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Work and Energy

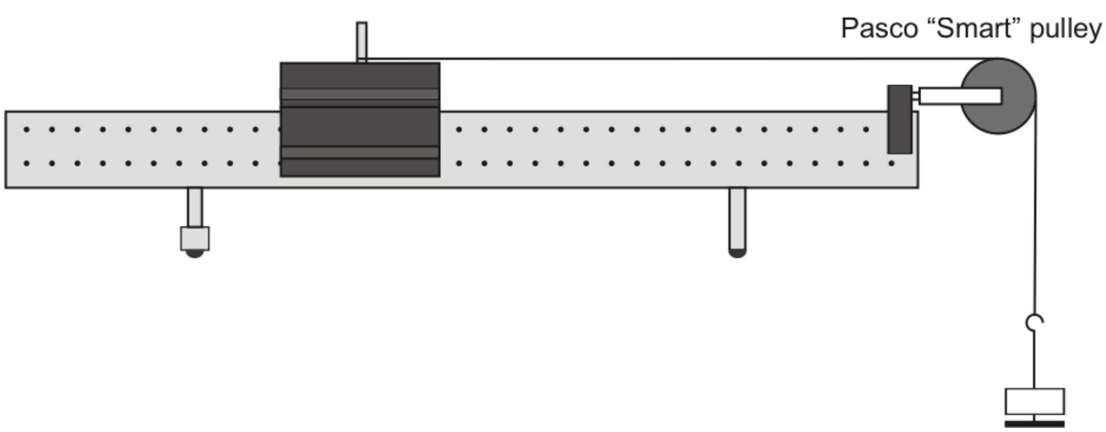
Spreadsheet for part 2:
https://docs.google.com/spreadsheets/d/1TzgGfc28DZy0IXofP3Ask50Ls_I7s51Gb-MODfS7Hwg/edit?usp=sharing

Learning Outcomes

1. Use work-energy relationships to make predictions.
2. Integrate multiple physics concepts to solve a variety of problems
3. Create and perform experiments that make experimental determinations and predictions of unknown quantities.

Materials and Apparatus

- Laptop
- Pasco Capstone software
- "frictionless" pulley
- Smart Gate
- air track and air cart
- hanging mass



Experiment 1 - Work and Energy

An air cart of mass M_c is tied to a mass m by a string that hangs over a light pulley of negligible friction.

- **Use the Work-Energy Theorem to predict a numerical value for the final speed of the cart of mass M_c after the hanging mass m falls a distance h.**

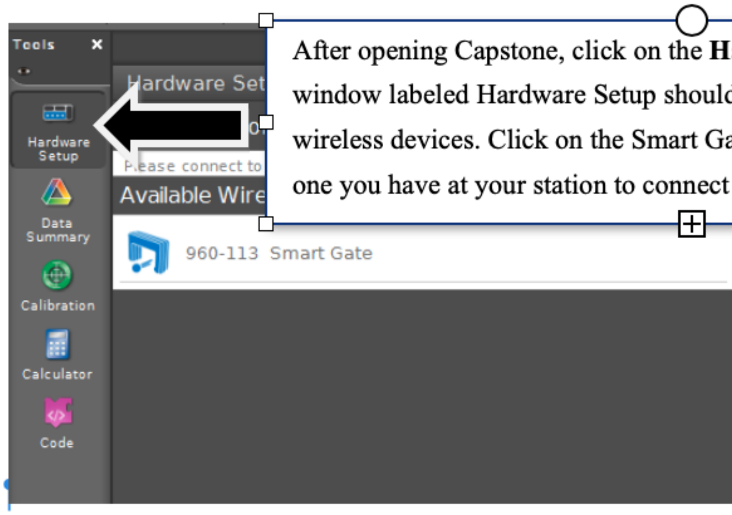
M=0.2 kg m=0.05 kg h=1.05 m

$$mgh = \frac{1}{2}Mv^2 + \frac{1}{2}mv^2 \qquad v = \sqrt{\frac{2mgh}{M+m}}$$

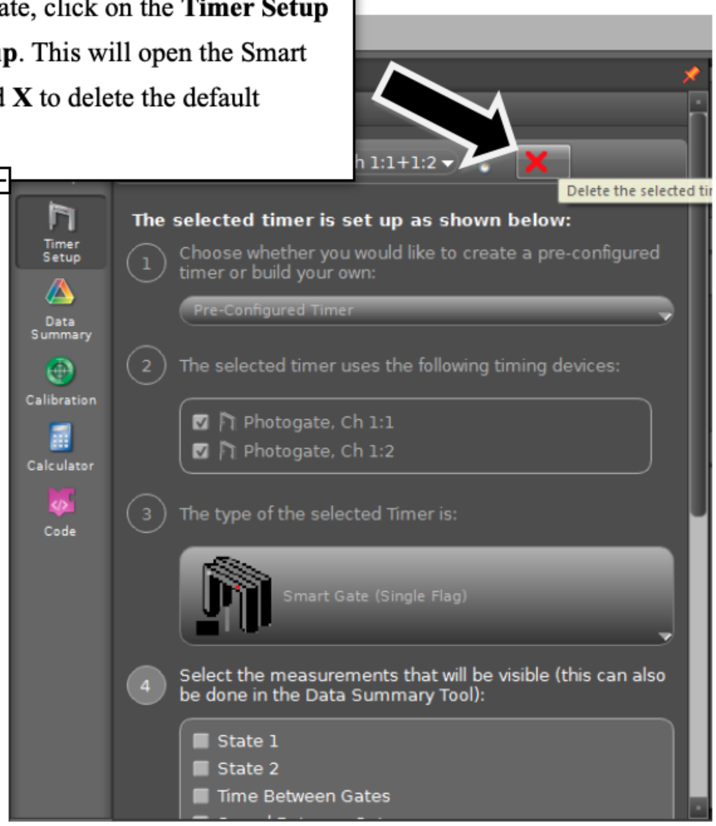
v=1.93 m/s

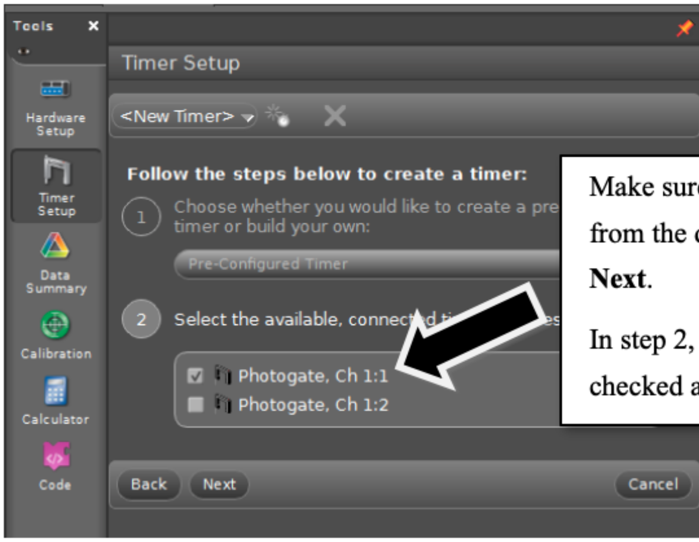
- After making your prediction, set up the air track, cart, pulley, Smart Gate and hanging mass as shown in the picture.
- Press the power button on the wireless Smart Gate to turn it on. This sensor will measure the angular speed (the number of revolutions per second) of the pulley as it rotates while the mass is falling. To configure the Smart Gate, so that it can use this data to measure the *linear speed* of the cart, open the Capstone software.

After opening Capstone, click on the **Hardware Setup** button. A window labeled Hardware Setup should open with a list of nearby wireless devices. Click on the Smart Gate that has the same ID as the one you have at your station to connect to it.



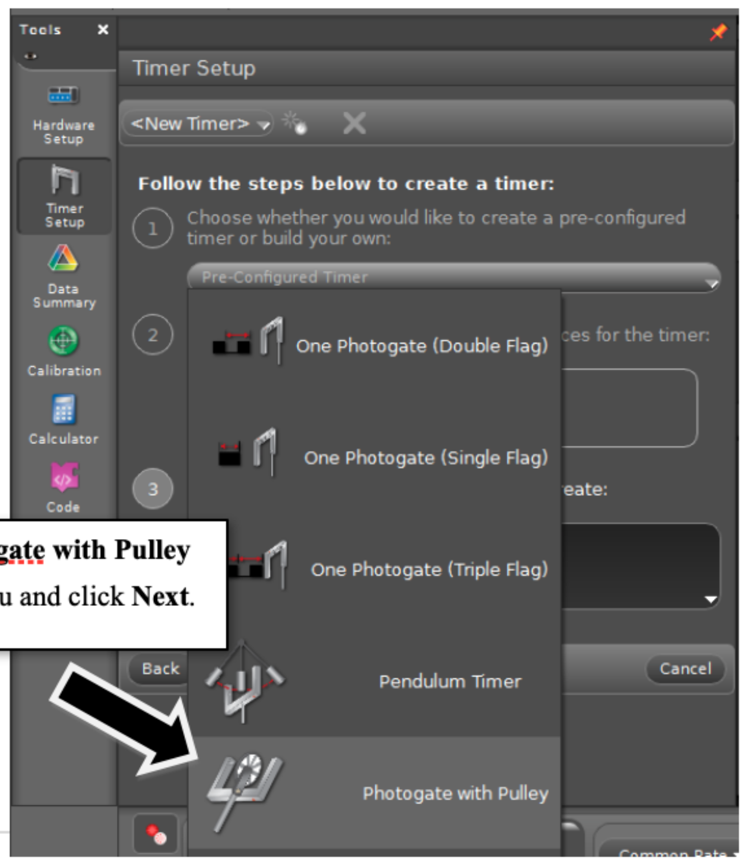
After connecting the Smart Gate, click on the **Timer Setup** button below **Hardware Setup**. This will open the Smart Gate settings. Click on the red **X** to delete the default settings shown.



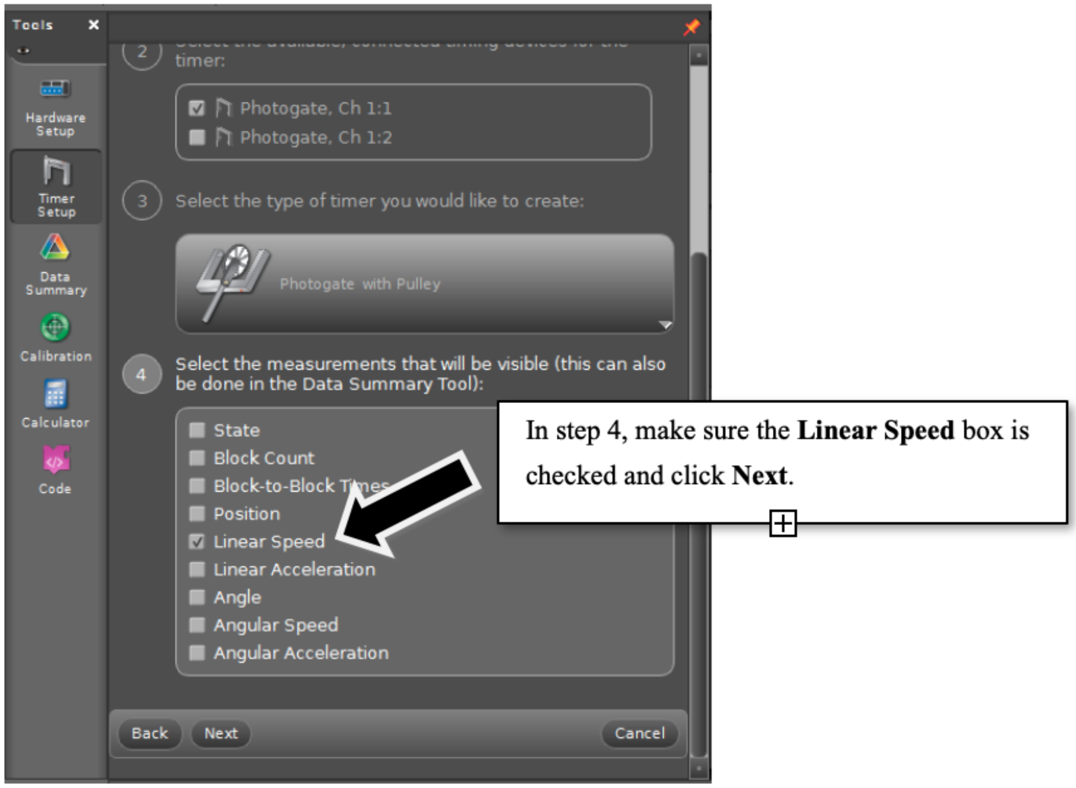


Make sure **Pre-Configured Timer** is selected from the drop-down menu in step 1 and click **Next**.

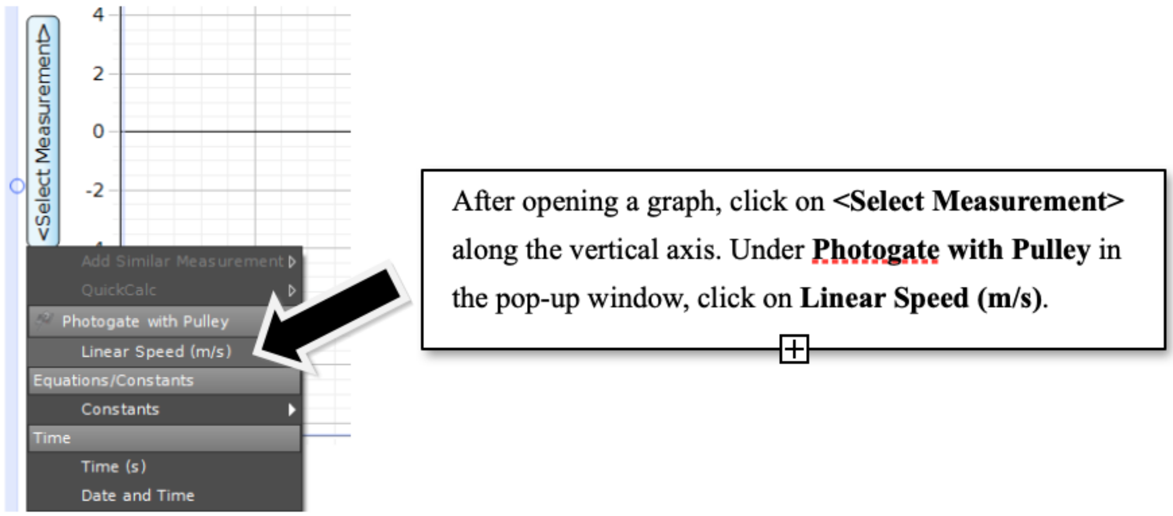
In step 2, only leave the **Photogate, Ch 1:1** box checked and click **Next** again.



In step 3, click on **Photogate with Pulley** from the drop-down menu and click **Next**.



- Continue clicking **Next** for the next several steps and then **Finish**. Click on the **Timer Setup** button to close the Timer Setup window. The Smart Gate is now configured to measure the linear speed of the cart as it moves down the air track.
- Double-click on the **Graph** icon to open a new graph.



- Position the cart near the center of the track, click the **Record** button and turn the air track blower on. **Using your linear speed vs. time graph, measure the final speed of the cart after the hanging mass *m* falls a distance *h*.**

We recorded a final speed of 1.81 m/s.

- **Calculate a % difference to compare your numerical results for the speed of the air cart to its experimentally measured value.**

$$\frac{1.93-1.81}{0.5(1.93+1.81)} = 6.4\%$$

a. **How closely do these results compare?**

The results are reasonably close to the expected value.

b. **Do these results agree within the limits of experimental uncertainty? Account for any differences between these results.**

No it doesn't fall into the limits of experimental uncertainty because the difference between our calculations and the recorded result is greater than 0.05 m/s. This difference is due to the friction due to the pulley that was not considered in our calculations.

- **Which method would be easier to use to find the speed of the cart: the Work-Energy Theorem or Newton's 2nd Law?**

The Work-Energy Theorem is easier since we need less information and we don't need to calculate or measure the acceleration.

a. **Do you think that these methods would give you similar results?**

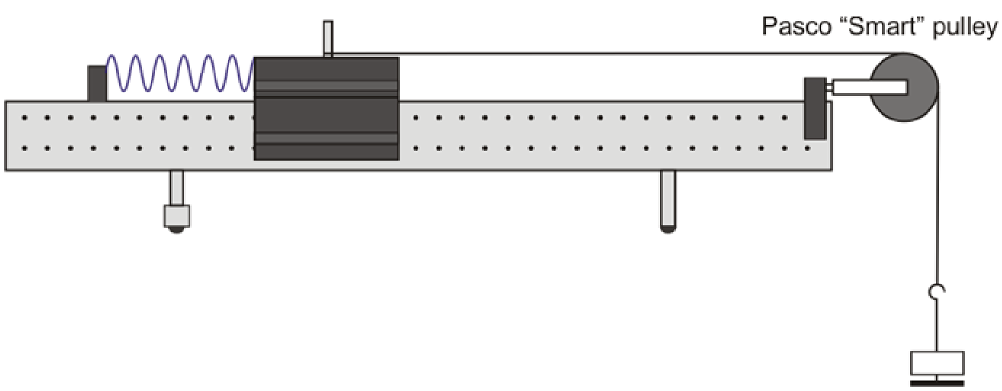
Yes they would give similar results.

b. **Why are you able to ignore the work done by the string when using conservation of energy for the whole system of the falling mass and the air cart?**

Since when looking at the whole system, the tensions of the string for each object are action-reaction forces, therefore they have the same magnitudes but opposite directions. Due to this, the work done by the string on each individual object cancels each other out and we are able to ignore it.

Experiment 2 - Conservation of Energy

A spring having elastic constant k is attached to one end of an air cart of mass M_c. The other end of the air cart is tied to a mass m by a string that hangs over a light pulley of negligible friction. The air cart is released from rest when the spring is at its ***relaxed*** length.



Use conservation of energy to predict the maximum distance the air cart will stretch the spring. Express your answer in terms of k, the spring constant.

$$mg\Delta x = W_{sp}$$

$$mg\Delta x = \frac{1}{2}k\Delta x^2$$

$$\Delta x = \frac{2mg}{k}$$

$$\boxed{\Delta x = \frac{0.98}{k}}$$

If the mass of the mass hanger increases by Δm, predict how far the cart will move from its starting point. Express your answer in terms of k, the spring constant.

$$(m+\Delta m)g\Delta x = \frac{1}{2}k\Delta x^2$$

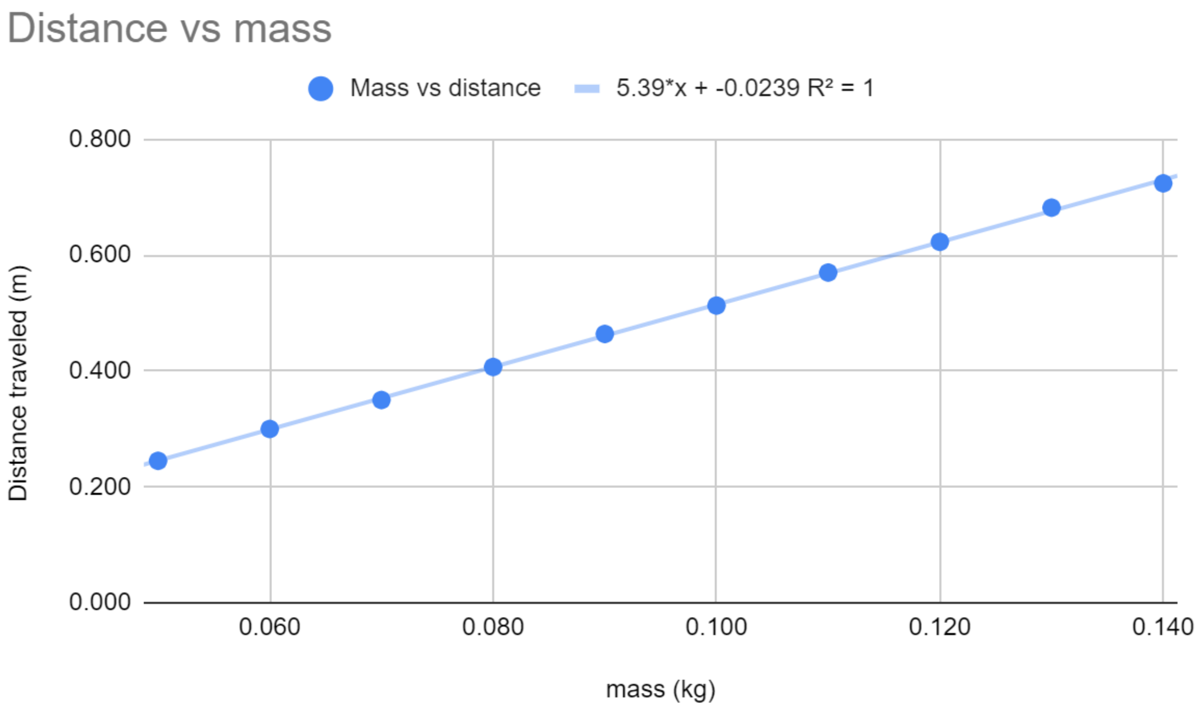
$$\Delta x = \frac{2(m+\Delta m)}{k}$$

$$\Delta x = \frac{19.6(m+\Delta m)}{k}$$

Add masses to the hanging mass and measure the extension of the spring for 10 different masses. Plot your results. (Use a spreadsheet)

https://docs.google.com//d/1TzgGfc28DZy0IXofP3Ask50Ls_I7s51Gb-MODfS7Hwg/edit?usp=sharing
[spreadsheets]

Based on the line of best fit, what is the value of k, the spring constant? Explain.



$$\Delta x = \frac{19.6(m+\Delta m)}{k}$$

$$\frac{\Delta x}{m+\Delta m} = \frac{19.6}{k}$$

$$5.39 = \frac{19.6}{k}$$

$$k = \frac{19.6}{5.39}$$

$$\boxed{k = 3.64 \text{ N/m}}$$

Use a spring scale to measure the spring constant. Explain how you do this.

3.23 N/m. Measure the length of the spring at equilibrium and then when the spring is stretched and the spring scale shows 1 newton measure the new length. Then divide 1 by the difference of both lengths.

Calculate the percent difference between your measurement of the spring constant. Do they agree?

12.07% is the percent difference.

$$\frac{3.64-3.2258}{\left(\frac{3.64+3.2258}{2}\right)} = 0.1207 = 12.07\%$$

Which measurement do you trust more? Why?

We (the people) trust our measurements more than the scale because of a larger sample size of ten measurements rather than a singular measurement done with the spring scale. Assuming the method of recording data was rigorous and accurate, it would have a much more precise and accurate result compared to the spring scale, and in the line of best fit equation, we had an **R^2 value of 1.**

Run#	Total Mass (kg)	Starting point (m)	End point (m)	Distance traveled (m)	Slope of mass/distance
1	0.050	0.12	0.365	0.245	5.39
2	0.060	0.12	0.420	0.300	
3	0.070	0.12	0.470	0.350	
4	0.080	0.12	0.527	0.407	
5	0.090	0.12	0.584	0.464	
6	0.100	0.12	0.633	0.513	
7	0.110	0.12	0.690	0.570	
8	0.120	0.12	0.743	0.623	
9	0.130	0.12	0.802	0.682	
10	0.140	0.12	0.844	0.724