

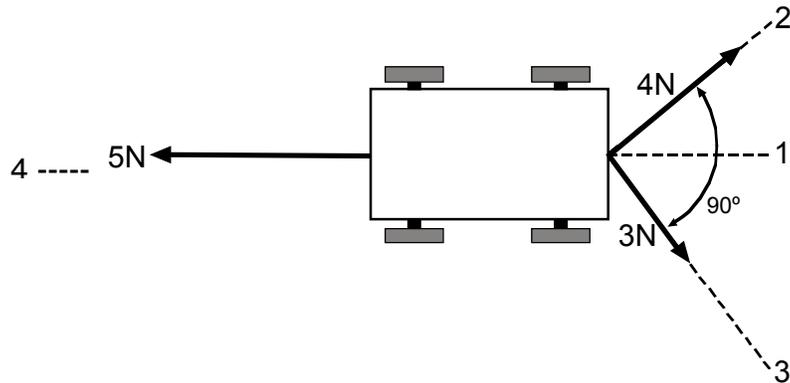
## PHYSICS TEST

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. After a light wave has reflected from a smooth glass mirror hanging on a wall:
  - a. it may be traveling in a different direction.
  - b. it is traveling at a different speed than before it hit the mirror.
  - c. its wavelength is different.
  - d. its energy is greater.
  - e. All of the above.
2. Copper is a good electrical conductor because:
  - a. it has a high melting temperature.
  - b. no electrons can flow through it.
  - c. few electrons can flow through it.
  - d. electrons flow readily through it.
  - e. it can also be a good insulator.
3. An astronaut weighs 150 pounds on the surface of the Earth. How much would he weigh standing on a planet exactly like Earth except it is one-half as far from the Sun?
  - a. More than 150 pounds.
  - b. 150 pounds.
  - c. Less than 150 pounds.
  - d. He would be weightless.
  - e. It is impossible to tell.
4. Two positively charged objects are located 1 cm apart. If the distance between the objects is doubled to 2 cm, the electric force between the objects:
  - a. is doubled.
  - b. is halved.
  - c. is four times stronger.
  - d. is one fourth as strong.
  - e. is unchanged.
5. If the amplitude of a wave were increased:
  - a. the velocity of the wave would increase.
  - b. the frequency of the wave would increase.
  - c. the period of the wave would increase.
  - d. the energy transferred would increase.
  - e. the wavelength would increase.

GO TO QUESTION 6 >>

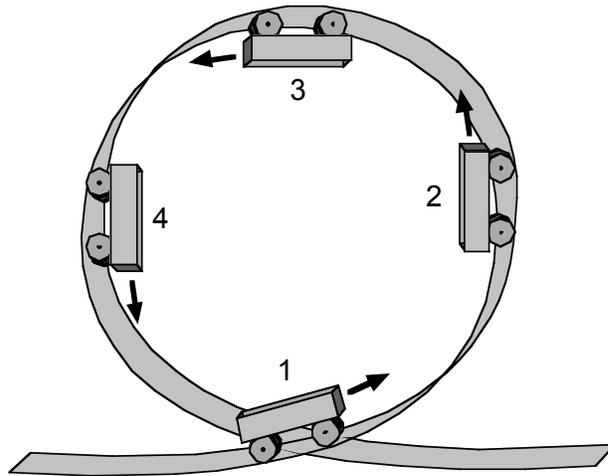
6. If the cart is being pulled simultaneously toward points 2, 3 and 4, toward which point will the cart most likely move?



- a. 1  
b. 2  
c. 3  
d. 4  
e. The cart won't move.
7. A car with a full tank of gasoline is driven non-stop until the tank is empty. What happened to the gasoline's energy?
- a. All of it could have been used to move the car.  
b. Some moved the car and some powered the stereo, lights and other equipment.  
c. Some moved the car, some powered the car's equipment, and some heated the engine.  
d. Some moved the car, some powered the car's equipment, some heated the engine, and some went into noise and friction.  
e. Some moved the car, some powered the car's equipment, some heated the engine, some went into noise and friction, and some energy was destroyed.

GO TO QUESTION 8 >>

8. A roller coaster cart goes through a loop as shown below. At which point is there no gravity?



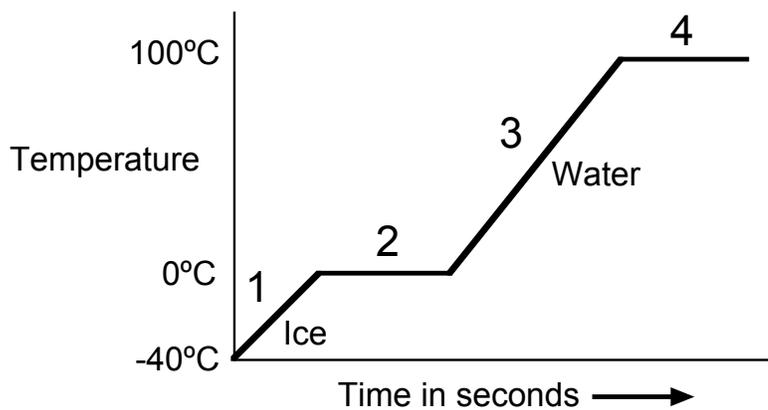
- a. 1
  - b. 2
  - c. 3
  - d. 4
  - e. Gravity is the same everywhere.
9. If you are at rest and are watching a moving object and it suddenly changes direction, you can be sure that the object:
- a. was acted on by a net force.
  - b. was not acted on by a net force.
  - c. is not being acted on by any force.
  - d. is gaining kinetic energy.
  - e. is losing kinetic energy.
10. A battery works by:
- a. storing electrical energy.
  - b. creating chemical energy.
  - c. converting chemical energy into electrical energy.
  - d. converting electrical energy into kinetic energy.
  - e. converting electrical energy into chemical energy.
11. People wear light-colored clothes in the summer because the clothes:
- a. reflect more radiation.
  - b. prevent sweating.
  - c. are not as heavy as dark clothes.
  - d. let more air in.
  - e. are made of cotton.

GO TO QUESTION 12 >>

12. In a hydrogen atom, an electron orbits a proton. What is true about the forces between the electron and proton?
- Gravity is stronger than the electric force.
  - The radioactive force is stronger than the electric force.
  - The electric force is stronger than gravity.
  - The electric force is equal to gravity in strength.
  - There is no force between the electron and proton.
13. A baseball is hit into the air. At the top of its trajectory:
- the baseball is not subject to a net force.
  - the baseball is subject to a net force.
  - the baseball is not accelerating.
  - Both a and c are true.
  - Both b and c are true.
14. Light waves:
- do not oscillate.
  - oscillate in proportion to their velocity.
  - oscillate in the direction they are moving.
  - oscillate at right angles to the direction they are moving.
  - Only c and d.
15. How do radio waves and x-rays differ?
- They travel at different speeds in a vacuum.
  - Only radio waves can be reflected.
  - They have different wavelengths.
  - Only two of the above are true.
  - a, b and c are all true.
16. An electric charge moving at right angles to magnetic field lines experiences:
- a force at right angles to its direction of motion.
  - a force parallel to its direction of motion.
  - a force that opposes its motion.
  - a force in the direction of the source of the magnetic field.
  - no force.
17. If you looked at a continuous spectrum in a darkened room through a red filter, the spectrum would appear:
- the same except the red portion would be black.
  - black except the red portion would remain red.
  - as shades of red except the red portion would be black.
  - as shades of red except the red portion would be a brighter red.
  - the same as if there was no filter present.

**GO TO QUESTION 18 >>**

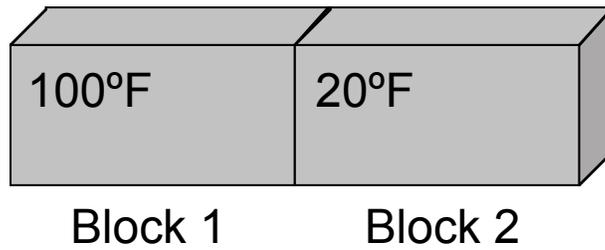
18. Why does each kind of atom have a unique emission spectrum?
- The lines represent the differences between quantized energy levels for that atom.
  - Each kind of atom has a different shape, which makes the lines appear in different places.
  - Each kind of atom has a different charge, which makes it emit energy differently.
  - The lines represent the number of electrons in the outermost energy level that will ionize.
  - Attempts by scientists to model the cause of the different spectra have been unsuccessful.
19. The primary purpose of an electric motor is to convert:
- electrical energy to heat energy.
  - magnetic energy to electrical energy.
  - electric energy to mechanical energy.
  - mechanical energy to heat energy.
  - mechanical energy to electrical energy.
20. Ice is placed in a container which is heated steadily and continuously. The ice is initially below its freezing point, and during the heating process it turns to water and finally the water boils. The graph below shows how the temperature varies with time during the heating process.



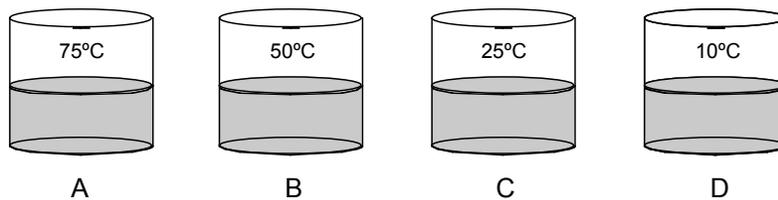
- Four distinct portions of the graph are labeled 1, 2, 3 and 4. Which portions represent *phase changes*?
- Portions 1 and 3 only.
  - Portions 2 and 4 only.
  - Portions 1 and 4 only.
  - Portions 2 and 3 only.
  - All portions.
21. An inventor wants to develop a light that uses 100% of the electricity it receives to emit visible light. What would a scientist say about this idea?
- Such lights already exist and are in use now.
  - The lights would cost so much to make that few people could afford to buy them.
  - The science involved is very complicated and the effort would take many years.
  - The inventor must discover how to prevent energy destruction.
  - Such a light is impossible to build.

GO TO QUESTION 22 >>

22. Metal block 1 is at a temperature of  $100^{\circ}\text{F}$ ; identical metal block 2 is at  $20^{\circ}\text{F}$ . If the blocks are in contact, as shown below, what will happen?



- a. Only heat will flow from block 1 to block 2.  
b. Cold will flow from block 2 to block 1.  
c. Heat will flow from block 1 to block 2; cold will flow from block 2 to block 1.  
d. Equal amounts of heat will flow between the two blocks.  
e. Cold will be absorbed by block 1; heat will be absorbed by block 2.
23. If there is an electric force:
- a. there must be two charged objects touching each other.  
b. there must be two charged objects, but they do not have to touch.  
c. there is only one charged object and its charge is positive.  
d. there is only one charged object and its charge is negative.  
e. there must be a complete circuit.
24. Materials that make good electrical conductors must:
- a. be solid.  
b. be flexible enough to bend easily.  
c. allow electrons to flow easily.  
d. Only b and c.  
e. a, b, and c.
25. Four containers of water with different temperatures as shown below are placed on a table in a room where the temperature is  $25^{\circ}\text{C}$ . After four hours, which beaker of water will have lost the most heat energy to the room?

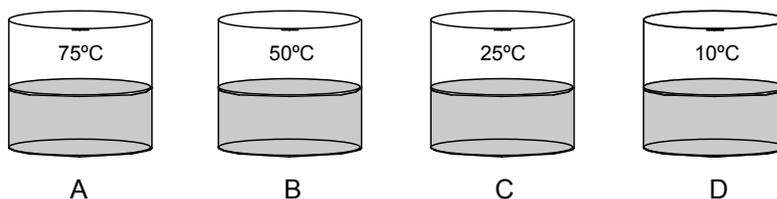


- a. A  
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c. C  
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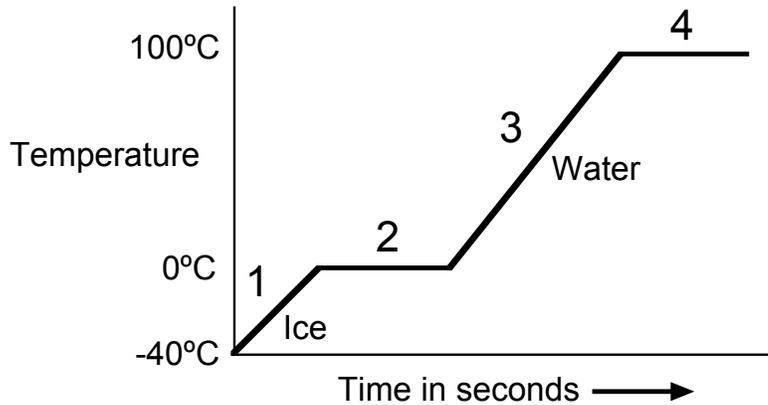


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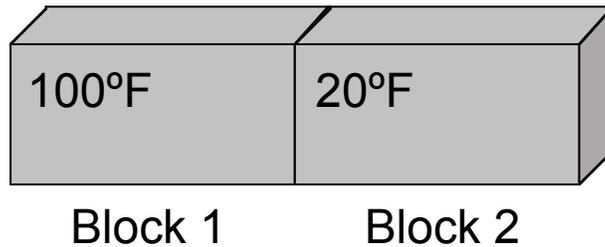
GO TO QUESTION 10 >>

10. Ice is placed in a container which is heated steadily and continuously. The ice is initially below its freezing point, and during the heating process it turns to water and finally the water boils. The graph below shows how the temperature varies with time during the heating process.



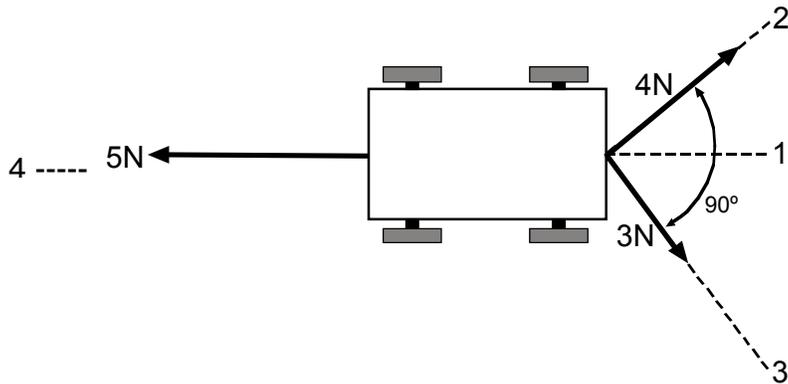
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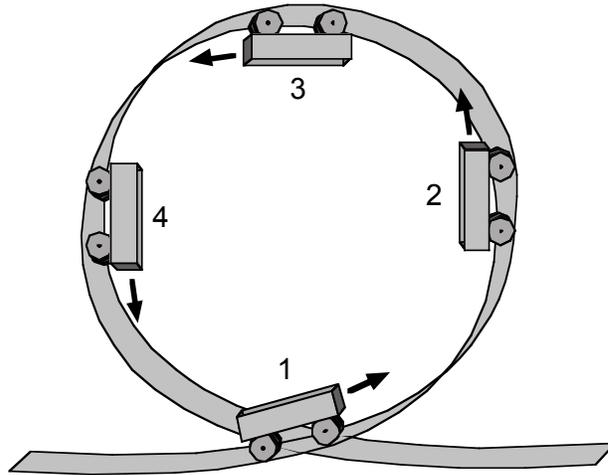
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14. If the cart is being pulled simultaneously toward points 2, 3 and 4, toward which point will the cart most likely move?



- 1
  - 2
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  - 4
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 e. Gravity is the same everywhere.
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 c. is not being acted on by any force.  
 d. is gaining kinetic energy.  
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20. A baseball is hit into the air. At the top of its trajectory:
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 e. All of the above.

GO TO QUESTION 22 >>

22. People wear light-colored clothes in the summer because the clothes:
- reflect more radiation.
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  - are not as heavy as dark clothes.
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25. In a hydrogen atom, an electron orbits a proton. What is true about the forces between the electron and proton?
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  - The radioactive force is stronger than the electric force.
  - The electric force is stronger than gravity.
  - The electric force is equal to gravity in strength.
  - There is no force between the electron and proton.

## Grades 9–12 Physics Tests

The tests in this section contain items related to 12 of the grades 9–12 standards in physical science related to physics from the NRC's *National Science Education Standards (NSES)*; below are the standards as stated in the *NSES*.

9–12 Physics Standard 1:

"Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship  $F = ma$ , which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object."

9–12 Physics Standard 2:

"Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them."

9–12 Physics Standard 3:

"The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them."

9–12 Physics Standard 4:

"Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules."

9–12 Physics Standard 5:

"Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators."

9–12 Physics Standard 6:

"The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered."

9–12 Physics Standard 7:

"Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion."

9–12 Physics Standard 8:

"Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels."

9–12 Physics Standard 9:

"Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter."

9–12 Physics Standard 10:

"Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength."

9–12 Physics Standard 11:

"Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance."

9–12 Physics Standard 12:

"In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons."

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 9–12 tests are intended for use primarily with high school physics students. The tests can also be administered to any persons who possess at least a 9th 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 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
1	21	<p>After a light wave has reflected from a smooth glass mirror hanging on a wall:</p> <ul style="list-style-type: none"> <li>a. it may be traveling in a different direction.</li> <li>b. it is traveling at a different speed than before it hit the mirror.</li> <li>c. its wavelength is different.</li> <li>d. its energy is greater.</li> <li>e. All of the above.</li> </ul>	<b>10</b>	A: 67% (n=327)	Although two thirds of students responded correctly to this question, students who did not were very likely to score lower overall on our national field tests. 24% of students chose E, which suggests that these students may have an incomplete model for the behavior of light. The remaining options were chosen by less than 5% each.
2	17	<p>Copper is a good electrical conductor because:</p> <ul style="list-style-type: none"> <li>a. it has a high melting temperature.</li> <li>b. no electrons can flow through it.</li> <li>c. few electrons can flow through it.</li> <li>d. electrons flow readily through it.</li> <li>e. it can also be a good insulator.</li> </ul>	<b>12</b>	D: 86% (n=600)	The very high response to the correct choice suggests that students have a basic understanding of electrical conductivity. Note: If students did not answer this question correctly, they made lower total scores on our national field tests.

<sup>1</sup> These test items are valid psychometrically and represent standards commonly included in grades 9–12 physics curricula. Please note: The items do not represent the entire domain of standards, as presented in the NRC standards.

<sup>2</sup> Students were selected randomly in classes as a nationally representative sample of all grades 6–8 students in U.S. public and private schools. The sample number (n) is included for each item because the number of students per item varied considerably.

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

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
3	13	An astronaut weighs 150 pounds on the surface of the Earth. How much would he weigh standing on a planet exactly like Earth except it is one-half as far from the Sun? a. More than 150 pounds. b. 150 pounds. c. Less than 150 pounds. d. He would be weightless. e. It is impossible to tell.	2	B: 34% (n=233)	More students chose A (40%) than the correct response, suggesting they perceive the Sun's greater gravity as significantly affecting anything on earth. As with the first two questions, students who answered incorrectly on this item tended to score lower overall on the test than those that responded correctly.
4	16	Two positively charged objects are located 1 cm apart. If the distance between the objects is doubled to 2 cm, the electric force between the objects: a. is doubled. b. is halved. c. is four times stronger. d. is one fourth as strong.. e. is unchanged.	3	D: 30% (n=357)	The most popular choice, chosen by 44%, was B, revealing common misconceptions about the force of attraction or repulsion between two objects and the distance between them.
5	15	If the amplitude of a wave were increased: a. the velocity of the wave would increase. b. the frequency of the wave would increase. c. the period of the wave would increase. d. the energy transferred would increase. e. the wavelength would increase.	9	D: 32% (n=357)	31% of students chose B, essentially the same number of students who were correct. Another 19% chose C.
6	14	If the cart is being pulled simultaneously toward points 2, 3 and 4, toward which point will the cart most likely move? (See diagram and choices in item on test.)	1	E: 31% (n=357)	Although E was most frequently chosen, 26% of students chose D and another 23% chose A.

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7	23	<p>A car with a full tank of gasoline is driven non-stop until the tank is empty. What happened to the gasoline's energy?</p> <p>a. All of it could have been used to move the car.</p> <p>b. Some moved the car and some powered the stereo, lights and other equipment.</p> <p>c. Some moved the car, some powered the car's equipment, and some heated the engine.</p> <p>d. Some moved the car, some powered the car's equipment, some heated the engine, and some went into noise and friction.</p> <p>e. Some moved the car, some powered the car's equipment, some heated the engine, some went into noise and friction, and some energy was destroyed.</p>	6	D: 47% (n=788)	Nearly half of students chose the correct response. Small numbers of students chose the other options, but these were equally dispersed with 17% choosing A, 7% picking B, 14% selecting C and 15% choosing E.
8	18	<p>A roller coaster cart goes through a loop as shown below. At which point is there no gravity? (See diagram and choices in item on test.)</p>	2	E: 72% (n=603)	With nearly three quarters of students selecting the correct answer, it appears that most students understand that gravity is basically the same everywhere for this scenario. The most frequent incorrect response was C, which was chosen by 17% of students. No other option was chosen by more than 5% of students.

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9	19	If you are at rest and are watching a moving object and it suddenly changes direction, you can be sure that the object: a. was acted on by a net force. b. was not acted on by a net force. c. is not being acted on by any force. d. is gaining kinetic energy. e. is losing kinetic energy.	1	A: 74% (n=368)	With three quarters of students responding correctly, less than 10% of students chose any other response (B: 5%, C: 7%; D: 8%; and E: 6%).
10	24	A battery works by: a. storing electrical energy. b. creating chemical energy. c. converting chemical energy into electrical energy. d. converting electrical energy into kinetic energy. e. converting electrical energy into chemical energy.	6	C: 57% (n=608)	The most common incorrect responses were related to common misconceptions; 18% of students chose A and 14% chose D.
11	22	People wear light-colored clothes in the summer because the clothes: a. reflect more radiation. b. prevent sweating. c. are not as heavy as dark clothes. d. let more air in. e. are made of cotton.	10	A: 88% (n=2130)	The very high correct response rate to this item may be due to personal experience. No more than 5% of students chose any other option.

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
12	25	In a hydrogen atom, an electron orbits a proton. What is true about the forces between the electron and proton? a. Gravity is stronger than the electric force b. The radioactive force is stronger than the electric force c. The electric force is stronger than gravity d. The electric force is equal to gravity in strength. e. There is no force between the electron and proton.	4	C: 13% (n=513)	Two options are more prevalent than the correct response: 29% of students chose D and another 27% chose E, both indicating misunderstandings about the relationship of subatomic particles and the forces affecting them.
13	20	A baseball is hit into the air. At the top of its trajectory: a. the baseball is not subject to a net force. b. the baseball is subject to a net force. c. the baseball is not accelerating. d. Both a and c are true. e. Both b and c are true.	1	B: 27% (n=421)	One third of students chose E, implying that they may have recognized that gravity was acting on the ball, but failing to understand that that means an acceleration would be occurring. This is a very difficult concept for students. 20% chose D, suggesting that they perceived no force or other effect on the ball.
14	4	Light waves: a. do not oscillate. b. oscillate in proportion to their velocity. c. oscillate in the direction they are moving. d. oscillate at right angles to the direction they are moving. e. Only c and d.	9	D: 23% (n=420)	The responses to this item were split fairly equally between the correct response (D), B (21%) and C (25%). These results suggest that students are unclear about the wave model for light.

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
15	6	How do radio waves and x-rays differ? a. They travel at different speeds in a vacuum. b. Only radio waves can be reflected. c. They have different wavelengths. d. Only two of the above are true. e. a, b and c are all true.	10	C: 41% (n=420)	The correct response was the most frequently chosen. One third of the students chose D and 20% of students chose E, i.e., that all three options (A-C) were correct.
16	8	An electric charge moving at right angles to magnetic field lines experiences: a. a force at right angles to its direction of motion. b. a force parallel to its direction of motion. c. a force that opposes its motion. d. a force in the direction of the source of the magnetic field. e. no force.	5	A: 46% (n=417)	The correct response was chosen by nearly half of students and was the most frequent response. The second most frequent was D, chosen by 21% of students.
17	3	If you looked at a continuous spectrum in a darkened room through a red filter, the spectrum would appear: a. the same except the red portion would be black. b. black except the red portion would remain red. c. as shades of red except the red portion would be black. d. as shades of red except the red portion would be a brighter red. e. the same as if there was no filter present.	11	B: 8% (n=517)	Few students chose the correct answer, while 52% chose D, highlighting a very common misconception concerning colored filters. I.e., that they add their color to the light passing through them or otherwise add their color to a scene.

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
18	5	<p>Why does each kind of atom have a unique emission spectrum?</p> <p>a. The lines represent the differences between quantized energy levels for that atom.</p> <p>b. Each kind of atom has a different shape, which makes the lines appear in different places.</p> <p>c. Each kind of atom has a different charge, which makes it emit energy differently.</p> <p>d. The lines represent the number of electrons in the outermost energy level that will ionize.</p> <p>e. Attempts by scientists to model the cause of the different spectra have been unsuccessful.</p>	11	A: 29% (n=413)	C drew essentially the same response (30%) as did the correct answer. The correct answer was the second most frequent and D was the third most commonly selected at 22%.
19	9	<p>The primary purpose of an electric motor is to convert:</p> <p>a. electrical energy to heat energy.</p> <p>b. magnetic energy to electrical energy.</p> <p>c. electric energy to mechanical energy.</p> <p>d. mechanical energy to heat energy.</p> <p>e. mechanical energy to electrical energy.</p>	5	C: 56% (n=655)	The students who responded incorrectly were fairly equally divided between most of the other options (A: 16%; B: 13%; D: 4%; and E: 11%).

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
20	10	Ice is placed in a container which is heated steadily and continuously. The ice is initially below its freezing point, and during the heating process it turns to water and finally the water boils. The graph below shows how the temperature varies with time during the heating process. (See graph in item on test.) Four distinct portions of the graph are labeled 1, 2, 3 and 4. Which portions represent <i>phase changes</i> ? a. Portions 1 and 3 only. b. Portions 2 and 4 only. c. Portions 1 and 4 only. d. Portions 2 and 3 only. e. All portions.	7	B: 46% (n=399)	Nearly half of the students chose the correct answer, while the most common incorrect response was A, chosen by 36% of the students. None of the other incorrect options attracted more than 10% each.
21	7	An inventor wants to develop a light that uses 100% of the electricity it receives to emit visible light. What would a scientist say about this idea? a. Such lights already exist and are in use now. b. The lights would cost so much to make that few people could afford to buy them. c. The science involved is very complicated and the effort would take many years. d. The inventor must discover how to prevent energy destruction. e. Such a light is impossible to build.	6	E: 37% (n=515)	24% of students chose D, which includes the misconception that energy can be destroyed, rather than converted into other forms of energy. 18% chose A.

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
22	11	(See figure in item on test.) Metal block 1 is at a temperature of 100°F; identical metal block 2 is at 20°F. If the blocks are in contact, as shown below, what will happen? a. Only heat will flow from block 1 to block 2. b. Cold will flow from block 2 to block 1. c. Heat will flow from block 1 to block 2; cold will flow from block 2 to block 1. d. Equal amounts of heat will flow between the two blocks. e. Cold will be absorbed by block 1; heat will be absorbed by block 2.	<b>8</b>	A: 49% (n=420)	The most common incorrect response (22%) was C. This response reflects the misconception that "cold" is an entity.
23	2	If there is an electric force: a. there must be two charged objects touching each other. b. there must be two charged objects, but they do not have to touch. c. there is only one charged object and its charge is positive. d. there is only one charged object and its charge is negative. e. there must be a complete circuit.	<b>3</b>	B: 44% (n=515)	Two incorrect options attracted approximately 20% of the students each, A and E.
24	12	Materials that make good electrical conductors must: a. be solid. b. be flexible enough to bend easily. c. allow electrons to flow easily. d. Only b and c. e. a, b, and c.	<b>12</b>	C: 71% (n=368)	The overall response to this item was rather good. The most common incorrect response was D, with an 11% rate, which seems to suggest that some students were thinking specifically about wires.

Item # Form 741	Item # Form 742	Text of item	Std. <sup>1</sup>	Correct response & percent responding correctly <sup>2</sup>	Commentary <sup>3</sup>
25	1	Four containers of water with different temperatures as shown below are placed on a table in a room where the temperature is 25°C. After four hours, which beaker of water will have lost the most heat energy to the room? (See figure and choices in item on test.)	7	A: 81% (n= 843)	Over three fourths of the students answered this item correctly; E was the most frequently chosen response with 12%, Students who chose any of the incorrect answers scored lower overall on our national field tests than those who chose the right answer.

#### Major Misconceptions in Grades 9–12 Physics

Listed below are some student physics 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.

- The force of gravity is always stronger than the electric force.
- An object at rest has no force acting on it.
- No net force exists on an object with an instantaneous speed of zero.
- The force of attraction or repulsion (electrostatic, magnetic or gravitational) between two objects is either independent of or directly related to the distance between the objects (e.g., tripling the distance reduces the force to one third its original value).
- Filters add color to light.
- Energy can be created or destroyed during energy transformations.
- Light reflects from a shiny surface in an arbitrary manner.

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

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

Driver, R., et al., *Making Sense of Secondary Science*, Philadelphia: Open University Press (1994).

Wandersee, J.H., et al., "Research on Alternative Conceptions in Science," in Gabel, D., (ed) *Handbook of Research on Science Teaching and Learning*, New York: Macmillan, pp. 177–210 (1994).