C3 Studying Two-Part Motion

Key Question: *What happens to the Energy Car as it travels down a hill and across a flat section of track?*

Acceleration is the rate at which velocity changes. Whether an object moves faster or slower, it accelerates. With increasing velocity, an object experiences positive acceleration. When an object's speed remains constant, the acceleration is zero. In this investigation, students compare time and distance measurements to describe the changing speed and acceleration of the Energy Car as it accelerates and then moves at a constant speed.

Learning Goals

- ✔ Predict the effects of a ramp with sloped and level sections on acceleration and speed
- ✔ Observe the motion of an object
- ✔ Analyze the motion of an object in order to describe speed and acceleration in terms of distance and time

GETTING STARTED

Time 55 minutes

Setup and Materials

1. Make copies of investigation sheets for students.
2. Watch the equipment videos.
3. You will need access to AC outlets for the DataCollectors.
4. Review all safety procedures with students.

Materials for each group

- Energy Car and Track
- DataCollector and two photogates
- Physics Stand
- 1 steel marble

Online Resources

Available at curiosityplace.com

- Equipment Videos: DataCollector, Energy Car and Track
- Skill and Practice Sheets
- Whiteboard Resources
- Animation: Car Speed and Position
- Science Content Video: More Speed vs. Time graphs
- Student Reading: Acceleration

Vocabulary

acceleration – the rate at which velocity changes

speed – describes how quickly an object moves, calculated by dividing the distance traveled by the time it takes

NGSS Connection

This investigation builds conceptual understanding and skills for the following performance expectation.

HS-PS2-1. *Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena.	PS2.A: Forces and Motion. PS2.B: Types of Interactions	Cause and Effect

BACKGROUND

Speed describes how quickly an object moves. Constant speed is easy to understand. However, almost nothing moves with constant speed for long. When a driver steps on the gas pedal, the speed of the car increases. When the driver brakes, the speed decreases. Even while using cruise control, the speed goes up and down as the car's engine adjusts for hills. Another important concept in physics is acceleration. Acceleration, an important concept in physics, is how we describe changes in speed or velocity.

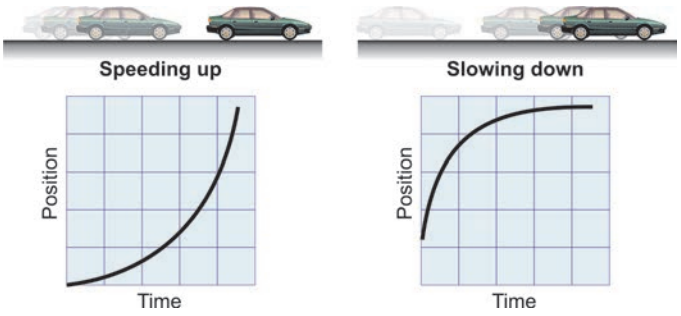
Speed and acceleration are not the same thing. You can be moving (non-zero speed) and have no acceleration (think cruise control). You can also be accelerating and not moving! But if the brakes are applied and the car slows down, it is accelerating because the speed is now changing (faster to slower).

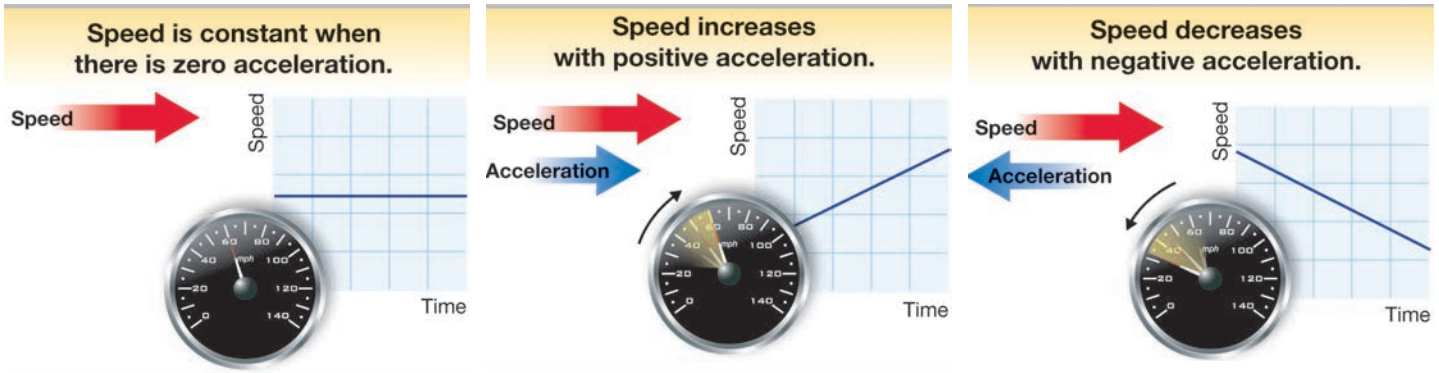
Acceleration describes how quickly speed changes. More precisely, acceleration is the change in velocity divided by the change in time. For example, suppose a powerful sports car changes its speed from 0 to 60 mph in 5 seconds. In English units the acceleration is 60 mph ÷ 5 seconds = 12 mph/second. In SI units, 60 mph is about the same as 100 km/h. The acceleration is 100 km/h ÷ 5 seconds, or 20 km/h/s.

A speed vs. time graph is useful for showing how the speed of a moving object changes over time. Think about a car moving on a straight road. If the line on the graph is horizontal, then the car is moving at a constant speed. The upward slope in the middle graph shows increasing speed. The downward slope of the bottom graph tells you the speed is decreasing. The word **acceleration** is used for any change in speed, up or down.

Acceleration can be positive or negative. Positive acceleration in one direction adds more speed each second. Things get faster. Negative acceleration in one direction subtracts some speed each second, Things get slower. People sometimes use the word *deceleration* to describe slowing down.

The position vs. time graph is a *curve* when there is acceleration. Think about a car that is accelerating (speeding up). Its speed increases each second. That means it covers more distance each second. The position vs. time graph gets steeper each second. The opposite happens when a car is slowing down. The speed decreases so the car covers less distance each second. The position vs. time graph gets shallower with time, becoming flat when the car is stopped.





5E LESSON PLAN

Engage

Review speed vs. time graphs with your students. Have your students sketch a speed vs. time graph for each of the following scenarios:

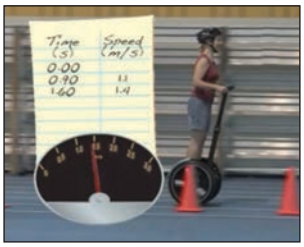
1. A car has increasing acceleration.
2. A car has decreasing acceleration.
3. A car has a constant acceleration.

Explore

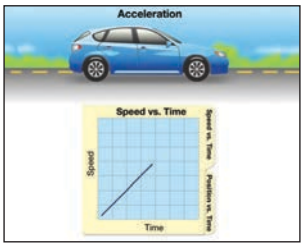
Have students complete investigation C3. In this investigation, students analyze and interpret the motion of the car on a two-part ramp.

Explain

Revisit the Key Question to give students an opportunity to reflect on their learning experience and verbalize understandings about the science concepts explored in this investigation. Curiosityplace.com resources, including student readings, videos, animations, and whiteboard resources, as well as readings from your current science textbook, are other tools to facilitate student communication about new ideas.



Science Content Video
More Speed vs. Time Graphs

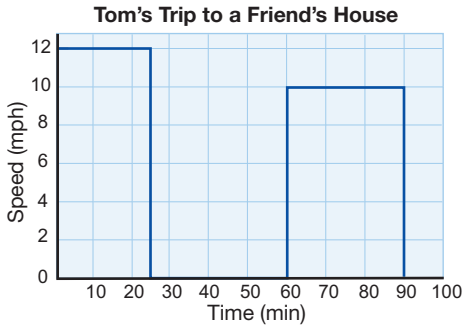


Animation
Car Speed and Position

Elaborate

Have your students come up with a scenario and then draw a speed vs. time graph of that scenario. Here is an example:

Tom rides his bicycle from home at a constant speed of 12 mph to his friend's house in 25 minutes. He spends 35 minutes there and returns home, riding at a constant speed of 10 mph in 30 minutes.



Evaluate

- ✔ During the investigation, use the checkpoint questions as opportunities for ongoing assessment.
- ✔ After completing the investigation, have students answer the assessment questions on the *Evaluate* student sheet to check understanding of the concepts presented.

Explore INVESTIGATION C3

Name _____ Date _____

C3 Studying Two-part Motion

What happens to the Energy Car as it travels down a hill and across a flat section of track?

In the previous Chapter 3 investigations, you explored the motion of the car on a flat track and again on a hill. This time, you will put the track together so it has both a hill and a flat section. What will the **speed** vs. time graph look like? You will soon find out!

Materials:

- ✔ Data Collector and 2 photogates
- ✔ Energy Car and Track
- ✔ Physics Stand
- ✔ 1 steel marble

❶ Predicting

You will set up the track so it has a steep incline and a flat section joined. What will the speed vs. time graph look like?

a. Draw a sketch of what you think the speed vs. time graph will look like. Put time on the *x*-axis and speed on the *y*-axis.

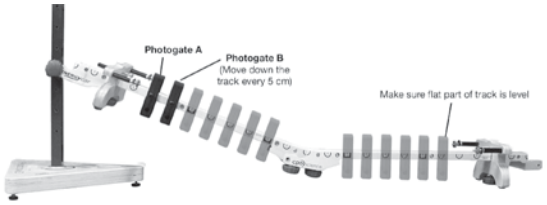
Title: _____

y-label: _____

x-label: _____

Explore INVESTIGATION C3

❷ Setting up the experiment

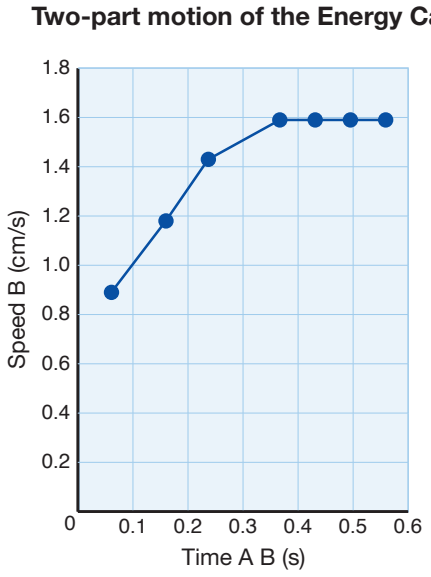


1. Join the steeper hill with the flat track and attach it to the fourth hole from the bottom.
2. Place a stop at the top of the track with the plunger all the way back so the end is flush with the stop.
3. Place the other stop at the bottom of the track; put a lump of clay on the plunger so the car won't bounce back through Photogate B when it is near the end.
4. Attach Photogate A as shown in the photo, and leave it there.
5. Photogate B will be placed every 5 centimeters, as shown in the photo.
6. Make sure the flat part of the track is level. Use the leveling feet on the physics stand base and on the bottom stop.
7. Place the Energy Car at the top of the track so it rests against the stop's plunger. Put one marble in the center of the car. Photogate B should be 5 centimeters from photogate A.

❸ Doing the experiment

1. Release the car and record the time through A, the time through B, the time from A to B, and the distance traveled in Table 1.
2. Move the photogate to the next 5-centimeter mark and repeat step 1. Do this all along the track until you reach the last mark possible. You will not be able to take time measurements at 35, 40, or 45 centimeters away from photogate A.

1a. Graph



Guiding the INVESTIGATION

❷ Setting up the experiment

This is a good point at which to review how to design and conduct investigations. Ask your students to list all of the variables in the system. What is the research question? Which variables are they controlling? What is the experimental variable?

Explore INVESTIGATION C3

Table 1: Energy car data

Distance A to B (cm)	Time A (s)	Time B (s)	Time AB (s)	Speed A (cm/s)	Speed B (cm/s)
5	0.0303	0.0154	0.1065	33.0	64.9
10	0.0305	0.0118	0.1743	32.8	84.7
15	0.0303	0.0098	0.2314	33.0	102.0
20	0.0303	0.0087	0.2771	33.0	114.9
25	0.0305	0.0078	0.3204	32.8	128.2
30	0.0305	0.0072	0.3569	32.8	138.9
50	0.0303	0.0064	0.4886	33.0	156.3
55	0.0305	0.0065	0.5521	32.8	156.3
60	0.0305	0.0065	0.5521	32.8	156.3
65	0.0307	0.0065	0.5858	32.6	153.8
70	0.0304	0.0065	0.6164	32.9	153.8
75	0.0307	0.0066	0.6522	32.6	151.5

❹ Analyzing the data

a. Find the speed at A and speed at B for each trial and record in Table 1. Remember, to find the speed of the car, use the width of the flag (1.00 centimeters) for the distance, and the time through the photogate for the time (s = d/t).

b. Look at the A speeds. What does this data tell you in general about the experiment?

The speeds at A were all almost the same. This makes sense because photogate A was in the same position throughout the experiment. Differences were due to release technique.

Explore INVESTIGATION C3

c. Look at the B speeds. What does this data tell you in general about the motion of the car as it moved down and across the track?

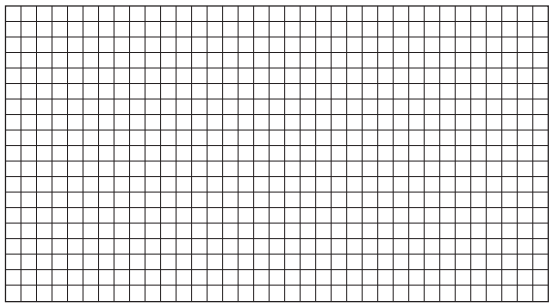
The speeds at B show that the car speeds up as it goes down the hill, and then goes at a relatively constant speed. It does slow down a little at the end, which makes sense because friction takes away some of the energy of motion.

❺ Graphing the data

a. Create a speed vs. time graph for the data. Put time AB (s) on the *x*-axis and speed at B (cm/s) on the *y*-axis. Draw a best fit line.

Title: _____

y-label: _____



x-label: _____

b. How does the graph compare to your prediction? Explain.

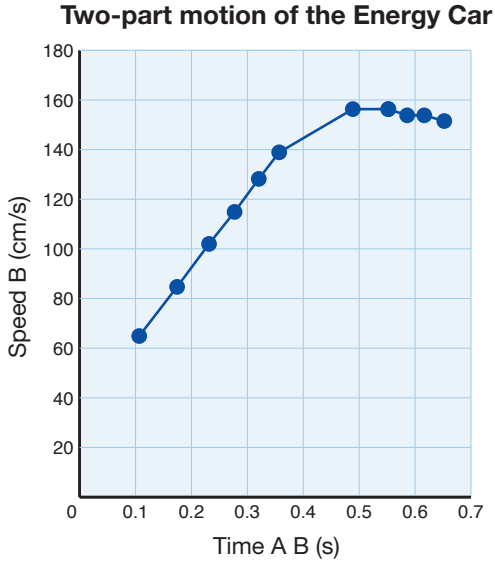
The graph looks similar to my prediction, but I predicted it would speed up faster and I did not predict it would slow down as much once it reached the flat section.

Guiding the INVESTIGATION

❹ Analyzing the data

If there is too much variation in speeds at photogate A, check to make sure that students are practicing consistent release techniques. It is a good idea to ask groups to assign this task to only one group member. Ask your students why this might be important. Tasks for other group members include: starting the DataCollector, moving photogate B, reading the times, recording the times, and calculating speeds.

5a. Graph



Explore

INVESTIGATION C3

6 Thinking about what you observed

✓ **a.** Where is the car accelerating? Justify your answer with evidence from the experiment.

The car is accelerating as it goes down the hill. The Speed vs. Time graph is a straight line that rises from left to right. This shows the speed is increasing.

✓ **b.** Where is the car moving at a constant speed? Justify your answer with evidence.

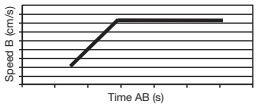
The car is moving at a constant speed when it reaches the flat part of the track, although it slows down a little at the end. The Speed vs. Time graph is a fairly flat, horizontal line. This shows that the speed was pretty constant, at about 156 cm/s.

Evaluate

INVESTIGATION C3

Name _____ Date _____

Use this graph to answer the following questions.



1. What is the shape of the line when the car is moving on the flat section of the track?

Flat

2. What is the shape of the line when the car is moving down the slopped section of the track?

The line is tilted upwards.

3. What is another name of speed/time?

Acceleration

4. Why is the speed of the car constant on the flat part of the track?

The car is no longer accelerating when it reaches the flat part of the track. The car accelerates initially due to the force of gravity. At the level section of the track the force of gravity is counteracted by the normal force of the ramp. There is some negative acceleration due to friction, but this is very slight. In general the car is no longer accelerating.

5. What does the "AB" indicate on the graph?

"AB" indicates that the graph is showing the time interval of the car moving between photogates A and B.

WRAPPING UP

Ask students to respond to the following question in their notebooks:

A cannonball is shot straight up several meters and falls straight back into the cannon a few seconds later. Sketch a velocity vs. time graph for cannonball from the moment it leaves the cannon until the moment it returns.