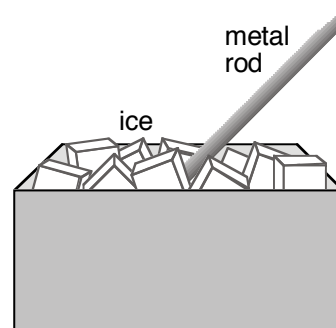


## PHYSICAL SCIENCE TEST

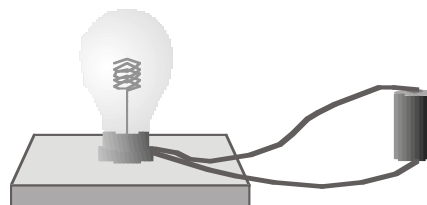
For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

- Jack opens a can of soda pop and lets it sit on his kitchen countertop. He goes off to do some chores and forgets about the opened can. When he returns several hours later, the weight of the opened can of soda pop will:
  - be more than the unopened can.
  - be less than the unopened can.
  - be the same as the unopened can.
  - depend on the relative humidity.
  - depend on the type of soda pop.
- Helium gas is used in balloons. When helium gas is cooled enough, it becomes a liquid. What do you think happens when helium turns into a liquid?
  - The helium has turned into water.
  - Some of the helium has turned into water.
  - The helium has turned into a different liquid.
  - Some helium has turned into water, some into another liquid and the rest is helium.
  - It is all still helium, but in a liquid form.

- Sue sticks one end of a metal rod into a box filled with ice. The end of the rod that is covered with ice becomes cold. After a while Sue places her hand on the upper end of the rod outside the box and feels that it is cold. What do you think has happened?
  - Cold has transferred from the lower end of the rod to the upper end.
  - The rod gave up heat to the ice.
  - Cold moved from Sue's hands towards the rod.
  - Heat moved from the rod to Sue's hand.
  - It depends on the original temperature of the rod.

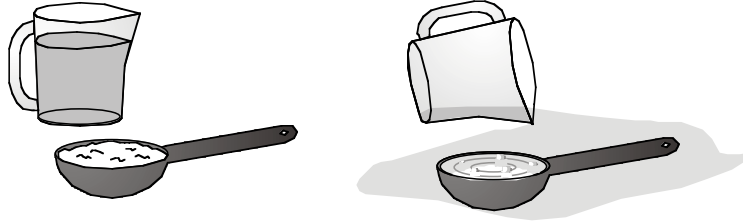


- A light bulb is connected to a battery by wires. The bulb is lit up. Nadia wants to know what is flowing through the wires. If a scientist were to cut the wire and look at it with a powerful magnifying glass, what do you think she would see?
  - Chemicals from the battery flowing through the wire.
  - Light flowing through the wire.
  - The wire will be hollow with nothing flowing through it.
  - Tiny sparks flowing through the wire.
  - The wire will be solid.



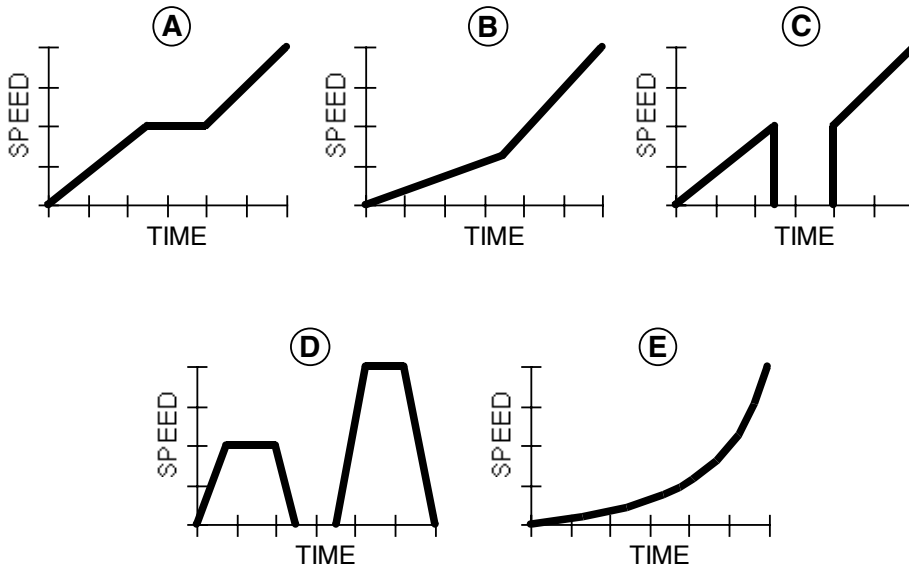
- John has built a special greenhouse in his backyard. By turning a special dial, John can choose which type of sunlight can enter the greenhouse. When only ultraviolet light is allowed to enter the greenhouse, what do you think will happen while John is standing inside the greenhouse?
  - John can see objects inside the greenhouse.
  - It is warmer inside the greenhouse than it is outside.
  - After a few hours, John begins to sunburn.
  - John can see objects outside the greenhouse.
  - John can only see a few objects.

6. Suzanne is baking a cake and has placed several ingredients on the countertop to use. She has scooped some baking soda into a measuring spoon. She accidentally knocks over a cup of vinegar and several drops spill onto the spoon with the baking soda. The baking soda begins to fizz where the vinegar spilled on it. When the fizzing stops, Suzanne notices that about half of the baking soda in the spoon is gone and there is now a liquid on the spoon. The baking soda "disappeared" because it:



- melted.
- combined with the vinegar and produced a new liquid.
- dissolved in the vinegar, but is still in the liquid.
- evaporated.
- was pushed off of the spoon by the fizzing.

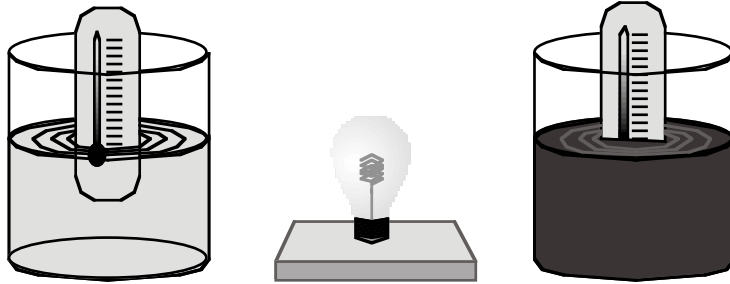
7. Carolyn walks a half mile to school. One morning, halfway to school, she stopped to watch a bird building a nest. When she realized she was late, she ran the rest of the way to school to avoid being marked late. Which graph below shows Carolyn's speed during her walk to school?



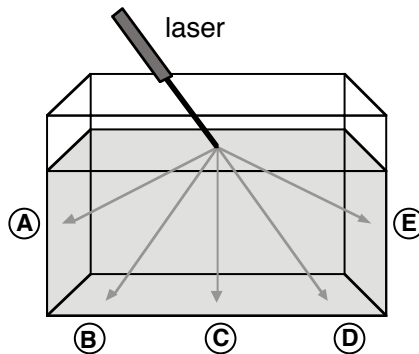
GO TO QUESTION 8 >>

8. Two identical jars are placed on a table with a light bulb between them. The bulb is turned on. One jar is filled with water and the other jar is filled with black ink. There is a thermometer hanging in each jar. What do you think will happen?

- The jar with water will be hotter than the jar with black ink.
- The jar with black ink will be hotter than the jar with water.
- There will be no difference in the temperature of the two jars.
- The temperature in both the jars will drop.
- The temperature in the jar with black ink will first drop and then increase.

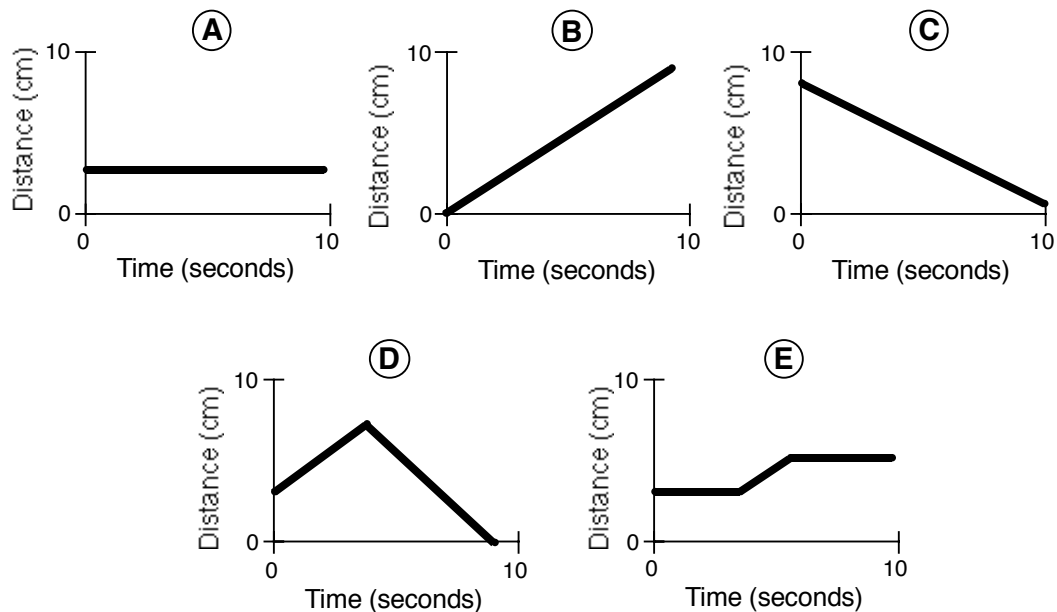


9. Look at the set up below. It shows a fish tank filled with water; the sides and bottom of the tank are all clear glass. If a red laser pointer were aimed into the tank as shown, at which lettered point do you think the laser beam would hit the glass?



10. Someone claims to have invented a system that converts sound energy into electrical energy. The inventor plans to put this system into a portable CD player so that the player's own sound can be used to recharge the player's own batteries. What do you think will happen when this CD player system is tested?
- The system should work fine, allowing unlimited running time for the player.
  - The system will work, but the player's volume will have to be kept in a narrow range, not too low, not too loud.
  - The system will work, but the player's volume will vary from low to high depending on whether or not the battery is being charged.
  - The system will be limited by the design of the battery: if it takes too long to fully charge, the battery may go dead.
  - The system will not work and the CD player will stop running after the battery is fully discharged.
11. It is a sunny day. Sean sits by the window and enjoys the sunshine. His mother tells him not to sit there for too long. However, Sean does not agree with her. Which one of the following statements do you agree with?
- Sean can get skin cancer from the ultraviolet radiation coming in with the sunlight.
  - Ultraviolet radiation is completely blocked by the window glass.
  - Ultraviolet radiation will not affect Sean in any harmful way.
  - Sean's risk depends upon the amount of sunlight.
  - The thickness of the window is important.

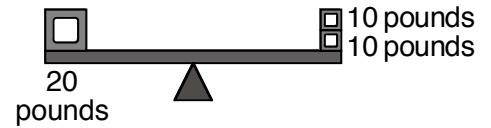
12. As part of an experiment, Jason mixes 2 cups of water at 200°F with 10 cups of water at 50°F. The temperature of the combined water is:
- 200°F.
  - closer to 200°F than to 50°F.
  - 125°F.
  - closer to 50°F than to 200°F.
  - impossible to estimate.
13. Mike thinks that he can turn copper into gold. He mixes a small amount of gold with a large amount of copper and heats them up until they melt. What do you think has happened?
- All the copper has turned into gold.
  - Some of the copper has turned into gold.
  - The copper has not changed into gold. It's just a mixture of gold and copper.
  - Copper and gold have turned into something completely new.
  - Not enough information to answer the question.
14. Kaitlyn is watching a wind-up toy walking across a table. She observes that the toy covers 1 cm every second for 10 seconds. Which graph below do you think most closely represents the toy's journey across the table?



15. A person claims that diamonds and the graphite in an ordinary pencil are made of the same material. A scientist's response would be that the claim is:
- False. The two substances are too different to be made of the same material.
  - False. Every substance is unique; no two substances are made of the same material.
  - Not able to be answered with the information given.
  - True. The substances look different because what's inside them is arranged differently.
  - True. The material is held together by a different substance, causing the different properties.

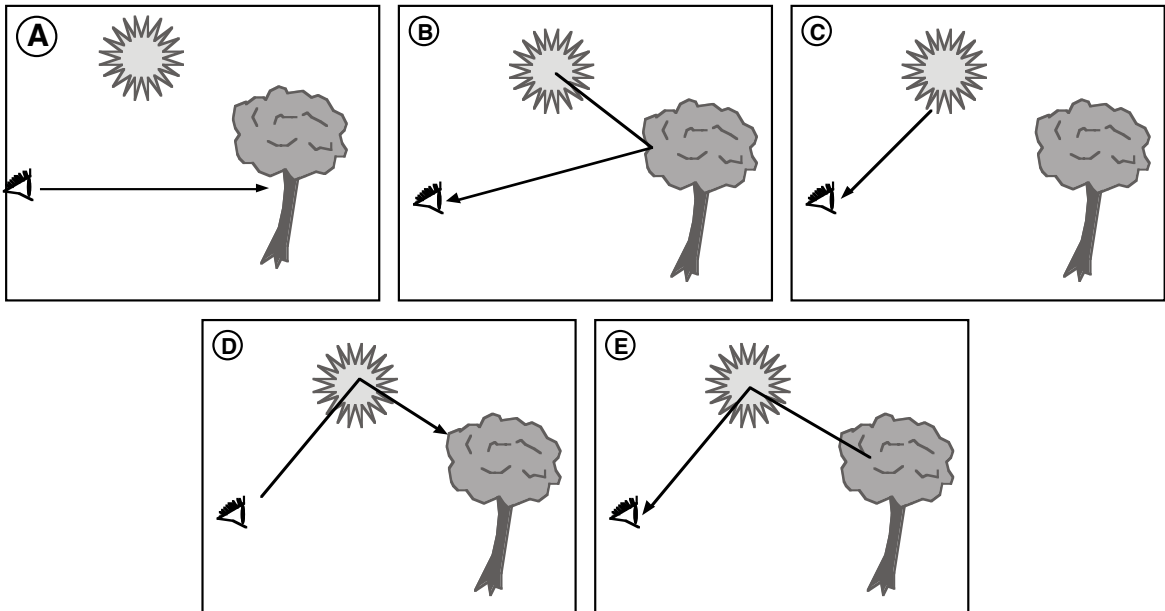
16. A see-saw has cinder blocks attached to it on both ends. The single block weighs 20 pounds and the two small blocks weigh 10 pounds each. What do you think will happen to the see-saw when its allowed to move?

- The side with the single block will move downward.
- The side with two small blocks will move downward.
- The see-saw will not move.
- The side with the single block will first move downward and then upward.
- The side with the small blocks will first move downwards and then upward.



17. Zahra is sitting in her backyard, looking at a tree. With which of the following statements about how she is able to see a tree do you agree?

- Light from her eye reaches the tree and she sees the tree.
- Light from the Sun reaches the tree and then her eye and she sees the tree.
- Light from the Sun reaches her eye and she sees the tree.
- Light from her eye reaches the Sun and then the tree and she sees the tree.
- Light from the tree reaches the Sun and then her eye and she sees the tree.



18. Imagine that you go to leave a room with an overhead light. The light is on. You move the wall switch to turn off the light, but the light stays on. What is probably wrong?

- The battery that powers the switch is dead.
- There is a break in the wire to the light bulb.
- The switch can no longer stop the flow of electricity through the wires
- The light fixture is broken.
- A surge of electricity is occurring in the building.

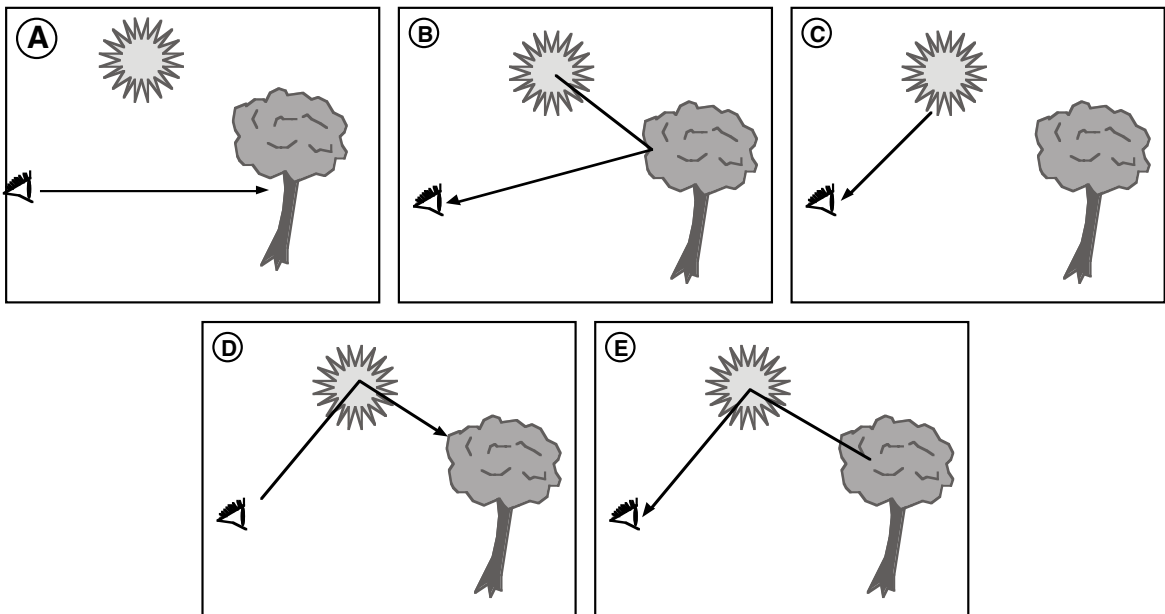
GO TO QUESTION 19 >>

19. A solid rubber ball sinks when placed in water. What will happen if the ball is cut in half and one of the smaller pieces is placed underwater?
- The smaller piece will rise.
  - The smaller piece will sink.
  - The smaller piece will stay motionless.
  - The smaller piece will dissolve.
  - There is no way to predict what will happen.
20. A pebble is dropped into a cup of water and sinks to the bottom of the cup. A solid metal bead of exactly the same size is dropped into the same cup and sinks to the bottom of the cup. How do the pebble and the metal bead compare?
- The metal bead and the pebble have the same density.
  - The metal bead and the pebble are the same mass.
  - The metal bead and the pebble are denser than water.
  - The metal bead and the pebble contain the same materials.
  - The metal bead and the pebble are as dense as the water.

## PHYSICAL SCIENCE TEST

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices for each question.

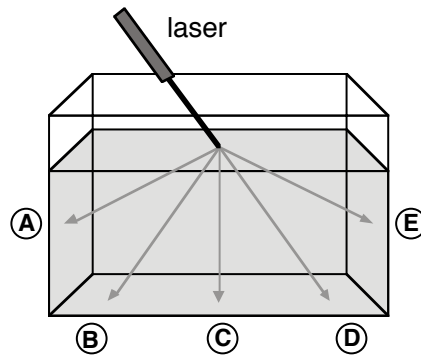
1. A pebble is dropped into a cup of water and sinks to the bottom of the cup. A solid metal bead of exactly the same size is dropped into the same cup and sinks to the bottom of the cup. How do the pebble and the metal bead compare?
  - a. The metal bead and the pebble have the same density.
  - b. The metal bead and the pebble are the same mass.
  - c. The metal bead and the pebble are denser than water.
  - d. The metal bead and the pebble contain the same materials.
  - e. The metal bead and the pebble are as dense as the water.
2. Zahra is sitting in her backyard, looking at a tree. With which of the following statements about how she is able to see a tree do you agree?
  - a. Light from her eye reaches the tree and she sees the tree.
  - b. Light from the Sun reaches the tree and then her eye and she sees the tree.
  - c. Light from the Sun reaches her eye and she sees the tree.
  - d. Light from her eye reaches the Sun and then the tree and she sees the tree.
  - e. Light from the tree reaches the Sun and then her eye and she sees the tree.



3. Imagine that you go to leave a room with an overhead light. The light is on. You move the wall switch to turn off the light, but the light stays on. What is probably wrong?
  - a. The battery that powers the switch is dead.
  - b. There is a break in the wire to the light bulb.
  - c. The switch can no longer stop the flow of electricity through the wires.
  - d. The light fixture is broken.
  - e. A surge of electricity is occurring in the building.

GO TO QUESTION 4 >>

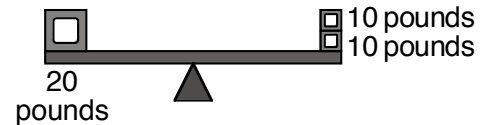
4. Look at the set up below. It shows a fish tank filled with water; the sides and bottom of the tank are all clear glass. If a red laser pointer were aimed into the tank as shown, at which lettered point do you think the laser beam would hit the glass?



5. It is a sunny day. Sean sits by the window and enjoys the sunshine. His mother tells him not to sit there for too long. However, Sean does not agree with her. Which one of the following statements do you agree with?
- Sean can get skin cancer from the ultraviolet radiation coming in with the sunlight.
  - Ultraviolet radiation is completely blocked by the window glass.
  - Ultraviolet radiation will not affect Sean in any harmful way.
  - Sean's risk depends upon the amount of sunlight.
  - The thickness of the window is important.

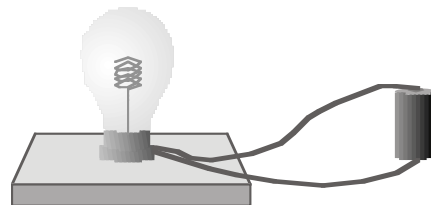
6. A see-saw has cinder blocks attached to it on both ends. The single block weighs 20 pounds and the two small blocks weigh 10 pounds each. What do you think will happen to the see-saw when its allowed to move?

- The side with the single block will move downward.
- The side with two small blocks will move downward.
- The see-saw will not move.
- The side with the single block will first move downward and then upward.
- The side with the small blocks will first move downwards and then upward.



7. A light bulb is connected to a battery by wires. The bulb is lit up. Nadia wants to know what is flowing through the wires. If a scientist were to cut the wire and look at it with a powerful magnifying glass, what do you think she would see?

- Chemicals from the battery flowing through the wire.
- Light flowing through the wire.
- The wire will be hollow with nothing flowing through it.
- Tiny sparks flowing through the wire.
- The wire will be solid.

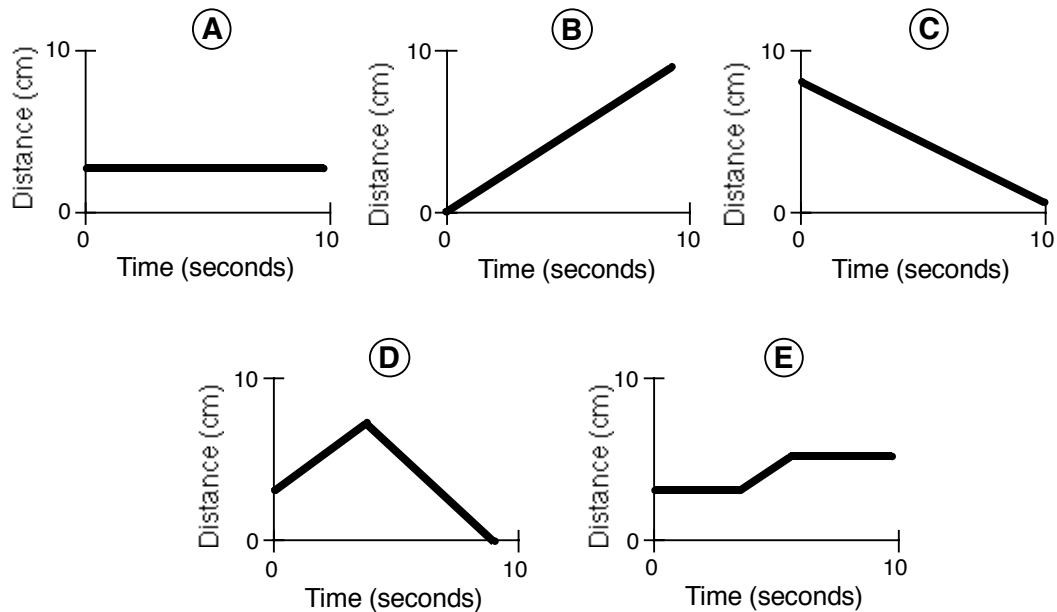


8. As part of an experiment, Jason mixes 2 cups of water at 200°F with 10 cups of water at 50°F. The temperature of the combined water is:

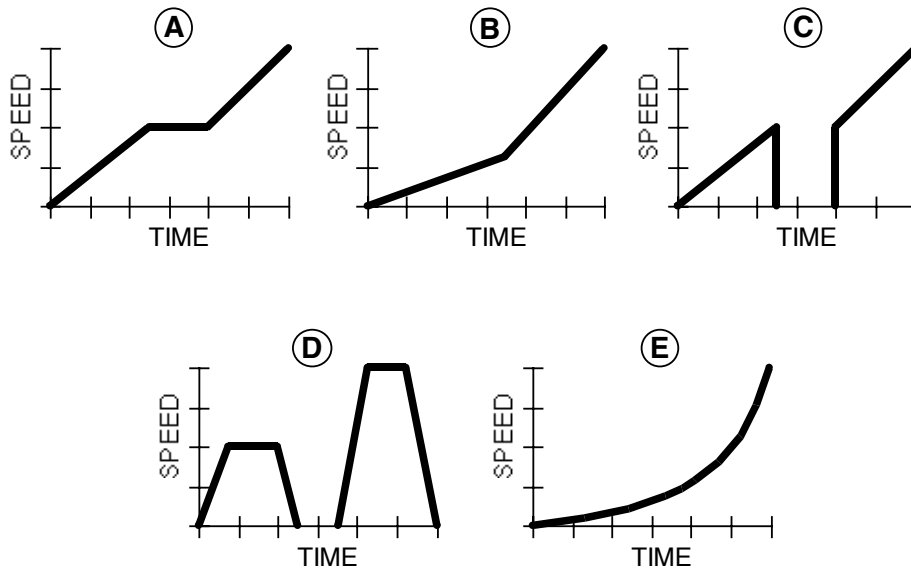
- 200°F.
- closer to 200°F than to 50°F.
- 125°F.
- closer to 50°F than to 200°F.
- impossible to estimate.



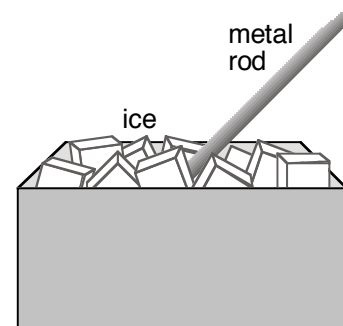
9. John has built a special greenhouse in his backyard. By turning a special dial, John can choose which type of sunlight can enter the greenhouse. When only ultraviolet light is allowed to enter the greenhouse, what do you think will happen while John is standing inside the greenhouse?
- John can see objects inside the greenhouse.
  - It is warmer inside the greenhouse than it is outside.
  - After a few hours, John begins to sunburn.
  - John can see objects outside the greenhouse.
  - John can only see a few objects.
10. A person claims that diamonds and the graphite in an ordinary pencil are made of the same material. A scientist's response would be that the claim is:
- False. The two substances are too different to be made of the same material.
  - False. Every substance is unique; no two substances are made of the same material.
  - Not able to be answered with the information given.
  - True. The substances look different because what's inside them is arranged differently.
  - True. The material is held together by a different substance, causing the different properties.
11. A solid rubber ball sinks when placed in water. What will happen if the ball is cut in half and one of the smaller pieces is placed underwater?
- The smaller piece will rise.
  - The smaller piece will sink.
  - The smaller piece will stay motionless.
  - The smaller piece will dissolve.
  - There is no way to predict what will happen.
12. Kaitlyn is watching a wind-up toy walking across a table. She observes that the toy covers 1 cm every second for 10 seconds. Which graph below do you think most closely represents the toy's journey across the table?



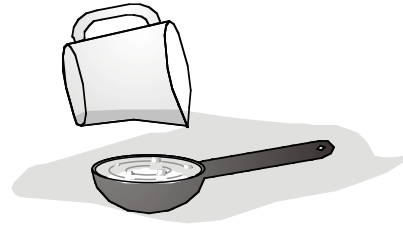
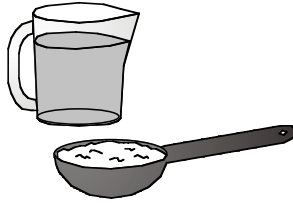
13. Helium gas is used in balloons. When helium gas is cooled enough, it becomes a liquid. What do you think happens when helium turns into a liquid?
- The helium has turned into water.
  - Some of the helium has turned into water.
  - The helium has turned into a different liquid.
  - Some helium has turned into water, some into another liquid and the rest is helium.
  - It is all still helium, but in a liquid form.
14. Carolyn walks a half mile to school. One morning, halfway to school, she stopped to watch a bird building a nest. When she realized she was late, she ran the rest of the way to school to avoid being marked late. Which graph below shows Carolyn's speed during her walk to school?



15. Mike thinks that he can turn copper into gold. He mixes a small amount of gold with a large amount of copper and heats them up until they melt. What do you think has happened?
- All the copper has turned into gold.
  - Some of the copper has turned into gold.
  - The copper has not changed into gold. It's just a mixture of gold and copper.
  - Copper and gold have turned into something completely new.
  - Not enough information to answer the question.
16. Sue sticks one end of a metal rod into a box filled with ice. The end of the rod that is covered with ice becomes cold. After a while Sue places her hand on the upper end of the rod outside the box and feels that it is cold. What do you think has happened?
- Cold has transferred from the lower end of the rod to the upper end.
  - The rod gave up heat to the ice.
  - Cold moved from Sue's hands towards the rod.
  - Heat moved from the rod to Sue's hand.
  - It depends on the original temperature of the rod.



17. Suzanne is baking a cake and has placed several ingredients on the countertop to use. She has scooped some baking soda into a measuring spoon. She accidentally knocks over a cup of vinegar and several



drops spill onto the spoon with the baking soda. The baking soda begins to fizz where the vinegar spilled on it. When the fizzing stops, Suzanne notices that about half of the baking soda in the spoon is gone and there is now a liquid on the spoon. The baking soda “disappeared” because it:

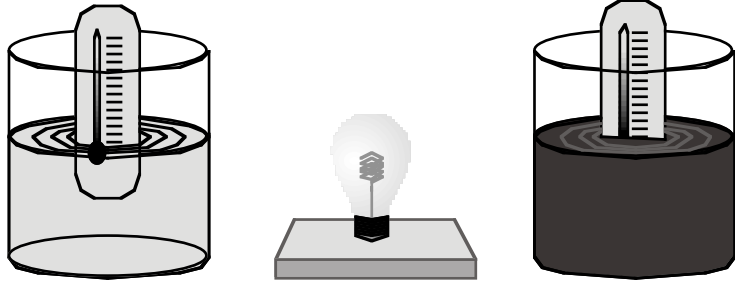
- melted.
  - combined with the vinegar and produced a new liquid.
  - dissolved in the vinegar, but is still in the liquid.
  - evaporated.
  - was pushed off of the spoon by the fizzing.
18. Jack opens a can of soda pop and lets it sit on his kitchen countertop. He goes off to do some chores and forgets about the opened can. When he returns several hours later, the weight of the opened can of soda pop will:
- be more than the unopened can.
  - be less than the unopened can.
  - be the same as the unopened can.
  - depend on the relative humidity.
  - depend on the type of soda pop.
19. Someone claims to have invented a system that converts sound energy into electrical energy. The inventor plans to put this system into a portable CD player so that the player’s own sound can be used to recharge the player’s own batteries. What do you think will happen when this CD player system is tested?
- The system should work fine, allowing unlimited running time for the player.
  - The system will work, but the player’s volume will have to be kept in a narrow range, not too low, not too loud.
  - The system will work, but the player’s volume will vary from low to high depending on whether or not the battery is being charged.
  - The system will be limited by the design of the battery: if it takes too long to fully charge, the battery may go dead.
  - The system will not work and the CD player will stop running after the battery is fully discharged.

GO TO QUESTION 20 >>

20. Two identical jars are placed on a table with a light bulb between them. The bulb is turned on. One jar is filled with water and the other jar is filled with black ink. There is a thermometer hanging in each jar.

What do you think will happen?

- a. The jar with water will be hotter than the jar with black ink.
- b. The jar with black ink will be hotter than the jar with water.
- c. There will be no difference in the temperature of the two jars.
- d. The temperature in both the jars will drop.
- e. The temperature in the jar with black ink will first drop and then increase.



## Grades 5–8 Physical Science Tests

The tests in this section contain items related to 11 of the grades 5–8 standards in physical science from the NRC's *National Science Education Standards (NSES)*; below are the standards as stated in the *NSES*.

Because the test items are based on the grades 5–8 *NSES* content standards, which were developed with student misconceptions in mind, there are no items that explicitly probe for atomic or molecular structure. Below is an explanatory excerpt from the *NSES*:

"Students usually bring some vocabulary and primitive notions of atomicity to the [middle school] science class, but often lack understanding of the evidence and the logical arguments that support the particulate model of matter. ...At this level [grades 5–8], elements and compounds can be defined operationally from their chemical characteristics, but few students can comprehend the idea of atomic and molecular particles."

Test items probing atomic and molecular structure can be found in the grades 9–12 chemistry tests (tests 731 and 732).

5–8 Physical Science Standard 1:

"A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties."

5–8 Physical Science Standard 2:

"Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group."

5–8 Physical Science Standard 3:

"Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter."

5–8 Physical Science Standard 4:

"The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph."

5–8 Physical Science Standard 5:

"If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion."

5–8 Physical Science Standard 6:

"Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways."

5–8 Physical Science Standard 7:

"Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature."

5–8 Physical Science Standard 8:

"Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye."

5–8 Physical Science Standard 9:

"Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced."

5–8 Physical Science Standard 10:

"In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers."

5–8 Physical Science Standard 11:

"The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation."

The items are identical on both test forms, but arranged in different sequences so that the forms can be used as a pretest/post-test pair (either form may be used as the pretest). Either form can be used by itself as a diagnostic test.

The 5–8 tests are intended for use primarily with 7th and 8th grade students. The tests can also be administered to any persons who possess at least a 7th grade reading level fluency in English.

**NOTE:** Administering the tests to anyone with less than the indicated minimum reading level may result in invalid test results due to the test performing more as a reading comprehension test rather than as a science test.

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
1	18	<p>Jack opens a can of soda pop and lets it sit on his kitchen countertop. He goes off to do some chores and forgets about the opened can. When he returns several hours later, the weight of the opened can of soda pop will:</p> <ol style="list-style-type: none"> <li>be more than the unopened can.</li> <li>be less than the unopened can.</li> <li>be the same as the unopened can.</li> <li>depend on the relative humidity.</li> <li>depend on the type of soda pop.</li> </ol>	1	B: 51%	Slightly more than half of the students in our sample answered correctly. No other options attracted more than 20%, with the most popular response being D, which may indicate that students believe that the possibility of any diffusion of carbon dioxide out of the soda and into the atmosphere may be affected by moisture in the air into which the gas is released.

<sup>1</sup> These test items are valid psychometrically and represent standards commonly included in middle school physical science curricula.

<sup>2</sup> Students (n varies from 1,020 to 2,300 per item) were selected randomly in classes to be a nationally representative sample of all grades 7 and 8 students in U.S. public and private schools.

<sup>3</sup> The commentary reflects item response patterns. Common misconceptions in physical science are discussed in a separate section.

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
2	13	<p>Helium gas is used in balloons. When helium gas is cooled enough, it becomes a liquid. What do you think happens when helium turns into a liquid?</p> <ol style="list-style-type: none"> <li>The helium has turned into water.</li> <li>Some of the helium has turned into water.</li> <li>The helium has turned into a different liquid.</li> <li>Some helium has turned into water, some into another liquid and the rest is helium.</li> <li>It is all still helium, but in a liquid form.</li> </ol>	3	E: 56%	<p>Some students may see all liquids being water at least partially since 11% each chose A and B. Other students may think that a phase change is a chemical change; choice C reflects this belief and was chosen by 12% of the students. Most students in our sample, however, chose the correct response and of those choosing the other options, the distractors were equally attractive. This equivalence suggests that students may also have been guessing among these options.</p>
3	16	<p>Sue sticks one end of a metal rod into a box filled with ice. The end of the rod that is covered with ice becomes cold. After a while Sue places her hand on the upper end of the rod outside the box and feels that it is cold. What do you think has happened?</p> <ol style="list-style-type: none"> <li>Cold has transferred from the lower end of the rod to the upper end.</li> <li>The rod gave up heat to the ice.</li> <li>Cold moved from Sue's hands towards the rod.</li> <li>Heat moved from the rod to Sue's hand.</li> <li>It depends on the original temperature of the rod.</li> </ol>	7	B: 18%	<p>Students at the middle school level and younger often do not understand that "cold" is not equivalent to "heat" as a form of energy. This misconception is documented in the response pattern to this item. More than half of the students in the sample (56%) chose A, while less than one fifth correctly responded. The small proportion choosing the correct answer could even be an artifact reflecting random guessing.</p>



Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
4	7	<p>A light bulb is connected to a battery by wires. The bulb is lit up. Nadia wants to know what is flowing through the wires. If a scientist were to cut the wire and look at it with a powerful magnifying glass, what do you think she would see?</p> <ol style="list-style-type: none"> <li>Chemicals from the battery flowing through the wire.</li> <li>Light flowing through the wire.</li> <li>The wire will be hollow with nothing flowing through it.</li> <li>Tiny sparks flowing through the wire.</li> <li>The wire will be solid.</li> </ol>	9	E: 24%	Middle school students hold many misconceptions concerning electrical current. In this item, the largest proportion of students (35%) indicated that one can see "sparks" flowing through the wire (D) and a substantial group (19%) believed that current is a flow of chemicals originating in the battery (A).
5	9	<p>John has built a special greenhouse in his backyard. By turning a special dial, John can choose which type of sunlight can enter the greenhouse. When only ultraviolet light is allowed to enter the greenhouse, what do you think will happen while John is standing inside the greenhouse?</p> <ol style="list-style-type: none"> <li>John can see objects inside the greenhouse.</li> <li>It is warmer inside the greenhouse than it is outside.</li> <li>After a few hours, John begins to sunburn.</li> <li>John can see objects outside the greenhouse.</li> <li>John can only see a few objects.</li> </ol>	11	C: 45%	Many students are familiar with the association between ultraviolet light and sunburn, perhaps because of the emphasis on use of sun screens. Almost half of students chose the correct option. The most popular misconception is B, which was chosen by 27% of students; students may have simply thought a greenhouse must always be warmer inside than outdoors. None of the other options attracted more than 10% of students.

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
6	17	<p>Suzanne is baking a cake and has placed several ingredients on the countertop to use. She has scooped some baking soda into a measuring spoon. She accidentally knocks over a cup of vinegar and several drops spill onto the spoon with the baking soda. The baking soda begins to fizz where the vinegar spilled on it. When the fizzing stops, Suzanne notices that about half of the baking soda in the spoon is gone and there is now a liquid on the spoon. The baking soda "disappeared" because it:</p> <ol style="list-style-type: none"> <li>melted.</li> <li>combined with the vinegar and produced a new liquid.</li> <li>dissolved in the vinegar, but is still in the liquid.</li> <li>evaporated.</li> <li>was pushed off of the spoon by the fizzing.</li> </ol>	2	B: 34%	<p>A popular demonstration in science classes is the chemical reaction of vinegar with baking soda. So it is interesting that only 34% of students chose the correct answer. Choice C was the most frequently chosen response (47%), which indicates that many students do not understand that the interaction between the vinegar and baking soda is a chemical reaction, evidenced by the gas that is generated ("fizzing"). The other choices attracted from 4% (both A and E) to 11% (D) of total responses.</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
7	14	<p>Carolyn walks a half mile to school. One morning, halfway to school, she stopped to watch a bird building a nest. When she realized she was late, she ran the rest of the way to school to avoid being marked late. Which graph below shows Carolyn's speed during her walk to school?</p> <p>See graphs in test item.</p>	4	D: 11%	<p>This item probes the ability of students to interpret a speed vs. time graph. Only E drew fewer students than the correct answer. A was the most popular choice, attracting 38% of responses, with C next most popular with a 26% response. The attraction to A in particular marks a common misconception based on students linking the motion of an object with the pattern of its graph line, regardless of the type of graph; in A, the graph line rises, runs horizontally for a while, then rises again, a pattern that would appeal to a student who is visualizing Carolyn's movement in terms of distance traveled, not speed of motion. This type of graph misinterpretation can persist into high school.</p>
8	20	<p>Two identical jars are placed on a table with a light bulb between them. The bulb is turned on. One jar is filled with water and the other jar is filled with black ink. There is a thermometer hanging in each jar. What do you think will happen?</p> <ol style="list-style-type: none"> <li>The jar with water will be hotter than the jar with black ink.</li> <li>The jar with black ink will be hotter than the jar with water.</li> <li>There will be no difference in the temperature of the two jars.</li> </ol>	6	B: 66%	<p>Most students apparently understand that different liquids have different light absorption characteristics based on the responses. One documented misconception is reflected in choice A, that water heats up well, but only 17% chose this answer. Fewer than 10% chose any one of the other three options (C, D and E).</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
		d. The temperature in both the jars will drop. e. The temperature in the jar with black ink will first drop and then increase.			
9	4	Look at the set up below. It shows a fish tank filled with water; the sides and bottom of the tank are all clear glass. If a red laser pointer were aimed into the tank as shown, at which lettered point do you think the laser beam would hit the glass?  See item on test for figure.	8	C: 30%	For this item, the proportions of students choosing the correct response (C) and the most common misconception (D) were the same, 30% for each choice. Among the remaining 40% of students, B was most popular (16%), followed by E (15%) and 9% choosing A. Unless students experiment with refraction, they are unlikely to think that the light beam will be affected by its passage from air into water.

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
10	19	<p>Someone claims to have invented a system that converts sound energy into electrical energy. The inventor plans to put this system into a portable CD player so that the player's own sound can be used to recharge the player's own batteries. What do you think will happen when this CD player system is tested?</p> <ol style="list-style-type: none"> <li>The system should work fine, allowing unlimited running time for the player.</li> <li>The system will work, but the player's volume will have to be kept in a narrow range, not too low, not too loud.</li> <li>The system will work, but the player's volume will vary from low to high depending on whether or not the battery is being charged.</li> <li>The system will be limited by the design of the battery: if it takes too long to fully charge, the battery may go dead.</li> <li>The system will not work and the CD player will stop running after the battery is fully discharged.</li> </ol>	10	E: 21%	<p>This item clearly shows that few students grasp the nature of the transfer of energy from one form to another; only one fifth of students responded correctly. The dominant misconception is represented by C, which was chosen by 24% of students, with D nearly the same at 23%. Choosing C or D suggests a belief in a 100% efficient transfer of energy from sound to battery to player to back to sound, just with diminished performance, rather than recognizing that the system will fail due to no energy transfer being 100% efficient. Choices A and B were selected at levels (13% and 18%, respectively) suggesting guessing.</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
11	5	<p>It is a sunny day. Sean sits by the window and enjoys the sunshine. His mother tells him not to sit there for too long. However, Sean does not agree with her. Which one of the following statements do you agree with?</p> <ol style="list-style-type: none"> <li>Sean can get skin cancer from the ultraviolet radiation coming in with the sunlight.</li> <li>Ultraviolet radiation is completely blocked by the window glass.</li> <li>Ultraviolet radiation will not affect Sean in any harmful way.</li> <li>Sean's risk depends upon the amount of sunlight.</li> <li>The thickness of the window is important.</li> </ol>	11	B: 10%	<p>This item is very difficult as it does require understanding the behavior of a form of light not visible to the human eye. The most popular choice was A at 41%, likely a result of students hearing about the health risks associated with sunlight. The next most popular choice was D (31%), which is essentially a modified version of A; choosing D over A actually suggests some thinking about risk in association with amount of exposure, so while D is also not correct, it might be considered as evidence of a more scientific view than A. C and D were chosen at nearly the same rate as the correct answer, B: even ordinary window glass filters UV radiation to the extent that indoor exposure to the Sun is not an issue.</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
12	8	<p>As part of an experiment, Jason mixes 2 cups of water at 200°F with 10 cups of water at 50°F. The temperature of the combined water is:</p> <ol style="list-style-type: none"> <li>200°F.</li> <li>closer to 200°F than to 50°F.</li> <li>125°F.</li> <li>closer to 50°F than to 200°F.</li> <li>impossible to estimate.</li> </ol>	7	D: 29%	<p>Most students do not understand the relationship between temperatures and volumes of the same material, in this case water. Although the correct answer was the most popular, choice B was nearly as popular at 27%. Choosing B suggests a misconception that "hot" is more "powerful" than "cold." E was selected by 22%, possibly because those students felt they needed an equation. C was chosen by 17%, with only 4% picking A, suggesting that nearly all students recognized that the temperature of the two quantities combined had to be between the two initial temperatures.</p>
13	15	<p>Mike thinks that he can turn copper into gold. He mixes a small amount of gold with a large amount of copper and heats them up until they melt. What do you think has happened?</p> <ol style="list-style-type: none"> <li>All the copper has turned into gold.</li> <li>Some of the copper has turned into gold.</li> <li>The copper has not changed into gold. It's just a mixture of gold and copper.</li> <li>Copper and gold have turned into something completely new.</li> <li>Not enough information to answer the question.</li> </ol>	2	C: 57%	<p>While a clear majority of students understood that mixing copper and gold simply by melting them results in a mixture, 19% chose D, indicating a belief that some sort of transformation occurs resulting in a material that is neither gold nor copper. This choice may indicate a misunderstanding about what is and is not a chemical reaction; some students may think the combination results in bronze or brass. The other options drew from 12% for B to 4% for A.</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
14	12	<p>Kaitlyn is watching a wind-up toy walking across a table. She observes that the toy covers 1 cm every second for 10 seconds. Which graph below do you think most closely represents the toy's journey across the table?</p> <p>See item on test for graphs.</p>	4	B: 58%	As with item 7, those students who did not choose the correct answer preferred (with a 26% response) the choice (A) that seemed to represent the object's physical motion. Choice A, a straight, horizontal line, could be seen as the straight line motion of the toy across the table. The other three options drew 4–6% each.
15	10	<p>A person claims that diamonds and the graphite in an ordinary pencil are made of the same material. A scientist's response would be that the claim is:</p> <ol style="list-style-type: none"> <li>False. The two substances are too different to be made of the same material.</li> <li>False. Every substance is unique; no two substances are made of the same material.</li> <li>Not able to be answered with the information given.</li> <li>True. The substances look different because what's inside them is arranged differently.</li> <li>True. The material is held together by a different substance, causing the different properties.</li> </ol>	3	D: 22%	This item probes for understanding the differences between the properties of a substance and the materials that comprise it. The dramatic difference in appearance and other properties between diamonds and graphite is not the result of their being composed of different materials. Approximately one fifth of the students in the sample knew this fact, while slightly more (25%) believe that the two substances are unique (choice B) or that there is not enough information to answer the question (C: 26%), which might actually be true for some students, depending on what they studied in their physical science course.
		<p>A see-saw has cinder blocks attached to it on both ends. The single block weighs 20 pounds and the two small blocks weigh</p>			Overall, this was an easy item, possibly because it involved something with which students had



Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
16	6	<p>10 pounds each. (See test item for picture.) What do you think will happen to the see-saw when its allowed to move?</p> <ol style="list-style-type: none"> <li>The side with the single block will move downward.</li> <li>The side with two small blocks will move downward.</li> <li>The see-saw will not move.</li> <li>The side with the single block will first move downward and then upward.</li> <li>The side with the small blocks will first move downwards and then upward.</li> </ol>	5	C: 62%	personal experience (a see-saw). However, 12% did choose B, which may indicate that the two separate blocks were seen as having more effect than the single block, although the total weight on each side was the same. The other choices drew from 6–10%.
17	2	<p>Zahra is sitting in her backyard, looking at a tree. With which of the following statements about how she is able to see a tree do you agree? (See diagrams in test item.)</p> <ol style="list-style-type: none"> <li>Light from her eye reaches the tree and she sees the tree.</li> <li>Light from the Sun reaches the tree and then her eye and she sees the tree.</li> <li>Light from the Sun reaches her eye and she sees the tree.</li> <li>Light from her eye reaches the Sun and then the tree and she sees the tree.</li> <li>Light from the tree reaches the Sun and then her eye and she sees the tree.</li> </ol>	8	B: 54%	Slightly more than half of the students correctly understood that we see objects only when light is scattered from the object (or emitted by it) and that light then enters the eye. The other students chose fairly equally among the other options, each of which involves the eye behaving in some sort of active manner, rather than its real behavior as a passive receiver; this notion of vision is a dominant misconception into high school. (A: 14%; C: 12%; D: 12%; E: 6%).
		Imagine that you go to leave a room with an overhead light. The light is on. You move the wall switch to turn off the light			The majority of students did not get this item correct. The most common misconception

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
18	3	<p>wall switch to turn off the light, but the light stays on. What is probably wrong?</p> <ol style="list-style-type: none"> <li>The battery that powers the switch is dead.</li> <li>There is a break in the wire to the light bulb.</li> <li>The switch can no longer stop the flow of electricity through the wires</li> <li>The light fixture is broken.</li> <li>A surge of electricity is occurring in the building.</li> </ol>	9	C: 37%	<p>common misconception was B, chosen by 28% of the students. Note that this option, which requires a wire to be broken, is at odds with the fact that the light is on, which requires an intact circuit to exist. Many students, even high school students after doing circuit labs, still do not grasp the fundamental concept of an electrical circuit's components. The other three choices drew from 9% to 13%.</p>
19	11	<p>A solid rubber ball sinks when placed in water. What will happen if the ball is cut in half and one of the smaller pieces is placed underwater?</p> <ol style="list-style-type: none"> <li>The smaller piece will rise.</li> <li>The smaller piece will sink.</li> <li>The smaller piece will stay motionless.</li> <li>The smaller piece will dissolve.</li> <li>There is no way to predict what will happen.</li> </ol>	1	B: 29%	<p>Nearly three quarters of the students answered this density item incorrectly. The dominant misconception was A, which drew 41% of the responses. This misconception may arise from everyday observation of small objects floating, without any quantitative study made, or from the notion that the smaller piece will weigh less and therefore be able to float, ignoring the issue that reduced volume is coupled with reduced mass. Fully understanding the relationship among mass, volume and density, particularly when applying it to predicting floating or sinking, is very hard; extensive work done by us even with non-physics graduate students has yielded outcomes similar to those with middle</p>

Item # Form 721	Item # Form 722	Text of item	Std. <sup>1</sup>	Correct response & percent <sup>2</sup> responding correctly	Commentary <sup>3</sup>
					school students.
20	1	<p>A pebble is dropped into a cup of water and sinks to the bottom of the cup. A solid metal bead of exactly the same size is dropped into the same cup and sinks to the bottom of the cup. How do the pebble and the metal bead compare?</p> <ol style="list-style-type: none"> <li>The metal bead and the pebble have the same density.</li> <li>The metal bead and the pebble are the same mass.</li> <li>The metal bead and the pebble are denser than water.</li> <li>The metal bead and the pebble contain the same materials.</li> <li>The metal bead and the pebble are as dense as the water.</li> </ol>	1	C: 62%	Students do much better with this density item than with item 19, partly because there are two different objects rather than one object being manipulated. The dominant misconception was B (16%), followed by A (14%). Both A and B involve making a more specific (and impossible) conclusion about the two objects based on very limited information (both sink in water and are the same size). D drew 5%, while E attracted only 3%.

#### Major Misconceptions in Grades 5–8 Physical Science

Listed below are some student physical science misconceptions. The list is not intended to be exhaustive, but rather a summary of some of the more common prior ideas we identified from our analysis of the student response patterns to the items on the tests.

- Gases have no mass.
- Heat and cold are substances or entities, and different from one another.
- Electricity flows through hollow wires and is used up by lights or appliances.
- The eye emits light (or otherwise behaves actively) in order for people or animals to see.

- Appliances or lights can still work in incomplete electrical circuits.
- Matter can be created and destroyed.
- Particles are not conserved in chemical or physical changes.
- Density and other characteristic properties of materials are dependent on the amount of material present. For example, the density of a small piece of rock is not the same as the density of the larger rock from which it came.
- Different forms or phases of the same substances are chemically different.
- Light is unaffected as it passes through transparent materials.

The following resources are useful for additional background information about students' science misconceptions:

Driver, R. (Ed.), *Children's Ideas in Science*, Philadelphia: Open University Press (1985).

Driver, R., *Pupil as Scientist?*, Philadelphia: Open University Press (1983).

Shapiro, B., *What Children Bring to Light: A Constructivist Perspective on Children's Learning in Science*, New York: Teachers College Press (1994).