WORK AND ENERGY

This guy is going about 120mph, so yes, he really *does* need the sci-fi robot helmet.

INTRODUCTION

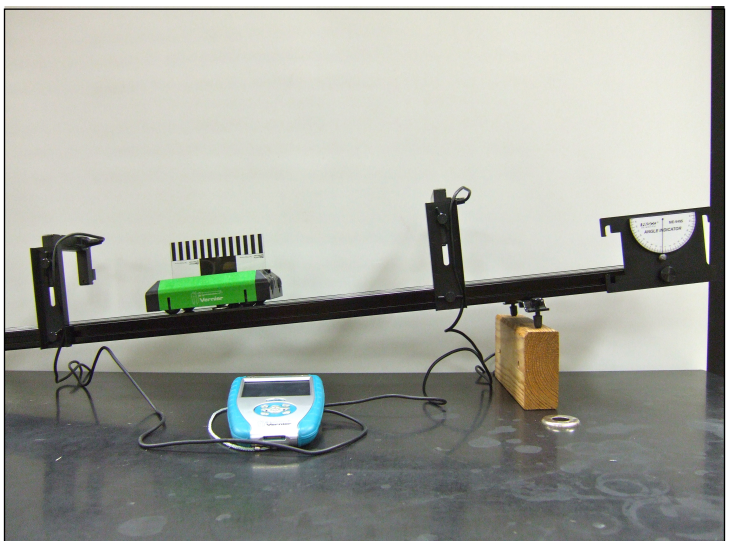
When a skier comes schussing down a hill, it's exciting to see how fast he is moving. If you're a skier yourself, then you already know all about energy conversion—where does that downhill speed come from? Where does that skier get his kinetic energy? We certainly know that things (not just skiers) get faster as they slide (or roll) downhill. We want to specifically look at energy conversion: how the energy of an object changes from potential to kinetic. We also want to look at how doing work on a system affects it.

It would be great if we could all strap on some skis and go test this on a snowy slope, but we only have an hour or so. We will just have to make do with examining energy conversion here in the lab using a cart on an inclined track.

If we start with the assumption that no energy is lost on the ramp, then the amount of total energy (kinetic plus potential) at the top of the ramp is the same as the amount of energy at the bottom. By calculating and comparing these values, we can verify the relationship—or modify our hypothesis to explain our actual observations.

OBJECTIVES

- Observe energy conversion from potential to kinetic
- Calculate the potential and kinetic energies of an object
- Analyze the work-energy theorem quantitatively
- Examine a priori assumptions and modify them in response to experimental data



Make sure that photogates are triggered by the wide blockout gap on the fence, and not the small pickets!

EQUIPMENT

- Vernier LabQuest unit
- Dynamics track and accessories
- Dynamics cart with picket fence attachment
- Two photogates
- Triple-beam balance

EXPERIMENTAL PROCEDURE

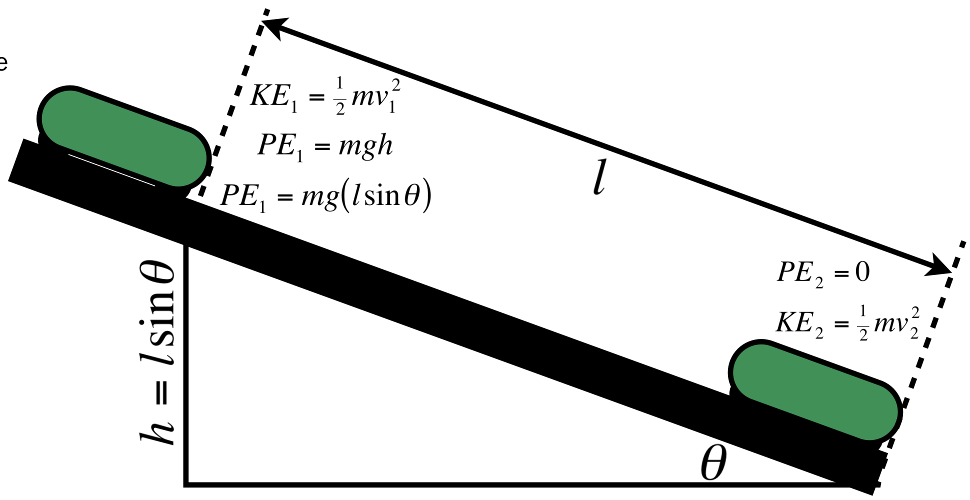
- Measure and record the mass of the cart (with the picket fence attached) in **kilograms**.
- Prepare the dynamics track by mounting the magnetic bumper at one end and the angle indicator at the other. Raise one end of the track to create an inclined plane, and **record the ramp angle**.
- Position the photogates exactly **0.50m (50 cm) apart** by clamping the mounting brackets so that the forward (or downramp) edges are spaced 50 cm apart.
- Attach the photogates to the brackets, making sure that the **5cm blockout gap** will trigger the gates (as opposed to the 1cm pickets).
- Plug the upramp photogate into the **DIG 1** channel of the LabQuest, and the downramp gate into **DIG 2**. When you switch the LabQuest on, you will need to tap the **Sensor** menu under the **Meter** tab, and select **Sensor Setup**. Tap the **Data Collection** menu, and change the **Photogate Mode** to **Gate**. You will see specified "**Length of object: 0.05m.**" This matches the blockout gap on the fence, and does not need to be changed. Tap **OK**.
- To collect data, one person should tap the **Go** button on the LabQuest, while a second person releases the cart from rest at the top of the ramp. When the cart passes through the lower gate, tap **Stop** to end the data collection. To verify that you have useful data, tap the **Table** tab. You should see clearly that each gate is unblocked/blocked a single time, and the velocity of the cart as it passes through each gate is automatically calculated. If either gate appears to have been triggered more than once, you should repeat the data run (no need to save flawed trials).
- If your data are acceptable, record the values for the velocities in your notebook. Save the run by tapping the **File Cabinet** icon under the **Graph** tab, then repeat two more trials. Save each trial.

Data & Analysis

If you have not already, organize your data into a neat table as shown.

Cart Mass (kg)		**Ramp Angle (°)**		**Ramp Length (m)**	

Trial	Potential Energy PE_1 (Joules)	Velocity v_1 (m/s)	Kinetic Energy KE_1 (Joules)	Total Energy $E_1 = PE_1 + KE_1$	Velocity v_2 (m/s)	Kinetic Energy KE_2 (Joules)
1						
2						
3						



1. Calculate the initial potential energy PE_1 of the cart. Notice that if we allow $h=0$ to be the position of the lower photogate, we only need to calculate PE one time: it will be the same at the top of the ramp for each trial. Use the equation shown on the right, remembering that l is the gate separation, which was kept constant: $l = 0.50$ m.
2. Calculate the kinetic energy of the cart at each position, using the velocity data you have recorded.
3. Calculate the total initial energy of the cart by adding together PE_1 and KE_1 ($E_1 = PE_1 + KE_1$). Notice that the total energy of the cart at the bottom of the ramp is simply KE_2, since PE_2 is zero by definition ($E_2 = KE_2$).
4. Compare the total energy at position 1 (E_1) with the total energy at position 2 (E_2). Are the values identical? Is there more energy at position 1 or position 2?
5. According to the work-energy theorem,

$$E_1 + W = E_2$$

   where W represents the work done by forces other than gravity. Does the cart gain or lose energy? If energy is not perfectly conserved, where does it go? As the cart travels down the ramp, is positive or negative work done on it? What forces are doing work on the cart?
6. If we defined the reference level for the potential energy as the tabletop (instead of the position of the second photogate), how would your calculations change? Think specifically of the PE values. Would setting the reference level at the tabletop change the amount of work done on the cart?
7. Go back to the ski slope; what forces (besides gravity) are doing work on that downhill skier? Why is the speed skier pictured able to achieve a speed of literally 120 mph (the world record is 156 mph!), when a typical Olympic skier will run at about 80 mph? Comment in terms of energy and work done on the skier!