
Energy of a Free Rolling Cart on an Inclined Plane

When a frictionless cart is projected up an inclined plane, the cart slows down until it reaches the top of its path and then speeds up on its way back down. In terms of energy, when the cart is released it has kinetic energy, KE . As it rises up the incline it slows down, loses kinetic energy, and gains gravitational potential energy, PE . As it starts down, still rolling freely, the stored gravitational potential energy is converted back into kinetic energy as the cart falls.

If there is no work done by frictional forces or the normal force to the incline, the total mechanical energy will remain constant. In this experiment, we will see if this works out for the freely rolling cart.

In this experiment, we will study these energy changes using a Motion Detector.

objectives

- Measure the change in the kinetic and potential energies as a cart rolls freely up and down an inclined plane.
- See how the total energy of the ball changes during the motion of the cart up and down the incline.

Materials

Power Macintosh or Windows PC LabPro Interface	Low friction track Astrolabe or other angle measuring device to measure the incline angle of the track
Logger <i>Pro</i>	Low friction cart to roll on track
Vernier Motion Detector	Lab jack to elevate one end of the track


Preliminary questions

For each question, consider the free motion of a cart projected up a frictionless ramp, starting just as the ball is released to just before it is caught. Assume that there is very little air resistance.

1. What form or forms of energy does the cart have while momentarily at rest at the top of the path?

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2. What form or forms of energy does the cart have while in motion near the bottom of the path?
 3. Sketch a graph of velocity vs. time for the cart.
 4. Sketch a graph of kinetic energy vs. time for the cart.
 5. Sketch a graph of potential energy vs. time for the cart.
 6. If there are no frictional forces acting on the cart, how is the change in the cart's potential energy related to the change in kinetic energy?

Procedure

1. Measure and record the mass of the cart you plan to use in this experiment.
2. Open the experiment file indicated by the lab instructor. Two graphs will be displayed, the vertical altitude of the cart above the motion detector and the velocity of the cart.
3. Connect the Motion Detector to DIG/SONIC 1 of the LabPro. Attach the Motion Detector to the lower end of the track, aiming upward along the track.
3. Using the lab jack elevate the end of the ramp at the opposite end from the motion detector about 5 degrees initially, as measured by the angle measuring device. Record angle in dialog box on screen and in the data table.
4. Hold the cart on the track about 0.3 m from the Motion Detector. In this step, you will project the cart up the ramp and let it rise and then fall back toward the Motion Detector. Have your partner click  to begin data collection. When the START button changes from green to red project the cart up the ramp after you hear the Motion Detector begin to click. Be careful not to project it so forcefully that it hits the upper end of the ramp. Verify that the height vs. time graph corresponding to the free-fall motion is parabolic in shape, without spikes or flat regions, before you continue. This step may require some practice. If necessary, repeat the toss, until you get a good graph. When you have good data on the screen, proceed to the Analysis section. Then return to procedure step 5 for the trial with larger angle.
5. Raise the angle of the ramp to about 15 degrees, record in data table and in dialog box on screen, and repeat Procedure step 4 and the analysis section for the new angle.

Data Table

Mass of the cart	(kg)
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
Position	Time	Height	Velocity	PE	KE	TE
	(s)	(m)	(m/s)	(J)	(J)	(J)
After release						
Top of path						
Before catch						

case 1: Angle = _____

Position	Time	Height	Velocity	PE	KE	TE
	(s)	(m)	(m/s)	(J)	(J)	(J)
After release						
Top of path						
Before catch						

CASE 2: Angle = _____

Analysis

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1. Click on the Examine tool, , and move the mouse across the height or velocity graphs of the motion of the ball to answer these questions.
 - a. Identify the portion of each graph where the cart had just left your hands and was in free motion. Determine the height and velocity of the cart at this time. Enter your values in the data table.
 - b. Identify the point on each graph where the cart was at the top of its path. Determine the time, height, and velocity of the cart at this point. Enter your values in the data table.
 - c. Find a time where the cart was moving downward, but a short time before it was caught. Measure and record the height and velocity of the cart at that time.
 - d. For each of the three points in the data table, calculate the Potential Energy (PE), Kinetic Energy (KE), and Total Energy (TE). The position of the Motion Detector as the zero of your height h .
 2. How well does this part of the experiment show conservation of energy? Explain.
 3. Logger *Pro* can graph the cart's kinetic energy according to $KE = \frac{1}{2} mv^2$ since you have supplied the cart's mass m , as well as the cart's potential energy according to $PE = mgh$, since you have supplied the angle of the ramp, which along with the measured distance from the motion detector allows the computer to calculate the height h . Here m is the mass of the ball, g the free-fall acceleration, and h is the vertical height of the ball measured from the position of the Motion Detector.
 4. Logger *Pro* will also calculate Total Energy, the sum of KE and PE , for plotting. Click on a graph's vertical axis label and then select "more" to have it display only the Kinetic Energy, the Potential Energy, and the Total Energy. Record the graph by printing it out, one copy for each lab group member.
 5. Inspect your kinetic energy vs. time graph for the free motion of the cart. Explain its shape. Consider only the portion of the graphs when the cart was freely moving.
 6. Inspect your potential energy vs. time graph for the free motion of the cart. Explain its shape.
 7. Inspect your total energy vs. time graph for the free motion of the cart. Explain its shape.
 8. Compare your energy graphs predictions (from the Preliminary Questions) to the real data from your data table.
 9. What do you conclude from this graph about the total energy of the cart as it moved up and down in free motion? Does the total energy remain constant? Should the total energy remain constant? Why? If it does not, what sources of extra energy are there or where could the missing energy have gone?

questions

1. What would change in this experiment if you used a very light cart?
2. What would happen to your experimental results if you entered the wrong mass for the cart in this experiment?