Name____

6th Grade - Grading Period 3 Overview

Ohio's New Learning Standards

- There are two categories of energy: kinetic and potential. Rocks, minerals and soils have common and practical uses. (6.PS.3)
- An object's motion can be described by its speed and the direction in which it is moving. (6.PS.4)

Combination of: 6.LS.1-4…

The content statements for sixth-grade Life Science are each partial components of a large concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories, Modern Cell Theory. It is recommended that the content statements be combined and taught as a whole. For example, the energy needs of cells can be interwoven with the function of mitochondria.

- Cells are the fundamental unit of life. (6.LS.1)
- All cells come from pre-existing cells. (6.LS.2)
- Cells carry on specific functions that sustain life. (6.LS.3)
- Living systems at all levels of organization demonstrate the complementary nature of structure and function. (6.LS.4)

Clear Learning Targets

"I can…":

1. _____ explain that objects and substances in motion have kinetic energy.

2. _____ explain that objects and substances can have energy as a result of their position.

3. _____ explore, investigate, and explain various types of potential and kinetic energy.

4. _____ describe an objects motion in relation to a reference point.

5. _____ calculate an object's speed based on the amount of time it takes to travel a certain distance.

6. _____ analyze and interpret position vs time and speed vs. time graphs in order to describe an object's motion.

Life Science "I can" statements…(to be determined)

Name____

6th Grade - Grading Period 3 Overview

Essential Vocabulary/Concepts

6.PS.3

- Electrical Energy
- Gravitational Potential Energy
- Kinetic Energy
- Potential Energy
- Sound Energy
- Thermal Energy

6.PS.4

- Distance
- Motion
- Position vs Time Graph
- Reference Point
- Speed
- Speed vs. Time Graph
- Time

6.LS.1 cont'd…

Plasma Membrane
Protista
Ribosome
Single-Cellular
Tissues
Vacuole

6.LS.2

Binary Fission
Cell Division
Cellular Growth and Repair
Chromosomes
Daughter Cell
Genetic Material
Mitosis
Parent Cell
Pre-existing Cells

LIFE SCIENCE

The content statements for sixth-grade Life Science are each partial components of a large concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories, Modern Cell Theory. It is recommended that the content statements be combined and taught as a whole.

***This content continues through 4th Grading Period**

6.LS.1

Cell
Cell Membrane
Cell Wall
Chloroplast
Eubacteria
Fungi
Lysosome
Microscope
Micrographs
Mitochondria
Modern Cell Theory
Multi-Cellular
Nucleus
Organelles
Organs
Reproduction
Traits

6.LS.3

Cells
Energy Transfer/Transformations
Gas Exchange
Homeostasis
Molecules
Organs
Organ Systems
Protein Building
Synthesis
Tissues
Waste Disposal

6.LS.4

Body Plans
Cells
Internal Structures
Organs
Organ Systems
Symmetry
Tissues

6th Grade Science Unit:

6.PS.3 Potential and Kinetic Energy

Unit Snapshot

Topic: Matter and Motion

Grade Level: 6

Duration:
~3 weeks

Summary (as stated in Ohio's New Learning Standards for Science)

There are many forms of energy, but all can be put into two categories: kinetic and potential. Kinetic energy is associated with the motion of an object. The kinetic energy of an object changes when its speed changes. Potential energy is the energy of position between two interacting objects. Gravitational potential energy is associated with the height of an object above a reference position. The gravitational potential energy of an object changes as its height above the reference changes. Electrical energy is associated with the movement of electricity through the wires of an electrical device. Thermal energy refers to the total amount of kinetic energy a substance has because of the random motion of its atoms and molecules. Sound energy is associated with the back and forth movement of the particles of the medium through which it travels. Provide opportunities to explore many types of energy. Virtual experiments that automatically quantify energy can be helpful since using measurements to calculate energy is above grade level.

Note: Using the word "stored" to define potential energy is misleading. The word "stored" implies that the energy is kept by the object and not given away to another object. Therefore, kinetic energy also can be classified as "stored" energy. A rocket moving at constant speed through empty space has kinetic energy and is not transferring any of this energy to another object.

Clear Learning Targets

"I can"…statements

_____ explain that objects and substances in motion have kinetic energy.
_____ explain that objects and substances can have energy as a result of their position.
_____ explore, investigate, and explain various types of potential and kinetic energy.

Suggested Timeframe

ENGAGE

EXPLORE

EXPLAIN

ELABORATE (~3 Weeks)

EVALUATE

EXTENSION/ INTERVENTION

OHIO'S NEW LEARNING STANDARDS:

6.PS.3 There are two categories of energy: kinetic and potential.

- Objects and substances in motion have kinetic energy.
- Objects and substances can have energy as a result of their position (potential energy).
  Note: Kinetic and potential energy should be introduced at the macroscopic level for this grade. Chemical and elastic potential energy should not be included at this grade; this is found in PS grade 8.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering)that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Frame-work for K-12 Science Education Scientific and Engineering Practices

STUDENT KNOWLDEGE:

Prior Concepts Related to Energy

PreK-2: A variety of sounds and motions are experienced. The sun is the principal source of energy (ESS). Plants get energy from sunlight (LS).
Grades 3-5: Objects with energy have the ability to cause change. Heat, electrical energy, light, sound and magnetic energy are forms of energy. Earth's renewable and nonrenewable resources can be used for energy (ESS). All processes that take place within organisms require energy (LS).

Future Application of Concepts

High School: Gravitational potential energy will be calculated for objects at varying heights and kinetic energy will be calculated for moving objects. Conservation of energy will be explored mathematically. Elastic potential energy will be calculated for different systems. Electric potential and electric potential energy will be introduced.

Grades 7-8: Conservation of Energy and methods of energy transfer, including waves, are introduced.
Chemical and elastic potential energy are explored.
High School: Standard formulas are used to calculate energy for different objects and systems.

Teacher Guide: Potential Energy on Shelves

Learning Objectives

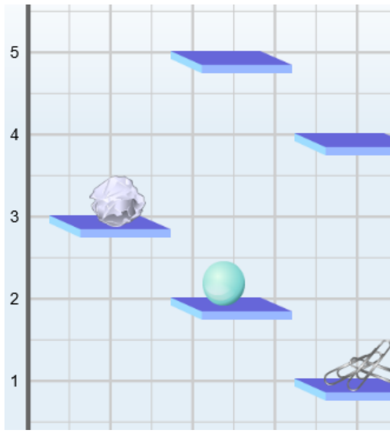
Students will …

- Identify the factors that affect an object's gravitational potential energy.
- Find the relationship between an object's height and its gravitational potential energy.
- Use the gravitational potential energy equation to calculate an object's weight, mass, and potential energy.
- Explain how changing an object's gravitational potential energy involves doing work.

Vocabulary

gravitational potential energy, kinetic energy, potential energy, weight, work

Lesson Overview



At first glance, a book on a shelf seems to have the same amount of energy as a book on the floor. Both are lying still, after all. But the book on the shelf has the potential to fall off the shelf and hit the floor with a big thump. This potential for movement is called *gravitational potential energy* because of its height relative to its counterpart at street level.

Students can discover the factors affecting an object's gravitational potential energy using the *Potential Energy on Shelves* Gizmo™. The Gizmo allows students to measure the potential energy of various objects placed on shelves at different heights above the floor.

The Student Exploration sheet contains three activities:

- Activity A – Students determine the factors affecting gravitational potential energy.
- Activity B – Students use the gravitational potential energy equation to calculate the weight and mass of various objects.
- Activity C – Students discover the relationship between work done on an object and its gravitational potential energy.

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (10 – 20 minutes)
   Bring a variety of small objects to class, such as marbles, ping pong balls, paper clips, coins, lead weights, and so on. Organize students into small groups and hand out an assortment of objects to each group. Have each group measure the masses of their

objects and set up a small sandbox. Then, instruct students to drop each object into the sandbox from the same height. Students should measure the size of the impact crater. Next, have students vary the heights from which they drop the objects. After allowing students to experiment with various heights, discuss the factors that affected the size of the impact craters.

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:

   - Why does increasing an object's height and/or mass increase its gravitational potential energy?
   - Why would an object's gravitational potential energy be higher if it was 100 m above the surface of Jupiter instead of 100 m above Earth?
   - Why is it necessary to do work to give an object gravitational potential energy?
   - Why does changing an object's horizontal position have no effect on its gravitational potential energy?

5. **Follow-up activities** (1 – 2 hours)
Have students explore conversions between kinetic and potential energy by completing the Student Exploration sheets for one or more of the following Gizmos: *Energy of a Pendulum*, *Energy Conversion in a System*, and *Roller Coaster Physics*.

Scientific Background

Although a boulder on a cliff may be perfectly still, it is capable of doing work if it falls. Because of the boulder's potential to do work, it has a type of energy known as *potential energy.* Work must be done on an object to give it potential energy. Due to the principle of conservation of energy, the potential energy of an object cannot exceed the amount of work done on the object.

There are two main kinds of potential energy: elastic potential energy and gravitational potential energy. Elastic potential energy comes from an object's shape. An elastic object that is stretched or compressed in some way will be able to spring back to its original shape when it is released. For example, when an archer stretches a bow, the bow gains elastic potential energy. This energy is converted back to kinetic energy when the bowstring is released.

Gravitational potential energy comes from an object's position in relation to a gravitational field. Gravitational potential energy is equal to the work done to lift an object to a given height. *Work* is defined as the product of force and distance. To lift an object, the minimum force required is equal to the weight of the object applied over a distance that is equal to the height. Therefore, gravitational potential energy is equal to the product of an object's weight and height, or the product of its mass (m), gravitational acceleration (g), and height (h). The equation for gravitational potential energy is: $GPE = mgh$.

For example, an elephant on a 100-meter cliff will have more potential energy than an elephant on a 10-meter cliff. An elephant will have more gravitational potential energy than a human standing on the same cliff. Similarly, an elephant 10 meters above Earth's surface would have more potential energy than an elephant 10 meters above the Moon's surface because of the greater force of gravity on Earth.

Technology Connection: Trebuchet

A trebuchet is an ancient siege weapon that uses gravitational potential energy to hurl missiles. The force of a missile hurled by a trebuchet is strong enough to pound a thick stone wall to dust. In fact, trebuchets destroyed so many town walls that some historians call them the nuclear bombs of the Middle Ages.

The most powerful trebuchets use counterweights to give their projectiles kinetic energy. One such trebuchet is shown at right. The missile is placed in a sling, which is attached to a long beam and a massive counterweight.

To operate a trebuchet, a pulley system is used to pull down the sling and raise the counterweight. When the loaded sling is released, the potential energy of the counterweight is converted to kinetic energy. As the counterweight falls, the beam rotates in an arc, pulling the sling until the sling swings ahead of the beam and the missile is released.

With the invention of guns and explosives, trebuchets eventually fell out of military use. However, they still are popular today for more light-hearted battles: pumpkin chunking contests. In fact, every fall dozens of trebuchets are lined up in Sussex County, Delaware, for the annual World Championship Punkin Chunkin competition. Currently, the world record for the longest pumpkin toss by a trebuchet is 2,034.21 m.

Selected Web Resources

Potential energy: http://www.physicsclassroom.com/class/energy/u5l1b.cfm, http://jersey.uoregon.edu/vlab/PotentialEnergy/

Gravitational potential energy: http://hyperphysics.phy-astr.gsu.edu/hbase/gpot.html

Trebuchet: http://www.redstoneprojects.com/trebuchetstore/trebuchet_history.html

Punkin Chunkin: https://www.punkinchunkin.com/

Related Gizmos:

Energy of a Pendulum: http://www.explorelearning.com/gizmo/id?390

Energy Conversion in a System: http://www.explorelearning.com/gizmo/id?416

Energy Conversions: http://www.explorelearning.com/gizmo/id?651

Roller Coaster Physics: http://www.explorelearning.com/gizmo/id?405

Sled Wars: http://www.explorelearning.com/gizmo/id?1055

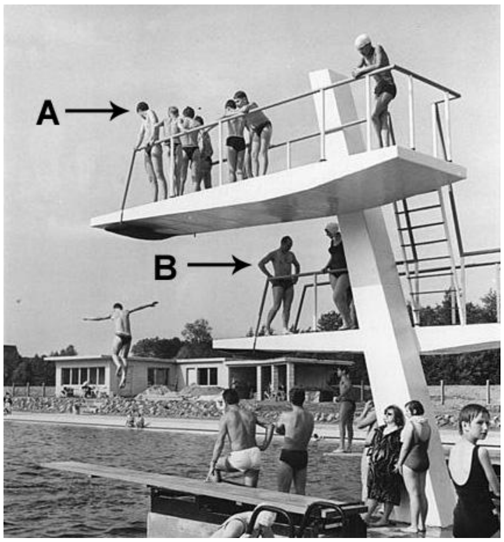
Trebuchet: http://www.explorelearning.com/gizmo/id?1054

Name: ______________________________ Date: ____________________

Student Exploration: Potential Energy on Shelves

Vocabulary: gravitational potential energy, kinetic energy, potential energy, weight, work

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)



1. Look at divers A and B in the picture at left. Which diver had to put the most effort into climbing to the top of his board? Explain.

   ____

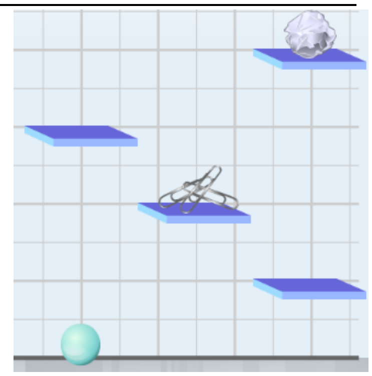
   ____

2. Which diver do you think will make the biggest splash? Explain. ____________________

   ____

   ____

Gizmo Warm-up



It takes energy to climb up to the top of a diving board, and of course a diver that leaps off the board and makes a big splash in the water also has a lot of energy. But how much energy does a diver have while he is standing at the top of the diving board?

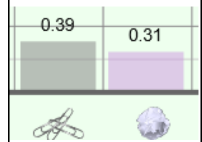
Even at the top of the board, the diver has energy—a type of energy called **potential energy**. Potential energy is the energy an object has because of its position or shape. Using the *Potential Energy on Shelves* Gizmo™, you will discover how gravity gives objects potential energy because of their position above the floor.

1. Which object on the SIMULATION pane most likely has the least potential energy? Why?

   ____

2. Click on the TABLE tab. The potential energy (*PE*) of each object is given in joules (J). List the objects in order from lowest to highest potential energies.

   ____

Activity A: **Factors affecting GPE**	Get the Gizmo ready: • Select the BAR CHART tab and turn on **Show numerical values**.	

Introduction: Because gravity pulls objects down to Earth's surface, objects lifted above Earth's surface have a type of potential energy called **gravitational potential energy**, or *GPE*.

Question: What factors affect how much gravitational potential energy an object ha

1. Identify: Circle the factors below that you think affect an object's potential energy.

mass vertical position velocity horizontal position

2. Observe: Drag the ball to the 1-m shelf on the SIMULATION pane.

   A. What is the ball's potential energy (*PE*)? _______________

   B. Move the ball to the 2-m shelf. What is its potential energy now? _______________

   C. What do you think the ball's potential energy will be on the 3-m shelf? The 4-m shelf?

   PE on 3-m shelf: _______________ *PE* on 4-m shelf: _______________

   Use the Gizmo to check your answers. (Click the control on the bar graph to zoom out.)

3. Summarize: What is the relationship between an object's height above the ground and its gravitational potential energy? ____

4. Describe: Move the ball from side to side (left to right) while trying to keep it at the same height. How does changing the horizontal position of the ball affect its potential energy?

   ____

5. Infer: Place the ball and the paper on the same shelf.

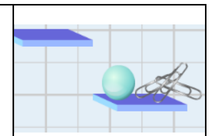
   A. Which object has more potential energy? ___________________________________

   B. Why do you think their potential energies are different? ________________________

   ____

6. Identify: What two factors affect how much gravitational potential energy an object has?

   ____

Activity B: Calculating GPE	Get the Gizmo ready: • You will need a calculator to complete this activity.	

Introduction: An object's gravitational potential energy depends on two factors: its height (*h*) and its **weight** (*w*). The equation for gravitational potential energy (*GPE*) is:

$$GPE = w \times h$$

Goal: Use the gravitational potential energy equation to determine the weight, mass, and potential energy of various objects.

1. Record: Position all three objects on the 1-m shelf and fill in the third column of the table.

Object	Height (m)	GPE (J or N•m)	Weight (N)
Ball	1 m		
Clips	1 m		
Paper	1 m		

2. Calculate: For each object, substitute the values you know into the gravitational potential energy equation to solve for weight. Record each object's weight in the fourth column.

3. Predict: Suppose the clips were placed on the 5-m shelf. What would their gravitational potential energy be? (Show your work.) ____

   Use the Gizmo to check your answer.

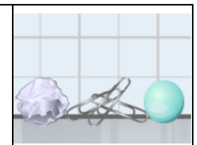
4. Calculate: An object's weight is determined by its mass (*m*) and the acceleration due to gravity (*g*) affecting that object: $w = mg$. On Earth, $g = 9.8 \text{ m/s}^2$.

   A. What are the masses (in kilograms) of the three objects on the Gizmo? (Note: $1 \text{ N} = 1 \text{ kg} \times \text{m/s}^2$)

      Ball: _____________ Clips: _____________ Paper: _____________

   B. Suppose a 4,000-kg elephant is hoisted 20 m above Earth's surface. What will the elephant's gravitational potential energy be? (Show your work in the space below.)

      ____

Activity C: Work and GPE	Get the Gizmo ready: • Place the ball, clips, and paper at 0 m.	

Introduction: Whenever you lift an object to place it on a shelf, you are doing **work**. Work occurs anytime a force causes an object to move.

Question: How much work is done to lift the ball, clips, and paper?

1. Observe: How much potential energy do the ball, clips, and paper have now? ___________

2. Calculate: The amount of work (W) done on an object is equal to the force (F) needed to lift the object (the object's weight) multiplied by the distance (d) the object is lifted: $W = F \times d$.

   Use the weight of the ball that you calculated in activity B to determine how much work would be required to lift the ball 2 meters above the zero position:

   ____

3. Analyze: Move the ball to the 2-m shelf.

   A. How much potential energy does the ball have now? ________________________

   B. How does the ball's potential energy relate to the amount of work needed to place the ball on the 2-m shelf? ____

   C. How much work would be needed to lift the ball from the 2-m shelf to the 5-m shelf, and how much potential energy would it have on the 5-m shelf? _______________

   ____

4. Predict: What do you think would happen to the ball's potential energy if it is knocked off the shelf and falls to the floor? ____

____

5. Think and discuss: Objects in motion have **kinetic energy**. As objects fall, their potential energy is converted into kinetic energy. How much kinetic energy do you think the ball would have just before it hit the floor if it were dropped from a 2-m shelf? Explain your answer.

____

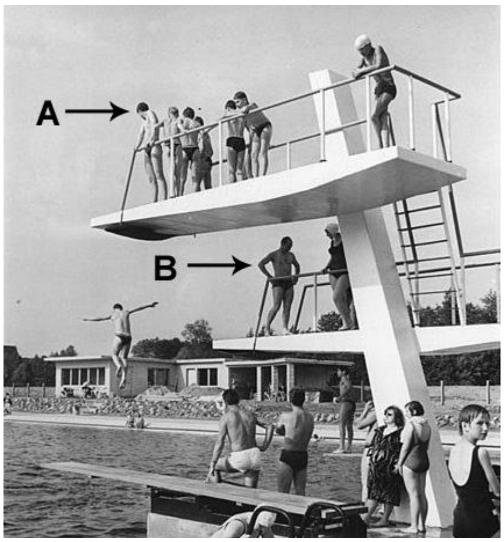
____

Potential Energy on Shelves **Answer Key**

Vocabulary: gravitational potential energy, kinetic energy, potential energy, weight, work

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]



3. Look at divers A and B in the picture at left. Which diver had to put the most effort into climbing to the top of his board? Explain.

   Answers will vary. [Diver A likely had to put the most effort into climbing his board because his board is higher.]

4. Which diver do you think will make the biggest splash? Explain.

   Answers will vary. [Diver A will likely make the biggest splash because he is jumping from a higher position.]

Gizmo Warm-up

It takes energy to climb up to the top of a diving board, and of course a diver that leaps off the board and makes a big splash in the water also has a lot of energy. But how much energy does a diver have while he is standing at the top of the diving board?

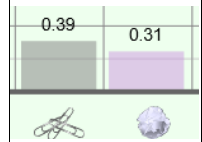
Even at the top of the board, the diver has energy—a type of energy called **potential energy**. Potential energy is the energy an object has because of its position or shape. Using the *Potential Energy on Shelves* Gizmo™, you will discover how gravity gives objects potential energy because of their position above the floor.

3. Which object on the SIMULATION pane most likely has the least potential energy? Why?

   The ball most likely has the least potential energy because it is sitting at ground level.

4. Click on the TABLE tab. The potential energy (*PE*) of each object is given in joules (J). List the objects in order from lowest to highest potential energies.

   Ball, paper, clips

Activity A: **Factors affecting GPE**	Get the Gizmo ready: • Select the BAR CHART tab and turn on **Show numerical values**.	

Introduction: Because gravity pulls objects down to Earth's surface, objects lifted above Earth's surface have a type of potential energy called **gravitational potential energy**, or *GPE*.

Question: What factors affect how much gravitational potential energy an object has?

7. Identify: Circle the factors below that you think affect an object's potential energy.

mass   vertical position   velocity   horizontal position

8. Observe: Drag the ball to the 1-m shelf on the SIMULATION pane.

   D. What is the ball's potential energy (*PE*)? *0.98 J*

   E. Move the ball to the 2-m shelf. What is its potential energy now? *1.96 J*

   F. What do you think the ball's potential energy will be on the 3-m shelf? The 4-m shelf?

   PE on 3-m shelf: *2.94 J*   *PE* on 4-m shelf: *3.92 J*

Use the Gizmo to check your answers. (Click the control on the bar graph to zoom out.)

9. Summarize: What is the relationship between an object's height above the ground and its gravitational potential energy? *As an object's height increases, so does its potential energy.*

10. Describe: Move the ball from side to side (left to right) while trying to keep it at the same height. How does changing the horizontal position of the ball affect its potential energy?

Changing the ball's horizontal position does not affect its potential energy.

11. Infer: Place the ball and the paper on the same shelf.

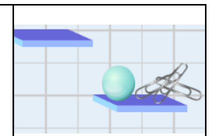
C. Which object has more potential energy? *The ball*

D. Why do you think their potential energies are different?

Answers will vary. [The ball has more mass than the paper.]

12. Identify: What two factors affect how much gravitational potential energy an object has?

Height above the ground and mass

Activity B: **Calculating GPE**	<u>Get the Gizmo ready</u>: • You will need a calculator to complete this activity.	

Introduction: An object's gravitational potential energy depends on two factors: its height (*h*) and its **weight** (*w*). The equation for gravitational potential energy (*GPE*) is:

$$GPE = w \times h$$

Goal: Use the gravitational potential energy equation to determine the weight, mass, and potential energy of various objects.

5. <u>Record</u>: Position all three objects on the 1-m shelf and fill in the third column of the table.

Object	Height (m)	GPE (J or N•m)	Weight (N)
Ball	1 m	*0.98 J*	*0.98 N*
Clips	1 m	*0.39 J*	*0.39 N*
Paper	1 m	*0.08 J*	*0.08 N*

6. <u>Calculate</u>: For each object, substitute the values you know into the gravitational potential energy equation to solve for weight. Record each object's weight in the fourth column.

7. <u>Predict</u>: Suppose the clips were placed on the 5-m shelf. What would their gravitational potential energy be? (Show your work.)

   0.39 N × 5 m = 1.95 J or N•m [Note: The Gizmo gives a value of 1.96 J]

   Use the Gizmo to check your answer.

8. Calculate: An object's weight is determined by its mass (*m*) and the acceleration due to gravity (*g*) affecting that object: $w = mg$. On Earth, $g = 9.8$ m/s^2.

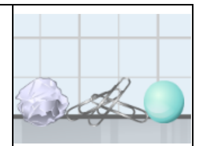
   C. What are the masses (in kilograms) of the three objects on the Gizmo? (Note: 1 N = 1 kg $\times$ m/s^2)

      Ball: *0.100 kg* Clips: *0.0398 kg* Paper: *0.0082 kg*

   D. Suppose a 4,000-kg elephant is hoisted 20 m above Earth's surface. What will the elephant's gravitational potential energy be? (Show your work.)

      GPE = 20 m $\times$ 9.8 m/s^2 $\times$ 4,000 kg

      GPE = 784,000 J

Activity C: **Work and GPE**	Get the Gizmo ready: • Place the ball, clips, and paper at 0 m.	

Introduction: Whenever you lift an object to place it on a shelf, you are doing **work**. Work occurs anytime a force causes an object to move.

Question: How much work is done to lift the ball, clips, and paper?

6. Observe: How much potential energy do the ball, clips, and paper have now? *0.00 J*

7. Calculate: The amount of work (W) done on an object is equal to the force (F) needed to lift the object (the object's weight) multiplied by the distance (d) the object is lifted: $W = F \times d$.

   Use the weight of the ball that you calculated in activity B to determine how much work would be required to lift the ball 2 meters above the zero position:

   0.98 N × 2 m = 1.96 J or N•m

8. Analyze: Move the ball to the 2-m shelf.

   D. How much potential energy does the ball have now? *1.96 J*

   E. How does the ball's potential energy relate to the amount of work needed to place the ball on the 2-m shelf? *The two values are equal.*

   F. How much work would be needed to lift the ball from the 2-m shelf to the 5-m shelf, and how much potential energy would it have on the 5-m shelf?

2.94 J of work is needed to lift the ball. It would have 4.90 J of potential energy.

9. Predict: What do you think would happen to the ball's potential energy if it is knocked off the shelf and falls to the floor?

   The ball's potential energy would be used to do work, leaving the ball with 0 J of potential energy.

10. Think and discuss: Objects in motion have **kinetic energy**. As objects fall, their potential energy is converted into kinetic energy. How much kinetic energy do you think the ball would have just before it hit the floor if it were dropped from a 2-m shelf? Explain your answer.

    The ball would have 1.96 J of kinetic energy because by the time the ball reached the floor all of its potential energy would have been converted to kinetic energy.

Teacher Guide: Roller Coaster Physics

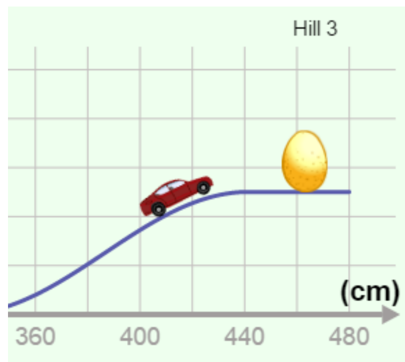
Learning Objectives

Students will…

- Understand how starting height affects the final speed of a toy car.
- Explore how kinetic and gravitational potential energy change as the car rolls down a hill.
- Explain how the potential, kinetic, and total energy of a moving object are related.
- Calculate gravitational energy and kinetic energy of a car.
- Predict the final speed of a car based on its initial height, assuming no friction.
- Determine which factors cause a toy car to break an egg.

Vocabulary

friction, gravitational potential energy, kinetic energy, momentum, velocity



Lesson Overview

The *Roller Coaster Physics* Gizmo™ addresses a variety of physical concepts—from momentum to conservation of energy—using a real-world example.

In the Gizmo, a toy car lies on a track with three hills of adjustable height. An egg sits at the end of the track. The kinetic energy of the car at the time of the collision determines whether the egg will break or not. The position, speed, potential energy, kinetic energy, or total energy of the car can be graphed.

The Student Exploration contains three activities:

- Activity A – Students see that the final speed of the car depends only on the height of the first and last hills.
- Activity B – Students determine the relationships between potential energy, kinetic energy, and total energy.
- Activity C – Students determine which factors cause the car to break the egg.

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (10 – 25 minutes)
   Show your students images or video clips of roller coasters gathered from the Internet. (See the **Selected Web Resources** below.) Point out that force is only added at the beginning of the ride. The remainder of the time, the cars roll freely over the tracks. Ask students what they notice about the different hills on the roller coaster. Are any of the hills or loops on the coaster higher than the very first hill? What would happen if they were? On what part of the track will the coaster go fastest? Slowest?

Prior to using the Gizmo (10 – 15 minutes)
Before students are at the computers, pass out the Student Explorations and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations.

2. **Gizmo activities** (10 – 15 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

3. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:

- Why doesn't the height of the middle hill affect the final velocity of the car?
- In a real roller coaster, the car is pulled to the top of the first hill and then released. What must be true of all the other hills in the roller coaster?
- In activity A, you discovered that, with no friction, only the overall height lost affects the final speed of the car. How is this explained by what you learned in activity B? (See the **Science Background** below for an explanation.)
- How would adding friction affect the following?
    - The speed of the car going down the hill.
    - The total energy (potential plus kinetic) of the car as it is moving.
    - The car's ability to return to its original height.

4. **Follow-up activity: Build a roller coaster!** (30 – 45 minutes)
The *Roller Coaster Physics* Gizmo is based on a series of experiments using toy cars, tracks, and raw eggs that were done in the ExploreLearning offices. Introduce the Gizmo by building your own track with adjustable hills and cars with different masses. You can use raw eggs as a target, or a less-messy substitute if you prefer. (For example, the car could knock over a wooden block.) Toy car racetracks are available in stores or can be donated by a parent. With your track, you can explore which scenarios cause the egg to be broken and which do not. By comparing cars of different masses, students will see that smaller cars need to be moving faster than larger cars to break the egg.

Scientific Background

An object has several types of energy. *Kinetic energy* (*KE* or *K*) is the energy of motion, and depends on the mass and speed of the object. *Gravitational potential energy* (*U*) is energy an object possesses based on its position. Gravitational potential energy depends on mass, height, and the strength of the gravitational field.

As an object falls through the air or rolls down a slope, it is accelerated by gravity. During this time, the gravitational potential energy of the object is converted to kinetic energy. This conversion follows the *law of conservation of energy*, which states that the total energy is constant in a closed system. If there is no friction, the kinetic energy of a freely-rolling car at the bottom of the hill is equal to the gravitational potential energy of the car at the top. If friction is present, some of the potential energy is converted to heat.

The equation for gravitational potential energy is $U = mgh$, where m is mass, g is gravitational acceleration (9.81 m/s^2 on Earth), and h is height. For example, a 1-kg car at a height of 10 meters has a potential energy of 98.1 joules (1 joule = 1 $kg \cdot m^2/s^2$).

The equation for kinetic energy is $K = \frac{1}{2}mv^2$. If a 1-kg car starts with 98.1 joules of potential energy at a height of 10 meters, it will have 0 joules of potential energy and 98.1 joules of kinetic energy at the moment it hits the ground. You can solve for the velocity of the object:

$$\frac{1}{2} \cdot 1 \text{ kg} \cdot v^2 = 98 \text{ kg} \cdot \text{m}^2/\text{s}^2 \qquad v^2 = 196 \text{ m}^2/\text{s}^2 \qquad v = 14 \text{ m/s}$$

As long as there is no friction in the system, the conversion from potential to kinetic energy is the same whether the object is in free fall or is rolling down a ramp. In either case, the only determinant of the final velocity of the object is the vertical distance it has fallen. Friction slows objects down and causes energy to be lost as heat.

In a real roller coaster, the car gathers potential energy as it is pulled to the top of the first hill. For the remainder of the ride, the car coasts freely, rolling up and down hills and loops as energy is converted from potential to kinetic and back again. Due to conservation of energy, the car can never go higher than the initial hill without the input of additional energy.

Historical Connection: History of roller coasters

The modern roller coaster owes its origin to the ice slides built for the amusement of Russian nobles in the 17th century. Visitors would climb stairs to the top of a tower, board a sled, and take a speedy ride to the bottom of the slope.

Wheeled roller coasters became popular in France in the 19th century, and soon made the jump across the Atlantic to America. The first roller coaster in the United States was the Mauch Chunk Switchback Railway in Pennsylvania, a former coal-carrying railroad that was repurposed as a scenic/thrill ride in 1874. By the early 20th century, primitive wooden roller coasters had sprouted up in amusement parks all over the country.

One of the oldest roller coasters still working today is Leap-the-Dips in Altoona, PA, built in 1902. This coaster features a height of 12 m (41 ft) and a maximum speed of 29 km/h (18 mph).

Selected Web Resources

Potential energy: http://www.physicsclassroom.com/class/energy/u5l1b.cfm

Roller coaster science: http://www.learner.org/interactives/parkphysics/coaster.html,

http://ffden-2.phys.uaf.edu/211_fall2002.web.dir/Shawna_Sastamoinen/Roller_Coasters.htm

Roller coaster photos: http://www.ultimaterollercoaster.com/coasters/pictures/

Roller coaster history: http://www.ultimaterollercoaster.com/coasters/history/

Related Gizmos:

Free-Fall Laboratory: http://www.explorelearning.com/gizmo/id?387

Inclined Plane – Sliding Objects: http://www.explorelearning.com/gizmo/id?27

Air Track: http://www.explorelearning.com/gizmo/id?12

Name: ______________________________________ Date: ________________________

Student Exploration: Roller Coaster Physics

Vocabulary: friction, gravitational potential energy, kinetic energy, momentum, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

Sally gets onto the roller coaster car, a bit nervous already. Her heart beats faster as the car slowly goes up the first long, steep hill.

1. What happens at the beginning of every roller coaster ride?

____

2. Does the roller coaster ever get higher than the first hill? ________

Explain. ____

____

Gizmo Warm-up

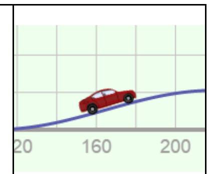
The *Roller Coaster Physics* Gizmo™ models a roller coaster with a toy car on a track that leads to an egg. You can change the track or the car. For the first experiment, use the default settings (**Hill 1** = 70 cm, **Hill 2** = 0 cm, **Hill 3** = 0 cm, 35-g car).

1. Press **Play** (▶) to roll the 35-gram toy car down the track. Does the car break the egg? __________

2. Click **Reset** (↺). Set **Hill 1** to 80 cm, and click **Play**. Does the car break the egg? ________

3. Click **Reset**. Lower **Hill 1** back to 70 cm and select the 50-gram toy car. Click **Play**. Does the 50-gram car break the egg? __________

4. What factors seem to determine whether the car will break the egg? ___________________
____
____

Activity A: **Roller coaster speed**	<u>Get the Gizmo ready</u>: • Click **Reset**. • Select the 35-g toy car.	

Question: What factors determine the velocity of a roller coaster?

1. <u>Observe</u>: Set **Hill 1** to 100 cm, **Hill 2** to 0 cm, and **Hill 3** to 0 cm. Be sure the **Coefficient of friction** is set to 0.00. (This means that there is no **friction**, or resistance to motion.)

   A. Click **Play**. What is the final speed of the toy car? _________________

   B. Try the other cars. Does the mass of the car affect its final speed? _______________

2. <u>Collect data</u>: Find the final speed of a toy car in each situation. Leave the last column blank.

Hill 1	Hill 2	Hill 3	Final speed	
40 cm	0 cm	0 cm		
40 cm	30 cm	0 cm		
60 cm	50 cm	20 cm		
60 cm	0 cm	0 cm		
60 cm	45 cm	0 cm		
90 cm	75 cm	30 cm		

3. <u>Analyze</u>: Look at the data carefully. Notice that it is organized into two sets of three trials.

   A. What did each set of trials have in common? _________________________________

   B. Did hill 2 have any effect on the final speed? _______________

   C. Label the last column of the table **Total height lost**. Fill in this column by subtracting the height of hill 3 from the height of hill 1.

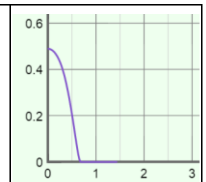
   D. What do you notice about the **Total height lost** in each set of trials? _____________

   ____

4. Draw conclusions: When there is no friction, what is the *only* factor that affects the final speed of a roller coaster? ______________________________

   What factors do *not* affect the final speed of a roller coaster? ______________________________

   ____

Activity B: **Energy on a roller coaster**	Get the Gizmo ready: • Click **Reset**. Select the 50-g car. • Check that the **Coefficient of friction** is 0.00. • Set **Hill 1** to 100 cm, and **Hill 2** and **3** to 0 cm.	

Question: How does energy change on a moving roller coaster?

1. Observe: Turn on **Show graph** and select ***E* vs *t*** to see a graph of energy (*E*) versus time. Click **Play** and observe the graph as the car goes down the track.

   Does the total energy of the car change as it goes down the hill? ______________________________

2. Experiment: The **gravitational potential energy** (*U*) of a car describes its energy of position. Click **Reset**. Set **Hill 3** to 99 cm. Select the ***U* vs *t*** graph, and click **Play**.

   A. What happens to potential energy as the car goes down the hill? ______________________________

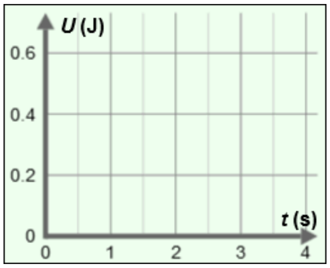
   B. What happens to potential energy as the car goes up the hill? ______________________________

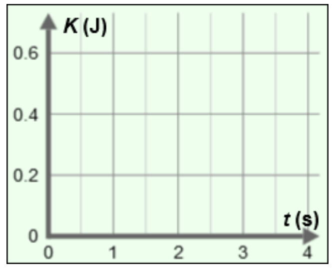
3. Experiment: The **kinetic energy** (*K*) of a car describes its energy of motion. Click **Reset**. Select the ***K* vs *t*** (kinetic energy vs. time) graph, and click **Play**.

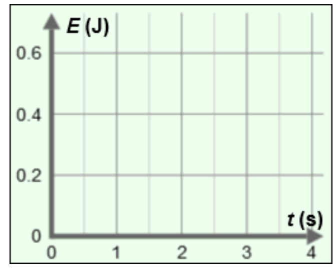
   A. What happens to kinetic energy as the car goes down the hill? ______________________________

   B. What happens to kinetic energy as the car goes up the hill? ______________________________

4. Compare: Click **Reset**. Set **Hill 1** to 80 cm, **Hill 2** to 60 cm, and **Hill 3** to 79 cm. Be sure the 50-g toy car is selected, and press **Play**. Sketch the ***U* vs *t***, ***K* vs *t***, and ***E* vs *t*** graphs below.







5. Draw conclusions: How are potential energy, kinetic energy, and total energy related?

____

____

6. Calculate: Gravitational potential energy (*U*) depends on three things: the object's mass (*m*), its height (*h*), and gravitational acceleration (*g*), which is 9.81 m/s^2 on Earth's surface:

$$U = mgh$$

Energy is measured in joules (J). One joule is equal to one 1 $kg \cdot m^2/s^2$. When calculating the energy of an object, it is helpful to convert the mass and height to kilograms and meters. (Recall there are 1,000 grams in a kilogram and 100 centimeters in a meter.)

A. What is the mass of the 50-gram car, in kilograms? _______________

B. Set **Hill 1** to 75 cm and the other hills to 0 cm. What is the height in meters? _______

C. What is the potential energy of the car, in joules? ___________

7. Calculate: Kinetic energy (K) depends on the mass and **velocity** of the object. (Velocity is the speed and direction of an object.) The equation for kinetic energy is:

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

With **Hill 1** set to 75 cm, click **Play** and allow the car to reach the bottom.

A. What is the final velocity (speed) of the car, in meters per second? _______________

B. What is the kinetic energy of the car, in joules? (Use the mass in kg.) _____________

C. How does the car's kinetic energy at the bottom of the hill compare to its potential energy at the top? ____

8. Challenge: With no friction, you can use the relationship between potential and kinetic energy to predict the velocity of the car at the bottom of this hill from its starting height. To do this, start by setting the kinetic and potential energy equations equal to one another:

$$K = U$$

$$\frac{1}{2}mv^2 = mgh$$

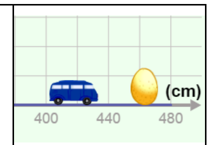
A. Use algebra to solve for the velocity. $v =$

B. With no friction, does the final velocity depend on the mass of the car? ____________

C. With no friction, does the final velocity depend on the steepness of the hill? ________

D. What is the final velocity of the car if the height of the hill is 55 cm (0.55 m)? _______

Use the Gizmo to check your answer.

Activity C: **Breaking the egg**	<u>Get the Gizmo ready</u>: • Click **Reset**. • Check that the **Coefficient of friction** is 0.00.	

Introduction: As the car rolls down a hill, it speeds up, gaining kinetic energy. The car also gains **momentum**. Momentum (p) is the product of an object's mass and velocity ($p = mv$).

Question: What determines whether the egg will break, the car's velocity or momentum?

1. <u>Form hypothesis</u>: Which factor(s) do you think determine whether the car breaks the egg?

   - ☐ The mass of the car only
   - ☐ The velocity of the car only
   - ☐ The momentum of the car
   - ☐ The kinetic energy of the car

2. <u>Collect data</u>: Use the Gizmo to find the *minimum* hill height at which each car breaks the egg. In the table below, fill in the hill height (in centimeters and meters), and the velocity of the car (in cm/s and m/s). Leave the last two columns blank for now.

Car mass (kg)	Height (cm)	Height (m)	Velocity (cm/s)	Velocity (m/s)	Momentum (kg•m/s)	Kinetic energy (J)
0.035 kg						
0.050 kg						
0.100 kg						

3. <u>Analyze</u>: Using the equations $p = mv$ and $K = \frac{1}{2}mv^2$, calculate the momentum and kinetic energy of each car. Remember to use the kg and m/s values for each calculation. Fill in the last two columns of the table.

   A. Does the car's mass alone determine whether the egg breaks? ___________________

   B. Does the car's velocity alone determine whether the egg breaks? _________________

C. Does the car's momentum determine whether the egg breaks? ___________________

D. Does the car's kinetic energy determine whether the egg breaks? _________________

Explain your answers: ____

____

____

4. Draw conclusions: What is the minimum energy required to break the egg? _______________

Roller Coaster Physics

Answer Key

Vocabulary: friction, gravitational potential energy, kinetic energy, momentum, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

Sally gets onto the roller coaster car, a bit nervous already. Her heart beats faster as the car slowly goes up the first long, steep hill.

3. What happens at the beginning of every roller coaster ride?

   The car is pulled up a long hill.

4. Does the roller coaster ever get higher than the first hill? *No.*

   Explain. *Answers will vary. [The roller coaster cannot go higher than the first hill because the total energy of the roller coaster cannot increase unless energy is added.]*

Gizmo Warm-up

The *Roller Coaster Physics* Gizmo™ models a roller coaster with a toy car on a track that leads to an egg.

You can change the track or the car. For the first experiment, use the default settings (**Hill 1** = 70 cm, **Hill 2** = 0 cm, **Hill 3** = 0 cm, 35-g car).

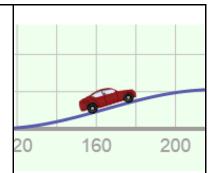
5. Press **Play** (▶) to roll the 35-gram toy car down the track. Does the car break the egg? *No.*

6. Click **Reset** (⟲). Set **Hill 1** to 80 cm, and click **Play**. Does the car break the egg? *Yes.*

7. Click **Reset**. Lower **Hill 1** back to 70 cm and select the 50-gram toy car. Click **Play**. Does the 50-gram car break the egg? *Yes.*

8. What factors seem to determine whether the car will break the egg?

   Answers will vary. Sample answer: The mass of the car and the speed of the car (determined by the height of the hill) determine whether the car will break the egg.

Activity A: **Roller coaster speed**	Get the Gizmo ready: • Click **Reset**. • Select the 35-g toy car.	

Question: What factors determine the velocity of a roller coaster?

5. Observe: Set **Hill 1** to 100 cm, **Hill 2** to 0 cm, and **Hill 3** to 0 cm. Be sure the **Coefficient of friction** is set to 0.00. (This means that there is no **friction**, or resistance to motion.)

   C. Click **Play**. What is the final speed of the toy car? *442.9 cm/s*

   D. Try the other cars. Does the mass of the car affect its final speed? *No.*

6. Collect data: Find the final speed of a toy car in each situation. Leave the last column blank.

Hill 1	Hill 2	Hill 3	Final speed	*Total height lost*
40 cm	0 cm	0 cm	*280.1 cm/s*	*40 cm*
40 cm	30 cm	0 cm	*280.1 cm/s*	*40 cm*
60 cm	50 cm	20 cm	*280.1 cm/s*	*40 cm*
60 cm	0 cm	0 cm	*343.1 cm/s*	*60 cm*
60 cm	45 cm	0 cm	*343.1 cm/s*	*60 cm*
90 cm	75 cm	30 cm	*343.1 cm/s*	*60 cm*

7. Analyze: Look at the data carefully. Notice that it is organized into two sets of three trials.

   E. What did each set of trials have in common? *The final speed was the same.*

F. Did hill 2 have any effect on the final speed? *No.*

G. Label the last column of the table **Total height lost**. Fill in this column by subtracting the height of hill 3 from the height of hill 1.

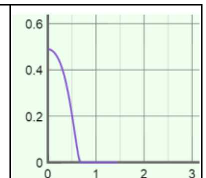
H. What do you notice about the **Total height lost** in each set of trials?

In each set of trials, the total height lost was the same.

8. <u>Draw conclusions</u>: When there is no friction, what is the *only* factor that affects the final speed of a roller coaster? *The only factor that affects the final speed is the total height lost.*

   What factors do *not* affect the final speed of a roller coaster?

   The final speed is not affected by the mass of the car or the height of the middle hill.

Activity B: **Energy on a roller coaster**	Get the Gizmo ready: • Click **Reset**. Select the 50-g car. • Check that the **Coefficient of friction** is 0.00. • Set **Hill 1** to 100 cm, and **Hill 2** and **3** to 0 cm.	

Question: How does energy change on a moving roller coaster?

9. <u>Observe</u>: Turn on **Show graph** and select ***E* vs *t*** to see a graph of energy (*E*) versus time. Click **Play** and observe the graph as the car goes down the track.

   Does the total energy of the car change as it goes down the hill? *No, it stays the same.*

10. <u>Experiment</u>: The **gravitational potential energy** (*U*) of a car describes its energy of position. Click **Reset**. Set **Hill 3** to 99 cm. Select the ***U* vs *t*** graph, and click **Play**.

A. What happens to potential energy as the car goes down the hill? *It decreases.*

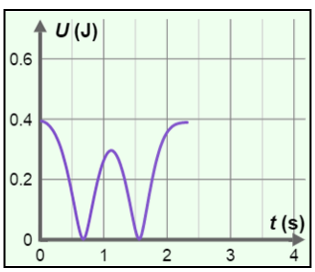
B. What happens to potential energy as the car goes up the hill? *It increases.*

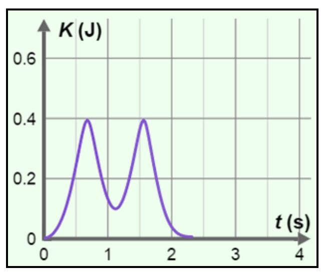
11. Experiment: The **kinetic energy** (*K*) of a car describes its energy of motion. Click **Reset**. Select the ***K* vs *t*** (kinetic energy vs. time) graph, and click **Play**.

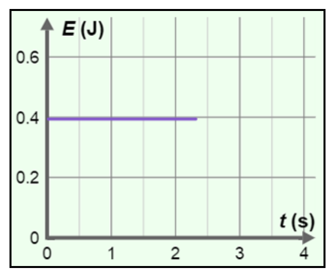
C. What happens to kinetic energy as the car goes down the hill? *It increases.*

D. What happens to kinetic energy as the car goes up the hill? *It decreases.*

12. Compare: Click **Reset**. Set **Hill 1** to 80 cm, **Hill 2** to 60 cm, and **Hill 3** to 79 cm. Be sure the 50-g toy car is selected, and press **Play**. Sketch the ***U* vs *t***, ***K* vs *t***, and ***E* vs *t*** graphs below.







13. Draw conclusions: How are potential energy, kinetic energy, and total energy related?

Answers will vary. [The total energy of the car is equal to the sum of its gravitational potential energy and its kinetic energy. As the car goes down a hill, gravitational potential energy is converted to kinetic energy, but the total energy of the car remains the same. As the car goes up a hill, kinetic energy is converted to gravitational potential energy.]

(Activity B continued on next page)

Activity B (continued from previous page)

14. Calculate: Gravitational potential energy (U) depends on three things: the object's mass (m), its height (h), and gravitational acceleration (g), which is 9.81 m/s^2 on Earth's surface:

$$U = mgh$$

Energy is measured in joules (J). One joule is equal to one 1 $kg \cdot m^2/s^2$. When calculating the energy of an object, it is helpful to convert the mass and height to kilograms and meters. (Recall there are 1,000 grams in a kilogram and 100 centimeters in a meter.)

D. What is the mass of the 50-gram car, in kilograms? *0.050 kg*

E. Set **Hill 1** to 75 cm and the other hills to 0 cm. What is the height in meters? *0.75 m*

F. What is the potential energy of the car, in joules? *0.368 J*

15. Calculate: Kinetic energy (K) depends on the mass and **velocity** of the object. (Velocity is the speed and direction of an object.) The equation for kinetic energy is:

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

With **Hill 1** set to 75 cm, click **Play** and allow the car to reach the bottom.

D. What is the final velocity (speed) of the car, in meters per second? *3.836 m/s*

E. What is the kinetic energy of the car, in joules? (Use the mass in kg.) *0.368 J*

F. How does the car's kinetic energy at the bottom of the hill compare to its potential energy at the top? *The two values are the same.*

16. Challenge: With no friction, you can use the relationship between potential and kinetic energy to predict the velocity of the car at the bottom of this hill from its starting height. To do this, start by setting the kinetic and potential energy equations equal to one another:

$$K = U$$

$$\frac{1}{2}mv^2 = mgh$$

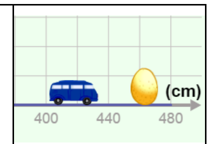
E. Use algebra to solve for the velocity. $v = \sqrt{2gh}$

F. With no friction, does the final velocity depend on the mass of the car? *No.*

G. With no friction, does the final velocity depend on the steepness of the hill? *No.*

H. What is the final velocity of the car if the hill height is 55 cm (0.55 m)? *3.285 m/s*

Use the Gizmo to check your answer. *[The Gizmo shows a speed of 328.5 cm/s.]*

Activity C: Breaking the egg	Get the Gizmo ready: • Click **Reset**. • Check that the **Coefficient of friction** is 0.00.	

Introduction: As the car rolls down a hill, it speeds up, gaining kinetic energy. The car also gains **momentum**. Momentum (*p*) is the product of an object's mass and velocity (*p* = *mv*).

Question: What determines whether the egg will break, the car's velocity or momentum?

5. Form hypothesis: Which factor(s) do you think determine whether the car breaks the egg? *[Hypotheses will vary.]*

☐ The mass of the car only ☐ The momentum of the car

☐ The velocity of the car only ☐ The kinetic energy of the car

6. Collect data: Use the Gizmo to find the *minimum* hill height at which each car breaks the egg. In the table below, fill in the hill height (in centimeters and meters), and the velocity of the car (in cm/s and m/s). Leave the last two columns blank for now.

Car mass (kg)	Height (cm)	Height (m)	Velocity (cm/s)	Velocity (m/s)	Momentum (kg•m/s)	Kinetic energy (J)
0.035 kg	*73*	*0.73*	*378.5*	*3.785*	*0.132*	*0.250*
0.050 kg	*51*	*0.51*	*316.3*	*3.163*	*0.158*	*0.250*
0.100 kg	*26*	*0.26*	*225.9*	*2.259*	*0.226*	*0.255*

7. Analyze: Using the equations $p = mv$ and $K = \frac{1}{2}mv^2$, calculate the momentum and kinetic energy of each car. Remember to use the kg and m/s values for each calculation. Fill in the last two columns of the table.

   A. Does the car's mass alone determine whether the egg breaks? *No.*

B. Does the car's velocity alone determine whether the egg breaks? *No.*

C. Does the car's momentum determine whether the egg breaks? *No.*

D. Does the car's kinetic energy determine whether the egg breaks? *Yes.*

Explain your answers: *Answers will vary.*

Sample answer: Cars with different minimum mass, velocity, and momentum values were able to break the egg. Only the energy values were consistent for each car.

8. Draw conclusions: What is the minimum energy required to break the egg? *~0.25 J*

Unit/Lesson Plan Title: Roller Coaster Potential or Kinetic???
Length of Unit/Lesson: 2 weeks

Internet,
Amusement Park Physics-Roller Coasters:
www.learner.org/exhibits/parkphysics and http://www.learner.org/interactives/parkphysics/index.html
Roller Coasters-Inventing the Scream Engine:
http://www.britannica.com/coasters/1920.html
How Stuff Works-RollerCoasters: Converting Energy
http://www.howstuffworks.com/roller-coaster2.htm
Funderstanding-Coasters
http://www.Funderstanding.com/k12/coaster

Unit/Lesson Summary:
Students will design a roller coaster out of pipe insulation and duct tape that a marble will roll down continuously once released. Students must follow specifications and limitations in their technical design. They will be responsible for coming up with their own sketches designs, construction, test and analysis of their structures. Students will understand that energy cannot be created or destroyed but only changed from one form to another. Also, that all energy can be considered to be either kinetic energy (energy of motion) or potential energy (depends on relative position), or energy contained by a field (electromagnetic waves). Students will create an ibook (or other comparable product) describing potential and kinetic energy.

Key Vocabulary:
Gravity Energy
Force
Mechanical Energy
Kinetic Energy
Potential Energy
Conservation of Energy

Essential Standard

- Understand forms of energy, energy transfer and transformation and conservation in mechanical systems.

Clarifying Objectives

- Explain how kinetic and potential energy contribute to the mechanical energy of an object.
- Explain how energy can be transformed from one form to another(specifically potential energy and kinetic energy) using a model or diagram of a moving object (roller coaster, pendulum, or cars on ramps as examples).

Essential Questions:

- How do roller coaster designs obey the laws of Physics?
- Where do the forces act in the roller coaster that converts Potential
- Energy (PE) to Kinetic Energy (KE)?
- Explain why loops are always placed at the beginning of rides instead of at the end.
- Have you ever wondered... Why do roller coasters begin with a really
- steep hill and continue with smaller hills and loops?

Materials/Resources Needed:

- Foam Pipe Insulation halves

- Duct tape

- Marbles
- Paper
  Pencil
- Computer with internet access
- ibook author application for ibook
- **Exploration/Engagement Activities:** Students will use the internet to see how energy and forces are acting on roller coasters. They will practice building roller coasters on http://www.learner.org/interactives/parkphysics/parkphysics.html

Accommodations for Differentiated Instruction: may include EC and ESOL modifications such as read alouds, abbreviated assignments and assessments, and collaborative group work.

Cross-Curricular Integration: Technology including research opportunities, creating a digital book and Vernier LabQuest usage.

Assessments: Pre-and Post- test, technological design of roller coaster, assessment of digital ibook and a short video (3-5 minutes demonstrating kinetic, potential or the law of conservation of energy.

Extension Activities: Amusement park rides, water park rides, and rides in the local playgrounds.

Supporting Documents

Teaching Notes-Copyright 2009 LessonSnips www.lessonsnips.com

Kinetic and Potential Energy

- Most of us think of energy as the power our bodies have to move or do work. We have a lot of energy when we are rested or excited, and less energy when we are tired or bored. But that is only one kind of energy. Energy is working all around us. It powers cars and gives us light.
- Energy keeps us warm and creates sound. Without energy, we could not grow, move, or even stay alive! To understand energy and how it helps make life possible, we must learn that there are two kinds of energy: kinetic and potential.

Kinetic

- "Kinetic" is another word for "motion." Scientists use it to define energy that is moving. For example, waves in the ocean have kinetic energy, because they are moving. Something as big as a plane in flight has kinetic energy, but size is not important. Atoms, which are the tiniest particles of matter, are also in motion. They have kinetic energy, too.
- Kinetic energy can appear in many forms.
  - Potential Energy
  - Radiant energy is kinetic energy that shows up as light, radio waves, and x-rays.
  - Thermal energy is kinetic energy that we call "heat." Heat is actually caused by the movement of vibrating molecules.
  - Electrical energy is kinetic energy that exists in the movement of electrical charges.
    - Lightening and the electricity that powers your home are two examples.

- Sound is also kinetic energy. It is created when a force causes an object or other matter to vibrate. We hear sound because force causes our eardrums to move.
- Motion energy is the simplest form of kinetic energy. It comes from the movement of matter from one place to another. Water flowing is an example of motion energy. So is wind.

- Scientists believe that energy is not created or destroyed. It simply gets transferred from one object or substance to another. So, if an object is not moving, how can it have energy? The other category of energy is potential energy.
- You might have learned that the word potential means a person has the ability to succeed. If you have great potential, you will likely reach your goals. Potential energy has the ability to become kinetic energy.

Potential energy is stored energy that will possibly become energy in motion. It is also the "energy of position," which means that an object's power comes from gravity.

- Potential energy also appears in several forms.
    - Gravitational energy comes from the potential power gravity can have on the object. Before he jumps from a plane, a skydiver has a great deal of stored, gravitational energy. He has more gravitational energy than a bungee jumper, because he is much higher.

Chemical energy is stored inside of atoms and molecules. These tiny particles are held together with bonds that have stored or "chemical" energy.

Stored mechanical energy is energy that is stored in an object before a force causes it to move. For example, when a rubber band is stretched, it has stored mechanical energy, or the potential to be in an object in motion.

Nuclear energy is stored in the information center of an atom: the nucleus. The nucleus is like the brain of an atom, and directs all of its activities. It is held together by a powerful energy. When a nucleus is divided or combined with another nucleus, this potential energy becomes one of the most powerful forces in the universe.

Scientists tell us that all energy is in motion, or has the potential to be in motion. Even objects that appear to be perfectly still have stored energy. This energy changes from potential to kinetic when it is acted upon by some force. Scientists have learned to harness this power and release energy when it is needed. In order to make sure our planet lives for a long time, scientists continue to look for ways to safely store, use, and recycle energy. The exercises on the next page will help you better understand the differences between kinetic and potential energy.

Pre-Post test on Kinetic and Potential Energy

Kinetic and Potential Energy Questions Read each question and circle the correct answer.

1. Energy

A. Thermal and light appears in two forms. What are they?
   A. Kinetic and electric
   B. Potential and kinetic
   C. Stored and active

2. Kinetic energy can be described as:
   A. Stored energy
   B. Energy in motion
   C. A chemical reaction
   D. Connected energy

3. Which of the following is NOT an example of kinetic energy?
   A. Gravity
   B. Sound
   C. Heat
   D. Light

4. Which of the following is NOT an example of potential energy?
   A. Gravitational pull
   B. Nuclear energy
   C. Chemical bonds
   D. Electricity

5. Which of the following has no energy?
   A. A wrecking ball
   B. A pot of water
   C. A moving vehicle
   D. None of the above

Read the descriptions below and identify each activity as an example of potential or kinetic energy by writing "P" or "K" on the line.

1. The energy that exists before baking soda and vinegar combine to create carbon dioxide gas. _____
2. A child on his way down a playground slide._____
3. Exploding fireworks._____
4. Ocean waves._____
5. A stunt driver at the top of a ramp._____
6. The flexed string of an archer's bow._____
7. Boiling water. _____
8. A glowing neon sign. _____
9. The sun. _____
10. The bond between hydrogen and oxygen that creates water. _____

Kinetic and Potential Energy Answers

Multiple Choice

1. C 2. B 3. A 4. D 5. D

Identification

1. P 2. K 3. K 4. K 5. P 6. P 7. K 8. K 9. K 10. P

Roller Coaster - Kinetic or Potential Energy????

Introduction

An amusement park has decided to open a theme park to be located in Landis, NC. It is an exciting time for the citizens of Landis. Finally, this small town will be put on the map for something big. The residents are anxiously anticipating the grand opening of the amusement park. However, the operators of the amusement park need your help. They want to design a new roller coaster with a car that runs as smoothly as a marble would down the track. Your team has been hired to design this new roller coaster track for this theme park. Your task is to design a model of the track you would like to build for this amusement park. Your model must demonstrate the law of conservation of energy, gravity, force, momentum, and especially kinetic and potential energy.

You are only allowed to use the following materials to build your model:

- Foam pipe insulation and duct tape.

You will be testing your design with a marble. The operators require:

• Three separate roller coaster design sketches on paper that includes at least one loop and one funnel.

• The sketches must include labels of potential and kinetic energy.

• A name that catches people's attention

• A color scheme.

• The coaster must meet all specifications.

You will have up to 3 class periods to build the coaster and submit it on the final day for testing.

Specifications

• The marble must roll continuously once it is released.

• Only duct tape may be used.

• You may use the room, walls, tables, floor, to create your design using the pipe insulation and tape to connect it.

• Coasters may not reach vertical height of more than 36 inches but not less than 28 inches.

• Coasters must have at least one loop.

• Coasters must have at least one funnel or helix.

• Timing begins when the marble is released from the starting device and ends when the marble crosses the finish line.

• Draw each of the roller coasters your team builds on a separate sheet of paper.

• Label the hills with the correct height, greatest potential energy and greatest kinetic energy.
• Label where the transformation of potential to kinetic energy begins.

Materials

- foam pipe insulation
- duct tape
- marble

You will need to research roller coasters and the physics involved in roller coasters.

After you build your roller coaster you will need to time your marble through your track. Repeat the timing at least three times.

Measure your height of your hills.

Follow up:

Calculate the potential energy of your marble:
PE= mxgxh

Trial 1: _____
Trial 2: _____
Trial 3: _____

Calculate the maximum velocity of your marble.
Marble= distance/shortest time

Calculate the kinetic energy of your marble.
KE= 1/2mv2

Trial 1: _____
Trial 2: _____
Trial 3: _____

Write a conclusion explaining three to four forces acting on the roller coaster and how these forces affect motion.

Explain two to three forms of energy used by the roller coaster to transfer energy. And explain the difference between two of them.

What changes did you make between your original design of your roller coaster and the final working model?

Create an ibook using ibook author or other comparable media.
Book specifications should include.

Title :
<u>What is potential and kinetic energy?</u>

- Chapter 1
- What is energy?
- Examples and Pictures
- Chapter 2
- What is the Law of Conservation of Energy?
- Examples and Pictures
- Chapter 3
- What is potential energy?
- Examples and Pictures
- Chapter 4
- What is kinetic energy? Examples and Pictures
- Chapter 5
- Science Around You (Real world examples)
- Chapter 6
- Key words and Definitions

Create a short video (3-5 minutes) that teaches one of the following concepts.

What is kinetic energy?
What is potential energy?
What is gravity?
What is momentum?
What is the conservation of energy?

6th Grade Science Unit:

Speed Racers

Unit Snapshot

Topic: Matter and Motion

Grade Level: 6 Lesson Duration: 15 days

Summary:

Students will experiment with objects to analyze and determine an object's speed and direction. Students will use mathematical skills to measure and graph an object's position and time.

Clear Learning Targets

"I can"…statements

____ describe an objects motion in relation to a reference point

____ calculate an object's speed based on the amount of time it takes to travel a certain distance.

____ analyze and interpret position vs time and speed vs. time graphs in order to describe an object's motion.

Activity Highlights and Suggested Timeframe

Days 1-3	**Engagement:** Students will learn how to read time. Students will explore speed, motion and time while completing the Speed Challenge. Measuring Time, Speed Challenge, Stopwatch Math
Days 4-7	**Exploration:** Students will explore time, which type of ramp is the fastest and how to graph the data. Students continue to explore speed and practice interpreting graphs (speed verses time & position verses time). 2B Speed Lab, GIZMO: Distance Time Graph
Days 8-10	**Explanation:** Students will explore speed, distance, and time using the speed equations from videos. Practice using the speed triangle to solve equations. Formula Challenge Motion Graph Notes
Days 11-13	**Elaboration:** Students will complete a lab to discover what kind of motion happens when an object rolls down a hill. Then students will create an obstacle course to complete and graph the results. 3B Position Speed, and Time Graph, Obstacle Course
Day 14 and on going Day 15	**Evaluation:** CPO Speed Skill and Practice 2.0, Analyzing Graphs of Motion with Numbers, Analyzing Graphs of Motion Without Numbers A teacher-created short cycle assessment will be administered at the end of the unit to assess all clear learning targets. **Extension/Intervention:** Based on the results of the short-cycle assessment, facilitate extensions and/or intervention activities.

LESSON PLANS

NEW LEARNING STANDARDS:

6.PS.4: An object's motion can be described by its speed and the direction in which it is moving.

- An object's position and speed can be measured and graphed as a function of time.

Note 1: This begins to quantify students' observations using appropriate mathematical skills.
Note 2: Velocity and acceleration rates should NOT be included at this grade level; these terms are introduced in high school.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering)that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Frame-work for K-12 Science Education Scientific and Engineering Practices

COMMON CORE STATE STANDARDS for LITERACY in SCIENCE:

**For more information: http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf*

CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

STUDENT KNOWLEDGE:

Prior Concepts Related to Forces and Motion

PreK-2: Sound is produced from vibrating motions. Motion is a change in an object's position with respect to another object. Forces are pushes and pulls that are necessary to change the motion of an object. Greater changes of motion for an object require larger forces.

Grades 3-5: The amount of change in movement of an object is based on the mass* of the object and the amount of force exerted. The speed of an object can be calculated from the distance traveled in a period of time.

Future Application of Concepts

Grades 7-8: The concept of fields is introduced to describe forces at a distance. The concept of force is expanded to include magnitude and direction.

High School: Acceleration is introduced. Complex problems involving motion in two-dimensions and free fall will be solved. Complex position vs. time graphs, velocity vs. time graphs, and acceleration vs. time graphs will be analyzed conceptually and mathematically with connections made to the laws of motion.

MATERIALS:

Engage

- "Speed Challenge" lab sheet.
- 2 timers per team
- 1 meter stick or trundle wheel per team
- 1 roll of masking tape per team
- 1 marker per team
- "Stopwatch Math" lab sheets

Explore

- computer and internet access for the Gizmo, Distance Time Graph

- Car
- Ramp
- Physics stand
- Student Text book

Explain

- Internet access for videos:
  Teacher Tube show the video, **How to solve a speed equation,** 1:31 minutes
  www.teachertube.com/viewVideo.php?video_id=199764
  YouTube or Bing videos, **Physics Tutorial: How to solve physics problems**, 6:06 minutes
  www.youtube.com/watch?v=calsn76D9gA
  BrainPop.com video, **Distance, Rate, Time**
- Speed Triangle
- Formula Challenge worksheets
- Motion and Graphs Notes
- Elmo, SmartBoard or overhead to display notes

Elaborate

- Student or teacher gathered supplies for obstacle course
- Notecards, timers, meter sticks or trundle wheels, tape measures
- Lab worksheets

VOCABULARY:

Primary
Distance
Motion
Position vs. Time Graph
Reference Point
Speed
Speed vs. Time Graph
Time

Secondary
Hypothesis
Speed vs. Time Graph
No motion = horizontal line on the horizontal axis
Constant speed = straight line above or below horizontal axis.
Faster Motion = line is farther away from the horizontal axis.
Slower Motion = line moving towards the horizontal axis.

SAFETY

- Students need to practice safety when using items that roll. They could be a tripping hazard if left unattended.
- Use extreme caution with the mouse trap car!
- Students should not be running during labs.

<table>
<tr><td>ADVANCED PREPARATION</td><td colspan="2">
• Gather materials for all labs.
• Teacher and students need to understand how to use the CPO Car Ramp and Timers.
• Make sure students are familiar with how to access the Gizmo.
• Find an area that students can design an obstacle course to complete simple tasks. Teacher can help to gather supplies the students may need for their obstacle course. However, students may need to bring items from home.
</td></tr>
<tr><td rowspan="2">ENGAGE
(3 days)

(What will draw students into the learning? How will you determine what your students already know about the topic? What can be done at this point to identify and address misconceptions? Where can connections are made to the real world?)</td><td colspan="2">Objective: Students will explore speed and motion through a "Speed Challenge". Students will become familiar with the measurable factors of distance, time and speed.</td></tr>
<tr><td>What is the teacher doing?
Day 1
1A Measuring Time Lab
• Place students into groups.
•
• Review lab: review how to use a timer.
• Answer Key for 1A Measuring Time is included
.

Day 2
Speed Challenge
• Place students into groups.
• Provide "Speed Challenge" lab for each student.
• Review lab: review how to use a timer and how to measure distance.

Day 3 or Homework
• Reinforce as needed
•</td><td>What are the students doing?
Day 1
1A Measuring Time Lab
1. Follow directions and answer questions to 1A Measuring Time Lab.

Day 2
Speed Challenge
2. Follow directions and answer questions to Speed Challenge.

Day 3 or Homework
•</td></tr>
<tr><td rowspan="2">EXPLORE
(4 days)

(How will the concept be developed? How is this relevant to students' lives? What can be done at this point to identify and address misconceptions?)</td><td colspan="2">Objective: Students continue to explore speed and practice interpreting graphs (speed verses time and position verses time). Recognize that faster objects have steeper lines on position vs. time graphs.</td></tr>
<tr><td>What is the teacher doing?
Days 4-5
• Complete activities at www.phet.colorado.edu to practice interpreting speed through graphs.
• Teacher decides which activities/simulations to complete</td><td>What are the students doing?
Days 4-5
1. Complete the activities</td></tr>
</table>

	Day 6-7 Distance Time Graph "Gizmo" www.explorelearning.com • Make sure there are computers and internet access available for the Gizmo. The teacher guide and answer key are included in the curriculum guide. This can be completed through whole class instruction, but it is recommended to complete the simulation lab individually if possible.	***Day 6-7*** 2. Complete the Distance Time Graph "Gizmo."
EXPLAIN **(3 days)** (What products could the students develop and share? How will students share what they have learned? What can be done at this point to identify and address misconceptions?)	**Objective:** Students will discover how to find the speed, distance, and time with questions using the equation - speed equals distance divided by time. The data will be used in graphs of position verses time and graphs of speed verses time.	
	What is the teacher doing? ***Day 8*** • On Teacher Tube show the video, **How to solve a speed equation,** 1:31 minutes www.teachertube.com/viewVideo.php?video_id=199764 • Consider going through YouTube or Bing videos to watch, **Physics Tutorial: How to solve physics problems**, 6:06 minutes www.youtube.com/watch?v=calsn76D9gA Pause video for students to try and solve the problems. At the conclusion of the video have student practice a few problems with the speed equation. • If teacher has a subscription to BrainPop.com, you can show the **Distance, Rate, Time** video. ***Day 9*** • Guide students in creating their own speed triangle. The directions are included in the curriculum guide. Have students use the speed triangle strategy to solve the Formula Challenge worksheet. Teacher may decide to have students complete the Formula Challenge worksheet as homework.	*What are the students doing?* ***Day 8*** 1. Watch videos and practice speed equation questions. ***Day 9*** *2.* Make your own speed triangle on a blank sheet of paper. Complete the Formula Challenge worksheet.

	Day 10 • Place the Motion Notes (included in the curriculum guide) on a SmartBoard, overhead or ELMO. Students fill in the Motion Graph worksheets according to the notes on the board. Instruct students to use the notes to answer the questions that are included. If time runs out, students can complete the worksheet for homework.	***Day 10*** *3.* Take Notes on the Motion Graph worksheet using the Motion Notes on the SmartBoard, overhead or Elmo. Complete the worksheets.
ELABORATE **(3 days)** (How will the new knowledge be reinforced, transferred to new and unique situations, or integrated with related concepts?)	**Objective:** Students will show their understanding of position, speed, and time graphs using student generated data.	
	What is the teacher doing? ***Day 11-13*** *Obstacle Course* • Teacher page is provided for a student created obstacle course. The goal is to have varying times of rest and movement for students to graph a distance time graph and a speed time graph. • Extension could be to take all the data and graphs and have students match the data to the graphs.	*What are the students doing?* ***Day 11-13*** *Obstacle Course* 2. Students will create a task to complete on an obstacle course. Each group of students will create part of an obstacle course, measure distance and take time to complete a task and travel a distance. 3. After data is collected, students will illustrate their motions with the use of a distance verses time graph and a speed verses time graph.
EVALUATE **(1 day and on-going)** (What opportunities will students have to express their thinking? When will students reflect on what they have learned? How will you measure learning as it occurs? What evidence of student learning will you be looking for and/or collecting?)	**Objective:** Students can show knowledge through formative assessments throughout the lesson and show their cumulative knowledge with summative assessments.	
	Formative *How will you measure learning as it occurs?* 1. Skill Sheet Speed 2.0 2. Stopwatch Math 3. Distance Time Graph "Gizmo"	**Summative** *What evidence of learning will demonstrate to you that a student has met the learning objectives?* 1. Analyzing Graphs of Motion with Numbers 2. Analyzing Graphs of Motion without Numbers 3. 3B Position, Speed, and Time Graphs 4. *Obstacle Course*

<table>
<tr><td rowspan="1">COMMON MISCONCEPTIONS</td><td colspan="2">

- Some students think that an object traveling at constant speed requires a force.
(Sir Isaac Newton built on Galileo's thoughts about objects in motion. Newton's First Law clearly states that a force is not needed to keep an object in motion. Slide a physics book across a tabletop and watch it slide to a rest position. The book in motion on the tabletop does not come to a rest position because of the absence of a force, rather the presence of a force, a force being the force of friction. The force of friction is what brings the book to a rest position. In the absence of friction, the book would continue in motion with the same speed and direction forever or at least until the end of the tabletop. Thus, a force is not required to keep any object horizontally moving in motion.)
- Some students think that time can be measured without establishing the beginning of the interval. The location of an object can be described by stating its distance from a given point, ignoring direction.
- Students believe that a line with a negative slope represents a falling object. (Students fail to understand the meaning of the quantities. Ex. If the quantity means distance from home, then a falling line, negative slope, does not represent a lowering altitude.)

</td></tr>
<tr><td>ACCELERATION</td><td>EXTENSION
1. Mouse Trap Car
Here are some suggested websites:
•http://www.pbs.org/saf/1208/teaching/teaching.htm
•http://diversity.cecs.ucf.edu/download/SECME_2011_Rules_Mousetrap_Car_M_H.pdf</td><td>INTERVENTION
1. In the CPO Physical Science textbook, have students read pp.34-40. Focus on the graphic illustrations on each page. The teacher can use the sample guided questions for pp. 40-43.

2. Calculation Speed at:
http://www.science-class.net/Lessons/Physics/Force_Motion/describing_motion_speed.pdf

3. PhET "The Moving Man" is an interactive simulation that shows graphs for different types of motion.
http://phet.colorado.edu/en/simulation/moving-man</td></tr>
<tr><td>DIFFERENTIATION</td><td colspan="2">How will you ensure that all students have access to this learning opportunity?

Lower-level:
Encourage students to work as a group of 2 or 3 when completing labs or Gizmo. Consider using supplementary videos, pictures, and appropriate leveled reading material.

Higher-Level:
Students may work alone while completing the Gizmo activity.
Students may work alone or with a partner to complete graphs. Then compare the graphs with another student or group. The groups need to defend and explain their answers to their peers.</td></tr>
</table>

	Strategies for meeting the needs of all learners including gifted students, English Language Learners (ELL) and students with disabilities can be found at ODE
ADDITIONAL RESOURCES	**Textbooks:** Science Textbook: **Websites:** • http://www.physicsclassroom.com/Class/1DKin/U1L3a.cfm • http://phet.colorado.edu/en/simulation/moving-man • Teacher Tube, **How to solve a speed equation,** 1:31 minutes www.teachertube.com/viewVideo.php?video_id=199764 • YouTube or Bing videos, **Physics Tutorial: How to solve physics problems**, 6:06 minutes www.youtube.com/watch?v=calsn76D9gA • www.BrainPop.com video, **Distance, Rate, Time** **Discovery Ed:** • http://app.discoveryeducation.com/search?Ntt=matter+and+motion **Fact of the Matter: Miniature Golf**, 5:16 minutes

Teacher Page for Measuring Time (TE pp.6-8)

Investigation 1A: Measuring Time

Today's investigation involves the measurement of time. There are two different ways the word "time" is used. Think for a minute. Can you think of two different meanings for the word time?

Allow for wait time. The most obvious response students will think of is the time on a clock, such as 1:30 PM. The other meaning for time is the time for something to occur, such as 10 seconds for someone to walk from one side of the room to the other.

The time for something to occur is called a time interval. What device is designed specifically to measure time intervals?

Students should realize that a stopwatch is used to measure time intervals. A clock can also be used, by watching the second hand, for example.

1 Using the timer as a stopwatch

In this investigation, you are going to use a stopwatch. The stopwatch is one of the functions of the photogate timer and it will measure a time interval. The stopwatch is started with the "A" button and reset with the "0" button. Take a minute and practice starting and resetting the stopwatch function.

Allow time for students to become familiar with the stopwatch function. Be sure you have used the stopwatch function so that you can help troubleshoot areas where students may experience difficulty.

2 Observing reaction time

Now that everyone knows how to correctly use the stopwatch function of the timer, let's play a game. Our game will involve reaction time. Who can tell me what reaction time means?

Reaction time is the amount of time for a signal to travel from your brain to a muscle to make it move.

It takes two people to play this game. One person in each group needs to be the watcher. The watcher's responsibility is to pick a number between 5 and 10 seconds. The other person will be the starter/stopper and will need to start and stop the stopwatch without looking at the display. When the stopwatch gets to the amount of time that the watcher has chosen, the watcher will say stop. The starter/stopper will stop the stopwatch as quickly as possible. Do this a few times to estimate the reaction time of the starter/stopper. Trade roles among group members to find everyone's reaction time.

Allow enough time for each student to practice being the watcher and starter/stopper.

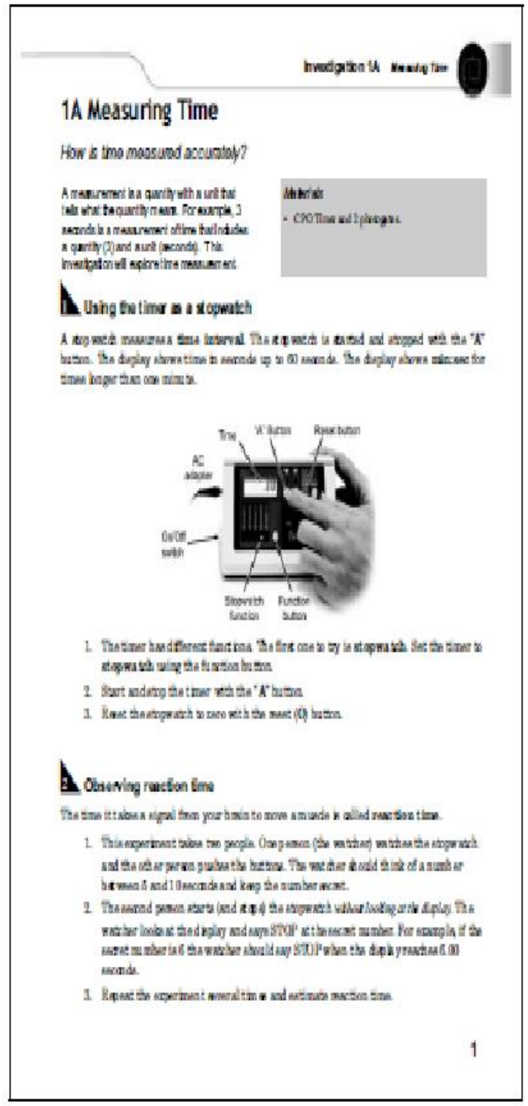
3 Mixed units for time

What are some units for time?

Answers include seconds, hours, minutes, years, centuries, etc.

What piece of information do you need to be able to convert between minutes and seconds?

Students should answer that it is necessary to know that there are 60 seconds in 1 minute. Write the conversion factor 1 minute = 60 seconds on the board.



Investigation 1A Measuring Time

1A Measuring Time

How is time measured accurately?

A measurement is a quantity with a unit that tells what the quantity means. For example, 3 seconds is a measurement of time that includes a quantity (3) and a unit (seconds). This investigation will explore time measurement.

Materials

- CPO Timer and 2 photogates

1 Using the timer as a stopwatch

A stopwatch measures a time interval. The stopwatch is started and stopped with the "A" button. The display shows time in seconds up to 60 seconds. The display shows minutes for times longer than one minute.

1. The timer has different functions. The first one to try is stopwatch. Set the timer to stopwatch using the function button.
2. Start and stop the timer with the "A" button.
3. Reset the stopwatch to zero with the reset (0) button.

2 Observing reaction time

The time it takes a signal from your brain to move a muscle is called reaction time.

1. This experiment takes two people. One person (the watcher) watches the stopwatch and the other person pushes the buttons. The watcher should think of a number between 5 and 10 seconds and keep the number secret.
2. The second person starts (and stops) the stopwatch *without looking at the display*. The watcher looks at the display and says STOP at the secret number. For example, if the secret number is 6 the watcher should say STOP when the display reaches 6.00 seconds.
3. Repeat the experiment several times and estimate reaction time.

1

Teaching Tip . . .

Research Questions

It is helpful to write the research question on the board so that students can refer to it at various stages of the investigation. Seeing the question repeatedly keeps students focused on gathering data and making observations that will help them answer the question by the end of the investigation.

Who can tell me how to find how many seconds there are in 6 minutes?

Answers will vary. Stop at this point and model the conversion. Use the steps outlined in Figure 1.1. Be sure to vocalize each step to reinforce it. This method is called the factor-label method. Additional practice in applying this method is provided in lesson 1.2.

Time is often given in mixed units, such as 2 hours, 10 minutes, and 15 seconds. How would this be displayed on a stopwatch?

Students should be familiar with mixed units from sporting events. The correct answer is 2:10:15.

Now you will use what you know about time intervals to answer some questions.

Allow students sufficient time to complete questions 3a-3f. Give assistance as needed.

4 Using the photogates

Now you will be using a photogate with the timer. A photogate contains an infrared light beam. It's similar to the kind of light a remote control uses, so you can't see it. The photogate senses when the light beam is broken. This information is used to start and stop the timer. Follow the directions in the investigation to learn how the photogate and timer work together.

Students should carefully read each step of the procedure and answer the questions.

5 Using the timer with two photogates

Now you will learn how two photogates can be used together to take three different measurements. Connect a second photogate to the timer and press reset. If you press the A and B buttons, you should see the lights turn on and off. Experiment with the photogates to answer the questions in Table 1.

Encourage students to spend as much time as they need to fully understand how the timer and photogates work. Refrain from giving away any answers. Students will learn much more by figuring it out themselves. Make sure students are clear in their explanations for the question, "What time interval does the clock measure?" A good answer for the first one (A light on, B light off) is, "the time the light beam in photogate A is blocked."

6 Another test to try

Think about how the timer and photogates work. Does the timer reset itself each time the photogate's light beam is broken, or do the times keep adding up? Follow the procedure in part 6 and answer the questions with your group members.

Students will find that the timer resets itself each time the photogate beam is broken

How many seconds are in 6 minutes?

Step 1: State the relationship between seconds and minutes.

60 seconds = 1 minute

Step 2: Write the relationship as a conversion factor.

$$\frac{60\ \text{sec}}{1\text{min}} \text{ Or } \frac{1\text{min}}{60\ \text{sec}}$$

Step 3: Identify the given quantity in the problem and the unit you want to eliminate.

Given the quantity is 6 minutes.
The unit to eliminate is minutes (min).

Step 4: Set up the problem to eliminate the unwanted unit.
Hint: Write the conversion factor with the unit you wish to eliminate in the denominator.

$$6\ \text{min} \times \frac{60\ \text{sec}}{1\text{min}} = ?$$

Step 5: Cancel units and complete the calculation.

$$6\ \cancel{\text{min}} \times \frac{60\ \text{sec}}{1\cancel{\text{min}}} = 360\ \text{sec}$$

Figure 1.1: Applying the factor label method

Investigation 1A: Data and Answers

1 Using the timer as a stopwatch

2 Observing reaction time

3 Mixed units for time

a. 4 hours, 23 minutes, and 15 seconds

b. It is impossible to tell without converting them all to the same single unit.

c. 15,000 seconds

d. 240 minutes

e. 15,795 seconds

f. smallest: 250 minutes (15,000 seconds); middle: 4 hours, 23 minutes, and 15 seconds (15,795 seconds); longest: 16,000 seconds

Name:

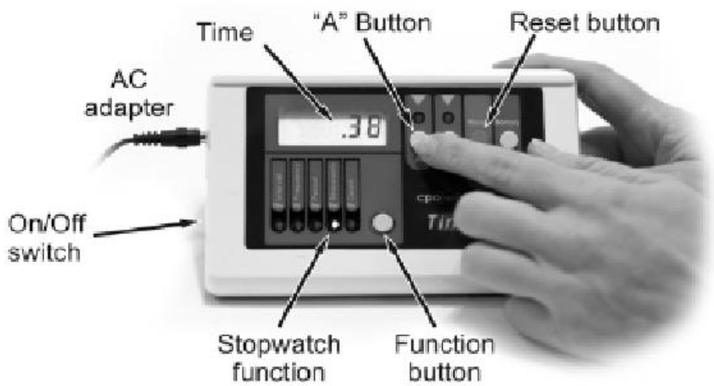
1A Measuring Time

How is time measured accurately?

A measurement is a quantity with a unit that tells what the quantity means. For example, 3 seconds is a measurement of time that includes a quantity (3) and a unit (seconds). This investigation will explore time measurement.

1 Using the timer as a stopwatch

A stopwatch measures a **time interval**. The stopwatch is started and stopped with the "A" button. The display shows time in seconds up to 60 seconds. The display shows **min:sec** for times longer than one minute.



1. The timer has different functions. The first one to try is **stopwatch**. Set the timer to **stopwatch** using the function button.
2. Start and stop the timer with the "**A**" button.
3. Reset the stopwatch to zero with the reset (**O**) button.

2 Observing reaction time

The time it takes a signal from your brain to move a muscle is called **reaction time**.

1. This experiment takes two people. One person (the watcher) watches the stopwatch and the other person pushes the buttons. The watcher should think of a number between 5 and 10 seconds and keep the number secret.
2. The second person starts (and stops) the stopwatch *without looking at the display*. The watcher looks at the display and says STOP at the secret number. For example, if the secret number is 6 the watcher should say STOP when the display reaches 6.00 seconds.
3. Repeat the experiment several times and estimate reaction time.

3 Mixed units for time

In physical science, you are usually going to measure time in seconds. However, time is often given in mixed units, which may include hours, minutes, and seconds. Consider the following three time intervals.

1. 16,000 seconds
2. 250 minutes
3. 4 hours, 23 minutes and 15 seconds (4:23:15)

a. Which one is in mixed units?

b. Can you tell which time is longest or shortest?

c. If 1 minute = 60 seconds, then how many seconds is 250 minutes?

d. If 1 hour = 60 minutes, then how many minutes are in 4 hours?

e. Use part (d) to figure out how many seconds are in 4:23:15.

f. Arrange the three measurements from smallest to largest:

Investigation 1A: Data and Answers

1 Using the timer as a stopwatch

2 Observing reaction time

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a. 4 hours, 23 minutes, and 15 seconds

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c. 15,000 seconds

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e. 15,795 seconds

f. smallest: 250 minutes (15,000 seconds); middle: 4 hours, 23 minutes, and 15 seconds (15,795 seconds); longest: 16,000 seconds

4 Using the photogates

a. The clock is started by blocking the light beam.

b. The clock is stopped by unblocking the light beam.

c. The clock measures the time interval during which the light beam was blocked.

5 Using the timer with two photogates

Table 1: Timer and Photogate Rules

A light	B light	How do you start the clock?	How do you stop the clock?	What time interval does the timer display?
On	Off	Block beam in photogate A	Unblock the beam	Time photogate A's beam is blocked
Off	On	Block beam in photogate B	Unblock the beam	Time photogate B's beam is blocked
On	On	Block beam in photogate A	Block beam in photogate B	Time from when A is first blocked to when B is first blocked
Off	Off	Can't start it	Doesn't start	None

a. It displays the time the A photogate's beam was blocked.

b. It displays the time the B photogate's beam was blocked.

c. It displays the time from when A is first blocked to when B is first blocked. This means that the timer takes measurements even when the A and B indicator lights are off. The lights indicate what the timer is displaying. The lights have no effect on the measurements, only the display.

6 Another test to try

a. The times start again from zero each time the photogate's beam is blocked.

b. If the times added, the time would keep getting larger each time the beam is blocked.

c. The time does not keep getting larger, so the timer must be resetting each time the photogate is blocked.

Speed Challenge

Name ____________________

Get Ready!

Step 1: Gather your materials!
Each team needs 2 timers, 1 meter stick or trundle wheel, 1 roll of masking tape, and 1 marker.

Step 2: Create your "race" track!
Find a spot in the hallway and measure off a 10 meter race track. Use three pieces of tape to mark the beginning, middle, and end of your track. Mark each distance (0 m, 5 m, and 10 m) on the tape with a marker.

Step 3: Go for it!
Each team member will need to perform the following tasks for each distance: hopping, walking backwards, walking (regular rate), and speed walking. Your team will need people with timers or stopwatches at the 5 meter and 10 meter points. Record the time it takes to perform each task.

NOTE: Speed walking is going as fast as you can without jogging or running!

Collect That Data!
Record your data from the experiment in the chart, then use the information to calculate the speed for each task and distance. Round answers to the nearest hundredth if needed. Label your answers!

Task	Distance	Time	Speed=d/t
Hopping	5m		
	10 m		
Walking Backwards	5m		
	10 m		
Walking	5m		
	10 m		
Speed Walking	5m		
	10 m		

Name ______________________________

Speed Challenge
Think About It!

1. Which task and distance resulted in the fastest speed?

   Task = _____________ Distance = _____________ Speed = _____________

2. Which task and distance resulted in the slowest speed?

   Task = _____________ Distance = _____________ Speed = _____________

3. How far could you speed walk in 10 minutes based on your speed for the 10 meter trial? Show your work!

4. How long would it take you to hop 30 meters based on your speed for the 5 meter trial? Show your work!

5. How far could you travel walking backwards in 15 minutes based on your results for the 5 meter trial? Show your work!

6. How long would it take you to walk (regular rate) 1 kilometer (or 1,000 m) based on your speed for the 10 meter trial? Show your work!

7. Are your results accurate? Why or why not?

Name ________________________________

Speed Challenge

Title: ____

Title:

Title: ____

Conclusion:
Write a paragraph discussing the results of this activity. Explain which data you choose to graph.

Speed Challenge Answer Key

1. Which task and distance resulted in the fastest speed? **Speed = Distance / Time**
Answers will vary

2. Which task and distance resulted in the slowest speed? **Speed = Distance / Time**
Answers will vary

3. How far could you speed walk in 10 minutes based on your speed for the 10 meter trial? Show your work!
Answers will vary. Students should use their results to calculate a distance using the formula S=D÷T. The speed would be equal to the speed from the speed walking 10 meter trial and time should be 10 minutes. *Students will need to multiply the speed by the time to find the distance.*

4. How long would it take you to hop 30 meters based on your speed for the 5 meter trial? Show your work!
Answers will vary. Students should use their results to calculate a distance using the formula S=D÷T. The speed would be equal to the speed from the hopping 5 meter trial and distance should be 30 meters. *Students will need to divide the distance by the speed to find the time.*

5. How far could you travel walking backwards in 15 minutes based on your results for the 5 meter trial? Show your work!
Answers will vary. Students should use their results to calculate a distance using the formula S=D÷T. The speed would be equal to the speed from the walking backwards 5 meter trial and time should be 15 minutes. *Students will need to multiply the speed by the time to find the distance.*

6. How long would it take you to walk (regular rate) 1 kilometer (or 1,000 m) based on your speed for the 10meter trial? Show your work!
Answers will vary. Students should use their results to calculate a distance using the formula S=D÷T. The speed would be equal to the speed from the walking 10 meter trial and distance should be 1000 meters. *Students will need to divide the distance by the speed to find the time.*

7. Are your results accurate? Why or why not?
Answers will vary.

Name: ______________________________ ______________

SKILL and PRACTICE 1.2

Stopwatch Math

READ

What do horse racing, competitive swimming, stock car racing, speed skating, many track and field events, and some scientific experiments have in common? The need for some sort of stopwatch, and people to interpret the data. For competitive athletes in speed-related sports, finishing times (and split times taken at various intervals of a race) are important to help the athletes gauge progress and identify weaknesses so they can adjust their training and improve their performance.

EXAMPLE

Three girls ran the following times for one mile in their gym class: Julie ran 9:33.2 (nine minutes, 33.2 seconds), Maggie ran 9:44.24 (nine minutes, 44.24 seconds), and Mel ran 9:33.27 (nine minutes, 33.27 seconds. In what order did they finish?

The girl who came in first is the one with the fastest (smallest) time. Compare each time digit by digit, starting with the largest place-value. Here, that would be the minutes place:

There is a "9" in the minutes' place of each time, so next, compare the seconds' place. Since Maggie's time has larger numbers in the seconds' place (44) than Julie or Mel (33), her time is larger (slower) than the other two. We know Maggie finished third out of the three girls. Now, comparing Julie's time (9:33.2) to Mel's (9:33.27), it is helpful to rewrite Julie's time (9:33.2) so that it has the same number of places as Mel's. Julie's time needs one more digit, so adding a zero onto the end of her time, it becomes 9:33.20. Notice that Mel's time is larger (slower) than Julie's (27 > 20). This means that Julie's time was fastest (smallest), so she finished first, followed by Mel, and Maggie's time was the slowest (largest).

PRACTICE

1. Put each set of times in order from fastest to slowest.

   a. 5.5 5.05 5 5.2 5.15

Fastest								Slowest

   b. 6:06.04 6:06 6:06.4 6:06.004

Fastest								Slowest

2. The table below gives the winners and their times from eight USA track and field championship races in the men's 100 meter run. Rewrite the table so that the times are in order from fastest to slowest. Please include the times and the years. Please note that the "w" that occurs next to some times indicates that the time was wind aided.

Year	2005	2004	2003	2002	2001	2000	1999	1998
Time	10.08	9.91	10.11	9.88w	9.95w	10.01	9.97w	9.88w
Name	Justin Gatlin	Maurice Greene	Bernard Williams	Maurice Greene	Tim Montgomery	Maurice Greene	Dennis Mitchell	Tim Harden

Time								
Year								

3. The following times were recorded during an experiment with battery powered cars. Please put them in order from fastest to slowest.

a. 1:22.4 1:24.007 1:25 1:22.04 1:23.117 1:23.2 1:24 1:33

Fastest							Slowest

b. 1:18.3 1:20.22 1:21.003 1:20 1:17.99 1:21.2 1:18.22

Fastest						Slowest

c. 1:25 1:24.99 1:24.099 1:25.001 1:24.9901 1:24.9899

Fastest					Slowest

4. Write a set of five times (in order from fastest to slowest) that are all between 26:15.2 and 26:15.24. Do not include the given numbers in your set.

Stopwatch Math Answer Key

1a

Fastest				Slowest
5	5.05	5.15	5.2	5.5

1b

Fastest			Slowest
6:06	6:06.004	6:06.04	6:06.4

2

Time	9.88w	9.88w	9.91	9.95w
Year	2002	1998	2004	2001

Time	9.97	10.01	10.08	10.11
Year	1999	2000	2005	2003

3a

Fastest							Slowest
1:22.04	1:22.4	1:23.117	1:23.2	1:24	1:24.007	1:25	1:33

3b

Fastest						Slowest
1:17.99	1:18.22	1:18.3	1:20	1:20.22	1:21.003	1:21.2

3c

Fastest					Slowest
1:24.099	1:24.9899	1:24.99	1:24.9901	1:25	1:25.001

4. Infinitely many solutions possible.

Fastest				Fastest
26:15.21	26:15.215	26:15.22	26:15.225	26:15.23

Investigation 2B: Speed

What is speed?

Speed is the rate at which an object covers distance. It is the distance traveled divided by the time taken.

What are some units you could use to measure speed?

Possible answers include miles per hour, meters per second, kilometers per hour, and centimeters per second.

Today you will be using the timer and photogates to measure the speed of a car rolling down a ramp. You will be using the unit centimeters per second.

1 Set up your car and ramp

When you set up the car and ramp, each group will attach the ramp to the physics stand at a different hole. This will make all of the ramps have a different slope. Each group will find the car's speed, and later we will compare all of the data to find out how the slope affects the car's speed.

Tell each group which hole they should be using. Spread out the assigned holes from 1-12 to get a good range of values.

Attach the photogates to the ramp. Plug the top photogate into input A of the timer. Plug the bottom photogate into input B.

Students may ask where along the track to connect the photogates. Tell them to connect them anywhere they choose. Students will later find out that where they connect the photogates does matter.

2 Your hypothesis

Look around the room at all of the ramps. Make a hypothesis about which ramp you think will have the fastest car. Explain your reasoning.

Allow time for students to write their responses.

3 Find the speed of the car

What two pieces of information do you need to find the car's speed?

The distance and time are needed.

What formula will you use?

Speed = distance/time.

Measure the distance between your photogates from center to center. Then make sure both the A and B lights are lit on your timer. Find the speed of your car. Repeat for a total of three trials.

Give students time to complete their measurements.

4 Analyzing your results

Now we will make a data table to compare the results of all of the groups.

Make at data table on the board. In one column, record the hole to which the ramp was attached. In the other column, record the average speed. Arrange the data in order of the attachment hole.

Are the results what you expected? Think about the data, and then we'll discuss it.

The data will not show that as the slope increases, the speed increases in a clear pattern. The data will be somewhat random. Give students some time to look at the data and think about the reason why it doesn't follow the pattern they expected. After sufficient wait time, lead a discussion about possible reasons. Students should realize that not all groups connected the photogates at the same location along the ramp and that the spacing between the photogates varied.

5 Design a better experiment

There are five major variables other than the ramp angle that need to be kept the same from group to group. Let's discuss these variables and decide how we will control each one to make the results of the experiment as accurate as possible.

The variables are the location of the top photogate, the location of the bottom photogate, the weight of the car, how the car is launched (dropped rather than pushed), and the height of the bottom of the track. Have a class discussion about how the groups will make sure they keep these variables the same.

6 A better experiment

Repeat the experiment, but this time make sure to control all of the variables except the ramp angle.

Each group should change the placement of the photogates and then run the experiment again.

7 Analyzing your results

Now we will compile the class data again.

Write the data on the board. In one column, record the hole to which the ramp was attached. In the other column, record the average speed. Arrange the data in order of the attachment hole.

Was your original hypothesis correct?

Students should write their responses.

The walking speed of an average person is 1 m/s or 100 cm/s. How does your car's speed compare?

Students should write their responses.

8 Exploring on your own

Read and answer the questions in the Exploring on your own section.

Students can finish these questions as homework or can do them with their group members in class. The first question requires access to the internet to do a few minutes of research.

2B SPEED ANSWER KEY
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Investigation 2B: Data and Answers

1 Set up your car and ramp

2 Your hypothesis

b. The ramp that is connected to the stand at the highest hole will have the fastest car. This is because the track that is connected the highest is the steepest, so it will speed up the most.

3 Find the speed of the car

Table 1: Speed of the car

Trial	Distance A to B (cm)	Time A to B (s)	Average speed (cm/s)
1	20	0.1443	138.6
2	20	0.1444	138.5
3	20	0.1445	138.4
Average speed of the car (cm/s)			138.5

4 Analyzing your results

a. Sample data table

Hole	Average speed (cm/s)
5	125.2
6	142.2
7	132.3
8	131.7
9	138.5
10	162.3

b. My hypothesis was correct that the fastest car was on the track that was connected at the highest hole, but the overall pattern of the speeds was not what I expected. The second fastest speed was for the car connected at the second lowest hole. Overall, there was not much of a pattern in the results. This was because different groups connected their photogates at different places. Some measured the speed near the top of the track, and some measured it near the bottom.

5 Design a better experiment

Table 2: Creating a controlled experiment

Variable	How we will control it
Location of top photogate	Put top photogate at the 20 cm mark
Location of bottom photogate	Put bottom photogate at 40 cm mark
Mass of car	None of the cars have weights added; measure with a balance to make sure cars are the same mass and add mass (clay or paper clips) if necessary
How car is released	Car is held at top of track with index finger and dropped without pushing
Height of bottom of track	Resting on table, use a level to make sure table is level

6 A better experiment

Table 3: Speed of the car: A controlled experiment

Trial	Distance A to B (cm)	Time A to B (s)	Average speed (cm/s)
1	20	0.1445	138.4
2	20	0.1442	138.7
3	20	0.1443	138.6
Average speed of the car (cm/s)			138.6

7 Analyzing your results

a. Sample data table

Hole	Average speed (cm/s)
5	107.2
6	115.9
7	123.9
8	131.8
9	138.6
10	145.7

Fastest Ramp **Name:** ______________________________

2B Speed

Which ramp is fastest?

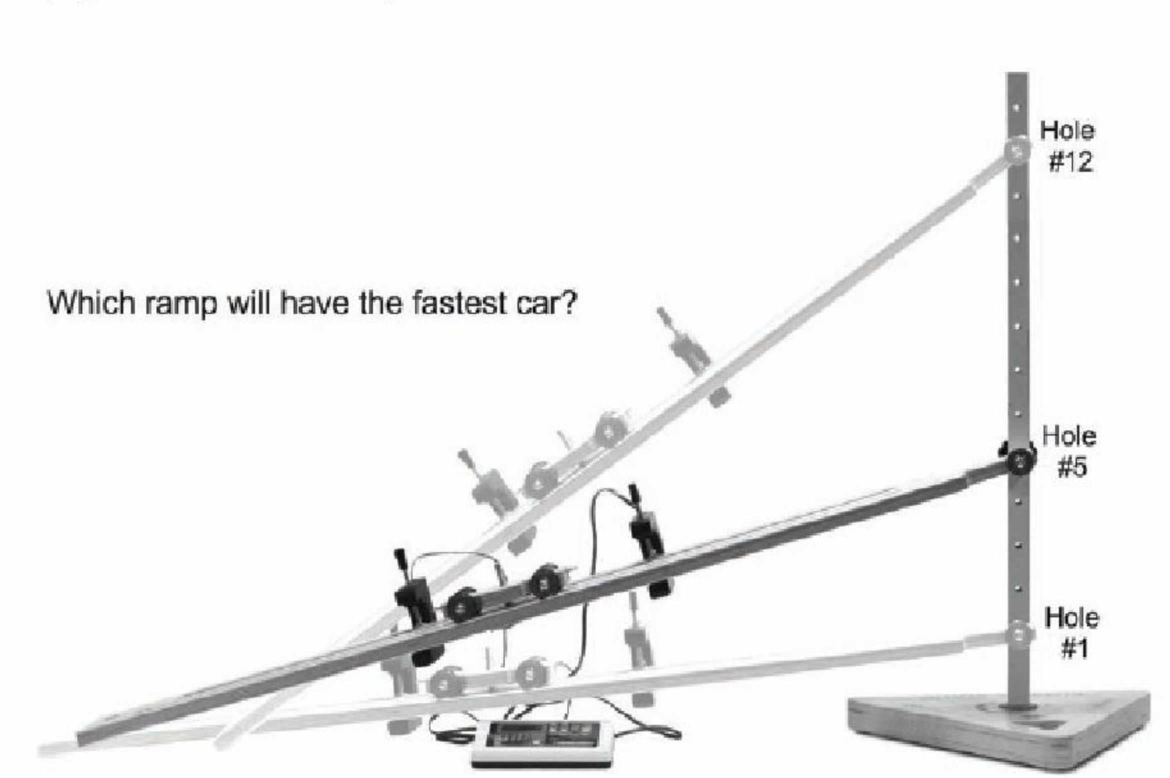
We do experiments to collect evidence that allows us to take a look at nature's mysteries. If an experiment is well planned, the results of the experiment can answer a question about how nature works. This investigation will look at the relationship between speed and angle for a car rolling down hill.

Materials

- Car and ramp
- Timer
- Physics stand

Speed describes how fast or slow something moves. You have to put two quantities together to describe your speed: the distance you traveled, and the time it took you to go that distance. An average walking speed is 1 m/s, or 100 cm/s. What is the average speed of the car as it rolls down the ramp?

1 Set up your car and ramp



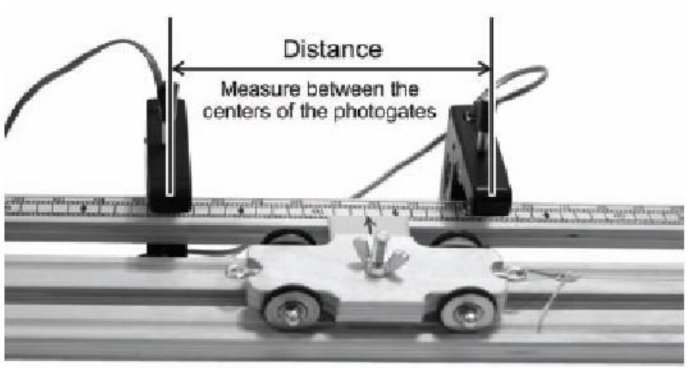
1. Set up the car and ramp as instructed by your teacher. Each group will put the ramp in a different hole of the physics stand. This means each group will have a different ramp angle.
2. To find the speed of the car, you need to know two things: the distance traveled, and the time it takes the car to go that distance. Put two photogates on the ramp so you can find how long it takes the car to go from one photogate to the other.

2 Your hypothesis

a. Look around at the other groups and compare the ramp angles.

b. Write your hypothesis, stating which ramp will have the fastest car. Explain the reasoning behind your hypothesis.

3 Find the speed of the car



$$\text{Speed} = \frac{\text{Distance between A and B}}{\text{Time from A to B}}$$

1. Record the distance between the two photogates.
2. Roll the car down the ramp and record the time it takes to go from photogate A to B. Be sure to read the timer when the A and B lights are both on!
3. Find the average speed by dividing distance by time (speed = distance/time).
4. Do two more trials so you have a total of three trials. Find the average speed from your three trials.

Table 1: Speed of the Car

Trial	Distance A to B (cm)	Time A to B (s)	Average Speed (cm/s)
1			
2			
3			
Average Speed of the Car (cm/s)			

4 Analyzing your results

a. Create a class data table that shows the average speed for each different ramp position.

- Class Data Table;

Hole	Average speed (cm/sec)

b. Do the groups' speeds agree with your hypothesis about which ramp should have the fastest car? Why or why not?

5 Design a better experiment

It was hard to compare results in the first experiment, because there were many differences in the car and ramp setups from group to group. Other variables (besides the ramp angle) changed, making it hard to compare results. A better experiment would make every variable the same except the one variable you are testing.

a. There are five major variables other than ramp angle that need to be kept the same from group to group. Discuss these variables and decide as a class how you will control each.

Table 2: Creating a Controlled Experiment

Variable	How we will control it

6 A better experiment

1. Repeat the first experiment, except this time be sure to control all variables other than ramp angle. Each group will still have a different ramp angle.

Table 3: Speed of the Car - A Controlled Experiment

Trial	Distance A to B (cm)	Time A to B (s)	Average Speed (cm/s)
1			
2			
3			
Average Speed of the Car (cm/s)			

7 Analyzing your results

a. Create a class data table that shows the average speed for each different ramp position.

Teacher Guide: Distance-Time Graphs

Learning Objectives

Students will…

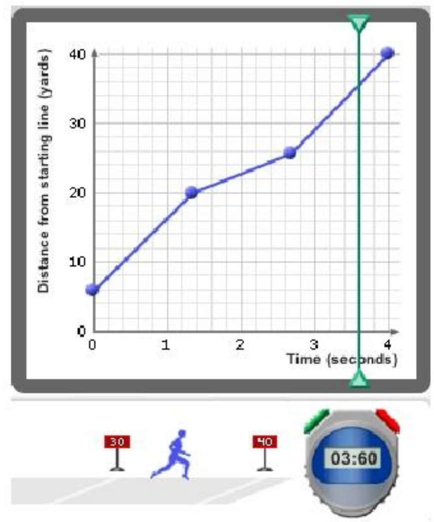
- Observe the relationship between a running person and a graph of distance vs. time.
  - Learn what the slope and *y*-intercept of the graph indicate about the runner.
  - Calculate the speed of the runner based on the graph.
- Interpret a graph showing the distances and times of two runners.
- Use distance-time graphs to solve word problems involving distance and speed.

Vocabulary

speed, *y*-intercept

Lesson Overview

The *Distance-Time Graphs* Gizmo™ shows a runner on a track and a graph that represents the runner's position over time. By manipulating the points on the graph, students can control the speed and direction of one or two runners. Students will gain graph sense as they manipulate graphs and compare them to the runner's motions.



Runner and graph

The Student Exploration contains three activities:

- Activity A - Students see how position and time are shown on a graph.
- Activity B - Students explore how a graph shows the direction and speed of a runner.
- Activity C - Students interpret graphs of two runners and use graphs to solve problems.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Make a distance-time graph** (45 - 60 minutes)

Introduce the Gizmo by graphing your students' movements. You will need a track or field marked off in 10-yard increments, several stopwatches, and students volunteering to be timers, recorders, and runners.

First, position a student with a stopwatch at each 10-yard marker. Position the runner at the starting line, and yell "Go!" The "timers" should all start their stopwatches at "go," and stop their watches when the runner passes by. The recorder can then record the distance and time coordinates for that runner. Do this for fast runners, slow runners, walkers, and people who vary their pace as they go along the course.

Graph the data, with time on the *x*-axis and distance from the start on the *y*-axis. Discuss how each graph shows the runner's position and speed.

2. **Prior to using the Gizmo** (10 - 15 minutes)

Before students are at the computers, pass out the Student Explorations and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (10 - 15 minutes per activity)

Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 - 30 minutes)

As students are working or just after they are done, discuss the following questions:

- How does the graph in the Gizmo show the direction a runner is moving?
- What does a horizontal line on the graph indicate?
- What would a vertical line on the graph indicate? Is this possible?
- How does the graph show that a runner is going fast? Slow?

5. **Follow-up activity: Can you run that graph?** (30 - 45 minutes)

Project the *Distance-Time Graphs* Gizmo to the front of the classroom, and ask for two volunteers: a "programmer" and a "runner." The programmer creates a graph on the Gizmo, and the runner tries to perform the animation that will go with the graph. Once the runner has done this, play the Gizmo to see how close the runner has come to the actual animation. For a fun challenge, have the runner try to match the movements of the Gizmo runner as the Gizmo is playing. Students can also switch roles, so that the runner performs a set of movements and the programmer tries to create a graph to match. Keep going until everyone has had a turn as either a runner or programmer.

Several Gizmos can be used as a follow-up to the *Distance-Time Graphs* Gizmo. The *Elevator Operator* Gizmo shows a graph of the vertical motion of an elevator. The *Distance-Time and Velocity-Time Graphs* Gizmo introduces the concept of a velocity-time graph. The *Modeling Linear Systems - Activity A* Gizmo uses a "cat chasing a mouse" scenario to graph a system of equations. See the **Selected Web Resources** on page 3 of this document for links to these Gizmos.

Sports Connection: The "Lightning Bolt" from Jamaica

In the 2008 Olympics in Beijing, China, the Jamaican sprinter Usain Bolt electrified the world by setting records and blowing away his competition in the 100- and 200-meter races. Bolt ran the 200-meter race in 19.30 seconds, an average speed of 10.4 m/s (37 km/h, or 23 mph).

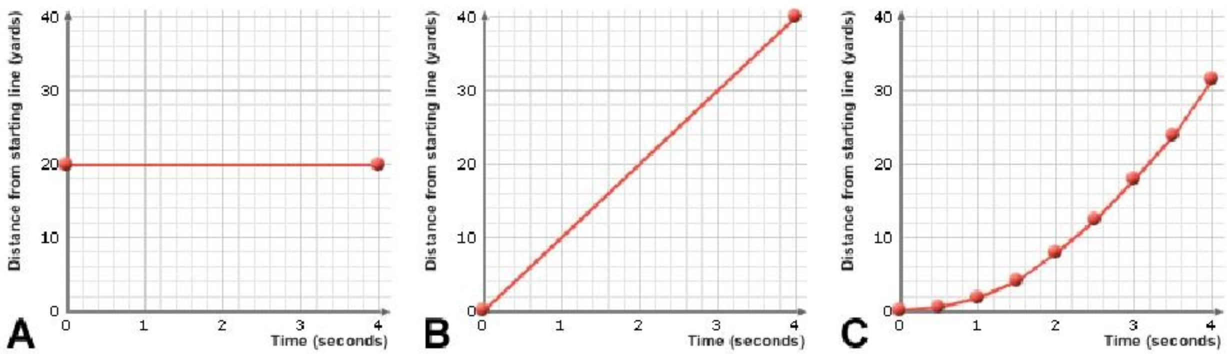
Bolt was born and raised in the small town of Trelawny, Jamaica. Bolt loved soccer and cricket, and his talent for running was soon apparent. Although he didn't always train seriously and loved practical jokes, Bolt steadily rose to the top in a sprinting-mad country. In Beijing, Bolt became as famous for his joyful dancing and other antics as for his stunning performances on the track. In the 100-meter race, Bolt had an untied shoelace and began celebrating victory with 20 meters to go in the race. In spite of this, he won and even set a new world record (9.69 s)!

Mathematical Background

The *Distance-Time Graphs* Gizmo shows a graph with time on the *x*-axis and distance from the starting line on the *y*-axis. This graph lets you describe and compare the motions of runners.

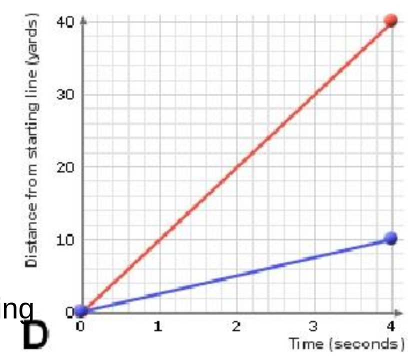
In reality, the graph in the Gizmo is probably best referred to as a *position-time graph*. The term *distance* can be misleading. In the Gizmo, we mean "distance from the starting line," so this value can increase or decrease, depending on which direction the runner runs. This should not be confused with "distance traveled," which can never decrease. (Think of your car's odometer.)

Several different situations can be shown on a position-time graph. A horizontal line (figure A) indicates that, as time goes by, position does not change. In other words, the object is standing still. A straight "uphill" or "downhill" line (figure B) means that, for each increment of time, the position changes by the same amount, so this object is moving at a constant speed.
A curve (figure C) shows that the position is changing by more and more (or less and less) each time increment. This means that the speed is changing—the object is accelerating.



The *slope* of the line indicates speed. Figure D shows a graph of a slow-moving object (blue) and a fast-moving object (red).
The fast-moving object moves 40 yards in 4 seconds, a speed of 40 ÷ 4 = 10 yds./sec. The slow-moving object goes 10 yards in 4 seconds, a speed of 10 ÷ 4 = 2.5 yds./sec.

The slope of the line can also indicate the direction of motion. A line with negative slope indicates that the runner is going backwards, moving back towards the starting line.



Selected Web Resources

Distance-time graphs:
http://www.broadeducation.com/htmlDemos/AbsorbPhysicsAdvd/DistanceTime/page.htm
Distance-time graphs: http://www.gcse.com/fm/dtg.htm
Position time graph: http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/1DKin/U1L3a.html
Distance-time graph activity: http://graphs.mathwarehouse.com/distance-time-graph-activity.php
Distance-time game: http://www.sycd.co.uk/dtg/
Usain Bolt: http://www.usain-bolt.info/Biography.html

Related Gizmos:
Elevator Operator: http://www.explorelearning.com/gizmo/id?1017
Distance-Time and Velocity-Time Graphs: http://www.explorelearning.com/gizmo/id?301
Modeling Linear Systems - Activity A: http://www.explorelearning.com/gizmo/id?278

Distance-Time Graphs *Answer Key*

Vocabulary: speed, *y*-intercept

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

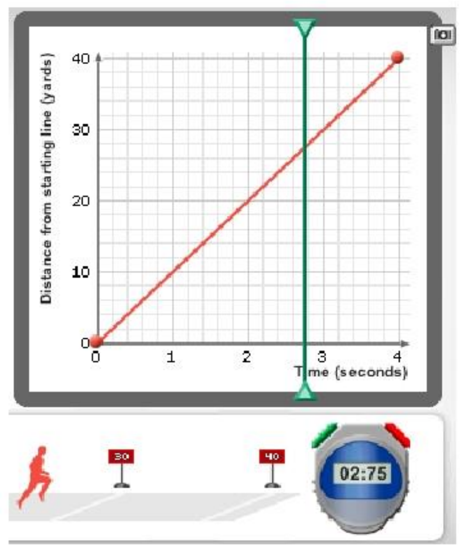
Max ran 100 feet in 10 seconds. Molly ran 60 feet in 5 seconds.

1. Who ran farther, Max or Molly? ***Max ran farther.***

2. Who ran faster? ***Molly***

   Explain: ***Molly ran 12 feet each second. Max ran 10 feet each second***.

Gizmo Warm-up
The *Distance-Time Graphs* Gizmo$_{TM}$ shows a graph and a runner on a track. You can control the motion of the runner by manipulating the graph (drag the red dots).



Check that **Number of points** is 2, and that under **Runner 1** both **Show graph** and **Show animation** are turned on.

The graph should look like the one shown to the right - one point at (0, 0) and the other point at (4, 40).

1. Click the green **Start** button on the stopwatch.

   What happens? ***The runner runs from left to right for 4 seconds, stopping at the 40-yard line.***

2. Click the red **Reset** button on the stopwatch. The vertical green **probe** on the graph allows you to see a snapshot of the runner at any point in time. Drag it back and forth. As you do, watch the runner and the stopwatch.

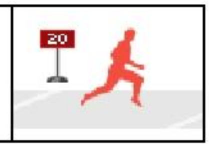
   A. What was the position of the runner at 1 second? ***10 yards***

   B. What are the coordinates of the point on the graph that tells you this? ***(1, 10)***

   C. When was the runner on the 30-yard line? ***At 3 seconds***

   D. What are the coordinates of the point on the graph that tells you this? ***(3, 30)***

Answer Key

Activity A: Runner position	Get the Gizmo ready: • Click the red **Reset** button on the stopwatch. • Be sure the **Number of Points** is 2.	

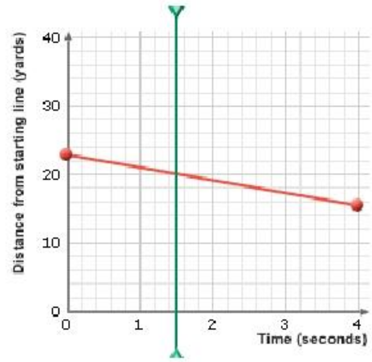
In the Gizmo, run the "race" many times with a variety of different graphs. (The red points on the graph can be dragged vertically.) Pay attention to what the graph tells you about the runner.

1. If a distance-time graph contains the point (4, 15), what does that tell you about the runner? (Be specific, and answer in a complete sentence.)

   This tells you that after 4 seconds of running, the runner was 15 yards from the starting line.

2. Look at the graph to the right. Notice where the green probe is. If you could see the runner and the stopwatch at this moment, what would you see?

   The runner would be on the 20 yard line, facing left. The stopwatch would read approximately 1.5 seconds (or 1:50).



3. Look at the image below, from the Gizmo. What must be true about this runner's graph?

   The graph of the runner must include the point (3.25, 25). [Students may also respond that the graph has a positive, or "uphill," slope at that point. This is because the runner is facing forward in the image, so he must be running from left-to-right.]

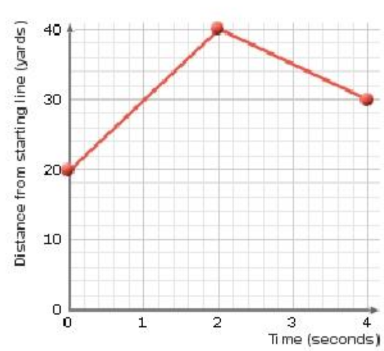
4. The point on the graph that lies on the *y*-axis (vertical axis) is called the ***y*-intercept**. What does the *y*-intercept tell you about the runner?

   The y-intercept indicates the starting position of the runner.

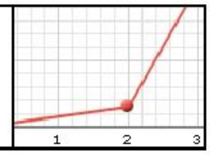
5. In the Gizmo, set the **Number of Points** to 3. Then create a graph of a runner who starts at the 20-yard line, runs to the 40-yard line, and finishes at the 30-yard line.

   A. Sketch your graph to the right.

   B. What is the *y*-intercept of your graph? ***(0, 20) or 20 yds.***



Answer Key

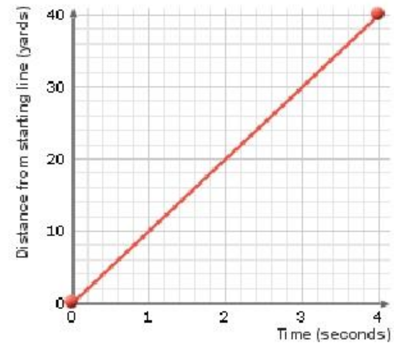
Activity B: Runner direction and speed	<u>Get the Gizmo ready:</u> • Click the red **Reset** button on the stopwatch.	

Run the Gizmo several times with different types of graphs. (Remember, the red points on the graph can be dragged vertically.) Pay attention to the speed and direction of the runner.
[Note: In each graph, there are several possible correct answers. Examples are given.]

1. Create a graph of a runner that is running forward (from left to right) in the Gizmo. Sketch your graph to the right.

   If the runner is moving from left to right in the Gizmo, how does the graph always look?

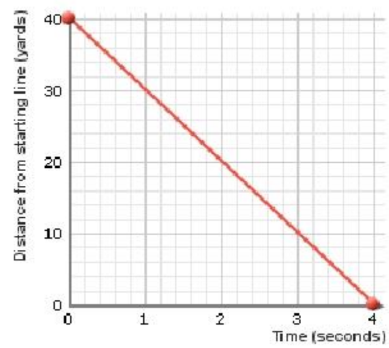
   The graph will have a positive slope. (The line will go from lower left to upper right.)



2. Click the red **Reset** button. Create a graph of a runner that is running from right to left. Sketch it to the right.

   How does the graph always look if the runner is moving from right to left in the Gizmo?

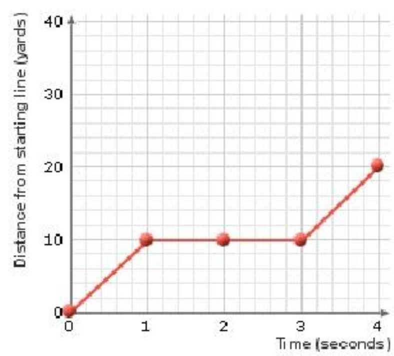
   The graph will have a negative slope. (The line will go from upper left to lower right.)



3. Change the **Number of Points** to 5. Create a graph of a runner that runs left-to-right for one second, rests for two seconds, and then continues running in the same direction. Sketch the graph to the right.

   How does a graph show a runner at rest?

   The line will be horizontal when the runner is at rest.



4. In general, how does a distance-time graph show you which direction the runner is moving?

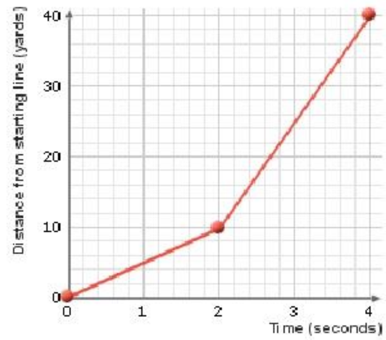
   The runner's direction is given by the slope of the graph. A positive slope (/) indicates the runner is moving forward, or from left to right. A negative slope (\ ) indicates the runner is moving backward, or from right to left.

(Activity B continued on next page)

Answer Key

Activity B (continued from previous page)

5. With **Number of Points** set to 3, create the graph shown at right. Your graph should include (0, 0), (2, 10), and (4, 40).



A. Where does the runner start? ***0 yard line***

B. Where will he be after 2 seconds? ***10 yard line***

C. Where will he be after 4 seconds? ***40 yard line***

D. In which time interval do you think the runner will be moving most quickly? (Circle your answer below.)

0 to 2 seconds　　　　2 to 4 seconds (circled)

6. Click the **Start** button and watch the animation. What about the runner changed after 2 seconds of running? ***The speed of the runner increased.***

7. **Speed** is a measure of how fast something is moving. To calculate speed, divide the distance by the time. In the Gizmo, the units of speed are yards per second (y/s).

A. In the first 2 seconds, how far did the runner go? ***10 yards***

B. In this time interval, how far did the runner go each second? ***5 yards***

C. In this time interval, what was the runner's speed? ***5 yards/second (5 y/s)***

8. Now look at the last two seconds represented on the graph.

A. In the last 2 seconds, how far did the runner go? ***30 yards***

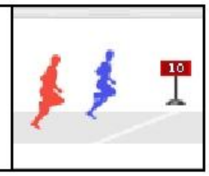
B. In this time interval, how far did the runner go each second? ***15 yards***

C. In this time interval, what was the runner's speed? ***15 yards/second (15 y/s)***

9. Click the **Reset** button. Experiment with a variety of graphs, focusing on the speed of the runner. In general, how can you estimate the speed of the runner by looking at a graph?

The steeper the line on the graph, the faster the runner.

Answer Key

Activity C: **Two runners, two graphs**	Get the Gizmo ready: • Click **Reset**. • Under **Runner 2**, turn on **Show graph** and **Show animation**.	

1. Experiment with the Gizmo to create each of the following results. (You can use any number of points in your graphs.) Each time you find a solution, click the **camera** ( ) next to the graph. Then paste the image into a blank document. Label all five images.
   [Answers will vary. Examples are shown at the end of this document.]
   - Runner 1 wins the race.
   - Runner 2 wins the race.
   - Runner 2 catches up to and passes runner 1.
   - Runner 2 is going in the opposite direction as runner 1.
   - Each runner goes at a different speed, but both reach the finish line together.

2. Based on your experiments, answer the following questions.

   A. How does the graph show if a runner gets a head start? ***The y-intercept will be greater for the runner with a head start.***

   B. How does the graph show which runner is faster? ***The graph with the steeper slope shows the faster runner.***

   C. How does the graph show which runner wins the race? ***The graph that reaches the 40-yard mark first belongs to the winner of the race.***

   D. How does the graph show a runner going back and forth? ***The line on the graph goes up and down.***

   E. What does it mean when the two runners' graphs cross? ***The point where the lines cross on the graph shows the time and distance at which one runner passes the other.***

3. Challenge: For **Runner 2**, turn off **Show graph**. Click **New** to generate a new random graph that you can't see for **Runner 2**. Click **Start**, and watch her run. Then try to adjust the graph for **Runner 1** so that his movements match the movements of **Runner 2**.

   Turn on **Show graph** to check each answer. (For a greater challenge, increase the **Number of points** before selecting **New**.)

   Check student work.

(Activity C continued on next page)

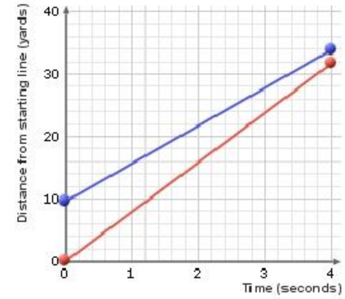
Answer Key

Activity C (continued from previous page)

4. <u>Challenge:</u> Use the Gizmo to model and solve the following word problems. Write the solutions in the spaces below. Sketch the graph you made to solve the question in the space to the right of each question.

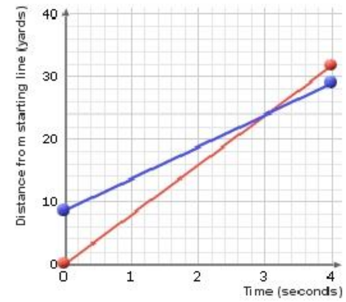
A. A dog is chasing a cat towards a tree. The cat has a 10-yard lead and runs at a speed of 6 yards per second. The dog runs at a speed of 8 yards per second. The tree is 30 yards away from the dog's starting position. Which animal will reach the tree first?

The cat reaches the tree first (in about 3.33 seconds). The dog reaches the tree in 3.75 seconds.



B. A police officer is chasing a purse-snatcher down a street. The thief starts 9 yards ahead of the officer and can run 20 yards in 4 seconds (5 y/s). The police officer can run 32 yards in 4 seconds (8 y/s). How long will it take the officer to catch the thief?

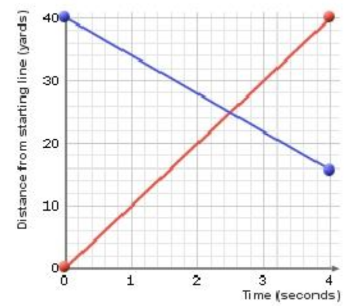
The police officer will catch the thief in 3 seconds.



C. In a football game, one team kicks off to the other. At the moment the receiver catches the ball, he is 40 yards from the nearest tackler. The receiver runs left to right at a speed of 10 yards per second (10 y/s). The tackler runs right to left at a speed of 6 yards per second.

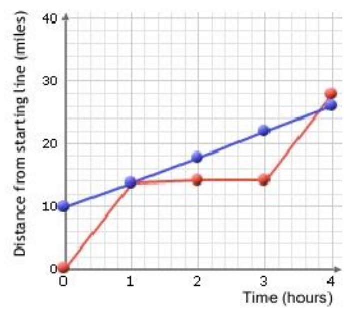
How long does it take before they collide? ***2.5 seconds***

How far does the receiver go? ***25 yards***



D. A tortoise challenges a hare to a four-hour race. The hare is so confident of winning that he allows the tortoise to start with a 10- mile lead. The hare runs at a speed of 14 miles per hour, but stops for a two-hour nap in the middle of the race. The tortoise plods along at 4 miles per hour the whole race. Who gets farther in four hours?

The hare (28 miles) goes farther than the tortoise (26 miles).

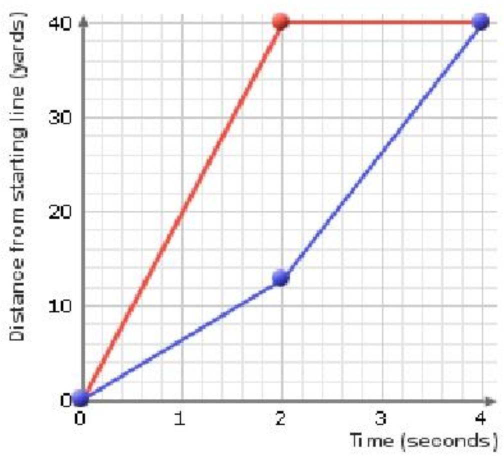


5. How are distance-time graphs useful? Explain, and if possible discuss your answer with your teacher and classmates.

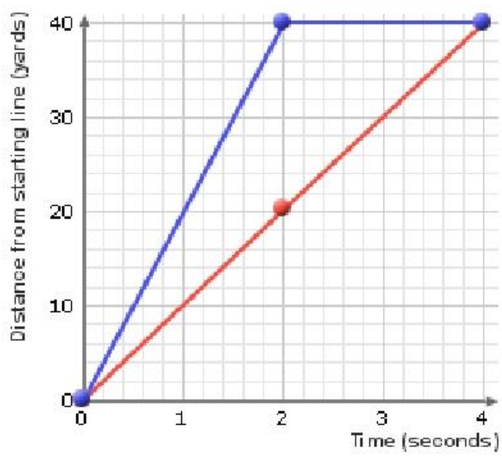
Answers will vary. Sample answer: Distance-time graphs show the starting position, direction, and speed of a moving object. If there are two objects, the distance-time graph can show which object is moving faster, which object has a head start, and when and where the two objects cross paths.

Answer Key

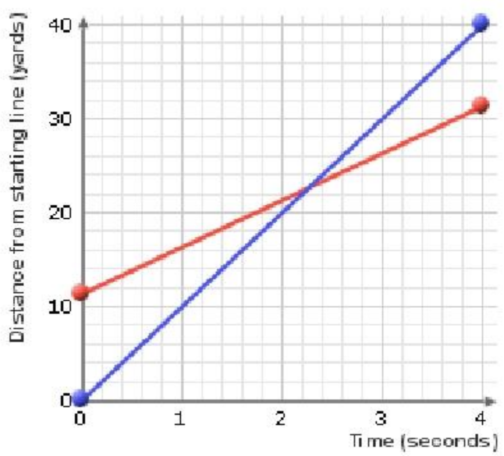
Sample graphs for Activity C, question 1 (actual student graphs will vary). Runner 1 graph is red, runner 2 graph is blue.



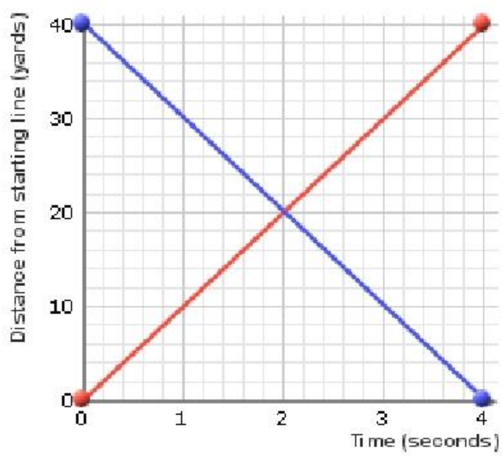
Runner 1 wins the race



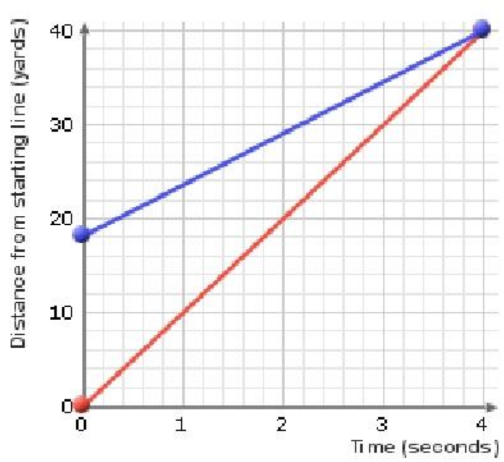
Runner 2 wins the race



Runner 2 catches up to and passes runner 1



Runner 2 is going the opposite direction as runner 1



Each runner goes at a different speed, but both reach the finish line together.

Name: ____ Date: _________________________

Student Exploration: Distance-Time Graphs

Vocabulary: speed, *y*-intercept

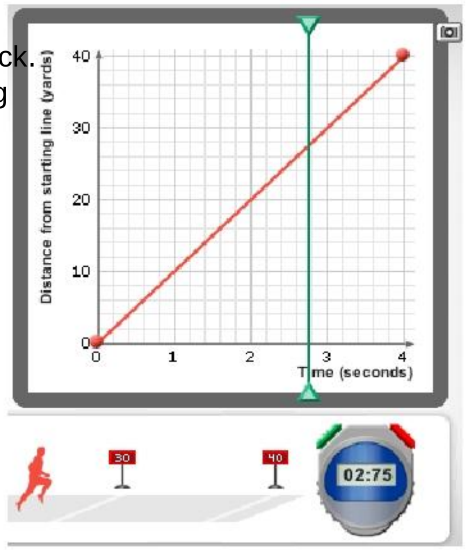
Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Max ran 100 feet in 10 seconds. Molly ran 60 feet in 5 seconds.

1. Who ran farther, Max or Molly? ________________

2. Who ran faster? ________________ Explain: ____________________________________

____

Gizmo Warm-up
The *Distance-Time Graphs* Gizmo$_{TM}$ shows a graph and a runner on a track. You can control the motion of the runner by manipulating the graph (drag the red dots).



Check that **Number of points** is 2, and that under **Runner 1** both **Show graph** and **Show animation** are turned on.

The graph should look like the one shown to the right - one point at (0, 0) and the other point at (4, 40).

3. Click the green **Start** button on the stopwatch.

What happens? _______________________________

____

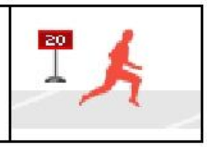
4. Click the red **Reset** button on the stopwatch. The vertical green **probe** on the graph allows you to see a snapshot of the runner at any point in time. Drag it back and forth. As you do, watch the runner and the stopwatch.

A. What was the position of the runner at 1 second? ______________________________

B. What are the coordinates of the point on the graph that tells you this? _____________

C. When was the runner on the 30-yard line? __________________________________

D. What are the coordinates of the point on the graph that tells you this? _____________

Activity A: **Runner position**	<u>Get the Gizmo ready:</u> • Click the red **Reset** button on the stopwatch. • Be sure the **Number of Points** is 2.	

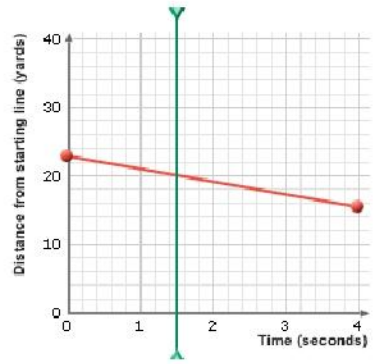
In the Gizmo, run the "race" many times with a variety of different graphs. (The red points on the graph can be dragged vertically.) Pay attention to what the graph tells you about the runner.

5. If a distance-time graph contains the point (4, 15), what does that tell you about the runner?

(Be specific, and answer in a complete sentence.) ___________________________________

____

6. Look at the graph to the right. Notice where the green probe is. If you could see the runner and the stopwatch at this moment, what would you see?



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7. Look at the image below, from the Gizmo. What must be true about this runner's graph?

____

____

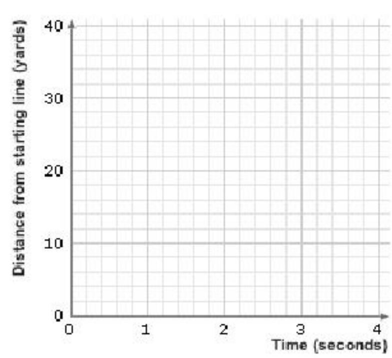
8. The point on the graph that lies on the *y*-axis (vertical axis) is called the ***y*-intercept**. What does the *y*-intercept tell you about the runner?

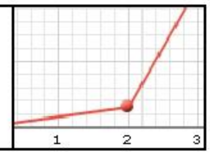
____

9. In the Gizmo, set the **Number of Points** to 3. Then create a graph of a runner who starts at the 20-yard line, runs to the 40-yard line, and finishes at the 30-yard line.

A. Sketch your graph to the right.

B. What is the *y*-intercept of your graph? _____________



Activity B: **Runner direction and speed**	<u>Get the Gizmo ready:</u> • Click the red **Reset** button on the stopwatch.	

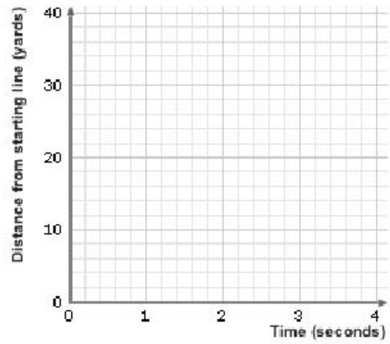
Run the Gizmo several times with different types of graphs. (Remember, the red points on the graph can be dragged vertically.) Pay attention to the speed and direction of the runner.

10. Create a graph of a runner that is running forward (from left to right) in the Gizmo. Sketch your graph to the right.

    If the runner is moving from left to right in the Gizmo, how does the graph always look?

    ____

    ____

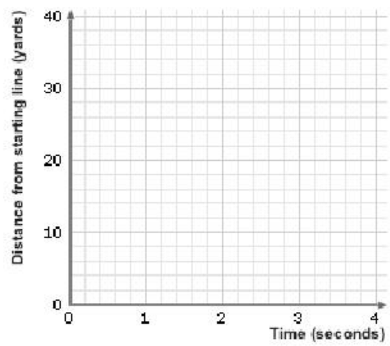


11. Click the red **Reset** button. Create a graph of a runner that is running from right to left. Sketch it to the right.

    How does the graph always look if the runner is moving from right to left in the Gizmo?

    ____

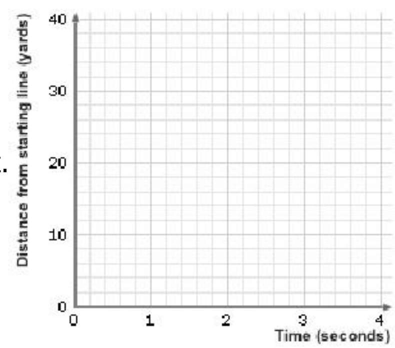
    ____



12. Change the **Number of Points** to 5. Create a graph of a runner that runs left-to-right for one second, rests for two seconds, and then continues running in the same direction. Sketch the graph to the right.

    How does a graph show a runner at rest? __________________

    ____



13. In general, how does a distance-time graph show you which direction the runner is moving?

    ____

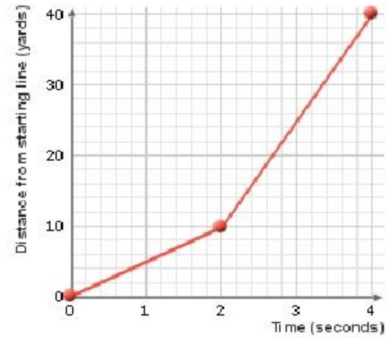
    ____

    ____

(Activity B continued on next page)

Activity B (continued from previous page)

14. With **Number of Points** set to 3, create the graph shown at right. Your graph should include (0, 0), (2, 10), and (4, 40).



A. Where does the runner start? ____________________

B. Where will he be after 2 seconds? ________________

C. Where will he be after 4 seconds? ________________

D. In which time interval do you think the runner will be moving most quickly? (Circle your answer below.)

0 to 2 seconds 2 to 4 seconds

15. Click the **Start** button and watch the animation. What about the runner changed after 2 seconds of running? ____

____

16. **Speed** is a measure of how fast something is moving. To calculate speed, divide the distance by the time. In the Gizmo, the units of speed are yards per second (y/s).

A. In the first 2 seconds, how far did the runner go? _____________________________

B. In this time interval, how far did the runner go each second? ___________________

C. In this time interval, what was the runner's speed? ____________________________

17. Now look at the last two seconds represented on the graph.

A. In the last 2 seconds, how far did the runner go? _____________________________

B. In this time interval, how far did the runner go each second? ___________________

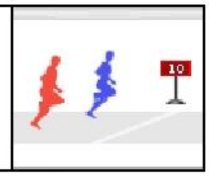
C. In this time interval, what was the runner's speed? ____________________________

18. Click the **Reset** button. Experiment with a variety of graphs, focusing on the speed of the runner. In general, how can you estimate the speed of the runner by looking at a graph?

____

____

____

Activity C: **Two runners, two graphs**	Get the Gizmo ready: • Click **Reset**. • Under **Runner 2**, turn on **Show graph** and **Show animation**.	

19. Experiment with the Gizmo to create each of the following results. (You can use any number of points in your graphs.) Each time you find a solution, click the **camera** ( ) next to the graph. Then paste the image into a blank document. Label all five images.

- Runner 1 wins the race.
- Runner 2 wins the race.
- Runner 2 catches up to and passes runner 1.
- Runner 2 is going in the opposite direction as runner 1.
- Each runner goes at a different speed, but both reach the finish line together.

20. Based on your experiments, answer the following questions.

A. How does the graph show if a runner gets a head start? ______________________

____

B. How does the graph show which runner is faster? ___________________________

____

C. How does the graph show which runner wins the race? _______________________

____

D. How does the graph show a runner going back and forth? _____________________

____

E. What does it mean when the two runners' graphs cross? _____________________

____

21. Challenge: For **Runner 2**, turn off **Show graph**. Click **New** to generate a new random graph that you can't see for **Runner 2**. Click **Start**, and watch her run. Then try to adjust the graph for **Runner 1** so that his movements match the movements of **Runner 2**.

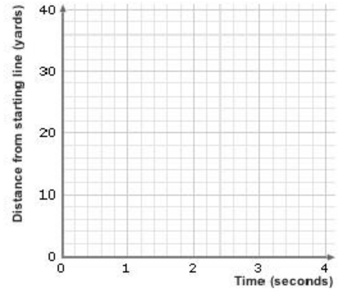
Turn on **Show graph** to check each answer. (For a greater challenge, increase the **Number of points** before selecting **New**.)

(Activity C continued on next page)

Activity C (continued from previous page)

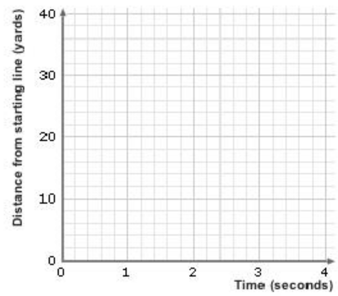
22. Challenge: Use the Gizmo to model and solve the following word problems. Write the solutions in the spaces below. Sketch the graph you made to solve the question in the space to the right of each question.

A. A dog is chasing a cat towards a tree. The cat has a 10-yard lead and runs at a speed of 6 yards per second. The dog runs at a speed of 8 yards per second. The tree is 30 yards away from the dog's starting position. Which animal will reach the tree first?



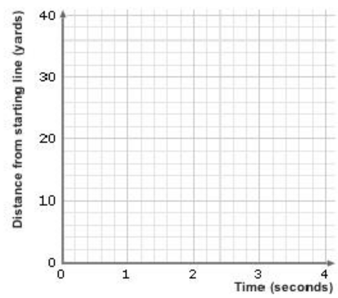
____

B. A police officer is chasing a purse-snatcher down a street. The thief starts 9 yards ahead of the officer and can run 20 yards in 4 seconds
(5 y/s). The police officer can run 32 yards in 4 seconds (8 y/s). How long will it take the officer to catch the thief?



____

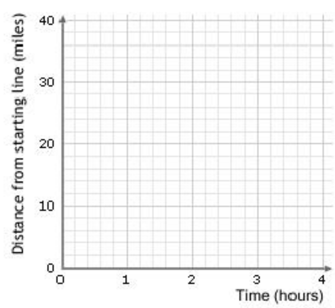
C. In a football game, one team kicks off to the other. At the moment the receiver catches the ball, he is 40 yards from the nearest tackler. The receiver runs left to right at a speed of 10 yards per second (10 y/s). The tackler runs right to left at a speed of 6 yards per second.



How long does it take before they collide? ___________

How far does the receiver go? _____________________

D. A tortoise challenges a hare to a four-hour race. The hare is so confident of winning that he allows the tortoise to start with a 10-mile lead. The hare runs at a speed of 14 miles per hour, but stops for a two-hour nap in the middle of the race. The tortoise plods along at 4 miles per hour the whole race. Who gets farther in four hours?



____

23. How are distance-time graphs useful? Explain, and if possible discuss your answer with your teacher and classmates.

____

____

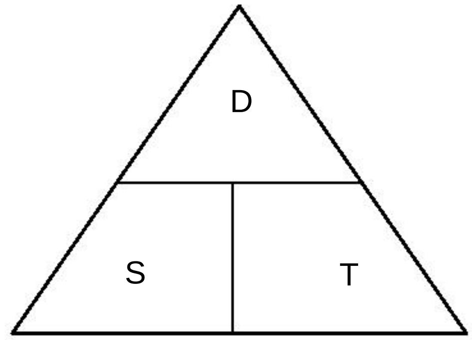
____

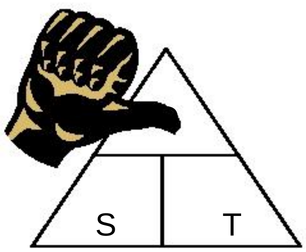
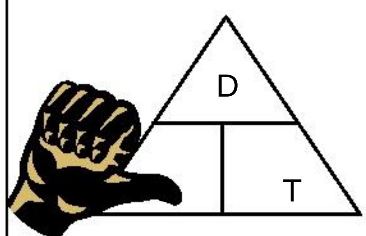
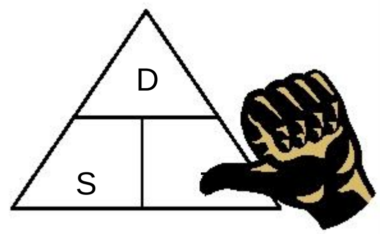
____

Strategy for Solving Speed, Distance, Time

Teacher page

1. Have student make an equilateral triangle.
2. Draw a line Horizontally
3. Draw a vertical from the midpoint on the horizontal line to the bottom of the triangle.
4. Label the top space with the letter "D" for distance.
5. Label the bottom left space with the letter "S" for speed.
6. Label the bottom right space with the letter "T" for time.
7. To solve each variable of distance, speed, or time; have students cover the variable that they want to solve. See Below.



Distance = speed x time	**Speed = distance / time**	**Time = distance / speed**
		

This page is helpful to students when they solve questions from the Physical Science Book:

Ancillary Materials → Skills and Practice Worksheets → 2.2 Speed

Formula Challenge

Name ______________________________________

What do the following units represent? Use D for distance, T for time, S for speed, or A for acceleration.

_____ 1. 14 km _____ 4. 6 hours _____ 7. 14 mi _____ 10. 1.4 m

_____ 2. 30 m/s _____ 5. 12 cm _____ 8. 3.2 sec _____ 11. 6 sec

_____ 3. 34 min _____ 6. 150 mph _____ 9. 25 ft _____ 12. 3 km/hr

Solve each problem! Be sure to show your work!

13. Goldie Goldfish, a speed swimmer, loves to race around the park's pond, which is 0.5 miles around. If she can swim 20 laps around the track in 2 hours, what is her average speed?

14. It takes Stu, a slimy slug, 20 minutes to travel from his favorite bush to the local trash can (a trip of 30 meters), and how far can he travel in 1 hour (60 minutes)?

15. At exactly 2:00 pm, Speedy the Snail crawls onto a meter stick at the 10 cm mark. If he reaches the 65 cm mark at exactly 2:10 pm, what is his speed?

16. If it takes Leaping Louie 5 minutes to jump 3 blocks, how long will it take for him to jump 15 blocks?

17. If Bert the Bat travels eastward at 40 mph with a tail wind of 6 mph, what is his actual speed?

Formula Challenge Answer Key

D 1. 14 km	**T** 4. 6 hours	**D** 7. 14 mi	**D** 10. 1.4 m
S 2. 30 m/s	**D** 5. 12 cm	**T** 8. 3.2 sec	**T** 11. 6 sec
T 3. 34 min	**S** 6. 150 mph	**D** 9. 25 ft	**S** 12. 3 km/hr

Solve each problem! Be sure to show your work!

13. Goldie Goldfish, a speed swimmer, loves to race around the park's pond, which is 0.5 miles around. If she can swim 20 laps around the track in 2 hours, what is her average speed?

20 x 0.5 = 10 miles ÷ 2 hours = 5 mph

14. It takes Stu, a slimy slug, 20 minutes to travel from his favorite bush to the local trash can (a trip of 30 meters), and how far can he travel in 1 hour (60 minutes)?

30 ÷ 20 = 1.5 m/min x 60 min = 90 m

15. At exactly 2:00 pm, Speedy the Snail crawls onto a meter stick at the 10 cm mark. If he reaches the 65 cm mark at exactly 2:10 pm, what is his speed?

65 cm - 10 cm = 55 cm ÷ 10 min = 5.5 cm/min

16. If it takes Leaping Louie 5 minutes to jump 3 blocks, how long will it take for him to jump 15 blocks?

3 blocks ÷ 5 min = 0.6 blocks/min 15 blocks ÷ 0.6 blocks/min = 25 min

17. If Bert the Bat travels eastward at 40 mph with a tail wind of 6 mph, what is his actual speed?

40 mph + 6 mph = 46 mph

Name: ______________________________

Motion Graphs

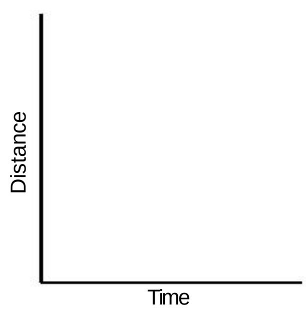
Describing the motion of an object is occasionally hard to do with words. Sometimes **graphs** help make motion easier to picture, and therefore easier to understand.

Remember:

- **Motion** ____
____
- **Speed** ____
____
- **Velocity** ____
____
- **Acceleration** ____
____

DISTANCE-TIME GRAPHS

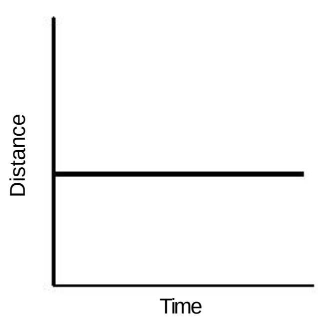
Plotting distance against time can tell you a lot about motion. Let's look at the axes:



Time is always plotted on the ________ (bottom of the graph). The further to the right on the axis, the longer the time from the start.

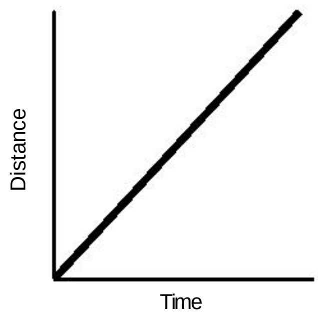
Distance is plotted on the ___________ (side of the graph). The higher up the graph, the further from the start.

If an object is not moving, a horizontal line is shown on a distance-time graph.



Time is increasing to the right, but its distance does not change. It is not moving. We say it is ___________.

If an object is moving at a constant speed, it means it has the same increase in distance in a given time.



Time is increasing to the right, and distance is increasing constantly with time. The object moves at a ________ ____________

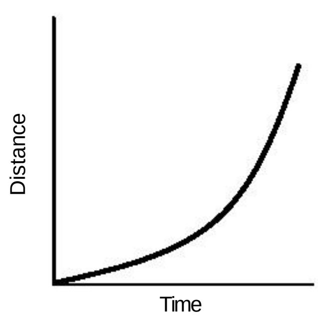
Constant speed ____________________
____

Let's look at two moving objects:
Both of the lines in the graph show that each object moved the same distance, but the steeper dashed line got there before the other one:

A steeper line indicates a larger distance
moved in a given time. In other words, __________________.

Both lines are __________, so both speeds are ____________.

Graphs that show acceleration look different from those that show constant speed.



The line on this graph is curving upwards. This shows an ______________________, since the line is getting steeper:

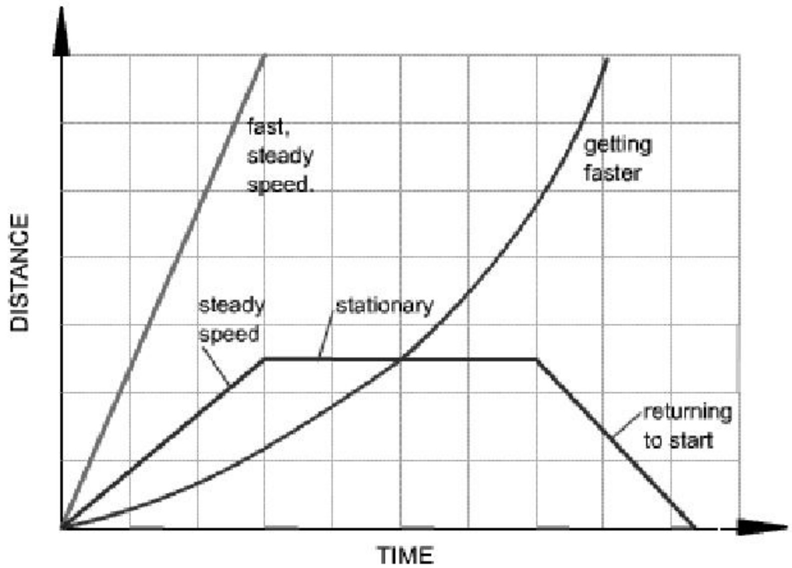
In other words, in a given time, the distance the object moves is change (getting larger). It is _____________.

M. Poarch - 2003
http://science-class.net

Summary:

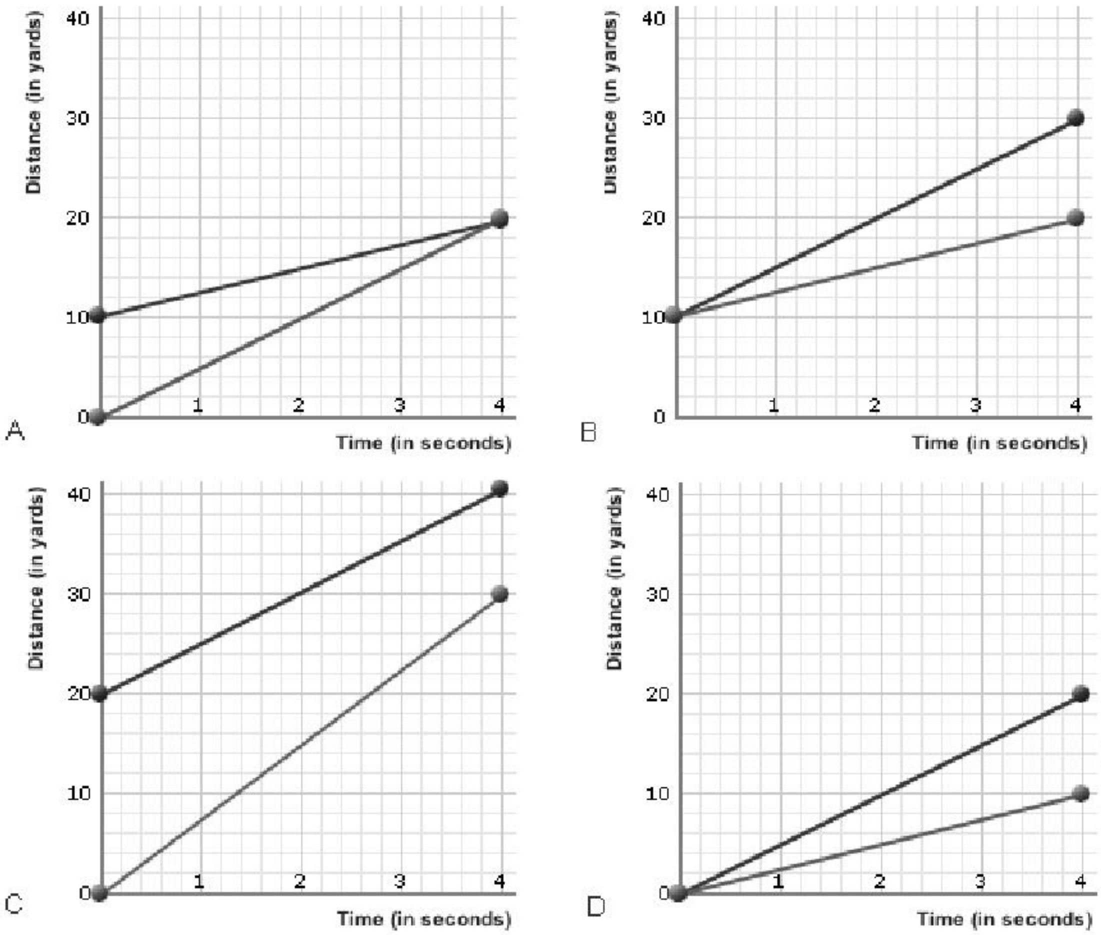
A distance-time graph tells us how far an object has moved with time.

- The ________ the graph, the ________ the motion.
- A ______________ line means the object is not changing its position - it is ________, it is at ________.
- A ______________ sloping line means the object is ______________ to the start.



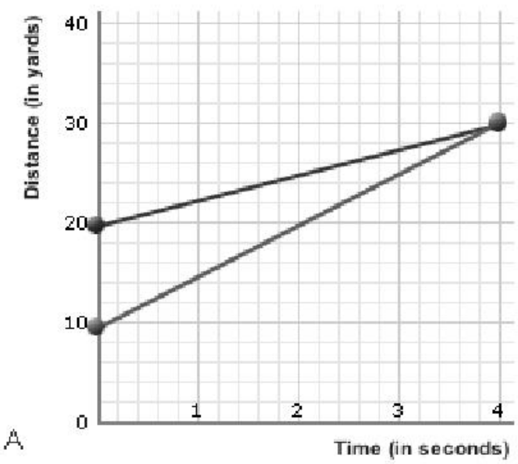
(Graph from: http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)

Examine the graphs below.

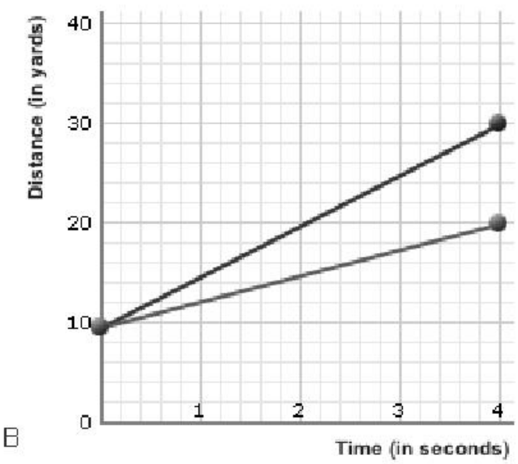


Which of the graphs shows that one of runners started 10 yards further ahead of the other? Explain your answer.

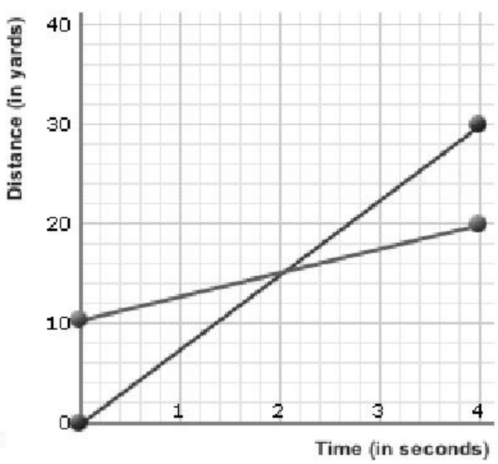
In which of the following graphs below are both runners moving at the same speed? Explain your answer.



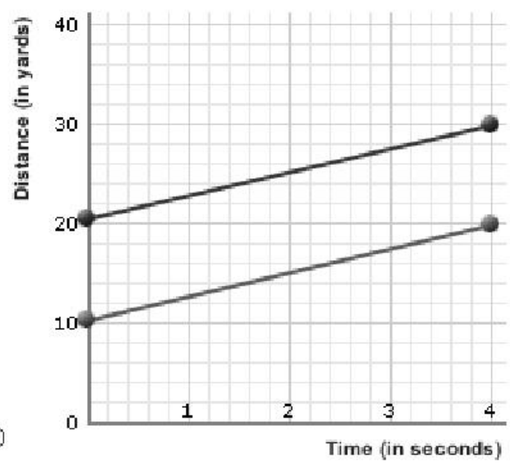
A



B



C

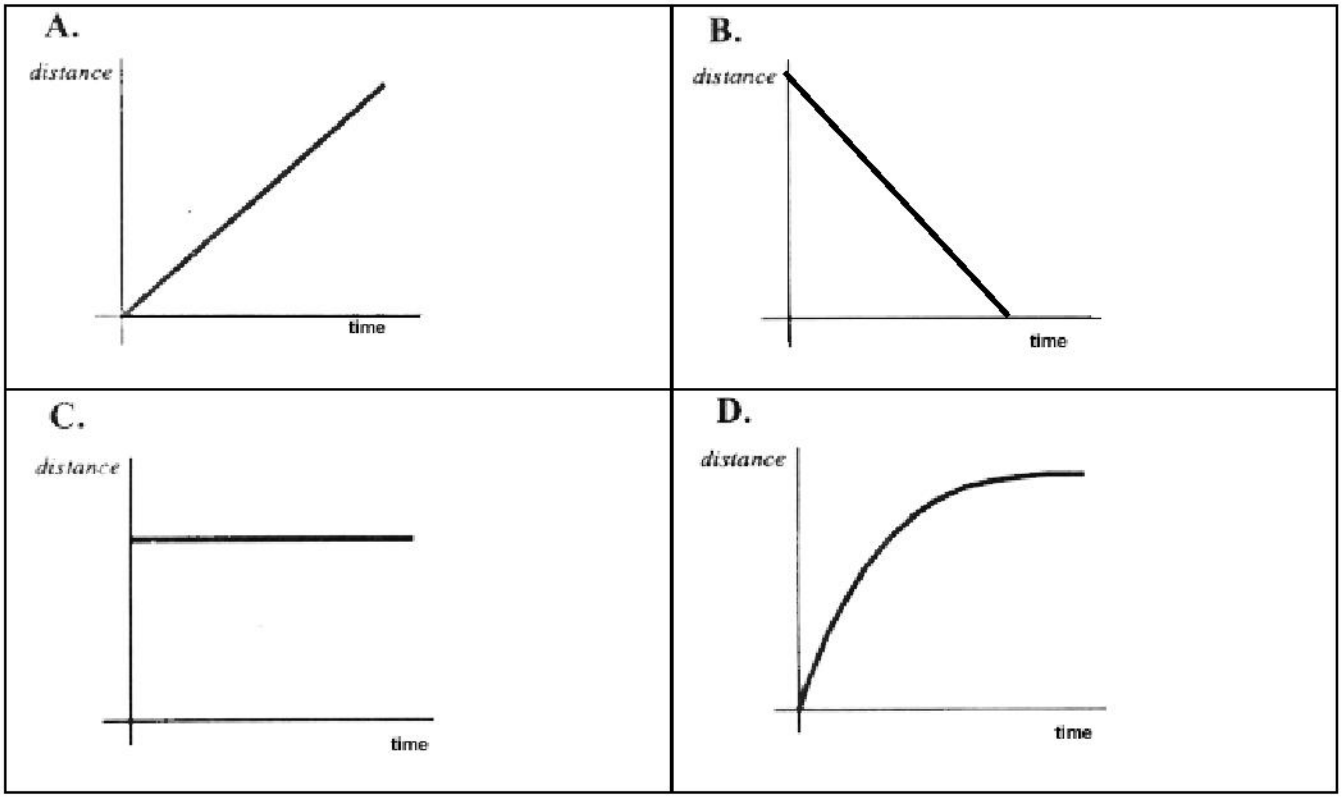


D

The distance-time graphs below represent the motion of a car. Match the descriptions with the graphs. **Explain your answers.**

Descriptions:

1. The car is stopped.
2. The car is traveling at a constant speed. 3. The speed of the car is decreasing. 4. The car is coming back.



Graph A matches description _____ because ___________________________________.

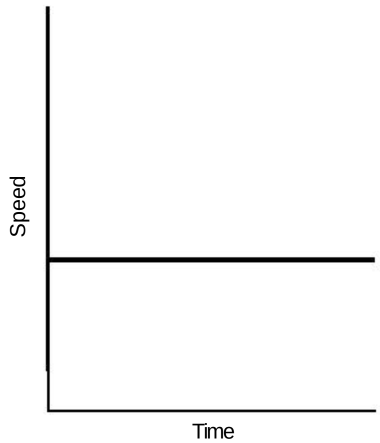
Graph B matches description _____ because ___________________________________.

Graph C matches description _____ because ___________________________________.

Graph D matches description _____ because ___________________________________.

SPEED-TIME GRAPHS

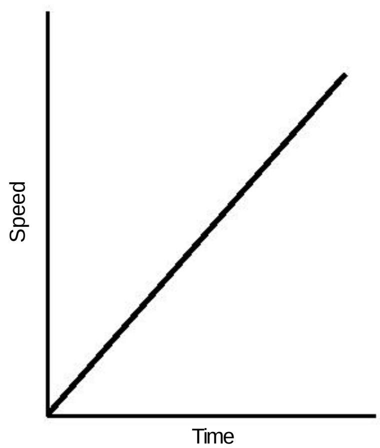
Speed-Time graphs are also called Velocity-Time graphs.



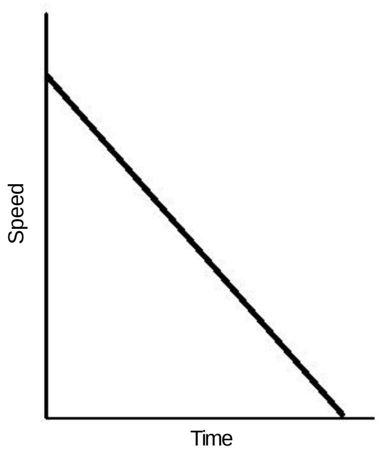
Speed-Time graphs look much like Distance-Time graphs. Be sure to read the labels!! **Time** is plotted on the ___________. Speed or velocity is plotted on the ________.

A straight horizontal line on a speed-time graph means that ____________________. It is not changing over time.

A straight line does **not** mean that the object is not moving!



This graph shows increasing speed.
The moving object is _______________.



This graph shows increasing speed.
The moving object has a ___________ ____________

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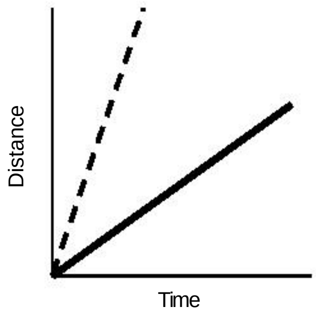
What about comparing two moving objects at the same time?



Both the dashed and solid line show increasing speed.

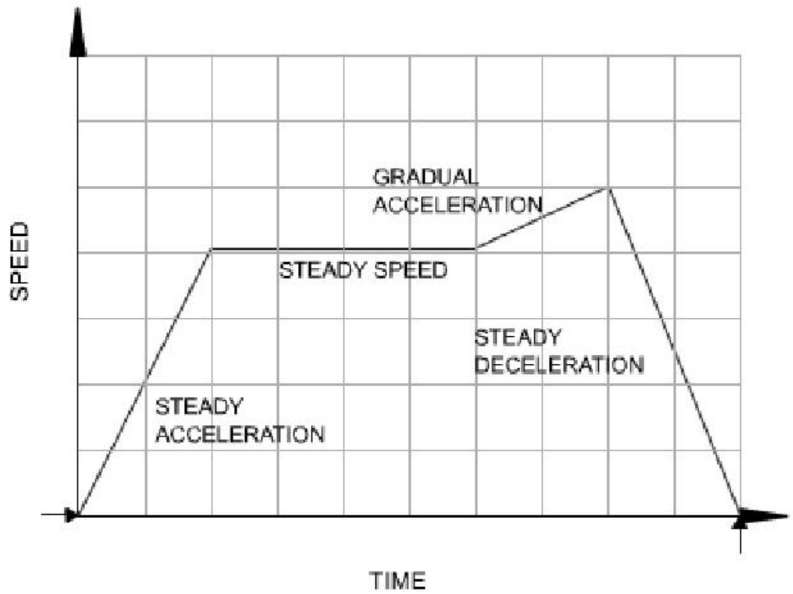
Both lines reach the same top speed, but the solid one takes longer.

The dashed line shows a ___________.

Summary:

A speed - time graph shows us how the speed of a moving object changes with time.

- The _________ the graph, the greater the ______________.
- A ________________ __________ means the object is moving at a ___________ __________.
- A ________________ sloping line means the object is _______________ down.



(Graph from: http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)

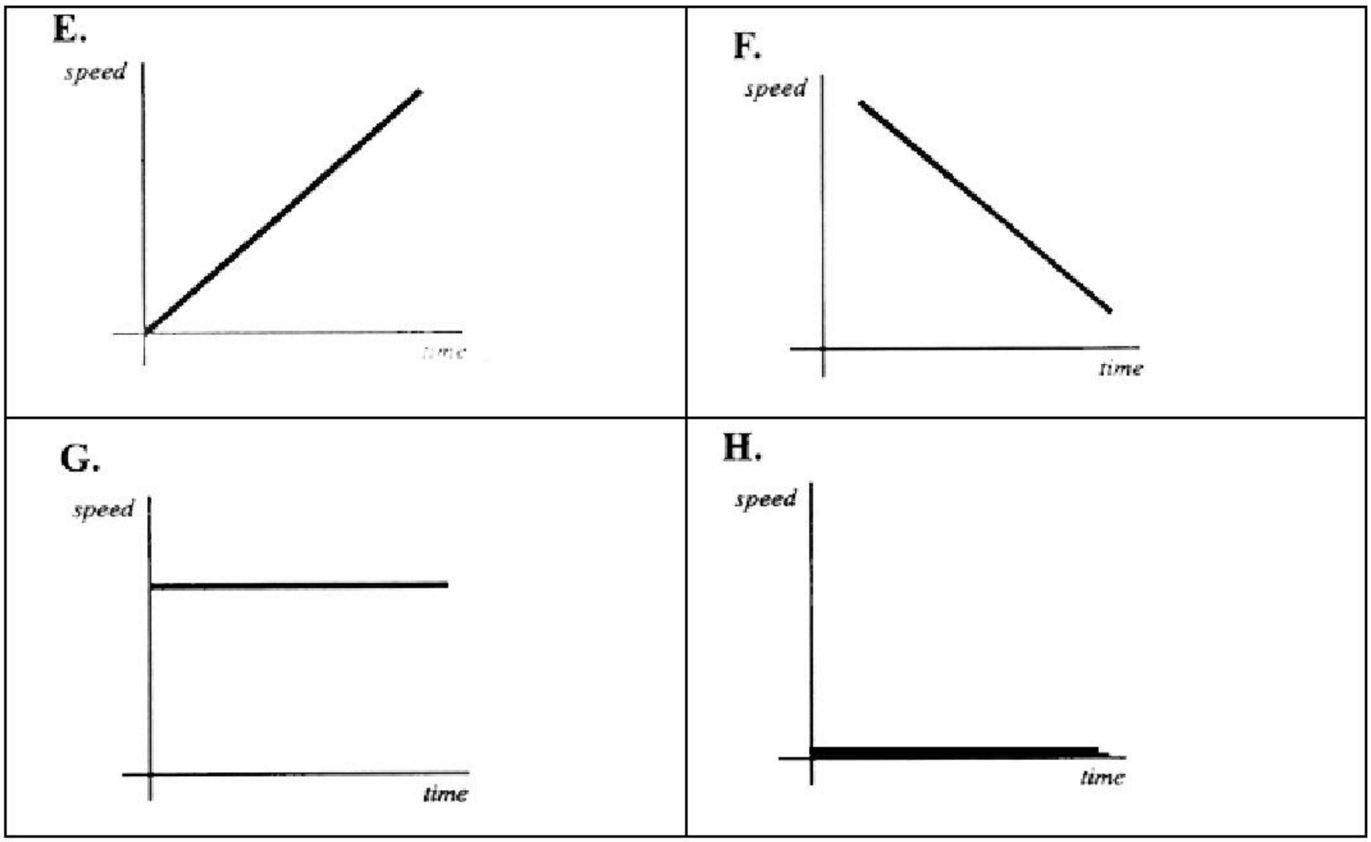
The speed-time graphs below represent the motion of a car. Match the descriptions with the graphs**. Explain your answers.**

Descriptions:

5. The car is stopped.

6. The car is traveling at a constant speed.

7. The car is increasing in speed at a constant rate. 8. The car is slowing down.



Graph E matches description _____ because ___________________________________.

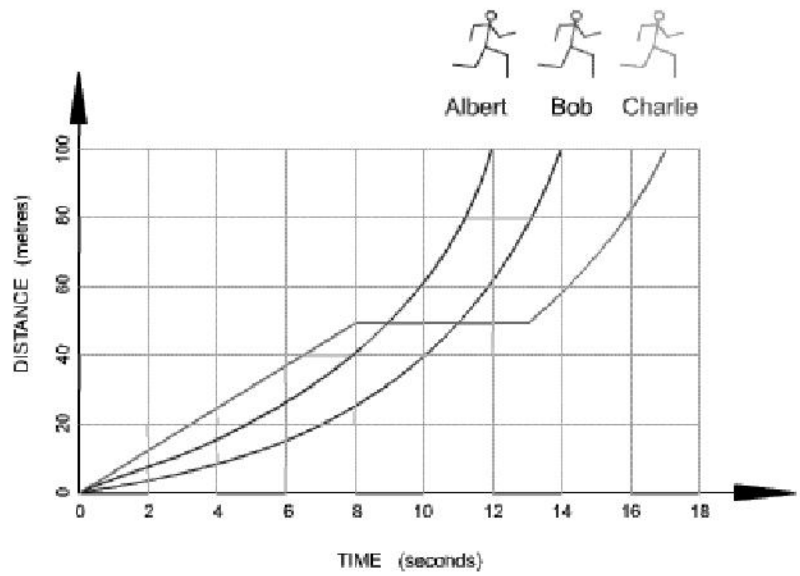
Graph F matches description _____ because ___________________________________.

Graph G matches description _____ because ___________________________________.

Graph H matches description _____ because ___________________________________.

Questions:

(Some questions adapted from http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)



Look at the graph above. It shows how three runners ran a 100-meter race.
Which runner won the race? Explain your answer.

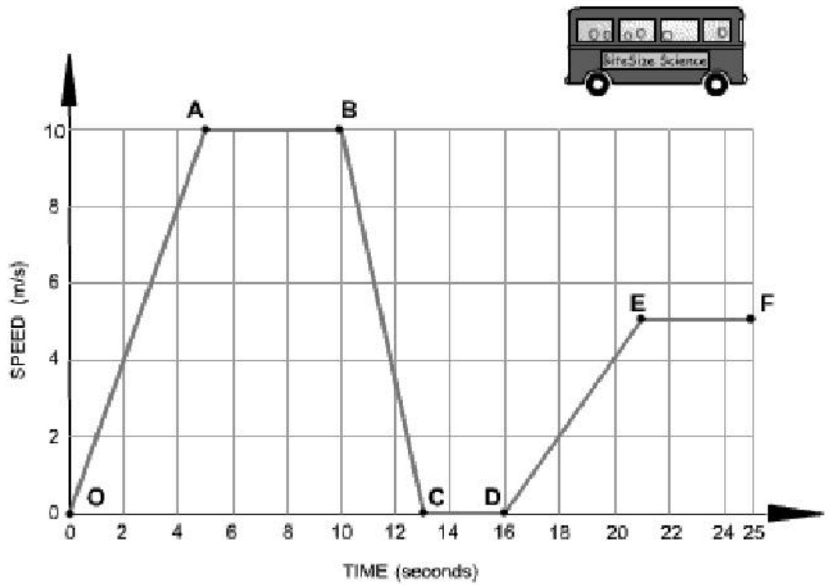
Which runner stopped for a rest? Explain your answer.

How long was the stop? Explain your answer.

How long did Bob take to complete the race? Explain your answer.

Calculate Albert's average speed. (Figure the distance and the time first!)

The graph below shows how the speed of a bus changes during part of a journey.



Choose the correct words from the following list to describe the motion during each segment of the journey to fill in the blanks.

- accelerating
- negative accelerating / decelerating
- constant speed
- at rest

Segment 0-A The bus is ______________________________. Its speed changes from 0 to 10 m/s in 5 seconds.

Segment A-B The bus is moving at a __________________________________of 10 m/s for 5 seconds.

Segment B-C The bus is ___________________________________. It is slowing down from 10 m/s to rest in 3 seconds.

Segment C-D The bus is ____. It has stopped.

Segment D-E The bus is ____.
It is gradually increasing in speed.

MOTION NOTES

Name: ______________________________

Motion Graphs

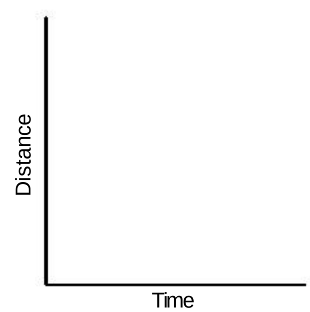
Describing the motion of an object is occasionally hard to do with words. Sometimes **graphs** help make motion easier to picture, and therefore easier to understand.

Remember:

- **Motion** is a change in position measured by distance and time.
- **Speed** tells us the rate at which an object moves.
- **Velocity** tells the speed and direction of a moving object.
- **Acceleration** tells us the rate speed or direction changes.

DISTANCE-TIME GRAPHS

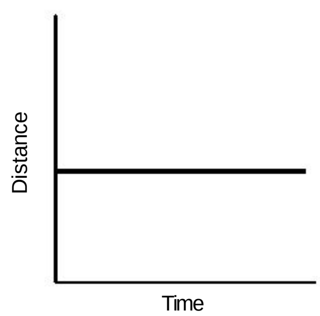
Plotting distance against time can tell you a lot about motion. Let's look at the axes:



Time is always plotted on the X-axis (bottom of the graph). The further to the right on the axis, the longer the time from the start.

Distance is plotted on the Y-axis (side of the graph). The higher up the graph, the further from the start.

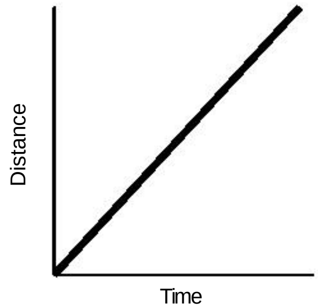
If an object is not moving, a horizontal line is shown on a distance-time graph.



Time is increasing to the right, but its distance does not change. It is not moving. We say it is **At Rest**.

MOTION NOTES

If an object is moving at a constant speed, it means it has the same increase in distance in a given time.



Time is increasing to the right, and distance is increasing constantly with time. The object moves at a **constant speed**.

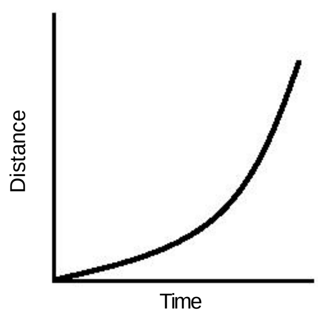
Constant speed is shown by straight lines on a graph.

Let's look at two moving objects:
Both of the lines in the graph show that each object moved the same distance, but the steeper dashed line got there before the other one:

A steeper line indicates a larger distance
moved in a given time. In other words, **higher speed**.

Both lines are **straight**, so both speeds are **constant**.

Graphs that show acceleration look different from those that show constant speed.



The line on this graph is curving upwards. This shows an **increase in speed**, since the line is
getting steeper:

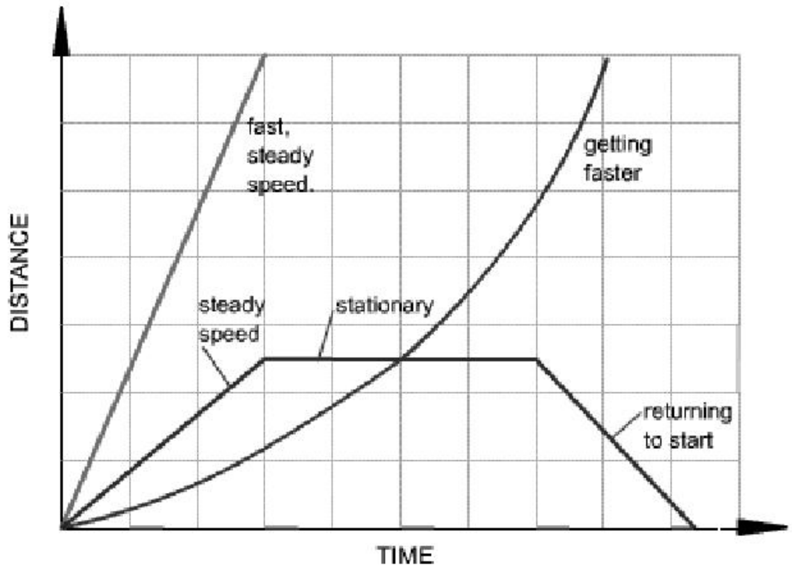
In other words, in a given time, the distance the object moves is change (getting larger). It is **accelerating**.

MOTION NOTES

Summary:

A distance-time graph tells us how far an object has moved with time.

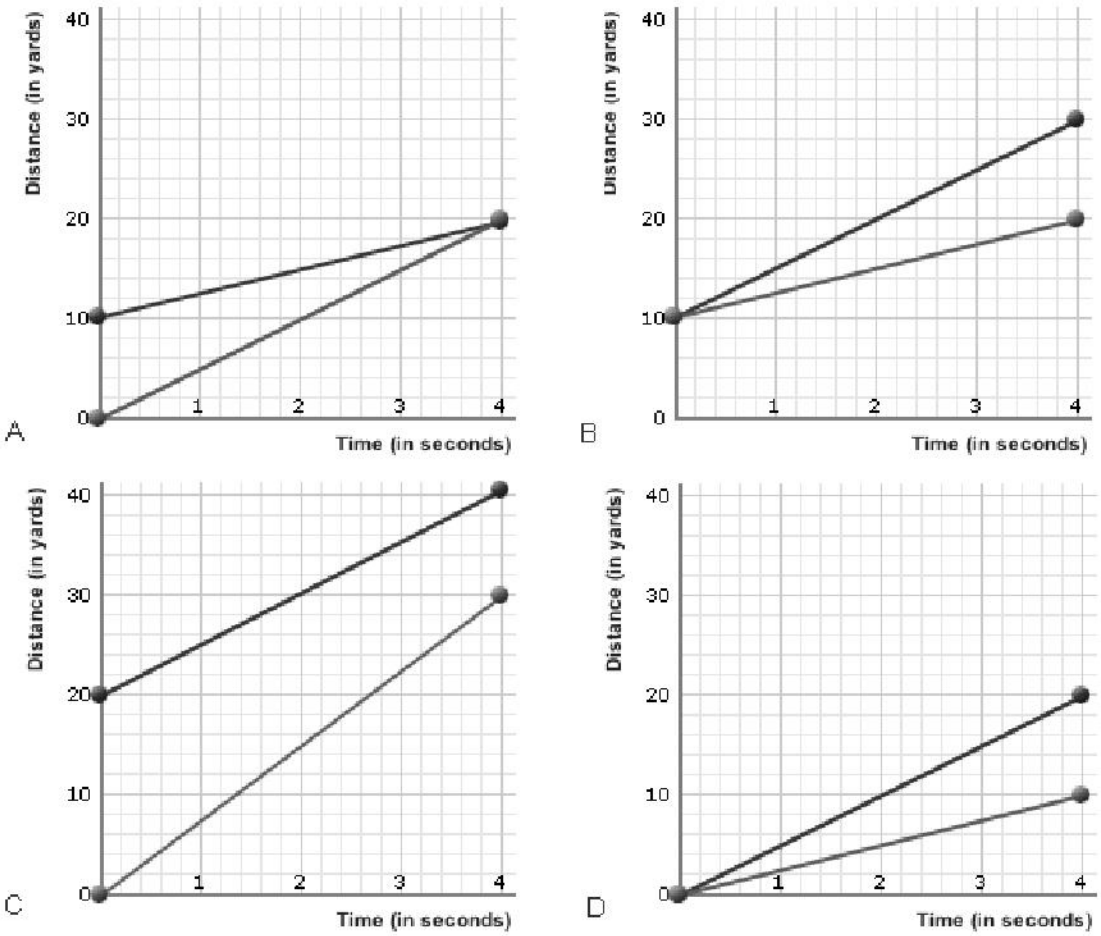
- The steeper the graph, the faster the motion.
- A horizontal line means the object is not changing its position - it is not moving, it is at rest.
- A downward sloping line means the object is returning to the start.



(Graph from: http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)

MOTION NOTES

Examine the graphs below.



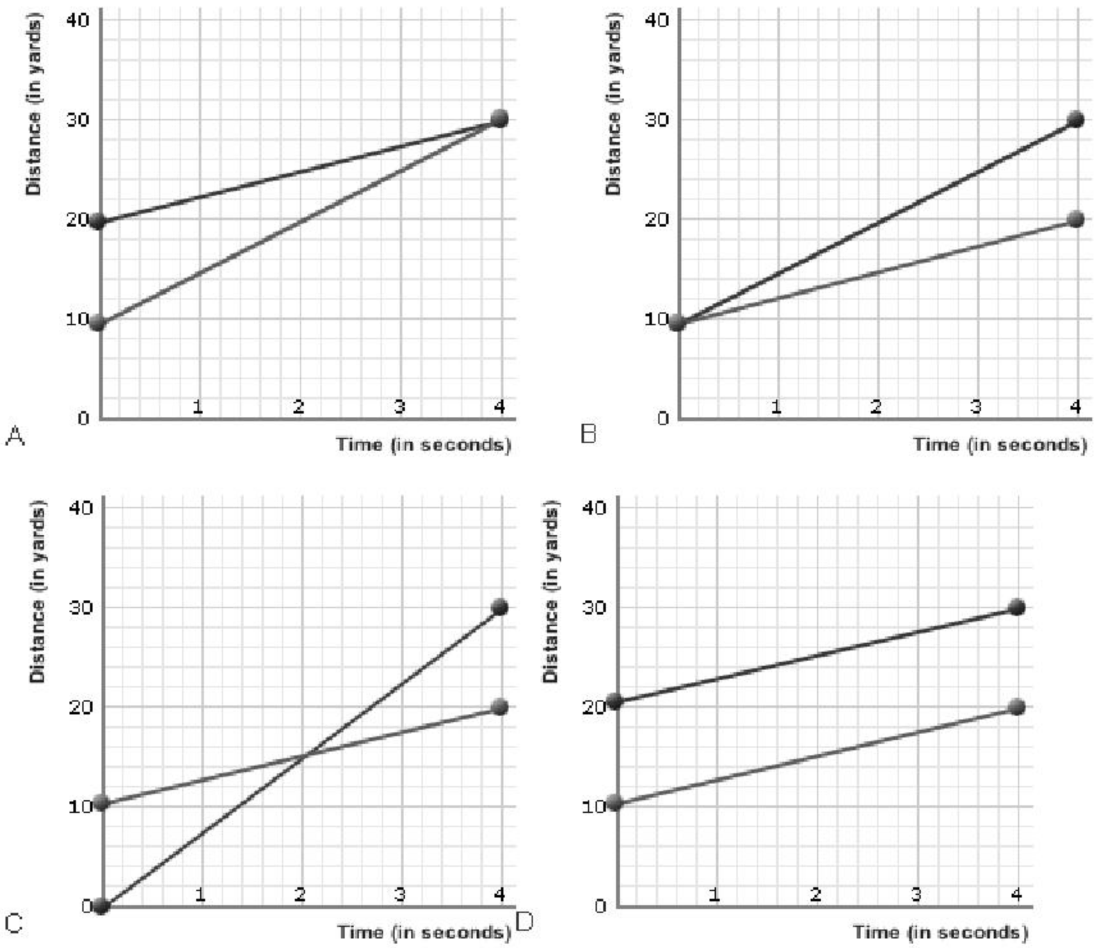
Which of the graphs shows that one of the runners started 10 yards further ahead of the other? Explain your answer.

Graph A

If you look at the time 0 sec on the x-axis and distance (in yards) on the y-axis, you can see that it has a runner on the 0 yard and 10 yard.

MOTION NOTES
In which of the following graphs below are both runners moving at the same speed? Explain your answer.

Graph D
Both have the sam e slope therefore they are covering the sam e distance at the sam e am ount of tim e.

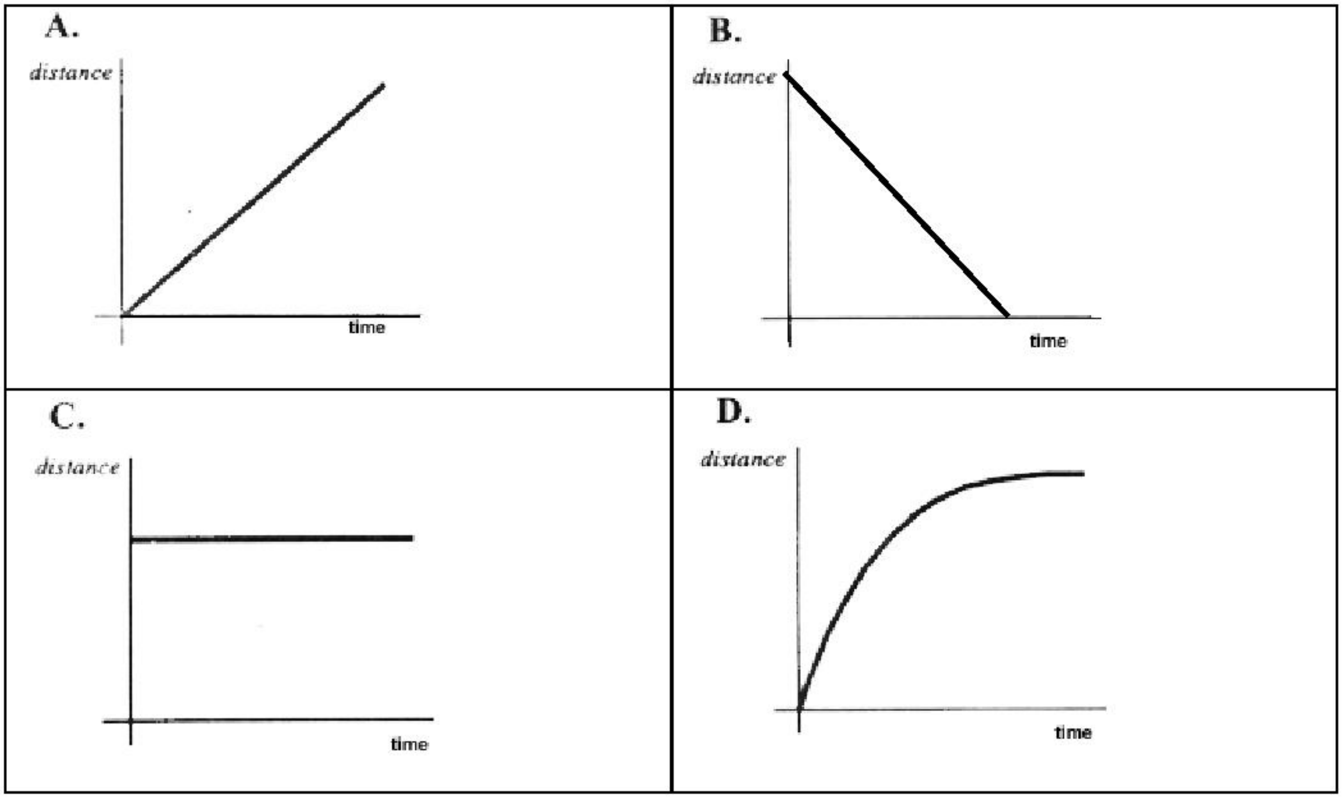


MOTION NOTES KEY

The distance-time graphs below represent the motion of a car. Match the descriptions with the graphs. **Explain your answers.**

Descriptions:

1. The car is stopped. ***C***
2. The car is traveling at a constant speed. ***A***
3. The speed of the car is decreasing. ***D***
4. The car is coming back. ***B***



Graph A matches description __***2***__ because ***Time and Distance both increase to the right in a straight line.***

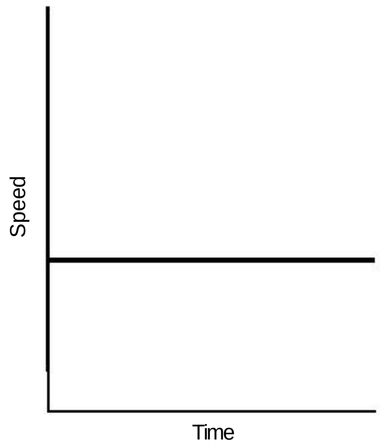
Graph B matches description __***4***__ because ***The line is sloping down showing a decrease in distance to the starting point.***

Graph C matches description __***1***__ because ***A horizontal line shows no change in distance over time, which means the object is not moving.***

Graph D matches description __***3***__ because ***The curved line is bending to the right show that as time goes on the distance covered is less, therefore it is slowing down.***

SPEED-TIME GRAPHS

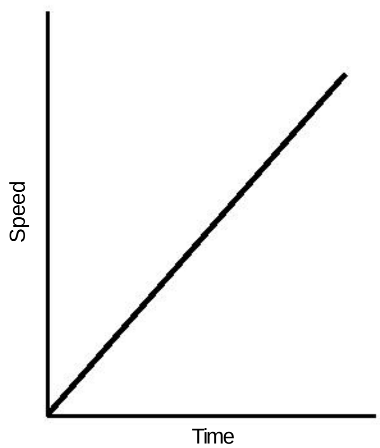
Speed-Time graphs are also called Velocity-Time graphs.



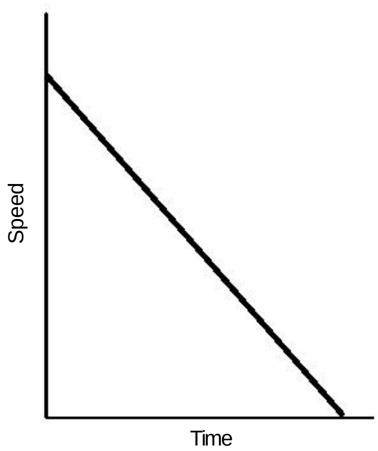
Speed-Time graphs look much like Distance-Time graphs. Be sure to read the labels!! Time is plotted on the X-axis. Speed or velocity is plotted on the Y-axis.

A straight horizontal line on a speed-time graph means that speed is constant. It is not changing over time.

A straight line does not mean that the object is not moving!

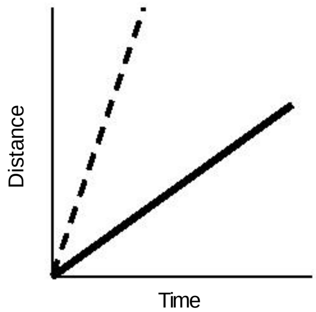


This graph shows increasing speed. The moving object is **accelerating.**



This graph shows increasing speed. The moving object has a **negative acceleration.**

What about comparing two moving objects at the same time?



Both the dashed and solid line show increasing speed.

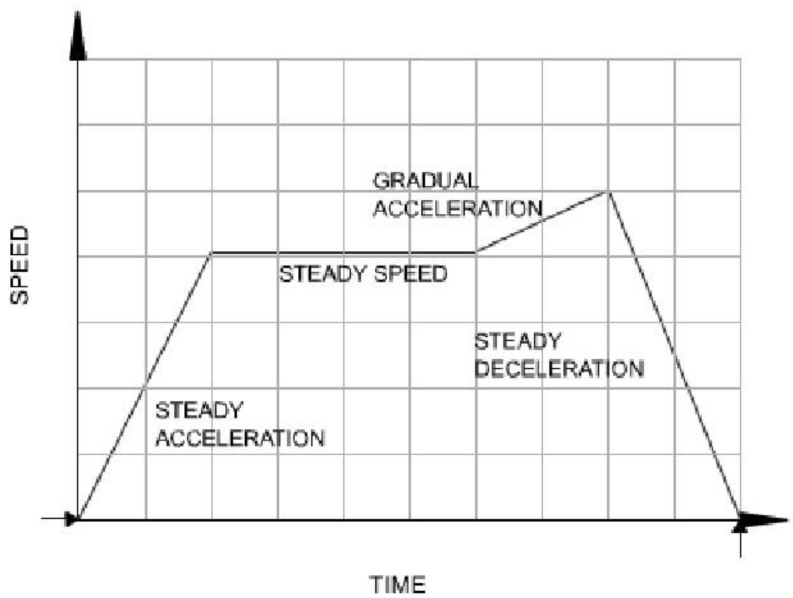
Both lines reach the same top speed, but the solid one takes longer.

The dashed line shows a greater acceleration.

Summary:

A speed - time graph shows us how the speed of a moving object changes with time.

- The steeper the graph, the greater the acceleration.
- A horizontal line means the object is moving at a constant speed.
- A downward sloping line means the object is slowing down.



(Graph from: http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)

The speed-time graphs below represent the motion of a car. Match the descriptions with the graphs**. Explain your answers.**

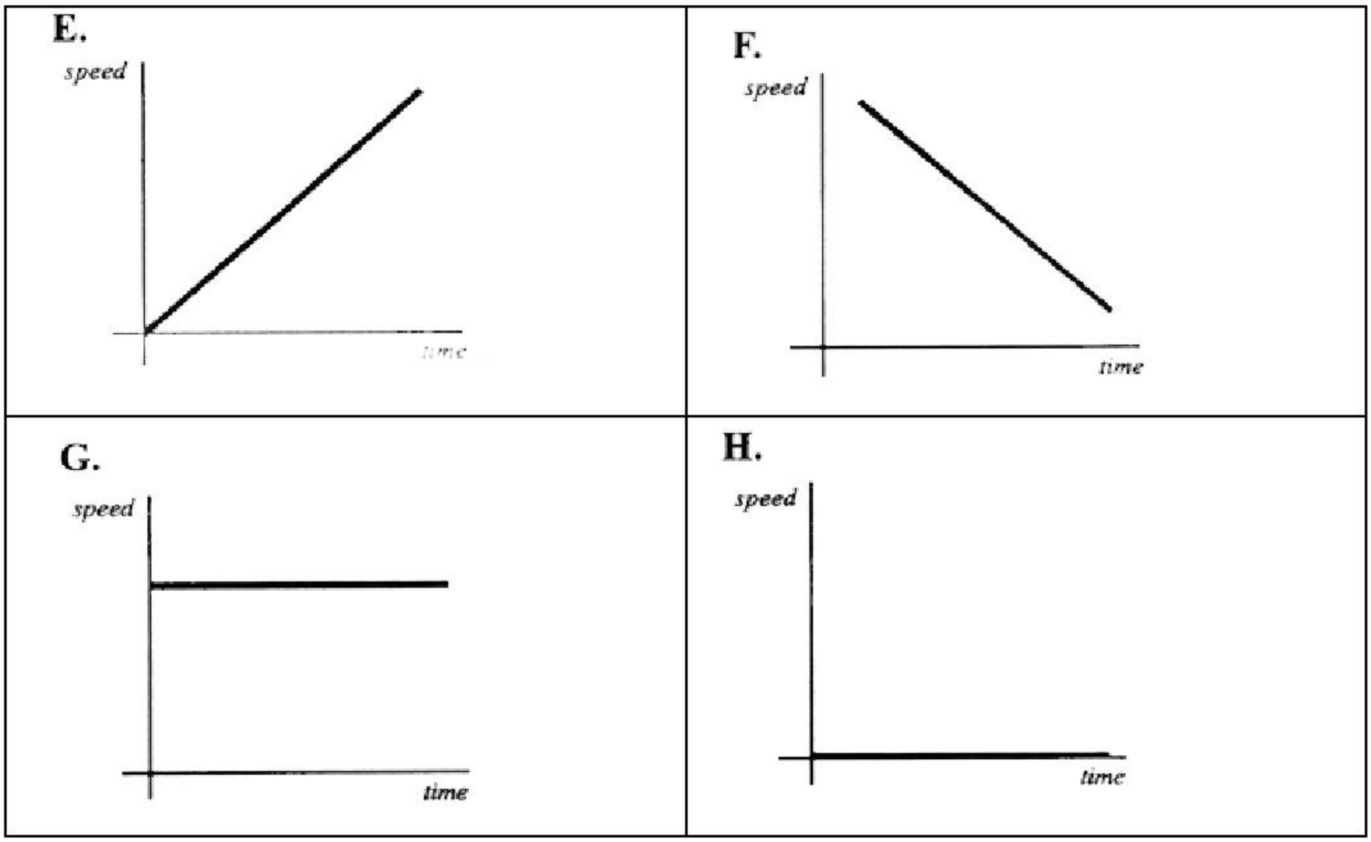
Descriptions:

5. The car is stopped. ***H***

6. The car is traveling at a constant speed. ***G***

7. The car is increasing in speed at a constant rate. ***E***

8. The car is slowing down at a constant rate. ***F***



Graph E matches description __***7***_ because ***speed and Time increase to the right.***___

Graph F matches description __***8***_ because ***the line is sloping down (getting slower as time goes on) and it is straight (showing a constant rate).***_

Graph G matches description __***6***__because ***the line is a straight horizontal line showing an increase in speed at a constant rate.***_

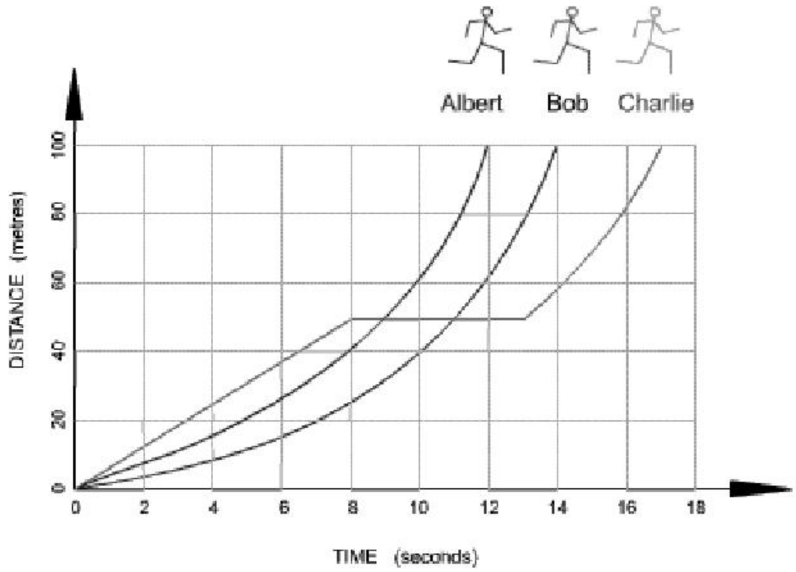
Graph H matches description __***5***_ because ***the line is a straight horizontal line at 0 speed, which means that it is stopped or not moving.***_

M. Poarch - 2003
http://science-class.net

Questions:

(Some questions adapted from http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/speedvelocityaccelerationfhrev2.shtml)

Bob covered 100 meters in 14 seconds, his average speed was 100m/14s = 7.14 m/s



Look at the graph above. It shows how three runners ran a 100-meter race.
Which runner won the race? Explain your answer.
Albert won since he covered 100 meters in 10 seconds. Bob covered 100 meters in 14 seconds and Charlie covered 100 meters in 16 seconds
Albert average speed = 100m/10s = 10 m/s Bob average speed = 100m/14s = 7.14 m/s
Charlie average speed = 100m/16 = 6.26 m/s

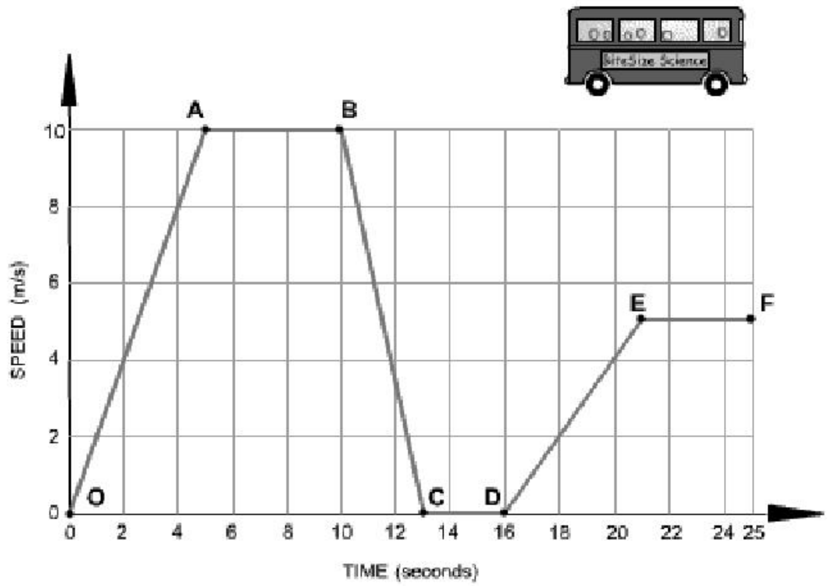
Which runner stopped for a rest? Explain your answer.
Charlie stopped and took a break at second 8 through 13, which means that he did not change his distance for 5 seconds, which is represented by a horizontal line.

How long was the stop? Explain your answer.
Charlie stopped at second 8 through 13, which means that he did not change his distance for 5 seconds, which is represented by a horizontal line.

How long did Bob take to complete the race? Explain your answer.

Calculate Albert's average speed. (Figure the distance and the time first!)
Albert speed = 100m/10s = 10 m/s

The graph below shows how the speed of a bus changes during part of a journey.



Choose the correct words from the following list to describe the motion during each segment of the journey to fill in the blanks.

- speeding up
- slowing down
- constant speed
- at rest

Segment 0-A The bus is _______***speeding up***___________. Its speed changes from 0 to 10 m/s in 5 seconds.

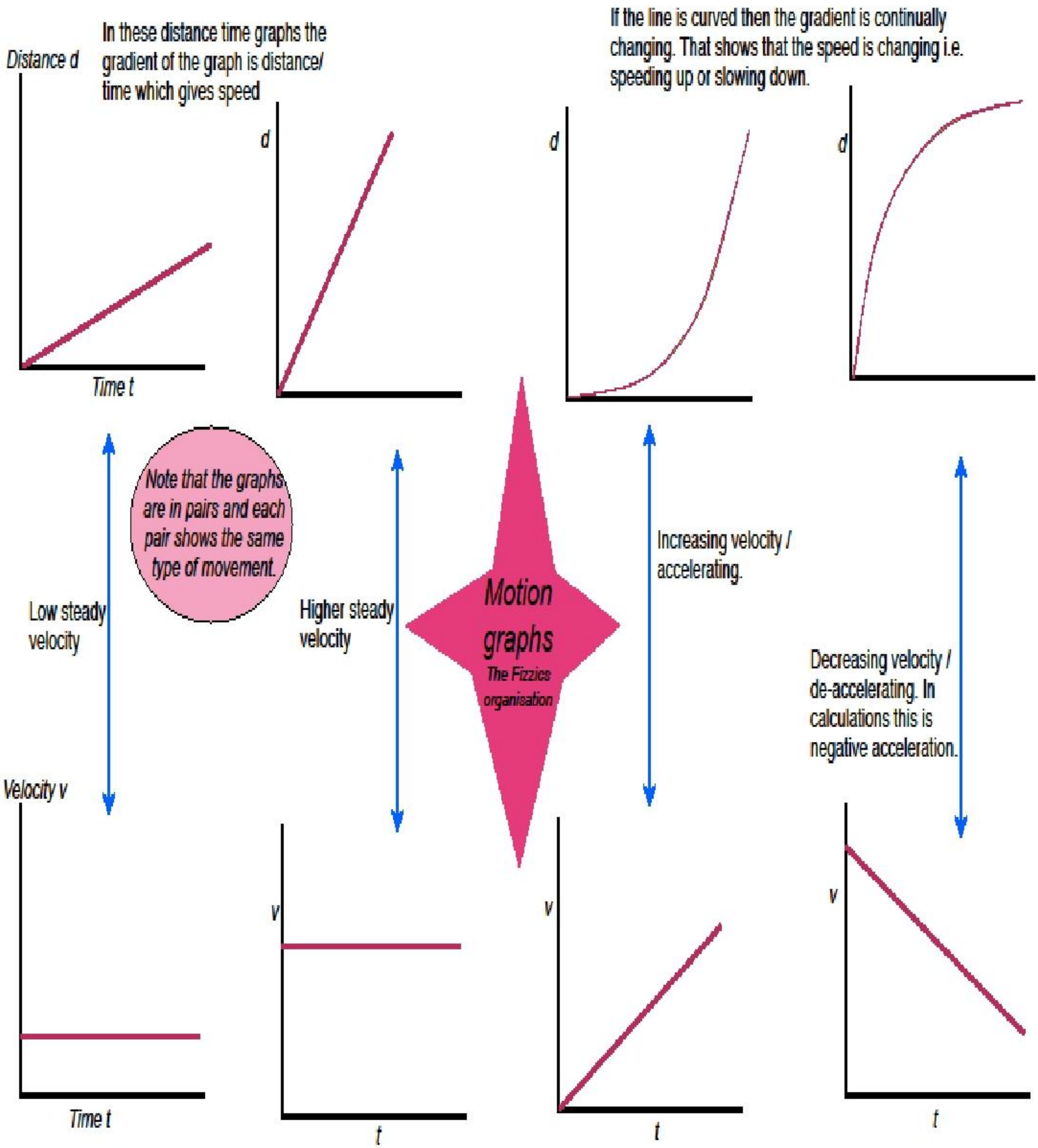
Segment A-B The bus is moving at a _______***constant speed***_________of 10 m/s for 5 seconds.

Segment B-C The bus is _______***slowing down***___________. It is slowing down from 10 m/s to rest in 3 seconds.

Segment C-D The bus is _______***at rest***_______. It has stopped.

Segment D-E The bus is _______***speeding up***___________. It is gradually increasing in speed.

Teacher Graphic Organizer for Distance v. Time and Speed v. Time graphs



The gradient of the line on a velocity time graph gives the acceleration. In the first two the horizontal line shows a steady speed (no acceleration)

A straight line shows constant acceleration. The downward gradient shows de- acceleration or negative acceleration.

http://www.fizzics.org/Documents/Motion%20graphs.pdf

Teacher Page
Skill and Practice Worksheet
Speed 2.0

There are varying levels of questions in the following worksheet. Below contains a graphic organizer to help with this, please adjust question as need. An answer template is available for students to use to complete the questions.

* Signify multiple questions within the number.

Basic Question	Average Question	Extended Questions
1, 2 , 3, 4 , 9 , 11 , 14 , 15, 16, 17, 18, 20	7, 8* , 10* , 12* , 13* , 21, 22, 23, 24,	5, 6, 19,
25*		

Name: ______________________________

Speed 2.0
Student Answer Sheet

____

Looking for	Solution
Given	
Relationships	

____

Looking for	Solution
Given	
Relationships	

____

Looking for	Solution
Given	
Relationships	

____

Looking for	Solution
Given	
Relationships	

Name: ________________________________

Speed

To determine the speed of an object, you need to know the distance traveled and the time taken to travel that distance. If you know the speed, you can determine the distance traveled or the time it took—you just rearrange the formula for speed, $v = d/t$. For example,

Equation...	Gives you...	If you know...
$v = d/t$	speed	distance and time
$d = v \times t$	distance	speed and time
$t = d/v$	time	distance and speed

Use the SI system to solve the practice problems unless you are asked to write the answer using the English system of measurement. As you solve the problems, include all units and cancel appropriately.

EXAMPLE ▶

Example 1: What is the speed of a cheetah that travels 112.0 meters in 4.0 seconds?

Looking for	Solution
Speed of the cheetah.	$\text{speed} = \frac{d}{t} = \frac{112.0\text{ m}}{4.0\text{ s}} = \frac{28\text{ m}}{\text{s}}$ The speed of the cheetah is 28 meters per second.
Given Distance = 112.0 meters Time = 4.0 seconds	
Relationship $\text{speed} = \frac{d}{t}$	

Example 2: There are 1,609 meters in one mile. What is this cheetah's speed in miles/hour?

Looking for	Solution
Speed of the cheetah in miles per hour.	$\frac{28\text{ m}}{\text{s}} \times \frac{1\text{ mile}}{1{,}609\text{ m}} \times \frac{3{,}600\text{ s}}{1\text{ hour}} = \frac{63\text{ miles}}{\text{hour}}$ The speed of the cheetah in miles per hour is 63 mph.
Given Distance = 112.0 meters Time = 4.0 seconds	
Relationships $\text{speed} = \frac{d}{t}$ and 1, 609 meters = 1 mile	

Name: ______________________________

PRACTICE

1. A bicyclist travels 60.0 kilometers in 3.5 hours. What is the cyclist's average speed?

Looking for	Solution
Given	
Relationships	

2. What is the average speed of a car that traveled 300.0 miles in 5.5 hours?

3. How much time would it take for the sound of thunder to travel 1,500 meters if sound travels at a speed of 330 m/s?

4. How much time would it take for an airplane to reach its destination if it traveled at an average speed of 790 kilometers/hour for a distance of 4,700 kilometers? What is the airplane's speed in miles/ hour?

5. How far can a person run in 15 minutes if he or she runs at an average speed of 16 km/hr? (HINT: Remember to convert minutes to hours.)

6. In problem 5, what is the runner's distance traveled in miles?

7. A snail can move approximately 0.30 meters per minute. How many meters can the snail cover in 15 minutes?

8. You know that there are 1,609 meters in a mile. The number of feet in a mile is 5,280. Use these equalities to answer the following problems:

   a. How many centimeters equals one inch?

   b. What is the speed of the snail in problem 7 in inches per minute?

9. Calculate the average speed (in km/h) of a car stuck in traffic that drives 12 kilometers in 2 hours.

10. How long would it take you to swim across a lake that is 900 meters across if you swim at 1.5 m/s?

    a. What is the answer in seconds?

    b. What is the answer in minutes?

11. How far will a you travel if you run for 10 minutes at 2 m/s?

12. You have trained all year for a marathon. In your first attempt to run a marathon, you decide that you want to complete this 26-mile race in 4.5 hours.

    a. What is the length of a marathon in kilometers (1 mile = 1.6 kilometers)?

    b. What would your average speed have to be to complete the race in 4.5 hours? Give your answer in kilometers per hour.

Name: ______________________________

2.2

13. Suppose you are walking home after school. The distance from school to your home is five kilometers. On foot, you can get home in 25 minutes. However, if you rode a bicycle, you could get home in 10 minutes.

    a. What is your average speed while walking?

    b. What is your average speed while bicycling?

    c. How much faster do you travel on your bicycle?

14. Suppose you ride your bicycle to the library traveling at 0.5 km/min. It takes you 25 minutes to get to the library. How far did you travel?

15. You ride your bike for a distance of 30 km. You travel at a speed of 0.75 km/ minute. How many minutes does this take?

16. A train travels 225 kilometers in 2.5 hours. What is the train's average speed?

17. An airplane travels 3,260 kilometers in 4 hours. What is the airplane's average speed?

18. A person in a kayak paddles down river at an average speed of 10 km/h. After 3.25 hours, how far has she traveled?

19. The same person in question 18 paddles upstream at an average speed of 4 km/h. How long would it take her to get back to her starting point?

20. An airplane travels from St. Louis, Missouri to Portland, Oregon in 4.33 hours. If the distance traveled is 2,742 kilometers, what is the airplane's average speed?

21. The airplane returns to St. Louis by the same route. Because the prevailing winds push the airplane along, the return trip takes only 3.75 hours. What is the average speed for this trip?

22. The airplane refuels in St. Louis and continues on to Boston. It travels at an average speed of 610 km/h. If the trip takes 2.75 hours, what is the flight distance between St. Louis and Boston?

23. The speed of light is about 3.00×10^5 km/s. It takes approximately 1.28 seconds for light reflected from the moon to reach Earth. What is the average distance from Earth to the moon?

24. The average distance from the sun to Pluto is approximately 6.10×10^9 km. How long does it take light from the sun to reach Pluto? Use the speed of light from the previous question to help you.

25. Now, make up three speed problems of your own. Give the problems to a friend to solve and check their work.

    a. Make up a problem that involves solving for average speed.

    b. Make up a problem that involves solving for distance.

    c. Make up a problem that involves solving for time.

Skill Sheet 2.2 Speed

1. 17 km/hr
2. 55 mph
3. 4.5 seconds
4. 5.9 hours; 490 mph
5. 4.0 km
6. 2.5 miles
7. 4.5 meters
8. Answers are:
   a. 2.54 cm/inch
   b. 12 inches/min
9. 6 km/hr
10. Answers are:
    a. 600 seconds
    b. 10 minutes
11. 1,200 meters
12. Answers are:
    a. 42 km
    b. 9.2 km/hr
13. Answers are:
    a. 0.2 km/min
    b. 0.5 km/min
    c. 0.3 km/min faster by bicycle
14. 12.5 km
15. 40 minutes
16. 90 km/hr
17. 815 km/hr or 800 km/hr
18. 32.5 km or 33 km
19. 8 hours
20. 633 km/hr
21. 731 km/hr
22. 1,680 km
23. 3.84×10^5 km
24. 2.03×10^4 seconds
25. Answers for 25 (a) - (c) will vary. Having students write their own problems will further develop their understanding of how to solve speed problems.

Obstacle Course
Teacher Page

Supplies: Notecards, Timers, Trundle wheels or Meter stick, Tape measure

Preparation: Make a decision about how to get supplies for the tasks.

Day 1

1. Get students into groups of 3 or 4.
2. Give each group a piece of paper for students to write down ideas of tasks that can be done in a classroom between 30-60 seconds.
3. Have each group share out ideas. Compile a list of tasks that are fun.
4. This can also be an opportunity for teachers to add a task that students need more work on in any subject area (for example, setting up proportions in math, summarize a reading passage etc.)
5. Share out different tasks.
6. Make a list of the top 15 tasks.
7. Each group chooses a task they would like to create.
8. With the class develop a rough draft of the obstacle course. Assign each group a location on the obstacle course.
9. Keep the distance between the each task between 3-6 meters.

Day 2

1. Have each group get supplies needed to complete their task.
2. Each group will go to the location on the on the course determined on the rough draft.
3. Students will set up their task then measure the distance to the next task, and complete their notecard with the Task Number, Title of their task and a simple illustration, and the distance it takes to go to the next task. The distance can be eliminated if students need more practice in measuring.
4. After each group is set up, check to make sure that each group has their measurements marked and their task ready.
5. Each group member will complete a different task, and a member of the group will measure the time it takes to go the distance, and the time it takes to complete the task. Groups should take turn.
    a. You could also have each student do all the tasks by completing 4 rounds if there are 4 students in each group.
6. Groups cannot go to the next task till the teacher instructs the class to start their next task.

Day 3

1. Have each group evaluate their data and create a position verses time graph and a speed verses time graph.

Name: ____________________________________

Task 1 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 2 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 3 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 4 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Name: ________________________________

Task 5 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 6 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 7 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Task 8 ____

Name	Time to complete task in seconds	Distance traveled	Time to travel to the next task

Name: ______________________________________

Task ___ ____			
Name	**Time to complete task in seconds**	**Distance traveled**	**Time to travel to the next task**

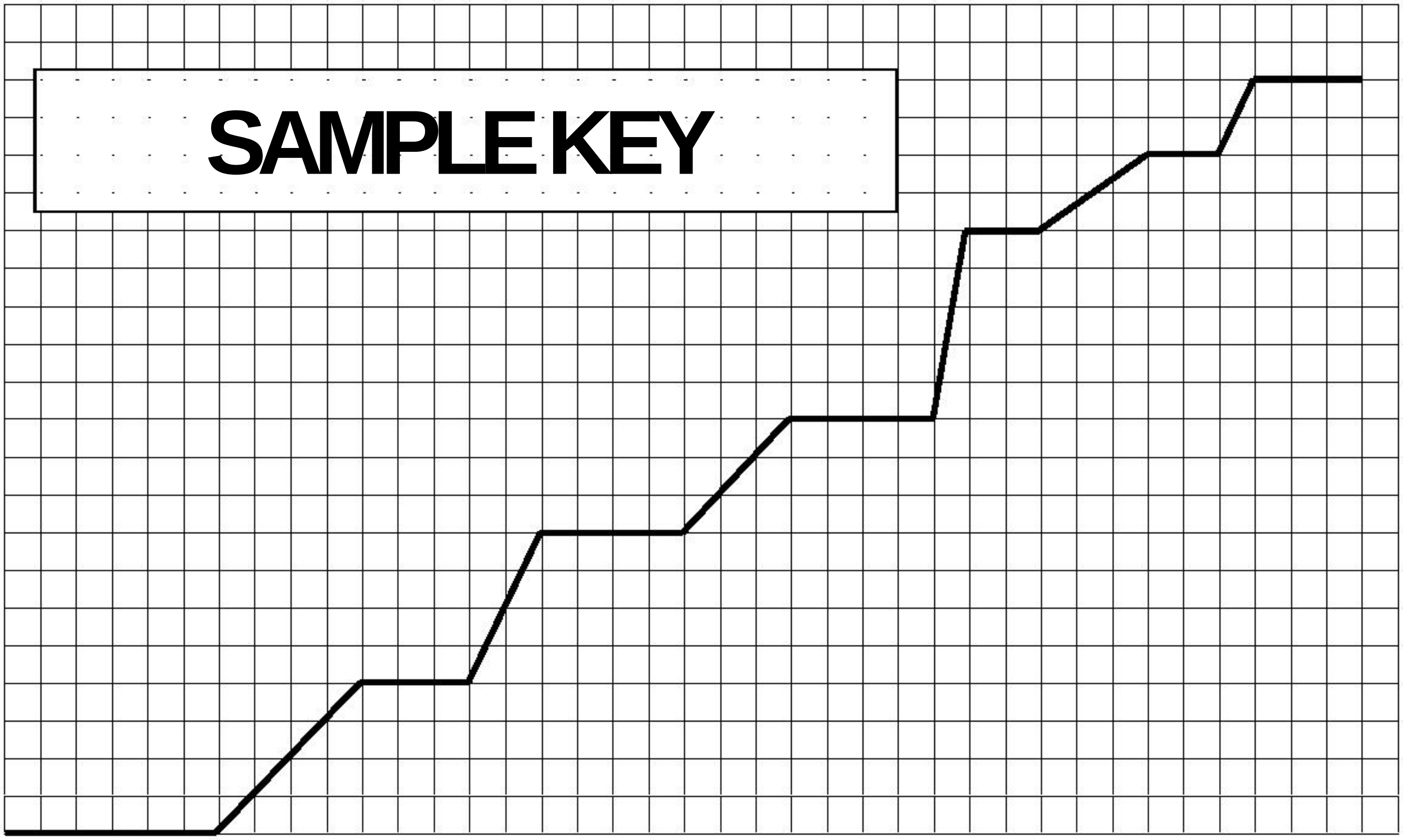
Task ___ ____			
Name	**Time to complete task in seconds**	**Distance traveled**	**Time to travel to the next task**

Task ___ ____			
Name	**Time to complete task in seconds**	**Distance traveled**	**Time to travel to the next task**

Task ___ ____			
Name	**Time to complete task in seconds**	**Distance traveled**	**Time to travel to the next task**

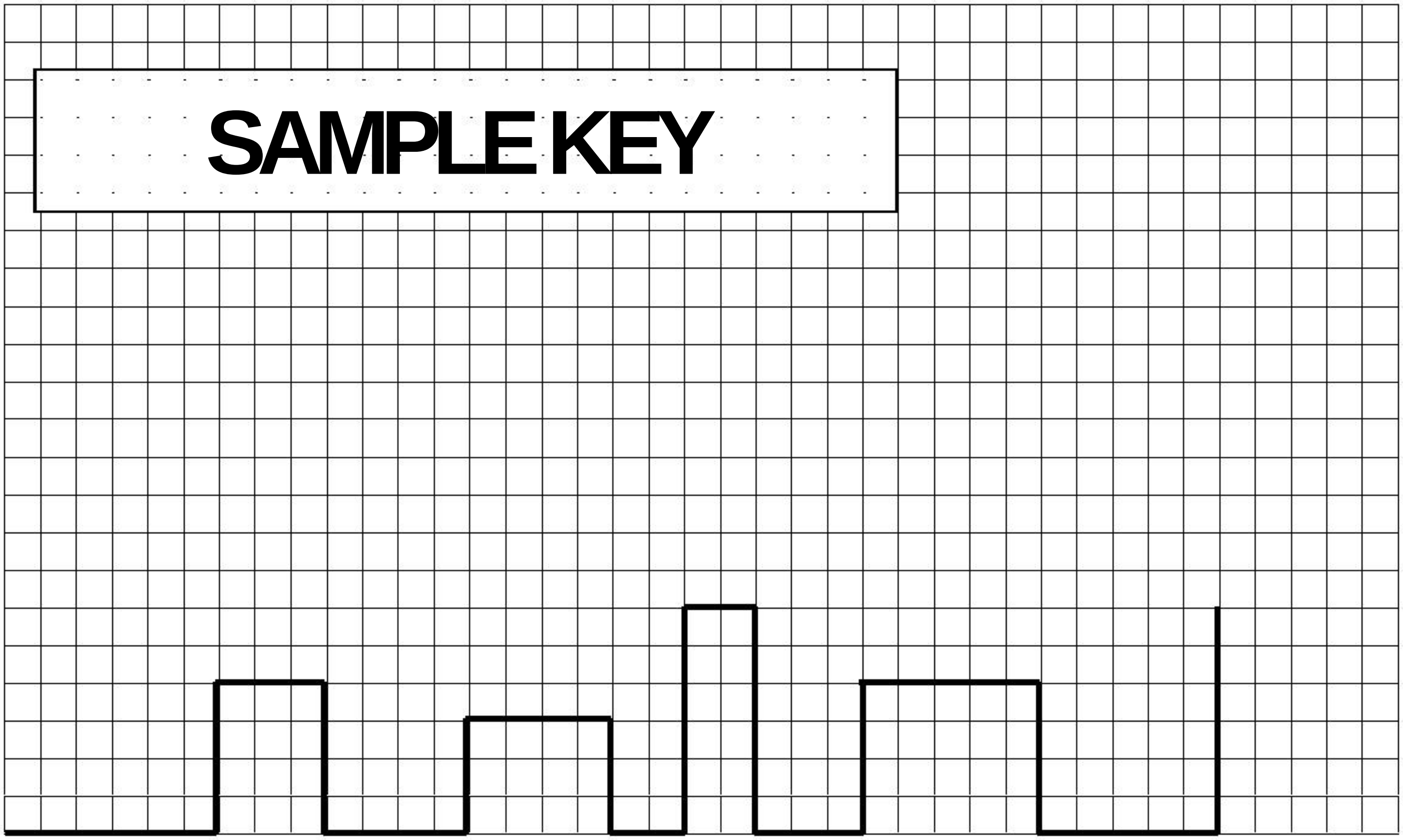
Sample KEY

Graph of Total Distance travelled verses time.



Sample KEY

Graph of speed verses time.



Name: ____________________ Date: ____________

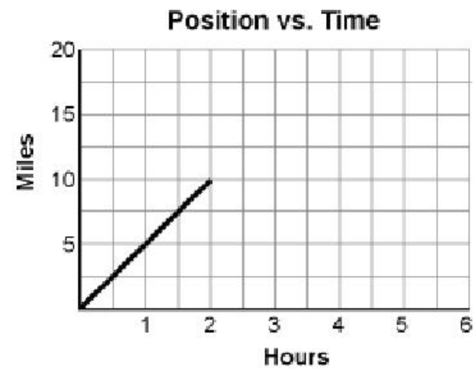
SKILL and PRACTICE 3.2

Analyzing Graphs of Motion With Numbers

READ

Speed can be calculated from position-time graphs and distance can be calculated from speed-time graphs. Both calculations rely on the familiar speed equation: $v = d/t$.

This graph shows position and time for a sailboat starting from its home port as it sailed to a distant island. By studying the line, you can see that the sailboat traveled 10 miles in 2 hours.



EXAMPLES

- **Calculating speed from a position-time graph**

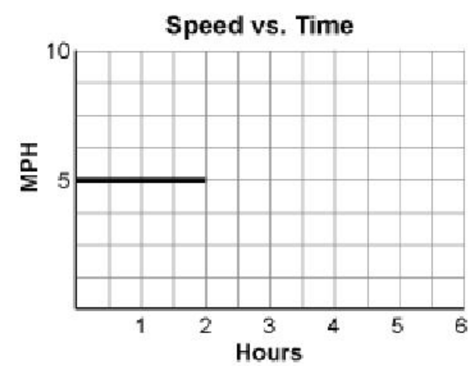
The speed equation allows us to calculate that the boat's speed during this time was 5 miles per hour.

$v = d/t$

$v =$ 10 miles/2 hours

$v =$ 5 miles/hour, read as 5 miles per hour

This result can now be transferred to a speed-time graph. Remember that this speed was measured during the first two hours.

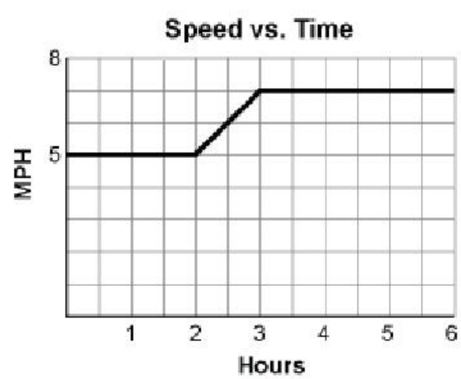


The line showing the boat's speed is horizontal because the speed was constant during the two-hour period.

- **Calculating distance from a speed-time graph**

Here is the speed-time graph of the same sailboat later in the voyage. Between the second and third hours, the wind freshened and the sailboat gradually increased its speed to 7 miles per hour. The speed remained 7 miles per hour to the end of the voyage.

How far did the sailboat go during the six-hour trip? We will first calculate the distance traveled between the third and sixth hours.



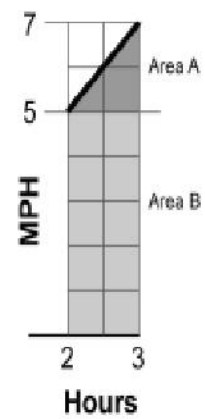
On a speed-time graph, distance is equal to the area between the baseline and the plotted line. You know that the area of a rectangle is found with the equation: $A = L \times W$. Similarly, multiplying the speed from the y-axis by the time on the x-axis produces distance. Notice how the labels cancel to produce miles:

$$\text{speed} \times \text{time} = \text{distance}$$

$$7 \text{ miles/hour} \times (6 \text{ hours} - 3 \text{ hours}) = \text{distance}$$
$$7 \text{ miles/}\cancel{\text{hour}} \times 3 \cancel{\text{ hours}} = \text{distance} = 21 \text{ miles}$$

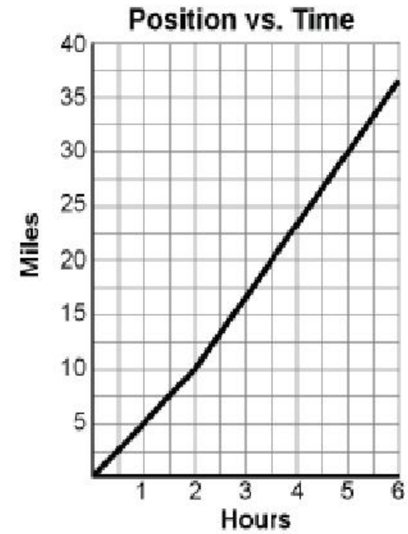
Now that we have seen how distance is calculated, we can consider the distance covered between hours 2 and 3.

The easiest way to visualize this problem is to think in geometric terms. Find the area of the triangle (Area A), then find the area of the rectangle (Area B), and add the two areas.



Area of triangle A Geometry formula	The area of a triangle is one-half the area of a rectangle. $\text{speed} \times \frac{\text{time}}{2} = \text{distance}$ $(7 \text{ miles/hour} - 5 \text{ miles/hour}) \times \frac{(3 \text{ hours} - 2 \text{ hours})}{2} = \text{distance} = 1 \text{ mile}$
Area of rectangle B Geometry formula	$\text{speed} \times \text{time} = \text{distance}$ $5 \text{ miles/hour} \times (3 \text{ hours} - 2 \text{ hours}) = \text{distance} = 5 \text{ miles}$
Add the two areas	$\text{Area A} + \text{Area B} = \text{distance}$ $1 \text{ miles} + 5 \text{ mile} = \text{distance} = 6 \text{ miles}$

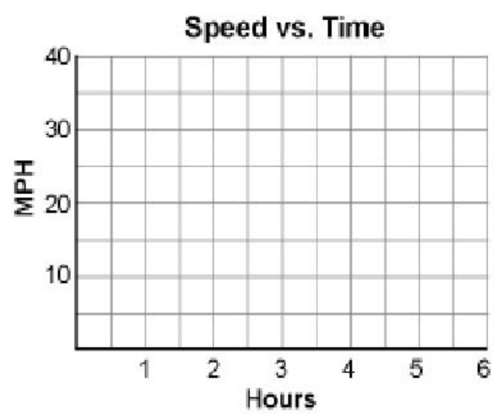
We can now take the distances found for both sections of the speed graph to complete our position-time graph:



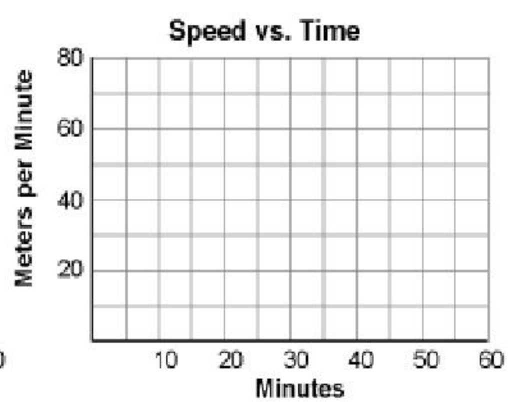
PRACTICE

1. For each position-time graph, calculate and plot speed on the speed-time graph to the right.

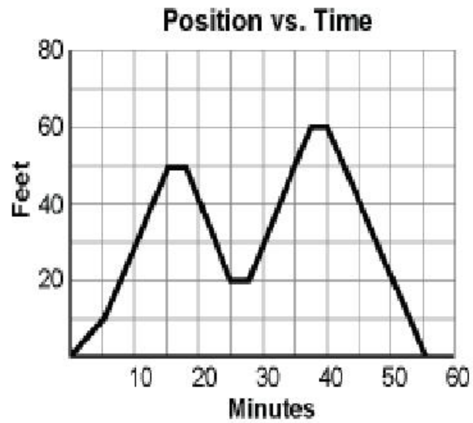
   a. The bicycle trip through hilly country

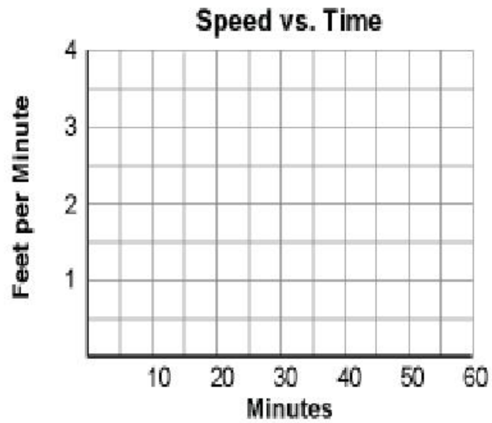


   b. A walk in the park



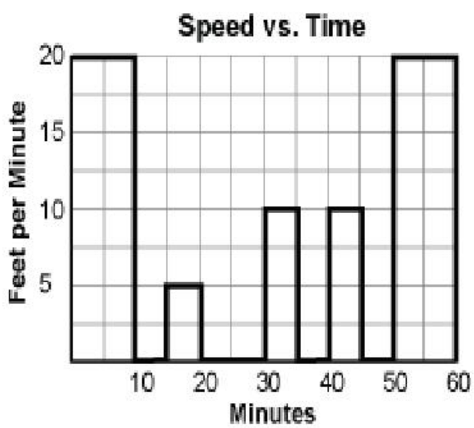
c. Strolling up and down the supermarket aisles

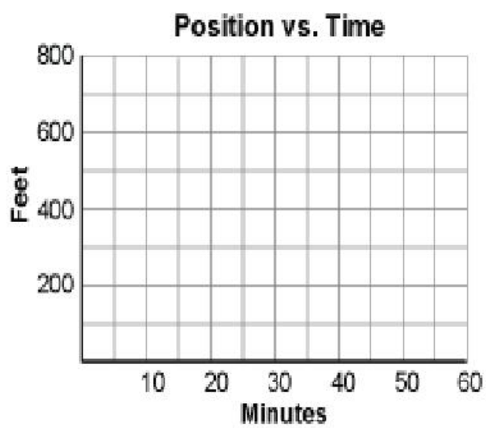




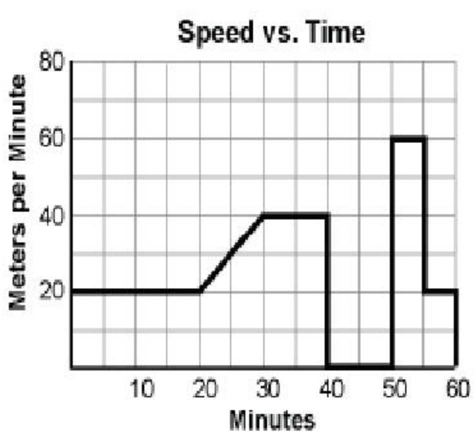
2. For each speed-time graph, calculate and plot the distance on the position-time graph to the right. For this practice, assume that movement is always away from the starting position.

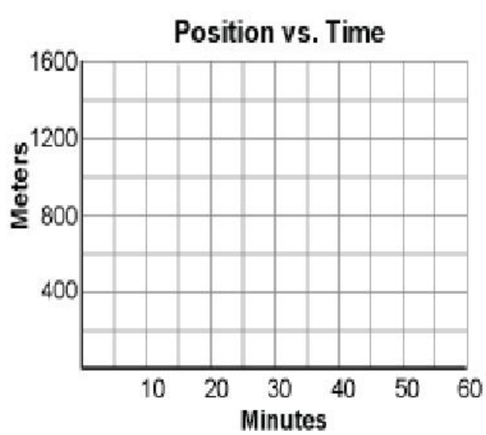
a. The honey bee among the flowers



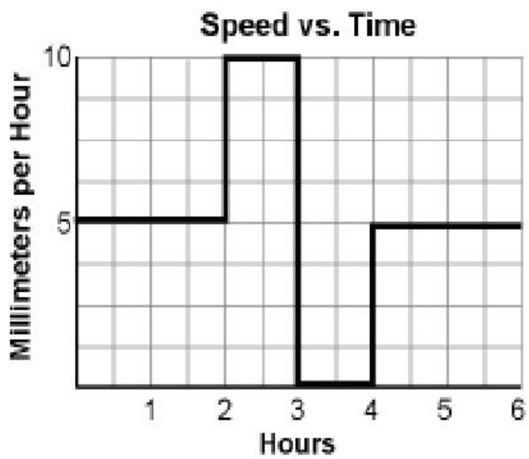


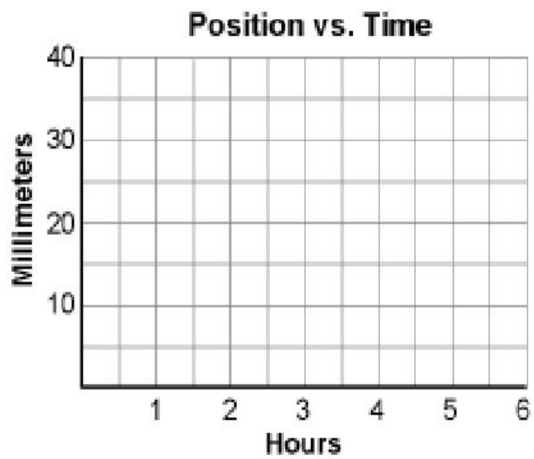
b. Rover runs the street





c. The amoeba

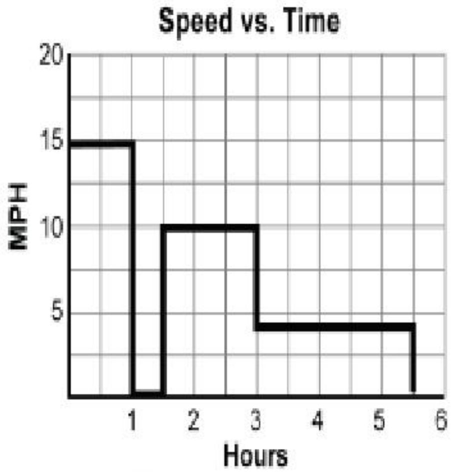

Speed vs. Time
Millimeters per Hour
10
5
1
2
3
4
5
6
Hours


Position vs. Time
Millimeters
40
30
20
10
1
2
3
4
5
6
Hours

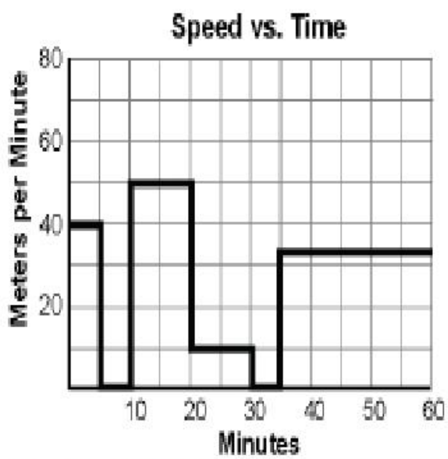
ANSWER KEY

Skill Sheet 3.2: Analyzing Graphs of Motion with Numbers

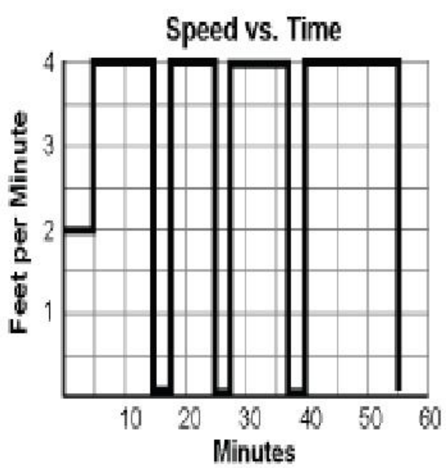
1. Answers are:
   a. The bicycle trip through hilly country.



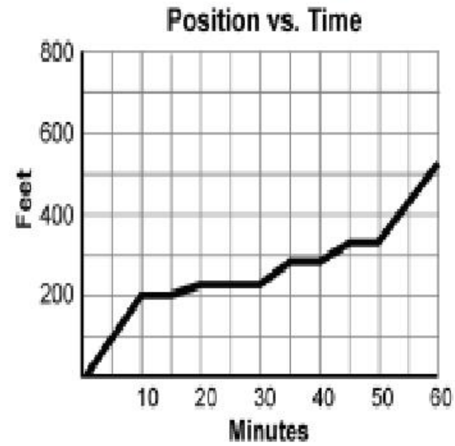
   b. A walk in the park.



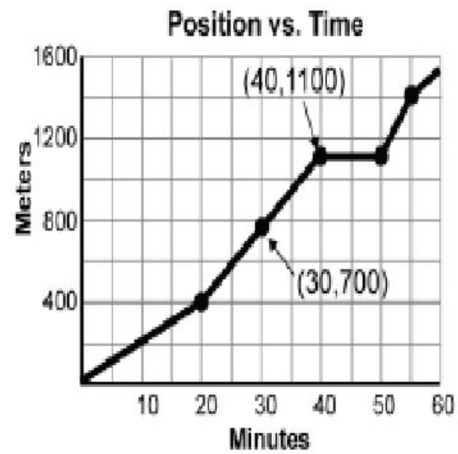
   c. Up and down the supermarket aisles.



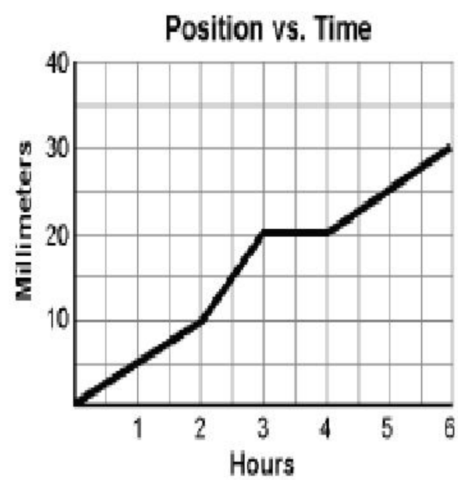
2. Answers are:
   a. The honey bee among the flowers.



   b. Rover runs the street.



   c. The amoeba.



1.

Name: ______________________ Date: ______________

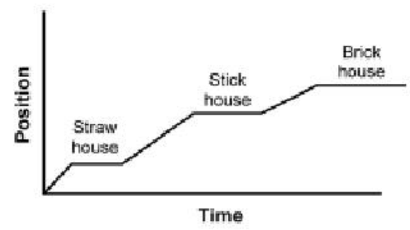
Analyzing Graphs of Motion Without Numbers

READ

Position-time graphs

The graph at right represents the story of "The Three Little Pigs." The parts of the story are listed below.

Position-time graph of the wolf in *The Three Little Pigs*

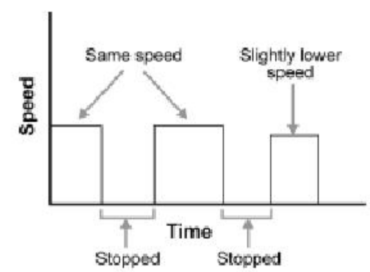


- The wolf started from his house. The graph starts at the origin.
- Traveled to the straw house. The line moves upward.
- Stayed to blow it down and eat dinner. The line is flat because position is not changing.
- Traveled to the stick house. The line moves upward again.
- Again stayed, blew it down, and ate seconds. The line is flat.
- Traveled to the brick house. The line moves upward.
- Died in the stew pot at the brick house. The line is flat.

The graph illustrates that the pigs' houses are generally in a line away from the wolf's house and that the brick house was the farthest away.

Speed-time graphs

A speed-time graph displays the speed of an object over time and is based on position-time data. Speed is the relationship between distance (position) and time, $v = d/t$. For the first part of the wolf's trip in the position versus time graph, the line rises steadily. This means the speed for this first leg is constant. If the wolf traveled this first leg faster, the slope of the line would be steeper.



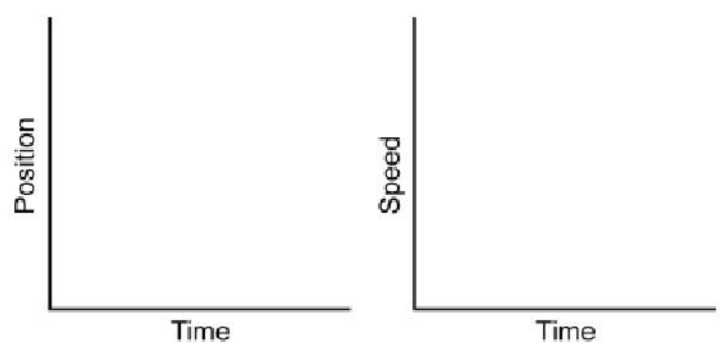
The wolf moved at the same speed toward his first two "visits." His third trip was slightly slower. Except for this slight difference, the wolf was either at one speed or stopped (shown by a flat line in the speed versus time graph).

PRACTICE

Read the steps for each story. Sketch a position-time graph and a speed-time graph for each story.

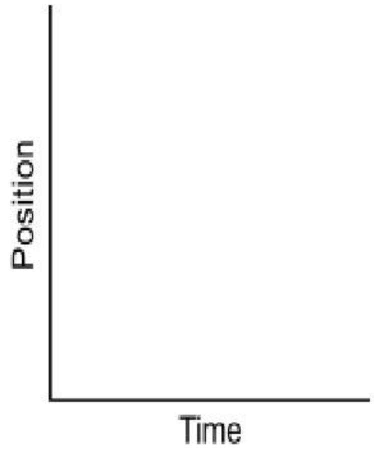
1. Graph Red Riding Hood's movements according to the following events listed in the order they occurred:

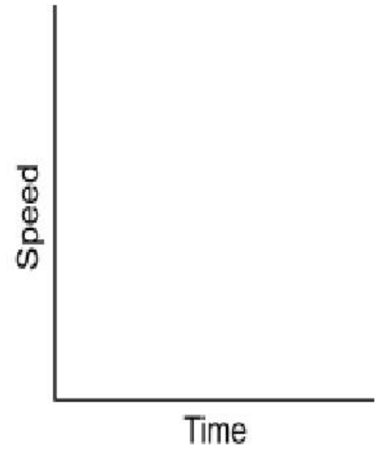
- Little Red Riding Hood set out for Grandmother's cottage at a good walking pace.
- She stopped briefly to talk to the wolf.
- She walked a bit slower because they were talking as they walked to the wild flowers.
- She stopped to pick flowers for quite a while.
- Realizing she was late, Red Riding Hood ran the rest of the way to Grandmother's cottage.



2. Graph the movements of the Tortoise and the Hare. Use two lines to show the movements of each animal on each graph. The movements of each animal is listed in the order they occurred.

- The tortoise and the hare began their race from the combined start-finish line. By the end of the race, the two will be at the same position at which they started.
- Quickly outdistancing the tortoise, the hare ran off at a moderate speed.
- The tortoise took off at a slow but steady speed.
- The hare, with an enormous lead, stopped for a short nap.

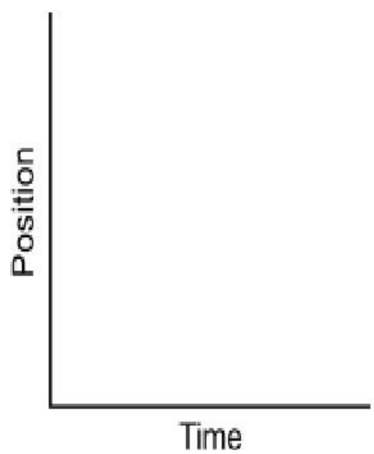


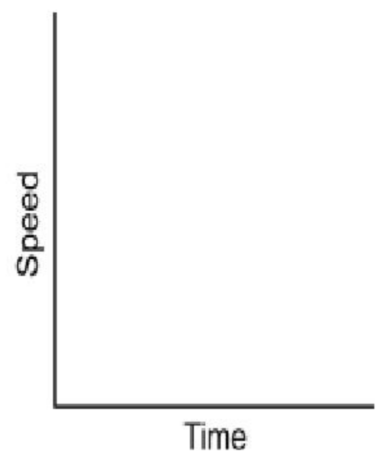


- With a startle, the hare awoke and realized that he had been sleeping for a long time.
- The hare raced off toward the finish at top speed.
- Before the hare could catch up, the tortoise's steady pace won the race with an hour to spare.

3. Graph the altitude of the sky rocket on its flight according to the following sequence of events listed in order.

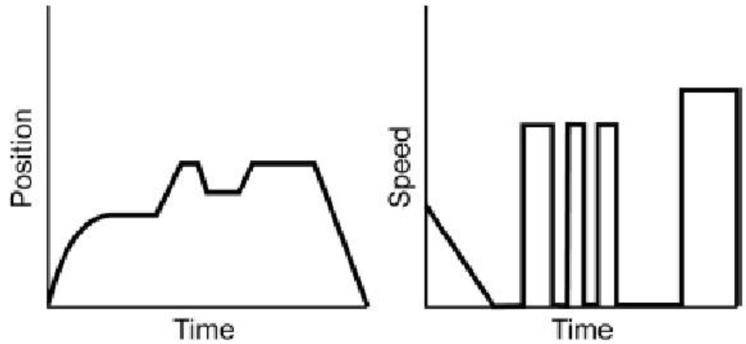
- The sky rocket was placed on the launcher.
- As the rocket motor burned, the rocket flew faster and faster into the sky.
- The motor burned out; although the rocket began to slow, it continued to coast even higher.
- Eventually, the rocket stopped for a split second before it began to fall back to Earth.





- Gravity pulled the rocket faster and faster toward Earth until a parachute popped out, slowing its descent.
- The descent ended as the rocket landed gently on the ground.

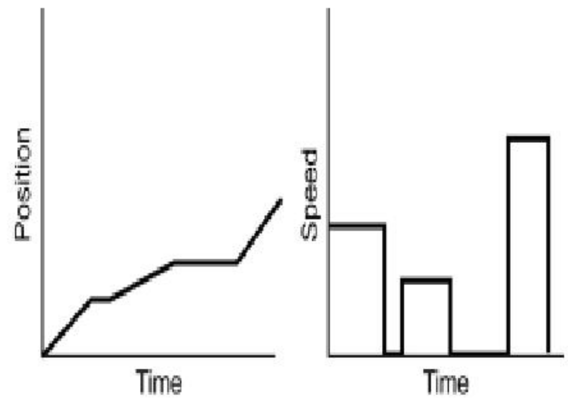
4. A story told from a graph: Tim, a student at Cumberland School, was determined to ask Caroline for a movie date. Use these graphs of his movements from his house to Caroline's to write the story.



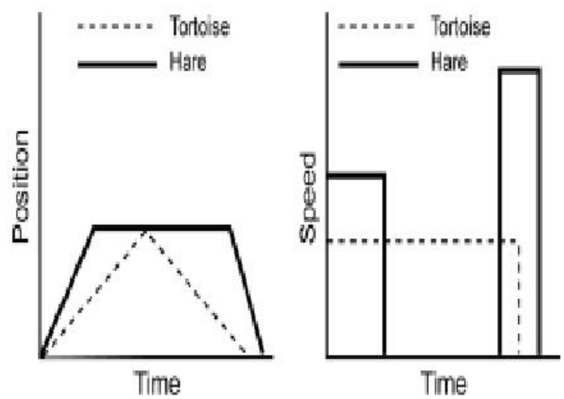
ANSWER KEY

Skill Sheet 3.2: Analyzing Graphs of Motion without Numbers

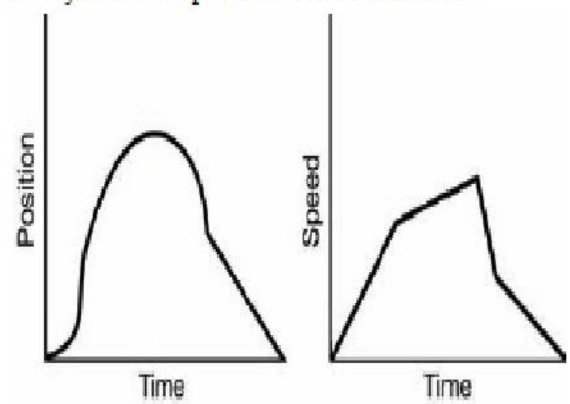
1. Little Red Riding Hood. Graph Little Red Riding Hood:



2. The Tortoise and the Hare. Use two lines to graph both the tortoise and the hare:



3. The Skyrocket. Graph the altitude of the rocket:



4. Each student story will include elements that are controlled by the graphs and creative elements that facilitate the story. Only the graph-controlled elements are described here.
   a. The line begins and ends on the baseline, therefore Tim must start from and return to his house.
   b. The line rises toward the first peak as a downward curved line that becomes horizontal. This indicates that Tim's pace toward Caroline's house slowed to a stop.
   c. Then the line rises steeply to the first peak. This indicates that after his stop, Tim continues toward Caroline's house faster than before.
   d. The first peak is sharp, indicating that Tim did not spend much time at Caroline's house on first arrival.
   e. The line then falls briefly, turns to the horizontal, and then rises to a second peak. This indicates that Tim left, paused, and then returned quickly to Caroline's house.
   f. The line then remains at the second peak for a long time, then drops steeply to the baseline. This indicates that after spending a long time at Caroline's house, Tim probably ran home.

INTERVENTION Activity: CPO Physical Science Teacher Edition
Chapter 2.2 p. 34-40
Sample Guiding Questions

1. **Pg.34: Explain which biker is moving faster?**
   Biker moving a 3 m/s, this means the biker goes 3 m. in 1 sec. Otherwise, the biker covers a greater distance in 1 sec.

2. **Pg. 35: Compare average speed to constant speed.**
   Average speed is the total distance divided by the total time. It does not tell you the speed you are going in a certain moment. Constant speed is the speed that stays the same at each second.

3. **Pg. 36: Answer the "Calculating distance from time and speed" Questions a and b**
   S=d/t: 20m/5s = 4m/sec
   T=d/s: 600km/50km/h = 12 hours

4. **Pg. 37: Explain which is faster 95 km/h or 59mph.**
   Both are about the same speed because they cover about the same distance in an hour.
   Come up with you're a speed that is about the same that has different units.
   1609.344m/h and 1mph

5. **Explain why step 1 in the four step technique is important to solving any problems.**
   Step 1 What is the problem? It is important to identify the problem or questions so that you know what you are going to answer.

6. **Summarize how to solve a design problem.**
   Solving a design problem can have many correct solutions. The solution you come up with requires writing clearly everything your solution needs to accomplish, identify the constraints, research, testing a prototype, analyzing the results and making adjustments. You may need repeat any area after analyzing the results to make adjustments.

6th Grade Science
LIFE SCIENCE: 6.LS.1 - 4
Unit Snapshots

Topic: Cellular to Multicellular

Grade Level: 6

Duration:
~3 weeks… *This content will continue through 4th Grading Period

***The content statements for sixth-grade Life Science are each partial components of a large concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories, Modern Cell Theory. It is recommended that the content statements be combined and taught as a whole.**

Standards Summary (as stated in Ohio's New Learning Standards for Science)

6.LS.1 Cells are the fundamental unit of life.
All living things are composed of cells. Different body tissues and organs are made of different kinds of cells. The ways cells function are similar in all living organisms.

Note 1: Specific information about the organelles that need to be addressed at this grade level will be found in the model curriculum.

Note 2: Emphasis should be placed on the function and coordination of these components, as well as on their roles in overall cell function.

CONTENT ELABORATION:

The content statements for sixth-grade Life Science are each partial components of a large concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories, Modern Cell Theory. It is recommended that the content statements be combined and taught as a whole. For example, the energy needs of cells can be interwoven with the function of mitochondria.

Modern Cell Theory states that all living things are made of cells. Cells are the basic unit of structure and function of all living things. Many organisms are single-celled and that one cell must carry out all the basic functions of life. Other organisms are multicellular and the cells that form these organisms can be organized at various levels to carry out all the basic functions of life. Different body tissues and organs can be made up of different kinds of cells. The cells in similar tissues and organs in animals are similar. The tissues and organs found in plants differ slightly from similar tissues in animals. Use Modern Cell Theory to exemplify how scientific theories are developed over time.

Microscopes, micrographs, safety procedures, models and illustrations must be used to observe cells from many different types of organisms. Representative cells from eubacteria (cynaobacteria), protista (algae, amoeba, diatoms, euglena, volvox) and fungi (common mushrooms, bread molds) must be observed for cell structures such as the cell wall, cell membrane and nucleus. Plantae cells (mosses, ferns and angiosperms) must be observed for the following cell components: nucleus, mitochondria, chloroplast, ribosome, plasma membrane, vacuole and lysosome. Mitochondria and ribosomes are not visible under regular light microscopes but may be viewed using micrographs or illustrations. The differences in sizes and shape of various cells and organelles must be noted. Size is a useful tool in identification of cells. The relationship between structure and function is a crosscutting theme for science and should be explored when investigating the structure and function of cellular organelles. Emphasis must be placed on the function and coordination of these components, as well as on the overall cell function, before introducing and reinforcing the names of these components (e.g., plant and algae cells contain plastids where the manufacture and storage of chemical compounds important to the cell occur). The most commonly described plastids are chloroplasts in green plant cells.

Microscopes must be used to view a variety of cells (see above), tissues (xylem, phloem, connective, muscle, nervous) and organs (leaf, stem, flower, spore, ganglia, blood vessels, eyes) to compare and contrast their similarities and differences.

Real-world applications, new technology and contemporary science must be used in this content (e.g., the presence of microbes in potable water can be a way to connect the solutions to real-world problems and biology).

Student Knowledge:

Prior Concepts Related to Species and Reproduction

PreK-2: Living things have specific traits and are made up of a variety of structures.
Grades 3-5: Organisms are made of parts.

Future Application of Concepts

High School: Details of cellular processes such as photosynthesis, chemosynthesis, cellular re cell division and differentiation are studied. Cellular organelles studied are cytoskeleton, Go and endoplasmic reticulum.

6.LS.2 All cells come from pre-existing cells.

Cells repeatedly divide resulting in more cells and growth and repair in multicellular organisms.

> Note: This is not a detailed discussion of the phases of mitosis or meiosis. The focus should be on reproduction as a means of transmitting genetic information from one generation to the next, cellular growth and repair.

CONTENT ELABORATION:

The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory. It is recommended that the content statements be combined and taught as a whole.

Modern Cell Theory states that cells come from pre-existing cells. Individual organisms do not live forever therefore reproduction is necessary for the continuation of every species.

Traits are passed onto the next generation through reproduction. In single-celled organisms, the process of binary fission produces a new organism. In multicellular organisms, cells multiply for growth and repair.

In this grade, mitosis is explored. All cells contain genetic materials. The genetic material must be described as chromosomes. The chemicals and chemical processes associated with the genetic material are reserved for high school biology. Chromosomes must be described as structures in cells that contain the genetic material. Microscopes, micrographs, models and illustrations can be used to observe cells from different organisms in the process of dividing. It is not appropriate to learn the names of the stages of mitosis. The focus is on observing cells dividing as evidence that cells come from pre-existing cells and genetic material is transmitted from parent cell to daughter cells.

The misconception of spontaneous generation can be included in discussions on this topic. The experiments of Redi and Pasteur can be used to explain how evidence can lead to new knowledge, better explanations and spur new technology.

Student Knowledge:

Prior Concepts Related to Species and Reproduction

PreK-2: Living things are made up of a variety of structures.

Grades 3-5: Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next.

Future Application of Concepts

Grade 8: More details about asexual and sexual reproduction will be studied.

6.LS.3 Cells carry on specific functions that sustain life.
Many basic functions of organisms occur in cells. Cells take in nutrients and energy to perform work, like making various molecules required by that cell or an organism. Every cell is covered by a membrane that controls what can enter and leave the cell. Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback and movement.

Note: Emphasis should be placed on the function and coordination of cell components, as well as on their roles in overall cell function.

CONTENT ELABORATION:
The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory.
In classrooms, it is recommended that the content statements be combined and taught as a whole (e.g., the energy requirements of cells can be interwoven with the function of mitochondria). Cells have particular structures that are related to their functions. These functions are regulated and controlled (e.g., a cell membrane controls what can enter and leave the cell).

The organization of living systems includes explanation of the role of cells, tissues, organs and organ systems that carry out life functions for organisms. These roles include maintaining homeostasis, gas exchange, energy transfers and transformation, transportation of molecules, disposal of wastes and synthesis of new molecules.
Connections are to be made between cellular organelles and processes.
Explore (3-D or virtually) conditions that optimize and/or minimize cellular function in a cell or an organism. Technology also can be used to run simulations to investigate specific outcomes and develop predictions about changes in functions.

Clear Learning Targets (To be determined)
"I can"…statements

____

____

Student Knowledge:
Prior Concepts Related to Organisms and Reproduction
PreK-2: Living things have specific traits. Living things require energy, water and a particular temperature range.
Grades 3-5: Organisms are made of parts.

Future Application of Concepts
Grades 7-8: Photosynthesis and respiration are compared.
High School: Details of cellular processes are studied. Molecules enter and leave the cell by the mechanisms of diffusion, osmosis and active transport.

6.LS.4 Living systems at all levels of organization demonstrate the complementary nature of structure and function.

The level of organization within organisms includes cells, tissues, organs, organ systems and whole organisms. Whether the organism is single-celled or multicellular, all of its parts function as a whole to perform the tasks necessary for the survival of the organism.
Organisms have diverse body plans, symmetry and internal structures that contribute to their being able to survive in their environments.

CONTENT ELABORATION:

The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory.
It is recommended that the content statements be combined and taught as a whole (e.g., levels of organization can be interwoven with the concept of cells as the fundamental unit of life).

Cells perform specialized functions in multicellular organisms. Groups of specialized cells form a tissue such as muscle. Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue and organ has a distinct structure and set of functions that serve the organism as a whole.
Organisms have diverse body plans, symmetry and internal structures. General distinctions among organisms (e.g., body plans, symmetry, internal structures) that support classifying them into a scientifically based system (a distinction of this grade level from Pre-K to 5) are explored. Organisms sorted into groups share similarities in external structures, internal structures and processes.

The commonality of life can be investigated through observing tissues, organs, cell structures (see limits in previous content statements), systems and symmetry (an approximate balanced distribution of duplicate body parts) for plants and animals.
Part of the exploration of the commonality of living systems can include comparison of cells, types of tissues, organs and organ systems between organisms (see other grade 6 content statements for details).

Inquiry and mathematical relationships should be drawn between cell size and the cell's ability to transport necessary materials into its interior. This link is critical for laying the foundation for the cell cycle in the grade 8.

Student Knowledge:

Prior Concepts Related to Organisms and Reproduction

PreK-2: Living things have specific traits. Living things require energy, water and a particular temperature range.
Grades 3-5: Organisms are made of parts.

Future Application of Concepts

Grade 8: Cellular reproduction is studied.
High School: The unity and diversity of life and the evolutionary mechanisms that contribute to the organization of living things are studied.

Below is an overview of many of the links you can use to teach Cell Theory:

- **The Cell**
- *The cell is the most basic unit of life.*
- A1.1 Cell Theory PowerPoint
- A1.1 Cell Theory PowerPoint (Blanks)
- A1.1 Check Your Reading
- Redi-Pasteur Chart
- Francesco Redi Comprehension Questions
- Microscope Part Chart
- Label The Microscope
- Microscope Application Questions
- Lab: Introduction to the Compound Light Microscope
- Cell Organelles PowerPoint
- Prokaryotes vs. Eukaryotes
- Cell Part Chart
- Label the Animal Cell
- Cell Project: Create a visual comparison of a plant and animal cell, identifying the structures and their function. Description and Rubric included.
- Cell Organelle Memory: Print the pdf on card stock, laminate and cut up for a great organelle/function review game
- Animal and Plant Cell diagrams: used in conjunction with the traditional venn diagram
- Macromolecule Chart
- Lab: Investigating Oil and Water
- Cell Membrane Questions
- Photosynthesis-Cellular Respiration Feedback Loop
- Lab: Investigating Fermentation
- How Do Cells Release The Energy From Glucose? blank flowchart - completed as cellular respiration and fermentation are explored
- How Do Cells Release The Energy From Glucose? completed flowchart

- Passive Transport worksheet used with class discussion and 2 demonstrations:
  - Smelly Balloons (place a dropper-full of extract in a latex balloon and blow up - scent will diffuse through the latex)
  - Raisin Osmosis (soak raisins in water overnight to demonstrate the movement of water across a membrane. Save un-hydrated raisins for comparison)
- Active Transport worksheet used with class discussion and simulation on ClassZone.com
- Weekly Article Questions:
  - From Stem Cell to Any Cell
  - Zap! Erasing Memory
  - A Change in Leaf Color
  - Catching Some Rays

- A3.1 Check Your Reading Questions
- Phases of the Cell Cycle
- Cell Cycle PowerPoint - Interphase, Mitosis and Cytokinesis
- Cell Cycle PowerPoint Blanks
- Interactive Mitosis Tutorial
- YouTube clips: The Stages of Mitosis, Mitosis in Real Time
- Interactive Meiosis Tutorial
- Mitosis-Meiosis Comparison

http://www.shellyssciencespot.com/Worksheets/Cell/A1.1PP.pdf

Cell Theory Section A1.1

The cell is the basic unit of living things…

Living things are different from nonliving things…

You are surrounded by life, but how would you define a living thing?

- Does it use energy?
- Does it move?
- Does it consume food and water?

Organism- any individual form of life that uses energy to carry out its activities.

Characteristics of Living Things ….(a review)

All living things:

- are made up of cells (organization).
- respond to the environment.
- have the ability to reproduce.
- move.
- grow and develop.
- perform metabolic processes.

Metabolism- the sum of the physical and chemical processes in an organism

Organization…

An organism's body must be organized in that enables it to meet its needs.

Some organisms are simple:
Bacteria
Archaea
Most Protists

Some organisms are more complex:
When different parts of the organism performs different functions.

Examples:
Humans, dogs, fish, mushrooms, oak trees

Needs for life…

Organisms need energy, materials, and living space.

All energy comes from the sun. Some organisms use this energy directly (photosynthesis) Others harness this energy by eating food

Materials needed:

- Carbon dioxide,
- oxygen,
- nitrogen,
- water

All living things are made up of cells….

The cell is the smallest unit of a living thing.

If an organism is unicellular, all functions of life happen within that one cell.

If an organism is multicellular, different cells have different jobs and they all work together.

The microscope led to the discovery of cells.

1660's – Robert Hooke discovered the cell
He looked at cork under the microscope (30x)
He noticed little compartments, which he named after the little rooms that monks lived in…"Cells"

1670's – Anton von Leeuwenhoek described microorganisms in pond water

He looked at pond water under the microscope (300x)
He noticed that the water was full of moving living things

Cell Theory… With the invention of the microscope and the contributions of many scientists, a very important question was answered in the 1850's.

The question was: Where do cells come from?

There are three concepts to the cell theory…
- Every living thing is made up of one or more cells.
- Cells carry out the functions needed to support life
- Cells come only from other living cells

Concept #1- A polar bear is made up of many cells!

Concept #3- All polar bears cell came from a single living cell. They divide and they grow to replace old dead cells!

Concept #2- Different cells in a polar bears body does different jobs.

Example: Fat cells provide insulation and energy, while red blood cells carry oxygen.

Name: ____________________________________
Date: ______________
Period: _____________

The cell is the basic unit of living things. Answer the following “Check Your Reading” questions: 1.

What four characteristics are common to all living things?

____
____
____

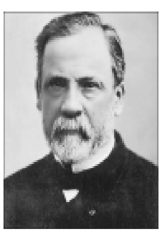
2. How did the invention of the microscope change the study of biology?

____
____
____

3. What do scientists mean when they say that life comes from life? Your answer should include the word cells.

____
____
____

Compare the contributions of the two scientists to the development of cell theory.

Scientist Name	What did he prove/disprove?	How did he do it?
Francesco Redi (1626-1697) 		
Louis Pasteur (1822-1895) 		

Francesco Redi and Controlled Experiments

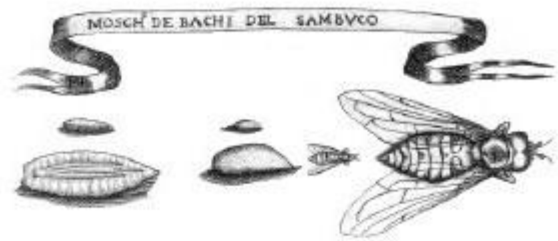
Most people can name one 17th century Italian scientist who challenged Aristotle's writings and changed the way science was done for centuries to come. There were actually two! Galileo was one. Francesco Redi was the other. Francesco Redi is famous for his demonstration of the use of controlled experiments and his challenge to the theory of spontaneous generation.

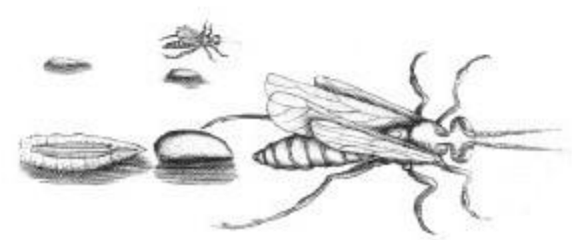
When a scientist designs an experiment it is important to eliminate as many unknowns as possible. For instance, if one were trying to assess the health effects of a drug on humans, there are many factors which may affect health..simply counting how many of the patients get better or worse when given the drug is not good enough. We want to know how many got better or worse specifically from the drug. One solution might be to introduce a control to compare the drug-based tests against some standard case. In these drug-tests one group is commonly given the drug and another group, the control group, is given a placebo (commonly a sugar-pill with no known health effects). The subjects do not know which type of pill they have been given. The drug results from the test group can then be compared against those of the control group and we can get a better idea of which effects result from the drug. This important advance in scientific methods was introduced only 25 years after the death of Galileo and only a few kilometres away from where he lived.

The Francesco Redi Experiment

Francesco Redi was able to disprove the theory that maggots could be spontaneously generated from meat using a controlled experiment. Spontaneous generation, the theory that life forms can be generated from inanimate objects, had been around since at least the time of Aristotle. Francesco took eight jars, placed meat in all the jars, but covered four of the jars with muslin. Maggots developed in the open jars but did not develop in the muslin-covered jars. Today controlled experiments are commonly demanded by scientific journals and are sometimes legally required by regulatory bodies (especially for pharmaceuticals). The image below is taken from *Esperienze intorno alla generazione degl' Insetti* (p.

187) where Francesco Redi published a description of the experiment in 1668 (see sidebar for digital copies of book).





We are taught that Galileo introduced the scientific method while Francesco Redi introduced the controlled experiment. Both beliefs may be simplistic, however. Francesco Redi and Galileo Galilei demonstrated their methods using very simple experiments then explained their procedures in clear and compelling ways. This is why both are so important. But scientists before Redi and Galileo had recognized the need to control variables and had described the sequence of steps described in Galileo's experimental method. When Galileo was still a young boy, Giuseppe Moletti, a professor at the University of Padua, conducted a series of experiments on free fall by dropping weights in different media (see Timeline of Classical Mechanics). His test with free fall in water and air specified that the balls must be of the same substance, weight and figure in order to remove doubt. In the same book, when Moletti described dropping balls of wood and lead from a tower to demonstrate that free fall doesn't depend on weight (as Aristotle had said) he was careful to eliminate size as a nuisance variable by conducting the experiment with wooden balls of different sizes [1] .

Being careful to control for the known variables doesn't guarantee that you will get the correct results. That is because "you don't know what you don't know". There might be variables that need to be controlled that you don't even know exist. This is why the famous Tower of Pisa experiment actually came up with incorrect results. Many consider the legend of the Tower of Pisa experiment to be a myth. The experiment did occur. It was conducted by Vincenzio Renieri, a Catholic monk (see Galileo's Battle for the Heaven's) and not Galileo as is commonly thought. Vincenzio was a friend of Galileo's. Like Moletti before him, Renieri, controlled for size when he dropped two balls of the same size (one of wood and one of lead.) He came up with the wrong results. There was almost 2 metres difference between the heavier and lighter balls when they hit the ground. Galileo described similar results in some of his works. These scientists could not have known that they needed to control for human physiology as well. Modern experiments with humans dropping balls of markedly different weights show that there is a tendency to grip the heavier ball more tightly and release it more slowly [2] .

Francesco Redi and the Galileo Affair

Francesco Redi lived during the time of the Galileo Affair. This event is presented as evidence for the "the recurring clash between religion and science" (see Galileo's Battle for the Heaven's). Francesco Redi's experiences counter this interpretation. Francesco Redi lived a comfortable life in Florence, walking the same streets and working for the same people that Galileo did (the Medicis). He died without encountering any problems with the Church. Galileo's use of Italian instead of Latin was supposed to be a problem with the Church. But with Francesco Redi, it wasn't. Any challenge to Aristotle was supposed to be a problem for the Church. It was Aristotle who proposed life-forms such as maggots spontaneously generated, and it was Redi who proved this false. The Galileo Affair was supposed to have caused the decline of science in Italy. Redi's important advances in the scientific method happened only a short time after the Galileo Affair in Galileo's adopted city.

The life and work of Francesco Redi provides cause to rethink the the Galileo Affair. The Galileo Affair is commonly presented as proof of the conflict between science and the church. Francesco Redi was defending scientific ideas that were as radical as Galileo's. His experience with the church was completely different. Could Galileo's personality and his personal and professional disagreements with the other scientists of the day explain the difference? And leaving personality aside, Francesco Redi may have had a better argument against Aristotle because he used better methods.

Name: _________________________

Date: ____________

Life Science Period: ___________

The Cell: Cell Theory Francesco Redi’s Experiment

After the reading the text explaining Francesco Redi’s experiment, answer the following questions in complete sentences.

1. Explain spontaneous generation.

____

____

____

2. What are maggots?

____

____

3. Why do flies often lay eggs on spoiled meat?

____

____

____

4. What was the control in Redi’s experiment?

____

____

5. Why did maggots not appear in the covered jars?

____

____

____

6. Why did maggots appear on the top of the veil?

____

____

____

Complete the following lab simulations with students to gain experience with Microscopes:

http://virtuallabs.nmsu.edu/micro.php

http://www.glencoe.com/sites/common_assets/science/virtual_labs/LS09/LS09.swf

Microscope Parts and Function

Complete the table identifying the function of the microscope parts listed.

Microscope Part	Function
Eyepiece (ocular lens)	
Body tube	
Revolving nosepiece	
Low power objective	
Medium power (scanning) objective	
High power objective	

Stage	
Stage clips	
Diaphragm	
Light source	
Arm	
Coarse adjustment knob	
Fine adjustment knob	
Base	

Label the microscope with the name of the indicated part.