physical significance of the slope of the vertical velocity vs. time graph? How does your value compare with expected values? Does the value of the slope change during and between consecutive bounces?

4) Does the experimental data demonstrate the Law of Conservation of Energy (COE)? Yes, no, maybe? Under which circumstances throughout the video clip does COE hold true?

5) Write a report describing motion from a kinematics and energy conceptual framework.