### 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.

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Prelab Activity:

1. A skier (whose mass is 65 kg) skis down a smooth (frictionless) ski slope, as shown in the diagram (which is not drawn to scale). The skier pushes off at the top with a speed of 5.0 m/s. If we define the absolute bottom of the slope to have zero gravitational potential energy, what is the gravitational potential energy of the skier (in Joules) when she is at the top of the slope (just before she pushes off)? What is the kinetic energy of the skier (in Joules) when she reaches the absolute bottom of the slope?
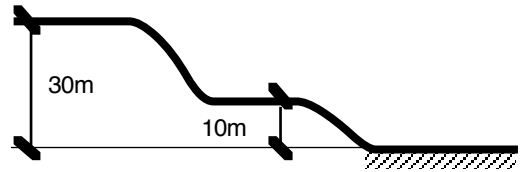
2. A 250 gram mass is placed on a horizontal spring. The spring has a spring constant $k = 590$ (N/m) and is at its equilibrium length.
   a) The spring is stretched so that it is 7.5 cm longer than its equilibrium length. How much elastic potential energy (in Joules) is stored in the spring now?
   b) Now the spring from part a) is released, what is speed of the mass as it passes through the equilibrium point ($x = 0$)?
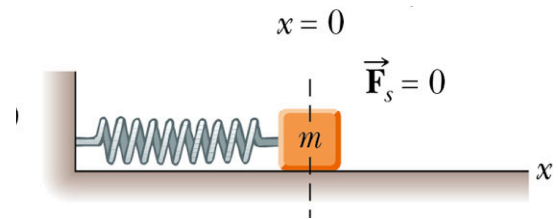
3. You release a frictionless cart at the top of each of the 2 ramps. On Ramp B, the cart is released from rest, but on Ramp A the cart is pushed at the top so that it has some initial velocity. The ramps have the same height as each other at the starting and finishing points. One has a small bump up 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?

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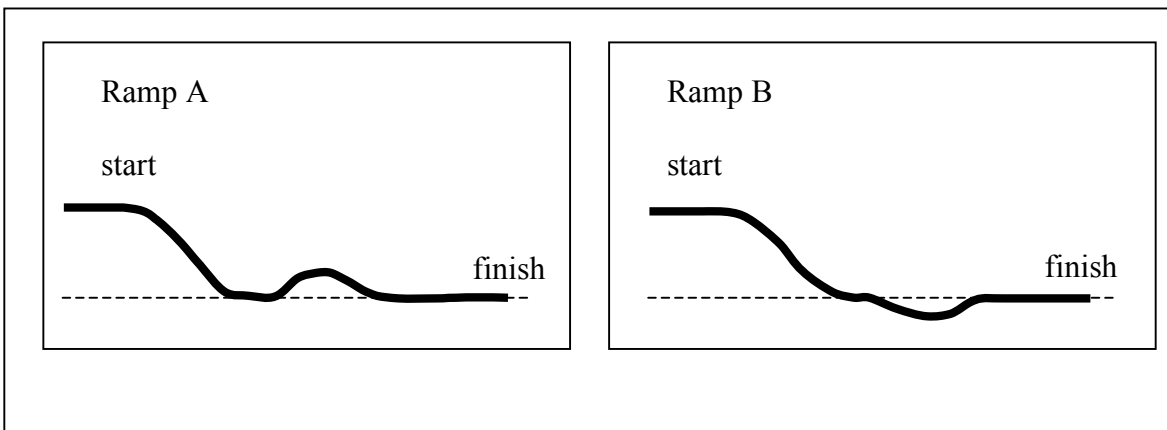
A. GROUP ACTIVITY

The TA's will hand out a question for you solve as a group.

You should write your solution on your whiteboard as if you are presenting your solution to the class.

You should copy the correct solution into your lab notebook.

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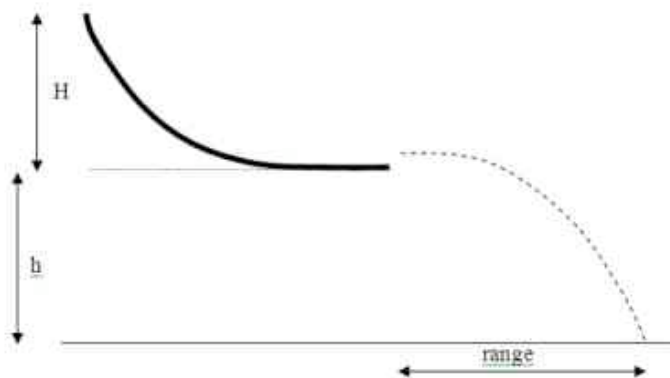
B3. Considering only the portion of the motion where the car is in contact with the ramp:

- 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 energy loss due to friction?

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 small steel 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.

Conclusion:

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