Investigation 10A: Inclined plane and the conservation of energy

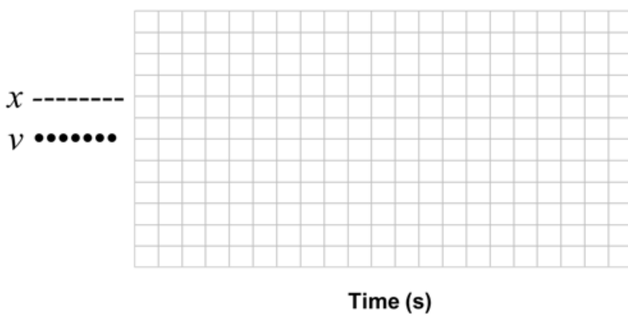
Essential question: What law governs the energy transformations of motion on an inclined plane?

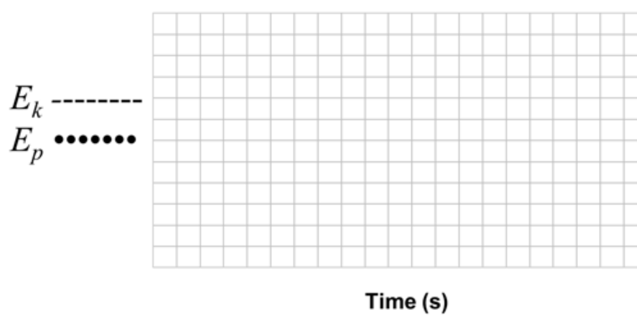
If you have ever skied down a mountain, biked down a hill, or ridden in a roller coaster you know going downhill causes your speed to increase. The higher the hill, the faster you can go (to a point). This investigation uses a cart on a frictionless track to explore how gravitational potential energy and kinetic energy change as motion changes. For example, if you want to design a roller coaster to reach 30 mph, how high must it be at the start?

Predictions

A cart starts from rest at the top of a frictionless slope. Sketch your predictions for the graphs of the following quantities as a function of time:

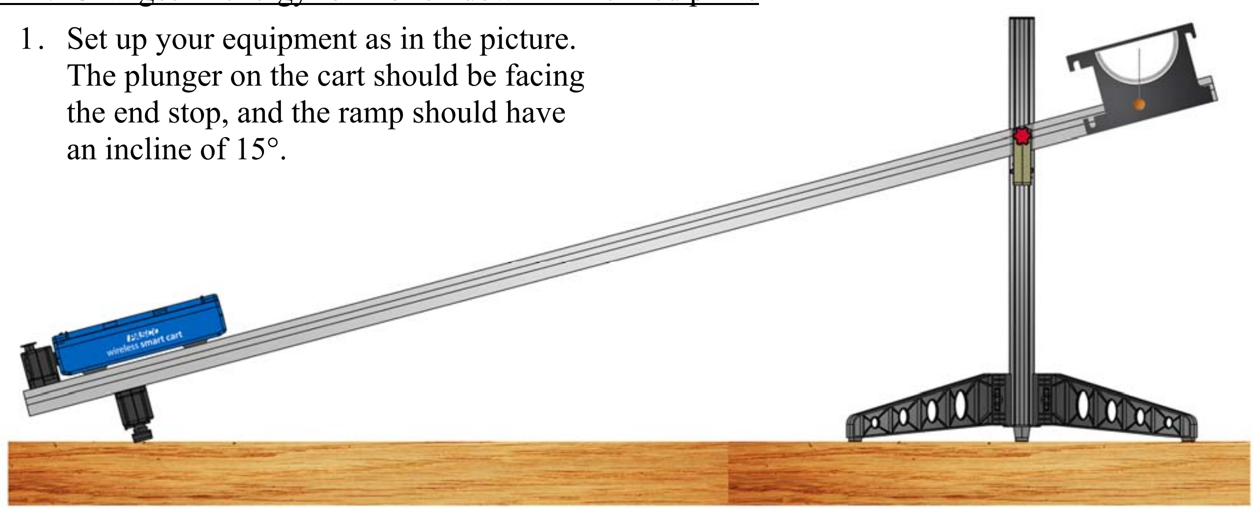
- position (x)
- velocity (v)
- kinetic energy (E_k)
- potential energy (E_p)





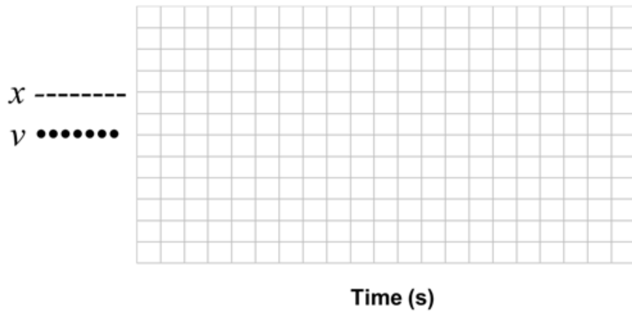
Part 1: Changes in energy for motion down an inclined plane

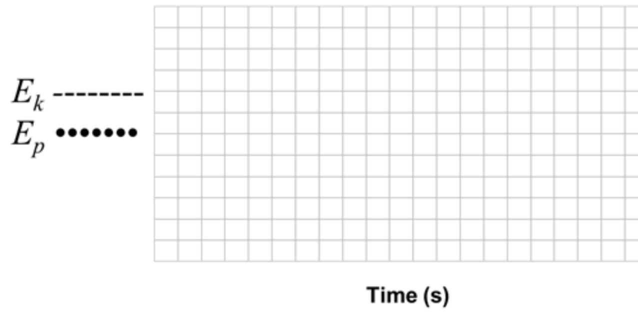
1. Set up your equipment as in the picture. The plunger on the cart should be facing the end stop, and the ramp should have an incline of 15°.



2. Open the experiment file **10A_ApplyingConservationOfEnergy**, and then connect your Smart Cart using Bluetooth.

3. Explore the motion of the cart on the ramp. Start recording data with the cart at the bottom of the ramp, then roll it to the top of the ramp and release it. Stop recording when the cart reaches the bottom. Answer the questions below for the time the cart was rolling down the ramp.





Questions

a. Sketch a copy of the actual position and velocity graph, only for the time where the cart was rolling down the track. What are the shapes of the graphs? Why?

b. Sketch a copy of the actual kinetic and potential energy graph, only for the time where the cart was rolling down the track. What are the shapes of the graphs? Why?

c. What is the total sum of the kinetic and potential energies at the top of the ramp when the cart is released? At the bottom? How are their changes related to each other?

d. What is the speed at the bottom of the ramp? Try adding a mass to the cart and take another set of data. How does the speed change? Why?

Part 2: Designing a roller coaster that reaches 30 mph.

1. Convert 30 mph into units of m/s. Your goal is to make this the final speed of the roller coaster when it reaches the bottom of the ramp. (Press more in your e-Book for conversion factors.)

2. Set the mass of the roller coaster to m = 2000 kg.

3. Vary the simulation parameters, such as the vertical height h_0 or inclination angle θ, in order to produce a speed of 30 mph at the bottom of the ramp. Record your roller coaster design data for an inclined plane in Table 1.

Table 1: Roller coaster design data (design speed of 30 mph)

angle θ (deg)	height h_0 (m)	speed v_0 (m/s)	friction μ	mass m (kg)	speed v (m/s)
		0	0	2000	

Is there more than one possible design? Explain.

4. The fastest roller coaster in the United States reaches a maximum speed of 128 mph. Estimate the height of this roller coaster.

Table 2: Roller coaster design data (design speed of 128 mph)

angle θ (deg)	height h_0 (m)	speed v_0 (m/s)	friction μ	mass m (kg)	speed v (m/s)
		0	0	2000	

Questions

a. How does changing the steepness of the roller coaster (while keeping the same initial height) affect the speed at the bottom of the ramp? Why?

b. How does changing the mass of the roller coaster affect its speed at the bottom? Why?

c. Research the *actual* height of the roller coaster in step #4 above. How well does your estimate agree with its actual height?