NAME PERIOD DATE

UNIT 4 - WORK AND KINETIC ENERGY

STRUCTURED

Driving Question | Objective

How is the work done on an object by a force related to the change in that object's kinetic energy? Investigate the relationship between the change in kinetic energy of an object experiencing a non-zero constant net force, and the work done by that net force on the object. Establish a measurement-based relationship between work and kinetic energy.

Materials and Equipment

- Data Collection System
- PASCO Smart Cart with hook[1]
- PASCO Dynamics Track with feet[2]
- PASCO Super Pulley with Clamp[3]
- PASCO Cart Masses, 250-g (4)
- PASCO Mass and Hanger Set
- Thread
- Balance, 0.1-g resolution, 2,000-g capacity (1 per class)

[1] www.pasco.com/ap37 — PASCO Smart Cart

[2] www.pasco.com/ap08 — PASCO PAStrack

[3] www.pasco.com/ap13 — PASCO Super Pulley with Clamp

Background

WORK

Work done on an object by a force is expressed as the product of the force and the magnitude of displacement of the object in the direction of that force:

$$\text{Work} = \text{Force} \times \text{Distance} \tag{1}$$

If a force is applied to an object whose resultant movement is not in the direction of the force, the work done on that object only includes that component of the force in the direction of the object's movement:

$$W = Fd\cos\theta \tag{2}$$

where d is the distance that the force F acts on the object, and θ is the angle between the applied force direction and the direction of displacement.

KINETIC ENERGY

An object's kinetic energy K is described by the equation:

$$K = \frac{1}{2}mv^2 \tag{3}$$

where m is the mass of the object and v is the object's speed.

Although work and kinetic energy are different quantities, they are closely related to each other in a mechanical system. In this lab you will investigate the relationship between the change in kinetic energy of a cart experiencing a non-zero constant net force and the work done by that force on the cart.

RELEVANT EQUATIONS

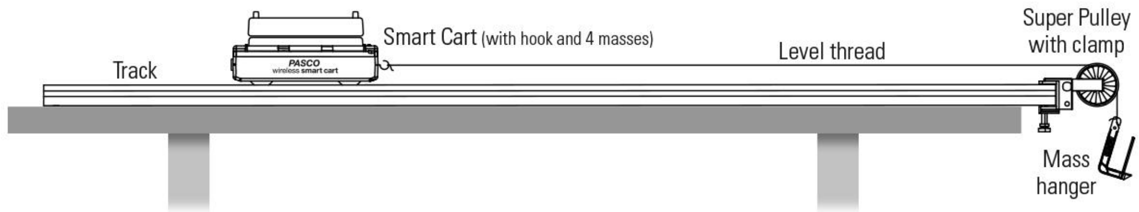
$$W = Fd\cos\theta \tag{2}$$

$$K = \frac{1}{2}mv^2 \tag{3}$$

Procedure

SET UP

1. Set up the equipment like the picture below.



NOTE: Make certain the pulley is hanging over the edge of the table, and the track is as level as possible. Adjust the height of the pulley so that the thread between the cart and the pulley is parallel with the surface of the track.

2. The hook on the front of the Smart Cart will measure the force applied by the tension in the string, while the cart's wheels measure its speed and position.

3. Power-on the Smart Cart and connect it wirelessly to your data collection system.

4. Create three graph displays: one graph of force versus time, one graph of position versus time, and one graph of velocity versus time.

COLLECT DATA

5. Unhook the thread from the cart, and then measure the mass of the cart plus the four 250-g cart masses. Record this value above Table 1 in the Data Analysis section below.

6. Set the cart on the track, and then "zero" the Smart Cart force sensor in your data collection system before re-attaching the thread to the force sensor hook.

7. Re-attach the thread to the hook on the cart, add 100 g of mass to the hanger, and then roll the cart back about 70 cm and hold it in place.

8. Wait for the hanging mass to stop swinging, and then start recording data.

9. Release the cart to roll freely down the track, and then catch the cart at the end of the track before it rolls into the pulley.

10. Use the tools in your data collection system to determine the speed of the cart after it has travelled about 0.1 m. Repeat for displacements of about 0.2 m, 0.3 m, 0.4 m, and 0.5 m. Record the chosen displacement and speed at that displacement in Table 1.

11. There should be very little variation in the force sensor measurement of the tension in the string while the cart was in motion. Find the average tension force only while the cart was in motion. Record that value above Table 1 in the Data Analysis section below.

Data Analysis

Mass of cart and masses (kg) = ____________________________

Tension (N) = ____________________________

Table 1: Work and kinetic energy of a cart

Measurement	Distance Travelled by Cart (m)	Speed at Distance Travelled (m/s)	Work Done by Tension ($kg \cdot m^2/s^2$)	Change in Kinetic Energy (J)
1				
2				
3				
4				
5				

1. Use Equation 2, the tension, and the distance travelled by the cart (in Table 1) to calculate the work done on the cart by gravity in each trial. Record your results for each trial into Table 1.

   NOTE: The angle θ is equal to the angle between the tension and the direction of displacement of the cart. Since the string is parallel to the track and the tension is in the direction of the displacement, this should be 0°.

2. Use Equation 3, the mass of the cart, and the speed data in Table 1 to calculate the change in kinetic energy of the cart from when it was released to when it reached the chosen displacement. Assume the kinetic energy of the cart when it was released was zero in each trial. Record your results into Table 1.

Analysis Questions

❓ 1. How does the data for the work done on an object compare to the object's change in kinetic energy?

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❓ 2. What were some unexpected factors that may have caused error in your measured values, and how could these have been avoided?

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❓ 3. How do the units associated with work compare to the units associated with change in kinetic energy?

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❷ 4. In one sentence, describe what you believe the mathematical relationship is between the work done by a non-zero constant net force on an object, and the change in that object's kinetic energy. Be specific, and use terms like "proportional to," "equal to," "inversely proportional to," and so on.

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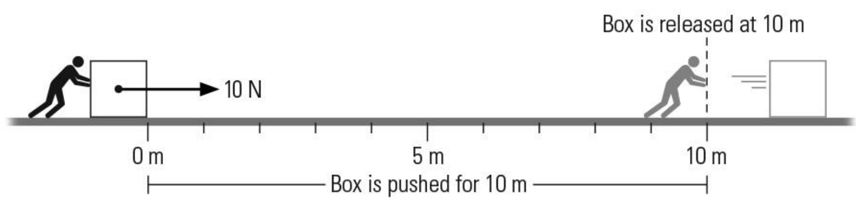
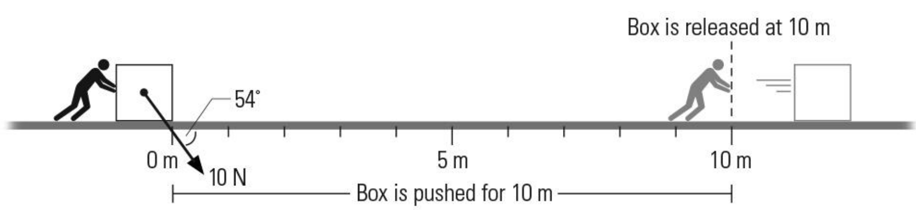
Synthesis Questions

❷ 1. A student pushes a 21-kg box horizontally along a frictionless surface for 10.0 m, and then releases the box to continue sliding. If the box is initially at rest, and the student pushes with a constant 10.0 N force, what is the box's speed when it is released?



❷ 2. If the student from the previous question hadn't pushed the box horizontally, but rather, at an angle of 54° relative to the frictionless surface, what would have been the box's speed when it was released?



❷ 3. Suppose an 18-wheel truck and trailer has a mass of 30,000 kg and is traveling with a speed of 24.5 m/s. If the driver slams on his brakes and begins to skid, what would the stopping distance be if the coefficient of kinetic friction between the truck's tires and the pavement is 0.50? Show you work.