Introductory Energy and Motion Lab

P4-1350

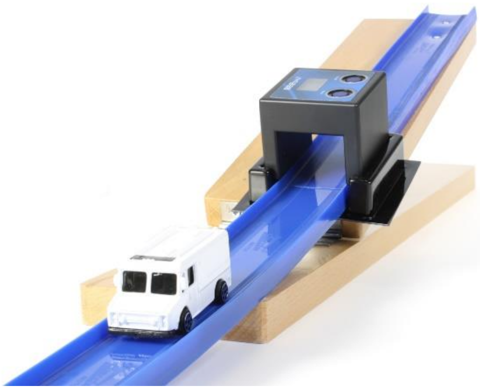
INSTRUCTIONAL GUIDE

Contents

- Adjustable ramp with angled wedges
- BeeSpi V Photogate Timer
- BeeSpi V Mounting Bracket
- 7 Track segments (one on ramp) with connectors
- Vehicle
- Instructional Guide

Recommended for Activity:

- Dry-Erase Markers (01-6012)
- Meter stick or ruler (P1-7072)
- Scale accurate to 0.1 g (02-7072)



Background

Students and teachers love to get to work fast rather than spend lab time setting up. This complete motion lab lets them quickly get to the task of collecting and analyzing data! The ramp for the Energy and Motion Lab adjusts to 10°, 20°, and 30° angles so students can use the same equipment to explore velocity, acceleration, gravity, kinetic energy, friction, and more! This teacher-developed kit includes comprehensive acceleration and mechanical energy labs that guide students through the physics behind changes in a car's velocity as it races down a ramp. The first lab guides students through the collection and manipulation of data to show acceleration as a constant rate of change. The second lab demonstrates conservation of energy through an investigation of potential and kinetic energy.

BeeSpi V

This lab incorporates the BeeSpi V self-contained photogate system which consists of two parallel infrared sensors. The results of the measurement are then viewed on the integrated display with a range of 0.00 to 99.99 in units of seconds, km/h, m/s or cm/s. No length measurements are required to garner an accurate reading from the BeeSpi. Objects larger than the 40 mm x 30 mm photogate aperture can still be measured but may require attaching a flag.

Teacher Notes

Lab 1: Introduction to Velocity and Acceleration:

Objective:
For a car rolling down an inclined plane, investigate the relationships between distance, time, velocity, acceleration, and the angle of the plane.

Student Learning Objectives:

1. Qualitatively describe and compare motion in two dimensions

   Key concepts: Two-dimensional motion, speed, direction, change in direction as acceleration

   Real-world context: Any object in motion such as thrown balls, roller coasters, life-sized cars on hills, etc. (great open-ended discussion topic)

2. Explain changes in an object's motion in terms of unbalanced forces in two dimensions

   Key concepts: Common accelerations such as speeding up, slowing down, turning; balanced forces, constant motion; amount of change is directly proportional to the magnitude of the unbalanced force and mass of the object

   Real-world context: Any time an object (or person) changes direction or speed—everyday motion (great open-ended discussion topic)

Lab 2: Introduction to Energy Conservation:

Objective:
Use a car rolling down an inclined plane as a model to investigate the transformation of potential energy into kinetic energy, thus demonstrating the key concept of energy conservation.

Student Learning Objective:

Explain changes in an object's motion in terms of conservation of energy.

Key concepts: Common accelerations such as speeding up, slowing down, turning; balanced forces, constant motion; amount of change is directly proportional to the magnitude of the unbalanced force and mass of the object. Conservation of energy is always a net zero process.

Real-world context: Any object lifted then dropped, knocked off a desk, etc. (great open-ended discussion topic)

Mass of the Vehicle:
The average mass of the vehicles used in this lab is 51.20 g ± 0.22 g. If no balance is available to the class, this mass may be used, but it is recommended that each vehicle's mass be confirmed by a balance before each experiment.

Related Products

Acceleration Car (P4-1980) This companion to our popular Constant Velocity Car demonstrates nearly constant acceleration. Simply pull back on the spring-loaded, die-cast truck, then release. Use a motion sensor or tape timer to measure the acceleration.

Constant Velocity Car (44-1090) This simple but powerful toy provides a visible source of uniform speed. Students can easily quantify and graph their results, starting them on the road to a conceptual understanding of motion.

Car and Ramp Lab (P4-1405) Experiment with distance, time, velocity and acceleration, Newton's laws and simple machines. The 120cm ramp attaches to the Workshop Stand at angles up to 65°.

Lab 1: Introduction to Velocity and Acceleration

Measuring a freely falling object is difficult because the velocity changes constantly. In fact, it increases about 10 meters per second every second. In other words, the distance the object falls each second becomes larger very quickly. Studying acceleration is simpler if this motion is slowed down by the use of an inclined plane.

This experiment requires taking measurements with the BeeSpi V Photogate. The BeeSpi V is made up of two photogates with a known distance between them, so when the photogates are tripped, the display will show the velocity of the object moving through the opening in meters per second.

Find the average velocity for each angle by performing several replicates. Standard deviation can also be calculated if desired. How does acceleration depend on potential energy?

Procedure

1. Set up the ramp using the 10° wedge.
2. Place the BeeSpi Photogate at the bottom of the ramp, just before the track begins curve.
3. Measure the distance d from the front of the car at the top of the ramp to the middle of the photogate.
4. Press either button on the photogate to turn it on. Press the start button to get the timer ready for measurement. You should see "m/s" flashing in the bottom right corner of the display. If you see "sec," press and hold the start button until you see "m/s" flashing.
5. Release the car at the top of the ramp and record the measurement in your data table.
6. Take four more measurements for a total of five replicates.

Repeat steps 3 through 6 for the 20° and 30° wedges. Remember to release the car from the same spot every time. It may help to mark this point on the ramp. After all your experimental data has been collected in the data table, use the acceleration formula below to fill in the last column.

$$acceleration = \frac{(V_f - V_i)^2}{2d}$$

Sample Calculation:
If the distance from the starting point of the front of the vehicle is 0.3 m, and the final velocity as measured by the photogate is 1.23 m/s:

$$acceleration = \frac{(1.23\ m/s\ = 0.00\ m/s)^2}{2(0.03\ m)} = \mathbf{2.52\ m/s^2}$$

Notice that V_i will always be zero since the vehicle is starting from rest.

Data Table

10°	**Distance (m)**	**V_i (m/s)**	**V_f (m/s)**	**Accel. (m/s)²**
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				

20°	**Distance (m)**	**V_i (m/s)**	**V_f (m/s)**	**Accel. (m/s)²**
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				

30°	**Distance (m)**	**V_i (m/s)**	**V_f (m/s)**	**Accel. (m/s)²**
Trial 1				
Trial 2				
Trial 3				
Trial 4				
Trial 5				

Discussion

Answer the following questions on a separate sheet:
What is acceleration?

What evidence do you have that shows the car is accelerating?

What happens to the acceleration as the angle of the ramp is increase? Use your data to explain what happens.

What relationship do you observe between V_f and d?

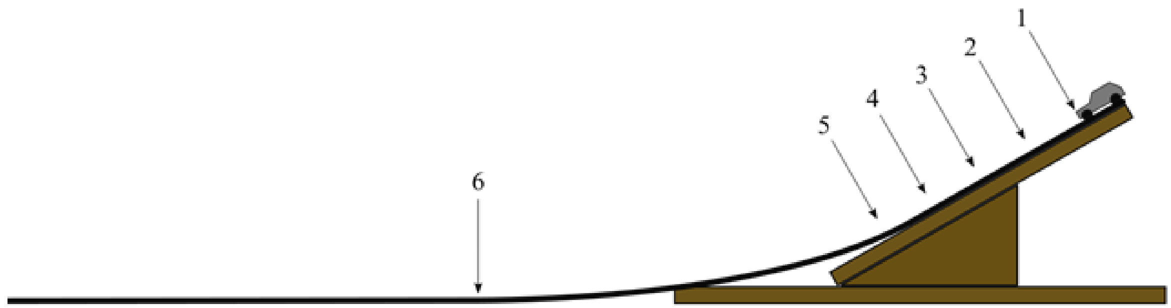
Lab 2: Introduction to Energy Conservation

Measuring a freely falling object is difficult because the velocity changes constantly. In fact, it increases about 10 meters per second every second. In other words, the distance the object falls each second becomes larger very quickly. Studying acceleration is simpler if this motion is slowed down by the use of an inclined plane.

This experiment requires taking measurements with the BeeSpi Photogate. The BeeSpi is made up of two photogates with a known distance between them, so when the photogates are tripped, the display will show the velocity of the object moving through the opening in meters per second.

Calculate the kinetic and potential energy by measuring velocity at 5 different points on the ramp. Is energy conserved at every point?

Procedure



1. Set up the ramp using the 20° wedge.
2. Position the car at the top of the ramp so the back of the car is lined up with the end of the ramp. Mark this spot with washable marker.
3. From the first point, mark intervals of 5 cm going down the ramp. You should have a total of 5 marks on the ramp as shown below.
4. Find the height in meters of each point by measuring from the surface the apparatus is sitting on to each point on the ramp. Record these measurements in the data table.
5. Mark a sixth point where the ramp flattens out.
6. Record the mass of the car in kg. Remember that 1 kg = 1000 g.
7. At point 1, the velocity is zero. What is the kinetic energy?
8. Place the BeeSpi on Point 2 and press either button on the photogate to turn it on. Press the start button to get the timer ready for measurement. You should see "m/s" flashing in the bottom right corner of the display.

   If you see "sec," press and hold the start button until you see "m/s" flashing.
9. Release the car from the top of the ramp and record the velocity in the data table.

Repeat steps 8 and 9 for a total of 5 results for each point. Remember to release the car from the same spot every time. It may help to mark this point on the ramp. After taking the experimental measurements, your data table should be complete.

Data Table

Point 1 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Point 2 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Point 3 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Point 4 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Point 5 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Point 6 Height:	
Trial	Velocity (m/s)
1	
2	
3	
4	
5	

Mass of the Vehicle (in kg): ____________________

With all this data, we can now calculate the kinetic and potential energy at each point with the equations below.

$$potential\ energy\ (PE) = mass \times height \times 10\ m/s^2$$

$$kinetic\ energy\ (KE) = {}^1\!/_2\, mass \times velocity^2$$

Fill in the following conservation table to discover whether or not energy was conserved or not.

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
PE (J)						
KE (J)						
PE+KE (J)						

Discussion

Answer the following questions on a separate sheet:
What does it mean to say energy is conserved? Answer in terms of kinetic and potential energy.

Did you find that energy was conserved in the experiment? What evidence do you have? Does your experimental result agree exactly with your expected result?

In this experiment, energy was transformed from potential energy to kinetic energy. Where else could energy have gone?