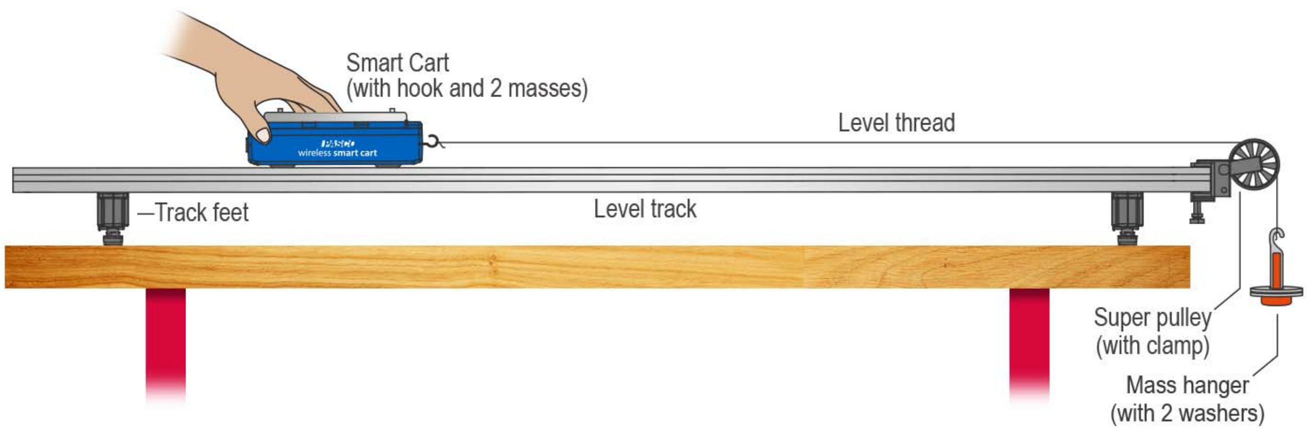
Investigation 10B: Work and energy

Essential questions: How is the work done on a system related to its change in energy?
How is the efficiency of a system calculated?

Have you ever pulled a swing back and let it go? The work you do to pull the swing backward and upward is converted into gravitational potential energy. When you let it go, gravitational force does work on the swing pulling it downward and speeding it up, transforming its gravitational potential energy into kinetic energy. Gravity does work on the swing; as a result, the swing's kinetic energy changes. In this investigation you will explore the relationship between work and kinetic energy by measuring the work done on a cart to accelerate it, and then comparing that work to the cart's change in kinetic energy.

Part 1: Constant Force

1. Set up the equipment like the picture below.



2. Open the experiment file **10B_WorkEnergyTheorem**, and then connect the Smart Cart using Bluetooth.
3. Unhook the thread from the cart and measure the mass of the cart plus the two 250-g cart masses. Record the mass value above the table on the next page.
4. In your software, zero the Smart Cart force sensor while nothing is touching the hook.
5. Reattach the thread, and then roll the cart all the way to the end of the track opposite the pulley and hold it in place.
6. Start recording data, and then release the cart to roll freely down the track. Catch the cart before it rolls into the pulley. Data recording stops automatically after 1.5 seconds.
7. Use the tools in your software to determine the net work W_{net} done on the cart (W_{net} = area under your force versus position data), and the measured final speed of the cart. Record the work and speed values in the Part 1 row in the table on the next page.

Part 2: Variable Force

1. Unhook the hanging mass from the thread, and then set the cart at the end of the track opposite the pulley so it rests in place.
2. Have a group member hold the loose end of the thread in their hand at the other end of the track (no tension in the thread). Zero the force sensor.

3. Start recording data, and then pull on the string so the cart rolls down to the other end of the track. Catch the cart before it rolls into the pulley.

   NOTE: The force that you apply to the string does not need to be so soft that the cart barely rolls; but don't pull the thread so hard that the cart rolls into the pulley and off the end of the track.

4. Use the tools in your software to determine the work done on the cart, and the cart's measured final speed. Record both values next to Part 2 in the table below.

Mass of cart and cart masses (kg) = ______________________

Table: Work and speed data for a cart experiencing an applied force

	W_{net} (N·m) Area under F vs. x	Measured Final Speed (m/s)	Calculated Final Speed (m/s)
Part 1			
Part 2			

Questions

a. Use the work-energy theorem to derive an equation for the final speed of the cart v_f in terms of mass m and net work W_{net}. Assume the initial speed of the cart is zero. Show your work.

b. Use the equation you derived and your measured value for W_{net} to calculate the theoretical final speed of the cart for Part 1 and Part 2. Record the result in your table.

c. How does the theoretical final speed of the cart compare the experimental (measured) value in both parts? If the values are different, what do you think caused the difference?

d. How efficient was the work done to change the cart's kinetic energy in each part? Explain the significance of the values you obtain.

$$\text{Efficiency} = \frac{\Delta E_k}{W_{net}} \times 100\%$$

e. If you do 0.621 N·m of work on a cart (same mass as the cart in this experiment) to accelerate it from rest, what would the cart's final speed be if the efficiency of the work was 90.3%?

<u>Applying new knowledge</u>

1. A 1500 kg car accelerates from rest to a speed of 25 m/s over a distance of 45 meters.
   a. What is the change in kinetic energy of the car?
   b. What is the net work done on the car?
   c. What is the net force applied to the car?

2. A 1500 kg car traveling at 20 m/s skids to a stop. The force of friction between the tires and the road is 12,000 N.
   a. What is the change in kinetic energy of the car?
   b. How far does the car skid?