Introduction

In this lab you will use conservation of mechanical energy to predict the motion of objects in situations that are difficult to analyze with force concepts.

Prelab Activity

Read sections 5.3, 5.4, 5.5 & 5.6 in Serway & Faughn

Answer the following questions. Please, SHOW ALL YOUR WORK:

1. If a particle's speed decreases by a factor of five, by what factor does its kinetic energy change?
2. Particle A has three times the mass and twice the kinetic energy of particle B. What is the speed ratio $\frac{v_A}{v_B}$?
3. A spring with spring constant k = 100 (N/m) is at its equilibrium length.
   a) How much elastic potential energy is stored in the spring?
   b) The same spring is stretched so that it is 10.0 cm longer than it was. How much elastic potential energy is stored in the spring now?
   c) A different spring with spring constant four times larger than in part (a) is compressed so that it is 4.0 cm shorter than its equilibrium length. How much elastic potential energy is stored in this spring?

A. Group Activity

The TA's will hand out a question for you solve as a group. You should write your solution on your whiteboard and be prepared to present your solution to the class.

After one group has presented their solution to the rest of the class, you should copy the correct solution into your lab notebook.

Then, you will test the validity of your solution with an experiment. Every person in your lab group should make at least one measurement, so in the end you will have 4-5 data points. Calculate the best estimate of the quantity and determine the range of experimental uncertainty.

B. CONSERVATION of MECHANICAL ENERGY and PROJECTILES:

You have a curved ramp with the bottom at the edge of the desk and you start with a car at rest at the top. The end of the ramp is horizontal. When the car leaves the ramp, it falls to the floor on a ballistic trajectory. The horizontal distance, between the end of the ramp and where the car hits the floor, is called the range.

By the end of this activity you should be able to use the concepts of gravitational potential energy and conservation of mechanical energy to predict the range of a projectile.

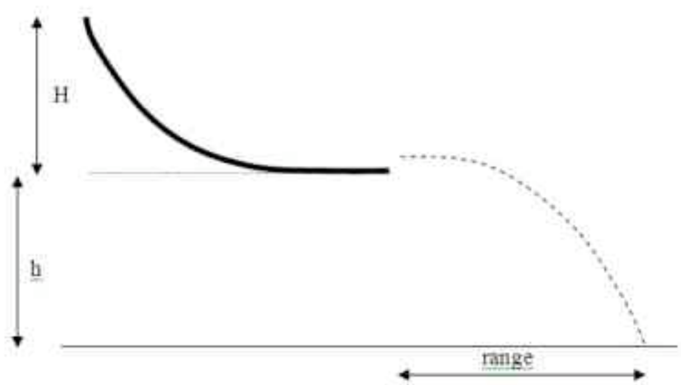
B1. Draw a sketch of the experimental setup. Label the quantities you think may be important for finding the range of the car.

B2. Considering only the portion of the motion where the car has left the ramp and is flying through the air:

- How would you find the range of a projectile using kinematics? What quantities do you need to know to find the range of a projectile?
- Can you measure all of these quantities with the equipment at hand? If not, which ones can't you measure?

B3. Considering only the portion of the motion where the car is in contact with the ramp:

- Write down the total mechanical energy of the car when it is at the top of the ramp and the bottom of the ramp. Where should you set the location of zero potential energy? Does it matter? Identify all the terms in your equations.
- Assuming there is no friction, will these two energies be the same? Does this help you calculate any of the quantities you cannot measure?



B4. Find an expression for the range of the car in terms of measurable and known quantities. Measure the quantities necessary to predict the range. Record these measurements in your notebook. Calculate what the range of your car will be.

B5. Practice releasing the car from the top of the track. Make sure the car remains in contact with the track until it reaches the end. Note qualitatively the outcome. Without measuring, does it look like the car lands in the same place each time?

B6. Release the car from the top of the ramp and measure the range of the car. Record your measurement in your notebook. Repeat the experiment a few times to get the average and spread of experimental values. Are there any peculiarities that you notice (during the trial or in the data) that might suggest that the data are unreliable?

B7. How does the measured value compare to the calculated value? How could you detect frictional losses in your data? Did you detect any frictional losses?

C. MECHANICAL ENERGY and FRICTION:

As the cart comes down the ramp, it "loses" energy to friction. This energy is transformed to heat energy, sound energy and maybe other forms of energy. A simple model for friction predicts that the energy lost from the car will depend on the work done. Work is calculated as the product of a force and a distance. Here the distance is the length of the ramp and the force depends on the mass of the cart. Both of these values (cart mass and ramp length) we can hold constant in our experiment. If we can measure the mechanical energy lost to friction we can use that value to predict the expected range for different initial heights of the car.

C1. Use your measured value for the range (from B6 above) to calculate the actual mechanical energy loss for the car. Does the value of total energy decrease due to friction?

C2. To demonstrate your skills, set the top of the track to a different height, keeping the track length constant and the track angle horizontal at the end. Given your model for the frictional losses, do you expect this setup to have the same energy loss as your earlier experiment?

C3. Taking account of friction, predict exactly where the car will land. Put a coffee can on the floor where you expect it to land. Check your numbers. When you are ready **get the TA as a witness** and make a run. Did you catch the car?

C4. To further demonstrate your skills, set the top of the track at a height so that the range of the car is 45 cm. Put a coffee can on the floor at 45 cm and make a run. Did you catch the car?

C5. What does the experiment tell you about our method of estimating the amount mechanical energy lost to friction?

D. CONSERVATION OF MECHANICAL ENERGY TRACK

In the front of the classroom, you will find two side-by-side ramps with different slopes. Release two tennis balls simultaneously from the top of the two ramps. Do both balls reach the end of the ramps at the same time? Can you explain this?

Can you detect a difference in the speeds of the two balls when they reach the end? Explain why the speeds are the same or different.

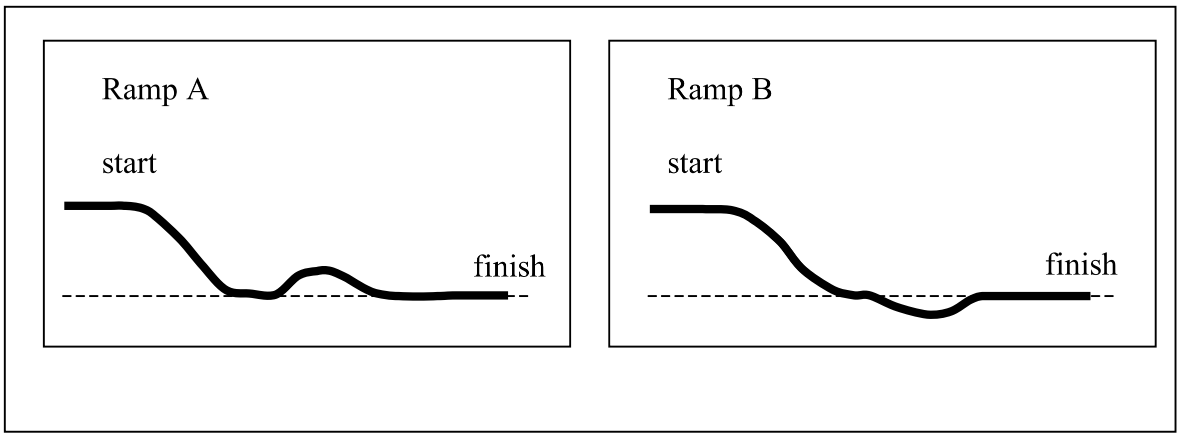
Postlab Activity

1. A roller coaster car starts from rest and rolls down a frictionless track, reaching speed v_f at the bottom.

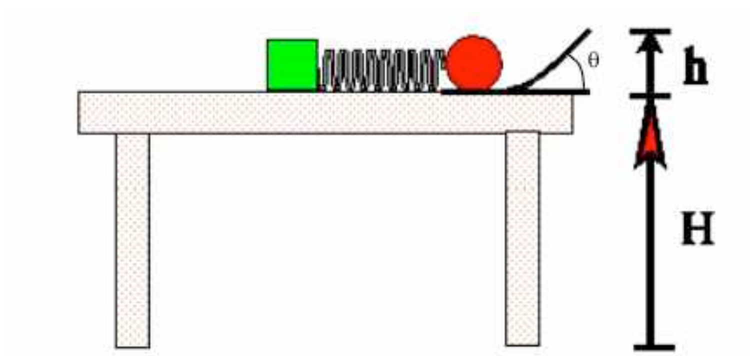
   a. If you want the car to go two times as fast at the bottom, by what factor must you increase the height of the track?

   b. Does your answer to part (a) depend on whether the track is straight or not? Explain.

2. You release a frictionless cart at the top of each of the 2 ramps. On Ramp B, the cart is released from rest, but on Ramp A the cart is pushed at the top so that it has some initial velocity. The ramps have the same height as each other at start and finish. One has a small bump up then down just before the end. The other has a small bump down then up. Which cart has the larger speed at the finish? Why?



3. A child's game consists of a block that attaches to a table with a suction cup, a spring connected to that block, a ball, and a launching ramp. By compressing the spring, the child can launch the ball up the ramp. The spring has a spring constant k, the ball has a mass m, and the ramp raises a height h. The spring is compressed a distance S in order to launch the ball. When the ball leaves the launching ramp its velocity makes an angle θ with respect to the horizontal.



(a) Calculate the velocity of the ball when it just leaves the launching ramp (both magnitude and direction. Be sure to specify your coordinate system.)

(b) The spring constant = 1000.0 N/m, the spring's compression is 4.00 cm, the ball's mass is 50.0 grams, the height of the ramp is 10.0 cm, and the top of the table is 1.00 m above the floor. With what total speed will the ball hit the floor? (Use g = 10.0 m/s^2)

4. Write a conclusion on the part of the lab assigned by your TA.