Name Period Date

Conservation of Energy

Driving Questions

How does the energy of a cart poised at the top of a hill compare to its energy at the bottom of the hill?

Background

Gravitational potential energy GPE, or energy of position, is defined by the equation:

$$\text{GPE} = mgh \qquad \textbf{Eq.1}$$

For an object on earth, the mass m and the acceleration due to gravity g, remain constant. Hence, only the change in height h influences any change in gravitational potential energy.

For kinetic energy KE, or energy of motion, the equation is:

$$\text{KE} = \frac{1}{2}m\boldsymbol{v}^2 \qquad \textbf{Eq.2}$$

For this same object of constant mass, any change in the kinetic energy is due to a change in velocity v.

For a closed system, the total energy TE is defined to be the sum of the different types of energy:

$$\text{TE} = \text{KE} + \text{GPE} + \text{Heat} + \text{Light}...$$

We will create our own closed system, and limit the forms of energy changing to kinetic and gravitational potential, to observe how they change and how they relate to the total energy of the system.

$$\text{TE} = \text{KE} + \text{GPE}$$

Materials and Equipment

For each student or group:

- Data collection system
- Motion sensor
- Dynamics track
- Dynamics track end stop
- Dynamics cart with plunger
- Dynamics track angle indicator
- Rod stand (to elevate track)
- Balance (1 per classroom)
- Pivot clamp

Safety

Follow all standard laboratory procedures.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

○	○	○	○	○
Connect the track to the rod stand using the rod clamp.	Use the distance traveled d and the angle of the track θ to calculate the maximum height h that the cart traveled.	Collect a run of position data with the cart standing still, and record the initial position of the cart.	From your graph, determine the distance d traveled by the cart.	Start collecting data, then tap the release button to launch the cart.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

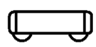
Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect the end stop to the end of the dynamics track. Then use the rod clamp to attach the track to the rod stand near the other end.

3. ☐ Connect the motion sensor to the end of the track with the face of the sensor pointed toward the end stop. Be sure the switch on the sensor is in the cart position.



4. ☐ Use the balance to determine the mass of your cart and record the mass in Table 1.

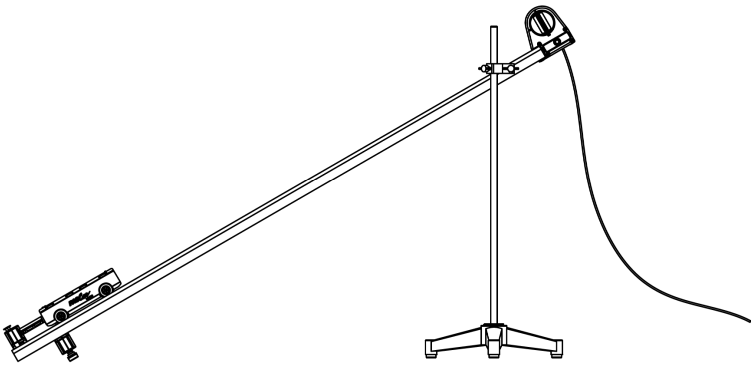
5. ☐ Connect the motion sensor to the data collection system. �(2.1)

6. ☐ Display Position on the y-axis of a graph with Time on the x-axis. �(7.1.1)

7. ☐ Display Velocity on the y-axis of a graph with Time on the x-axis. �(7.1.1)

8. ☐ Make sure that the sampling rate of your data collection system is at least 20 samples per second. �(5.1)

9. ☐ Place the cart, with the plunger extended, on the track against the end stop.



10. ☐ Record a data run that shows the initial position of the cart relative to the motion sensor, and record this value in Table 1. �(6.2)

11. ☐ Why do you think we set the cart in position with the plunger extended?

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12. ☐ Cock the plunger and then gently tap the release button to launch the cart. Be sure you use the same plunger position throughout this part of the lab.

13. ☐ Why do you think it is important to use the same plunger position?

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14. ☐ Observe the motion of the cart, making certain the cart never gets closer than 15 cm to the motion sensor.

15. ☐ What would you change if the cart gets too close to the motion sensor?

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16. ☐ Use your angle indicator to record the angle of the track θ in Table 1.

Collect Data

17. ☐ Cock the plunger and place the cart in position on the track with the plunger against the bumper.

18. ☐ Start data recording and then tap the release button to launch the cart. �(6.2)

19. ☐ Allow the cart to bounce once or twice before stopping data recording. �(6.2)

Analyze Data

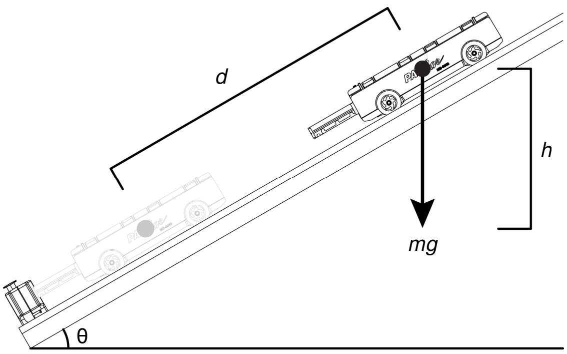
20. ☐ Sketch your graph of Position versus Time in the space provided in the Data Analysis section.

21. ☐ Use the data collection system to determine the difference between the initial position and the closest point to the motion sensor, or the distance traveled *d*. �(9.2)

22. ☐ Identify the points you used in your sketch.

23. ☐ Record the distance d you measured in Table 1.

24. ☐ Use the distance traveled d and the angle of the track θ to calculate the maximum height h that the cart traveled. Record your answer in Table 1.



25. ☐ Use the height *h*, the acceleration due to gravity *g* (9.8 m/s^2), and the mass of the cart *m* to calculate the gravitational potential energy of the system with the cart at the top of the track. Record your answer in Table 1.

26. ☐ Given that the cart momentarily comes to a complete stop before rolling back down the track, what is the kinetic energy of the system at this point? Why?

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27. ☐ Because the total energy of this system is comprised of the kinetic energy and the gravitational potential energy, what is the total energy of the system at this point?

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28. ☐ Sketch your graph of Velocity versus Time in the space provided in the Data Analysis section.

29. ☐ Find the maximum velocity v achieved by the cart on the data run. �(9.1)

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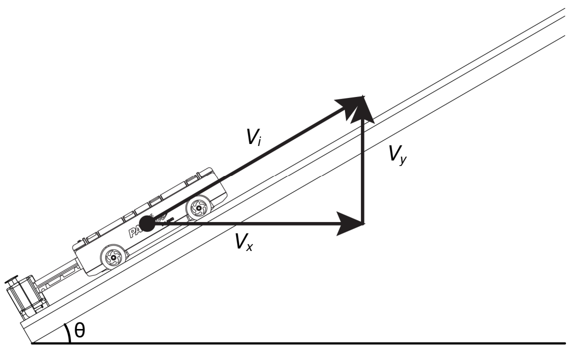
30. ☐ Identify the point you used in your sketch.

31. ☐ Record the maximum velocity v you measured in Table 1.

32. ☐ Use the maximum velocity of the cart v and the mass of the cart m to calculate the maximum kinetic energy of the system with the cart at the bottom of the track. Record the kinetic energy in Table 1.

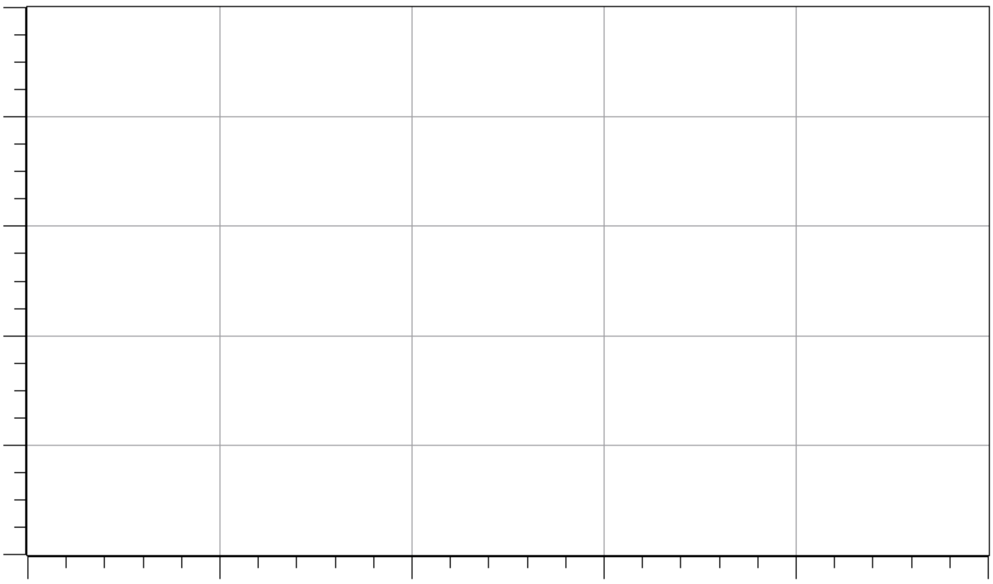


33. ☐ If the point at which the cart leaves the bumper is the lowest point of the system, what is the gravitational potential energy of the system at this point? Why?

34. ☐ Because the total energy of our system is comprised of the kinetic energy and the gravitational potential energy, what is the total energy of the system at this point?

Data Analysis

Position versus Time



Velocity versus Time

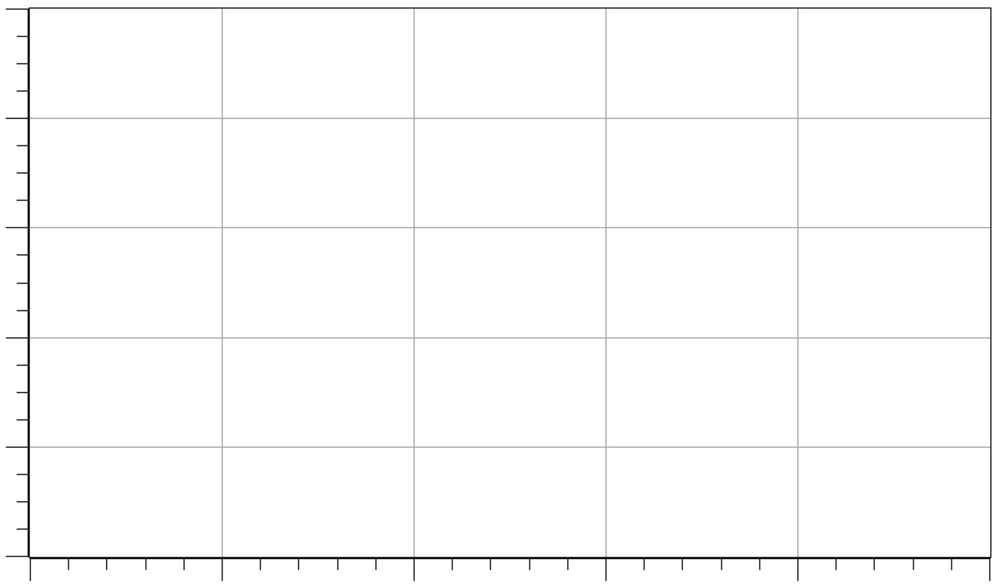


Table 1: System energy determination

Parameter	Values
Mass of cart (kg)	
Initial position (m)	
Track angle (degrees)	
Distance traveled (m)	
Maximum height (m)	
Maximum gravitational potential energy (J)	
Maximum velocity (m/s)	
Maximum kinetic energy (J)	
Time of your test point (s)	
Kinetic energy of your test point (J)	
Gravitation potential energy of your test point (J)	
Total energy of the system at your test point (J)	

1. ☐ Select a data point between the point of maximum kinetic energy and maximum gravitational potential energy as a test point and record the time of this point in Table 1.

2. ☐ Identify this point on both of the graphs you sketched above. �(7.1.5)

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3. ☐ Calculate the kinetic energy at this point and record the value in Table 1.

4. ☐ Calculate the gravitational potential energy at this point, and record the value in Table 1.

5. ☐ Calculate the total energy of the system at your test point, and record the value in Table 1.

Analysis Questions

1. How does the total energy of the system compare at the three different points in time that you investigated? Was energy conserved? Explain your answer.

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2. **At what point in the cart's path was the kinetic energy of the system greatest? Where did that original energy come from?**

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3. **In observing the motion of the cart, the second and third bounces of the cart were lower than the first, indicating less energy. Where did the energy go? In what form was it when it was lost?**

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Synthesis Questions

Use available resources to help you answer the following questions.

1. **An archer's bow can store 80 J of energy when drawn. If all that energy is converted to kinetic energy when the arrow is released, how fast is the 0.1 kg arrow traveling when it leaves the bow?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **How much gravitational potential energy does a 4 kg jug of milk set on the edge of a counter 1.2 m above the ground have?**

- **A.** 47.1 J
- **B.** 471 J
- **C.** 0 J
- **D.** There is not enough information to draw a conclusion.

2. A bobsled and rider have 100 kg of mass combined. They reach the bottom of the hill having attained a speed of 72 km/hr. Assuming all of their gravitational potential energy was converted to kinetic energy, how high was the hill?

- **A.** 204 m
- **B.** 42
- **C.** 20.4 m
- **D.** 264.2 m

3. A giant pendulum swings up to a height of 10 meters above the floor. When it reaches the bottom of its swing it is traveling at 14 m/s. What is the mass of the pendulum?

- **A.** 1000 kg
- **B.** 100 kg
- **C.** 9.81 kg
- **D.** There is not enough information to draw a conclusion.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. In an ideal "friction free" environment, a cart poised at the top of a hill has ____________ ____________ energy. As the cart begins to roll down the hill, this ____________ is transformed into ____________ energy. When the cart reaches the bottom of the hill the ____________ energy of the system is entirely comprised of kinetic energy. In the real world, some of this energy would be lost to ____________ in the form of heat.

2. Increasing the ____________ of an object increases its gravitational potential energy. Increasing the ____________ of an object increases the kinetic energy of the object. If the total ____________ is ____________, and the closed system only has these two types of energy, then an increase in one form of energy results in a ____________ in the other.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
Energy	Conserved
Friction	Decrease
Gravitational Potential	Energy
Kinetic	Lost
Partial	Height
Total	Kinetic
Work	Velocity