MASSACHUSETTS DEPARTMENT OF
ELEMENTARY AND SECONDARY
EDUCATION

Release of Spring 2022 MCAS Test Items

from the

High School Introductory Physics Paper-Based Test

July 2022
Massachusetts Department of Elementary and Secondary Education

MASSACHUSETTS DEPARTMENT OF
ELEMENTARY AND SECONDARY
EDUCATION

This document was prepared by the
Massachusetts Department of Elementary and Secondary Education
Jeffrey C. Riley
Commissioner

The Massachusetts Department of Elementary and Secondary Education, an affirmative action employer, is committed to ensuring that all of its programs and facilities are accessible to all members of the public. We do not discriminate on the basis of age, color, disability, gender identity, national origin, race, religion, sex or sexual orientation. Inquiries regarding the Department's compliance with Title IX and other civil rights laws may be directed to the Human Resources Director, 75 Pleasant St., Malden, MA 02148 781-338-6105.

Massachusetts Department of Elementary and Secondary Education
75 Pleasant Street, Malden, MA 02148-4906
Phone 781-338-3000 TTY: N.E.T. Relay 800-439-2370
www.doe.mass.edu

Overview of High School Introductory Physics Test

The spring 2022 high school Introductory Physics test was a next-generation assessment that was administered in two primary formats: a computer-based version and a paper-based version. The vast majority of students took the computer-based test. The paper-based test was offered as an accommodation for students with disabilities who are unable to use a computer, as well as for English learners who are new to the country and are unfamiliar with technology.

Most of the operational items on the high school Introductory Physics test were the same, regardless of whether a student took the computer-based version or the paper-based version. In places where a technology-enhanced item was used on the computer-based test, an adapted version of the item was created for use on the paper test. These adapted paper items were multiple-choice or multiple-select items that tested the same STE content and assessed the same standard as the technology-enhanced item.

This document displays released items from the paper-based test. Released items from the computer-based test are available on the MCAS Resource Center website at mcas.pearsonsupport.com/released-items.

Test Sessions and Content Overview

The high school Introductory Physics test was made up of two separate test sessions. Each session included selected-response questions and constructed-response questions. On the paper-based test, the selected-response questions were multiple-choice items and multiple-select items, in which students select the correct answer(s) from among several answer options.

Standards and Reporting Categories

The high school Introductory Physics test was based on learning standards in the April 2016 version of the *Massachusetts Science and Technology/Engineering Curriculum Framework*. These standards are grouped under the three content reporting categories listed below. Note that standard HS.PHY.1.8 is included in the Energy reporting category.

- Motion, Forces, and Interactions
- Energy
- Waves

The 2016 *Massachusetts Science and Technology/Engineering Curriculum Framework* is available on the Department website at www.doe.mass.edu/frameworks/current.html.

Some items on the high school Introductory Physics test are also reported as aligning to one of three MCAS Science and Engineering Practice Categories. The three practice categories are listed below.

- Practice Category A: Investigations and Questioning
- Practice Category B: Mathematics and Data
- Practice Category C: Evidence, Reasoning, and Modeling

More information about the practice categories is available on the Department website at www.doe.mass.edu/mcas/tdd/practice-categories.html.

The table at the conclusion of this document provides the following information about each released operational item: reporting category, standard covered, practice category covered (if any), item type, and item description. The correct answers for released selected-response questions are also displayed in the table.

Reference Materials

Each student taking the paper-based version of the high school Introductory Physics test was provided with an Introductory Physics Reference Sheet. A copy of the reference sheet follows the final question in this chapter. Each student also had sole access to a calculator.

During both high school Introductory Physics test sessions, the use of bilingual word-to-word dictionaries was allowed for current and former English learner students.

High School Introductory Physics

SESSION 1

This session contains 21 questions.

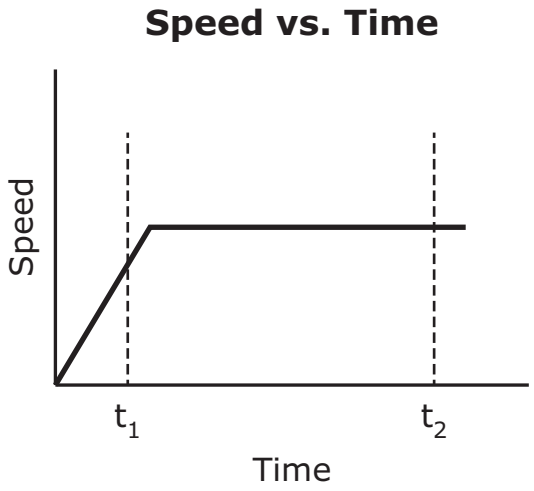
Directions

Read each question carefully and then answer it as well as you can. You must record all answers in this Test & Answer Booklet.

For some questions, you will mark your answers by filling in the circles in your Test & Answer Booklet. Make sure you darken the circles completely. Do not make any marks outside of the circles. If you need to change an answer, be sure to erase your first answer completely.

If a question asks you to show or explain your work, you must do so to receive full credit. Write your response in the space provided. Only responses written within the provided space will be scored.

1 The graph shows the speed of a rolling ball over time. In the graph, t_1 and t_2 represent two times during the ball's motion.



Which of the following setups would cause the ball to roll with the motion shown in the graph?

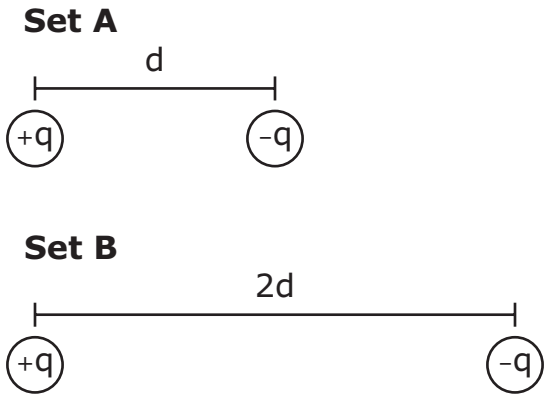
Ⓐ

Ⓑ

Ⓒ

Ⓓ

2 The diagram shows two sets of charges.



Which of the following describes the electric force between the charges?

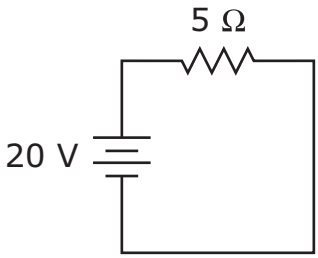
Ⓐ Set A has a larger force, which is attractive.

Ⓑ Set A has a larger force, which is repulsive.

Ⓒ Set B has a larger force, which is attractive.

Ⓓ Set B has a larger force, which is repulsive.

3 A simple circuit is shown.



Which of the following would reduce the total current in the circuit by half?

Ⓐ adding a 5 Ω resistor in parallel

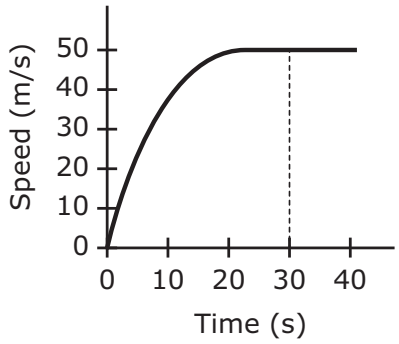
Ⓑ adding a 10 Ω light bulb in series

Ⓒ replacing the 20 V battery with a 10 V battery

Ⓓ replacing the 20 V battery with a 40 V battery

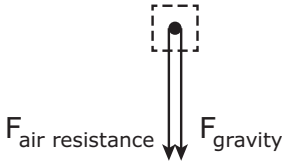
4 The graph shows how the downward speed of a skydiver changes from the moment the skydiver jumps out of an airplane to just before the skydiver's parachute opens.

Downward Speed vs. Time

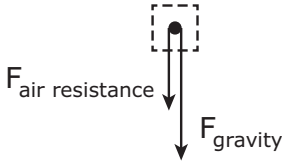


Based on the graph, which diagram represents the forces acting on the skydiver at 30 s?

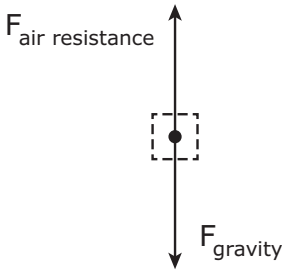
Ⓐ



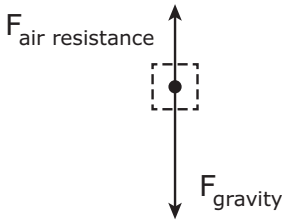
Ⓑ



Ⓒ



Ⓓ



5 A 5.0 kg object is accelerated from rest by a force of 20 N to a final velocity of 5.0 m/s. What is the final momentum of the object?

Ⓐ 4.0 kg • m/s

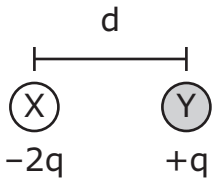
Ⓑ 25 kg • m/s

Ⓒ 100 kg • m/s

Ⓓ 500 kg • m/s

This question has two parts.

6 Two charged objects, X and Y, are separated by a distance, d, as shown.



Part A

Object Y is released so that it is free to move.

Which of the following describes the energy of object Y just before it is released?

Ⓐ Object Y has kinetic energy as a result of object X's electric field.

Ⓑ Object Y has potential energy as a result of object X's electric field.

Ⓒ Object Y has kinetic energy as a result of object X's relative motion.

Ⓓ Object Y has potential energy as a result of object X's relative motion.

Which of the following describes the energy and movement of object Y after it is released?

Ⓐ Object Y's energy is converted into kinetic energy as it moves toward object X.

Ⓑ Object Y's energy is converted into potential energy as it moves toward object X.

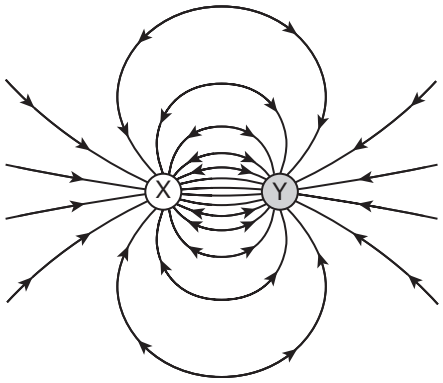
Ⓒ Object Y's energy is converted into kinetic energy as it moves away from object X.

Ⓓ Object Y's energy is converted into potential energy as it moves away from object X.

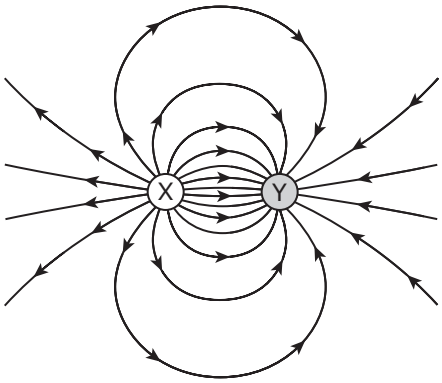
Part B

Which of the following diagrams represents the electric field lines around the two objects?

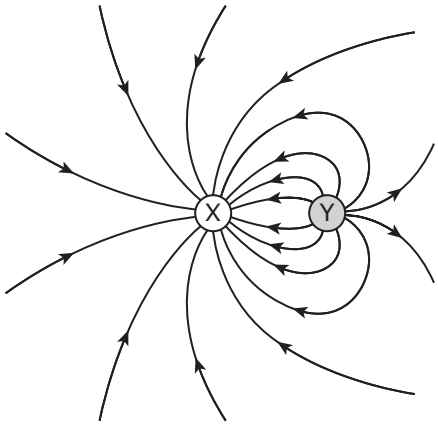
Ⓐ



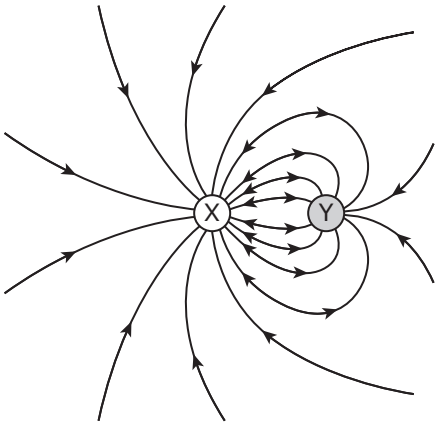
Ⓑ



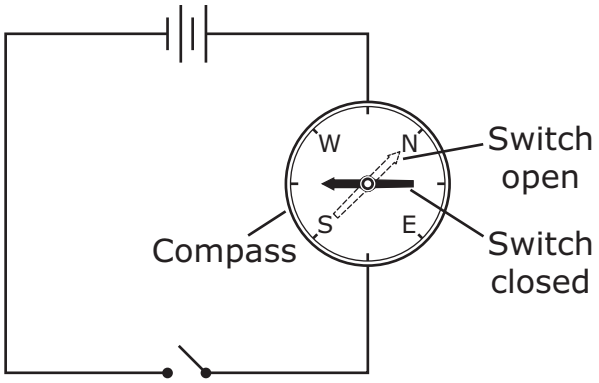
Ⓒ



Ⓓ



7 During an investigation, a student placed a compass above a wire in a circuit, as shown in the diagram.



The student recorded the position of the compass needle when the switch was open and when it was closed.

Which of the following claims is supported by evidence produced in this investigation?

Ⓐ An electric current produces a magnetic field.

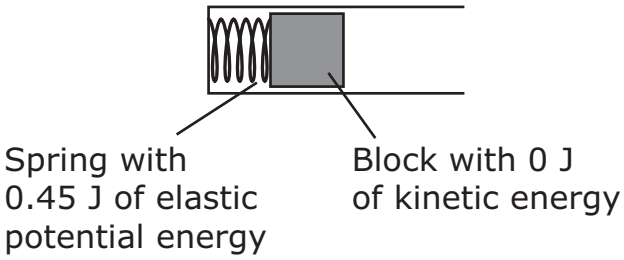
Ⓑ A magnetic field produces an electric current.

Ⓒ An electric current flows from a negative to a positive terminal.

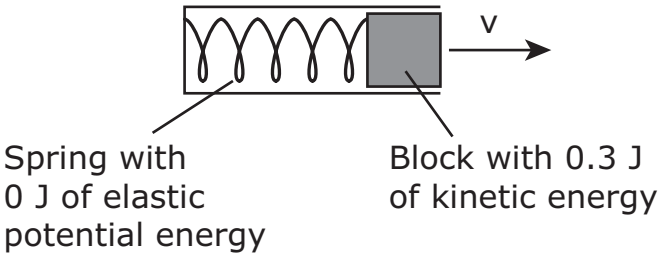
Ⓓ A magnetic field extends from the north pole of a magnet to its south pole.

8 A launcher was made with a spring held in place inside a tube. The diagrams show the launcher before and after energy was transferred from the spring to a block. Initially the block was held at rest, and the compressed spring stored 0.45 J of elastic potential energy.

Before



After



After the spring was released, the block exited the launcher with 0.3 J of kinetic energy. What was the percent efficiency of the launcher?

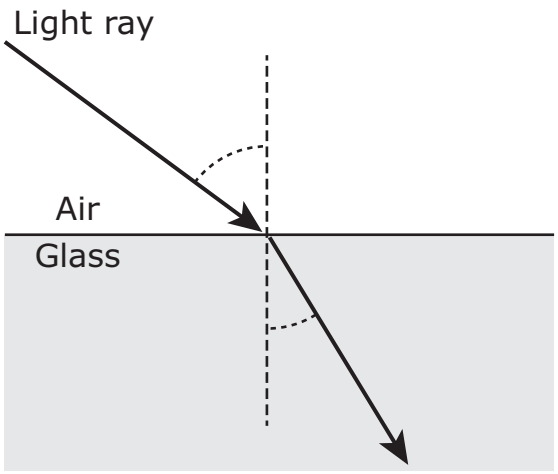
Ⓐ 15%

Ⓑ 67%

Ⓒ 75%

Ⓓ 150%

9 The diagram represents a light ray and its path as it travels from air to glass.



Which of the following best describes the angle of refraction as the light ray moves from air to glass?

Ⓐ The angle of refraction is equal to the angle of incidence because the speed of light increases.

Ⓑ The angle of refraction is smaller than the angle of incidence because the speed of light increases.

Ⓒ The angle of refraction is smaller than the angle of incidence because the speed of light decreases.

Ⓓ The angle of refraction is equal to the angle of incidence because the speed of light stays the same.

10 Ultraviolet radiation from the Sun can cause sunburn, but sitting in a classroom under visible light will not. This is because ultraviolet radiation particles have more energy than visible light particles.

Which of the following explains why ultraviolet radiation particles have more energy than visible light particles?

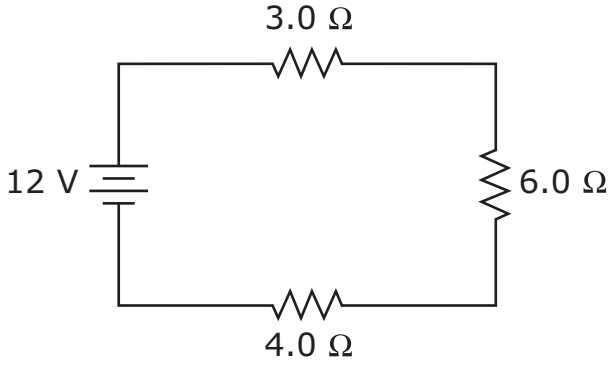
Ⓐ Ultraviolet radiation particles have a greater mass.

Ⓑ Ultraviolet radiation particles have a greater velocity.

Ⓒ Ultraviolet radiation particles have a greater frequency.

Ⓓ Ultraviolet radiation particles have a greater wavelength.

11 The diagram shows a series circuit containing a battery and three resistors.



What is the current in the circuit?

Ⓐ 0.92 A

Ⓑ 1.1 A

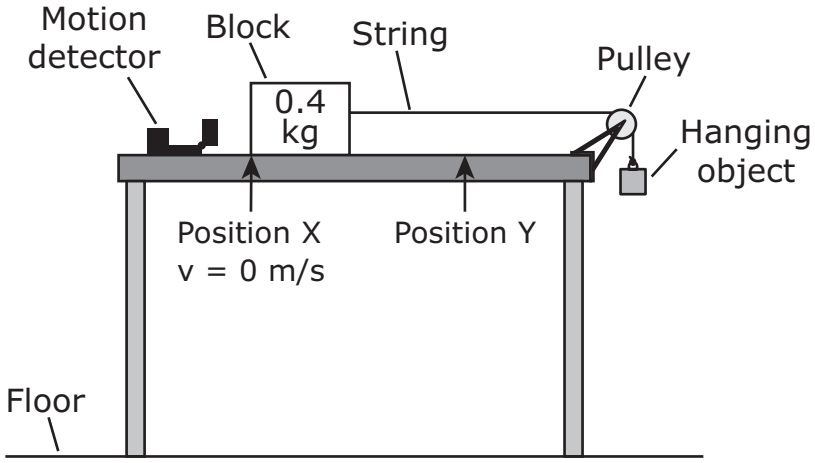
Ⓒ 9.0 A

Ⓓ 16 A

The following section focuses on an investigation that uses a motion detector.

Read the information below and use it to answer the selected-response questions and constructed-response question that follow.

Students in a physics class conducted an investigation using a motion detector. A motion detector can be used to measure the position, velocity, and acceleration of an object at different times as the object moves. The students used the setup shown in the diagram for their investigation.



When the students attached a hanging object to the string, the hanging object moved downward, and the block moved from position X to position Y on the table. The block and the hanging object moved with the same constant acceleration. Friction and air resistance acted on both the block and the hanging object as they moved.

The students completed five trials using the motion detector. In each trial, the block started from rest at position X. The students changed the mass of the hanging object for each trial. The table shows the data.

Trial	Mass of Block (kg)	Mass of Hanging Object (kg)	Acceleration of System (m/s^2)	Net Force Acting on System (N)
1	0.4	0.30	2.0	1.4
2	0.4	0.35	2.5	1.9
3	0.4	0.40	3.0	2.4
4	0.4	0.45	3.4	2.9
5	0.4	0.50	3.8	3.4

12 Which of the following best describes what happened to the energy of the hanging object as it moved closer to the floor?

Ⓐ The kinetic energy of the hanging object increased as its thermal energy decreased.

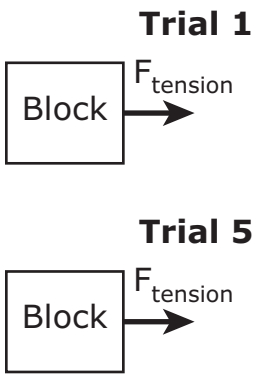
Ⓑ The kinetic energy of the hanging object decreased as its gravitational potential energy increased.

Ⓒ The gravitational potential energy of the hanging object decreased as its kinetic energy increased.

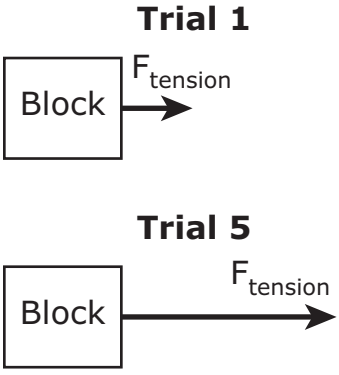
Ⓓ The gravitational potential energy of the hanging object increased as its thermal energy increased.

13 Which pair of diagrams best compares the tension force acting on the block at position Y in trial 1 with the tension force acting on the block at position Y in trial 5?

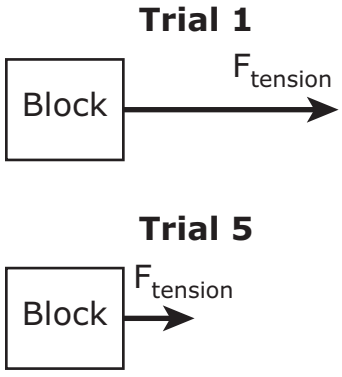
Ⓐ



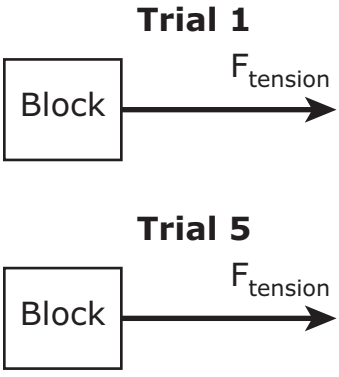
Ⓑ



Ⓒ



Ⓓ



14 In trial 5, the block traveled from position X to position Y in 0.69 s and had a velocity of 2.33 m/s at position Y. What was the kinetic energy of the block at position Y?

Ⓐ 1.09 J

Ⓑ 1.61 J

Ⓒ 6.43 J

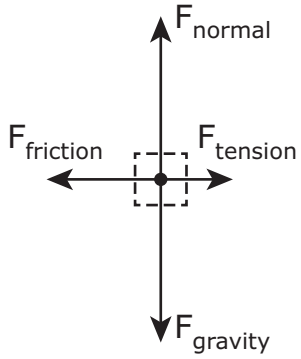
Ⓓ 8.04 J

This question has two parts.

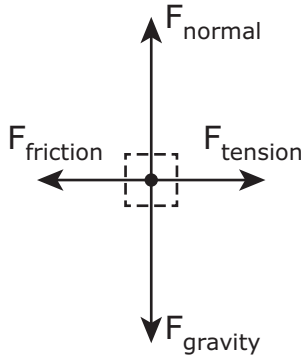
15 **Part A**

Which free-body force diagram best represents the forces that acted on the block as it accelerated across the table?

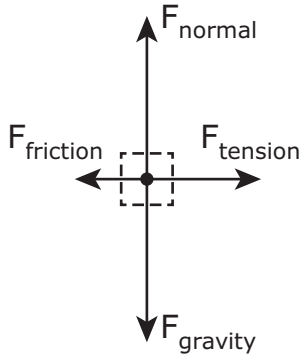
Ⓐ



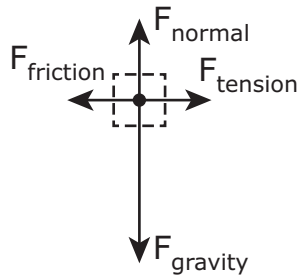
Ⓑ



Ⓒ



Ⓓ



Part B

As the block accelerated across the table, the speed of the block

Ⓐ increased.

Ⓑ decreased.

Ⓒ remained the same.

This question has three parts. Write your response on the next page. Be sure to label each part of your response.

16 For a new trial, the students used the same setup, but the hanging object was 0.6 kg, and they collected different data. During the trial, the students recorded the time it took the block to travel from position X to position Y and the change in velocity of the block between those positions. The table shows the data.

Mass of Block (kg)	Mass of Hanging Object (kg)	Time from X to Y (s)	Change in Velocity between X and Y (m/s)
0.4	0.6	0.6	2.65

A. Calculate the average acceleration of the system during the new trial. Show your calculations and include units in your answer.

B. The original distance between positions X and Y was 0.8 m. The students reduced the distance to 0.4 m. The students released the block from rest, allowing it to move the 0.4 m.

Determine whether the velocity of the block at position Y was greater than, less than, or equal to 2.65 m/s. Explain your reasoning.

C. Describe one way the students could decrease the acceleration of the system without changing the mass of the hanging object. Explain your reasoning.

16

17 The velocity of a 75 kg skier increases from 8 m/s to 12 m/s. What is the change in momentum of the skier?

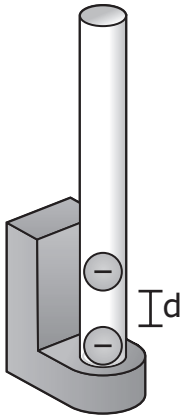
Ⓐ 300 kg • m/s

Ⓑ 600 kg • m/s

Ⓒ 900 kg • m/s

Ⓓ 1500 kg • m/s

18 The diagram shows a negatively charged sphere suspended a distance, d, above another negatively charged sphere in a glass tube.



Which of the following would increase the distance, d, the most?

Ⓐ adding more negative charges to both spheres

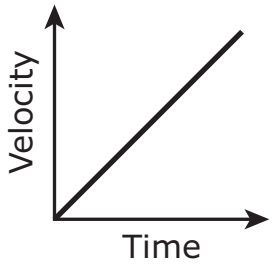
Ⓑ removing some negative charges from both spheres

Ⓒ adding more negative charges to one sphere and making the other sphere neutral

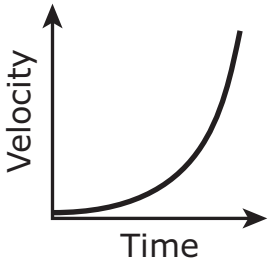
Ⓓ removing some negative charges from one sphere and making the other sphere neutral

19 Which graph represents the motion of an object that has zero net force acting on it?

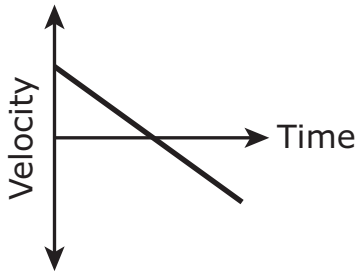
Ⓐ



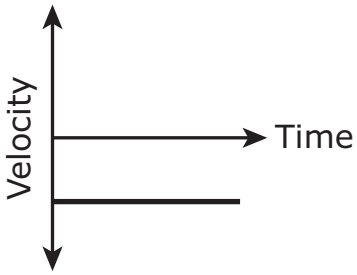
Ⓑ



Ⓒ

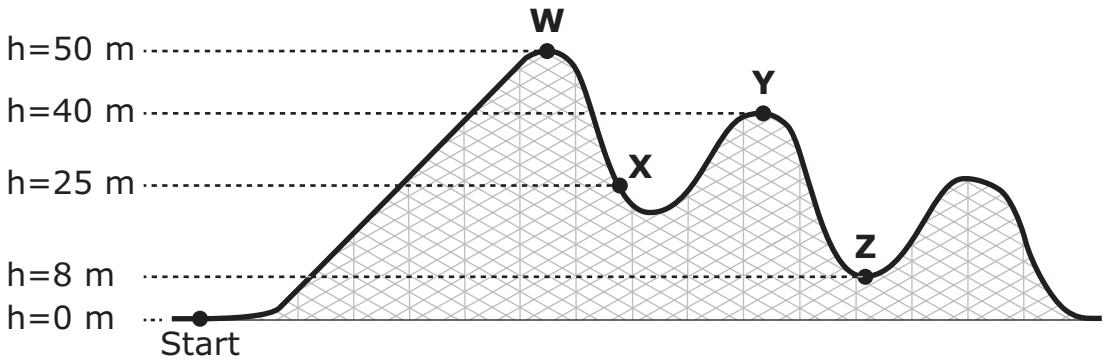


Ⓓ



This question has four parts. Write your response on the next page. Be sure to label each part of your response.

20 A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.



For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

A. Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

B. Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

C. Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

D. Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

20

This question has three parts. Write your response on the next page. Be sure to label each part of your response.

21 A person at a baseball game is seated 200 m away from a batter. The person sees the batter hit a ball, and then hears the sound of the ball being hit 0.58 s later.

A. Calculate the speed of the sound wave created when the bat hits the ball. Show your calculations and include units in your answer.

B. Besides the difference in speed of the two types of waves, describe **two** additional differences between the visible light waves and the sound waves produced when the ball is hit.

C. The game is also broadcast over the radio for people who cannot attend the game. Radio waves carry the broadcast signal.

One way that visible light waves differ from radio waves is that they can be seen by humans, while radio waves cannot. Describe a second difference between the two types of waves.

21

High School Introductory Physics

SESSION 2

This session contains 21 questions.

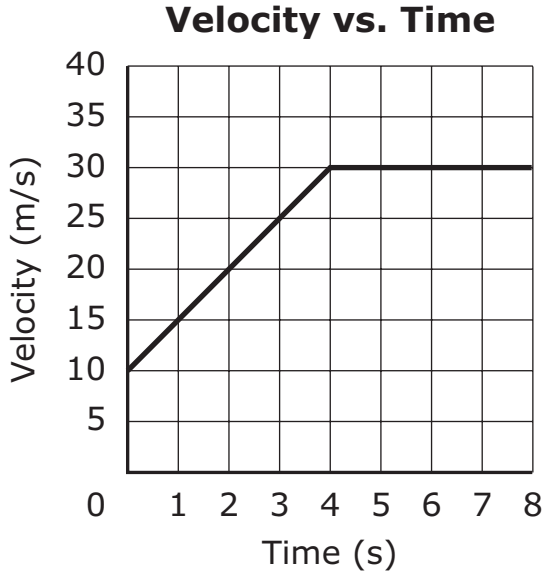
Directions

Read each question carefully and then answer it as well as you can. You must record all answers in this Test & Answer Booklet.

For some questions, you will mark your answers by filling in the circles in your Test & Answer Booklet. Make sure you darken the circles completely. Do not make any marks outside of the circles. If you need to change an answer, be sure to erase your first answer completely.

If a question asks you to show or explain your work, you must do so to receive full credit. Write your response in the space provided. Only responses written within the provided space will be scored.

22 The graph represents the motion of a car on a straight highway.



What distance did the car travel from 4 s to 8 s?

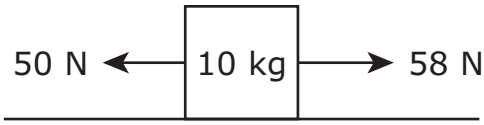
Ⓐ 80 m

Ⓑ 120 m

Ⓒ 200 m

Ⓓ 240 m

23 A box is at rest on a floor. Then a student drags the box across the floor. The diagram shows the horizontal forces acting on the box as it is being dragged.



Based on Newton's second law, what is the velocity of the box 1 s after the student starts dragging it?

Ⓐ 0.2 m/s

Ⓑ 0.8 m/s

Ⓒ 5.8 m/s

Ⓓ 10.8 m/s

24 Two rubber balls roll along a straight track toward each other at the same speed. The balls are the same size but have different masses. The two balls collide.

Which of the following best describes how the total momentum of the rubber balls is affected by the collision?

Ⓐ The total momentum stays the same, because the total momentum is conserved.

Ⓑ The total momentum is doubled, because each ball gains the other ball's momentum.

Ⓒ The total momentum is reduced by half, because each ball loses half of its momentum.

Ⓓ The total momentum becomes zero, because the momentum of each ball is equal and opposite.

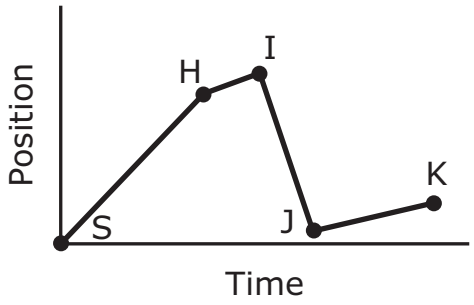
This question has two parts.

25 A hiker walked on a path.

Part A

The graph shows the position of the hiker versus time. The hiker started at position S. Four additional points on the graph are labeled H, I, J, and K.

Position vs. Time



At which point was the hiker farthest from the starting position?

Ⓐ point H

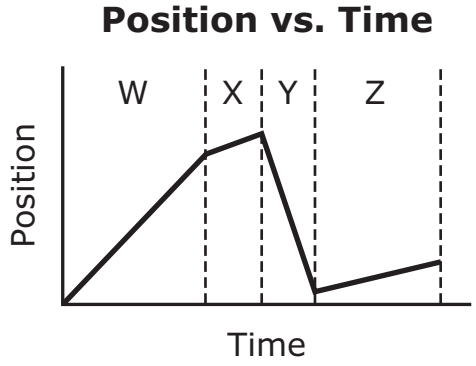
Ⓑ point I

Ⓒ point J

Ⓓ point K

Part B

The graph shows the hiker's position during four time intervals, W, X, Y, and Z.



During which time interval was the speed of the hiker the greatest?

Ⓐ interval W

Ⓑ interval X

Ⓒ interval Y

Ⓓ interval Z

26 A wave travels at 10 m/s with a wavelength of 2 m. What is the frequency of this wave?

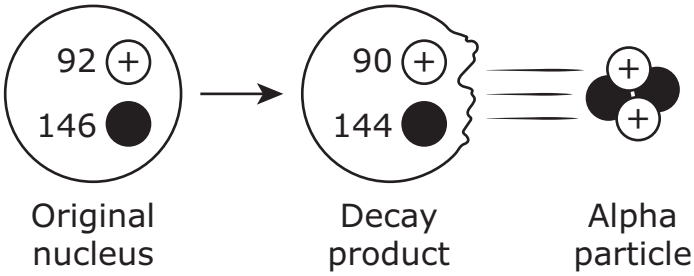
Ⓐ 0.2 Hz

Ⓑ 0.5 Hz

Ⓒ 5 Hz

Ⓓ 20 Hz

27 A type of radioactive decay is represented by the diagram.



Which of the following best describes what happens to the original nucleus during the decay process?

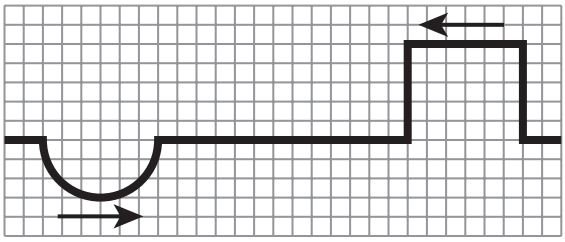
Ⓐ The original nucleus absorbs energy and its mass increases.

Ⓑ The original nucleus releases energy and its mass increases.

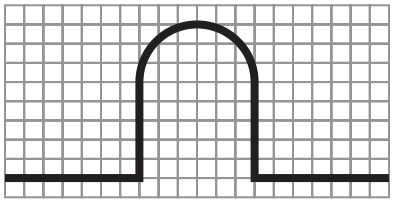
Ⓒ The original nucleus absorbs energy and its mass decreases.

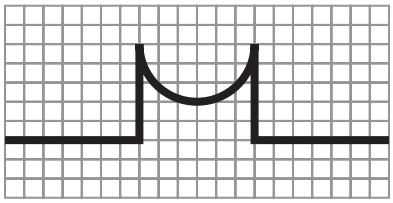
Ⓓ The original nucleus releases energy and its mass decreases.

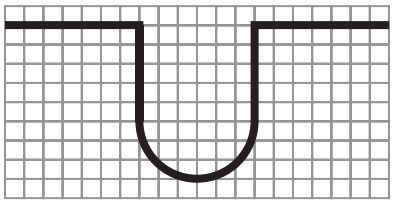
28 The diagram shows two wave pulses moving toward each other.

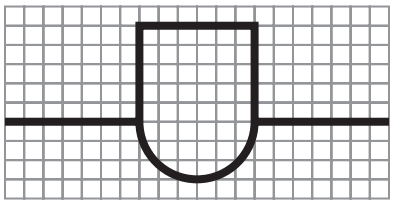


Which diagram shows the shape of the wave when the pulses directly overlap?

Ⓐ 

Ⓑ 

Ⓒ 

Ⓓ 

29 The table provides information about four pairs of objects.

Objects	Distance between Objects (m)	Mass of Each Object (kg)
S and T	1	2
U and V	1	1
W and X	2	2
Y and Z	2	1

Which pair of objects has the **greatest** gravitational attraction?

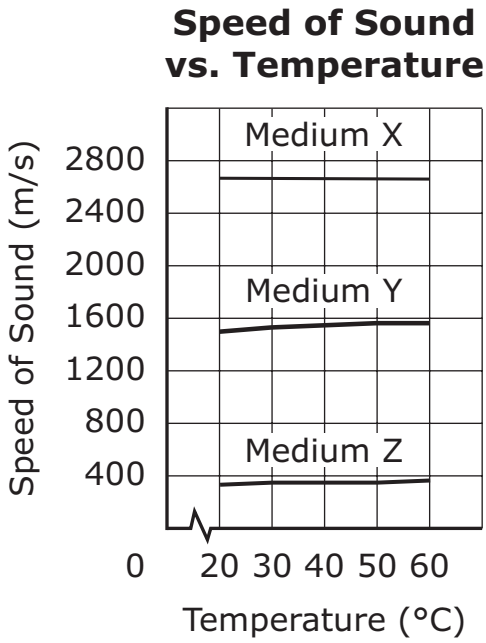
Ⓐ objects S and T

Ⓑ objects U and V

Ⓒ objects W and X

Ⓓ objects Y and Z

30 The graph shows the speed of sound at different temperatures in three media: X, Y, and Z.



The three media are air (a gas), silver (a solid), and water (a liquid). Based on the graph, each medium is represented by which letter?

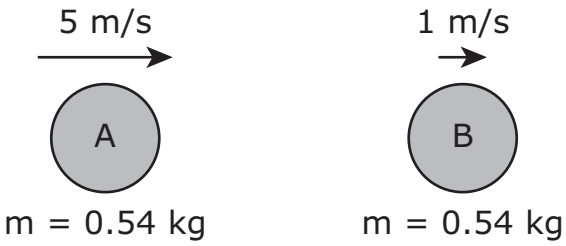
Ⓐ X: water
Y: silver
Z: air

Ⓑ X: silver
Y: water
Z: air

Ⓒ X: air
Y: silver
Z: water

Ⓓ X: water
Y: air
Z: silver

31 Two steel spheres, A and B, each have a mass of 0.54 kg. Each sphere is moving to the right at a different speed, as shown.



Sphere A collides with sphere B. After the collision, sphere A slows, but both spheres continue to move to the right.

Which of the following diagrams shows the velocity of each sphere after the collision?

Ⓐ

Ⓑ

Ⓒ

Ⓓ

32 An airbag helps prevent injuries to the driver of a car when the car comes to a sudden stop. Which of the following best describes how the airbag helps prevent injuries to the driver?

Ⓐ The airbag reduces the initial momentum of the driver, safely slowing the driver to a stop.

Ⓑ The airbag causes the driver to come to a stop over a larger time interval, reducing the force felt by the driver.

Ⓒ The airbag causes the driver to come to a stop over a smaller time interval, increasing the momentum of the driver.

Ⓓ The airbag exerts a greater force on the driver than the driver exerts on the airbag, safely slowing the driver to a stop.

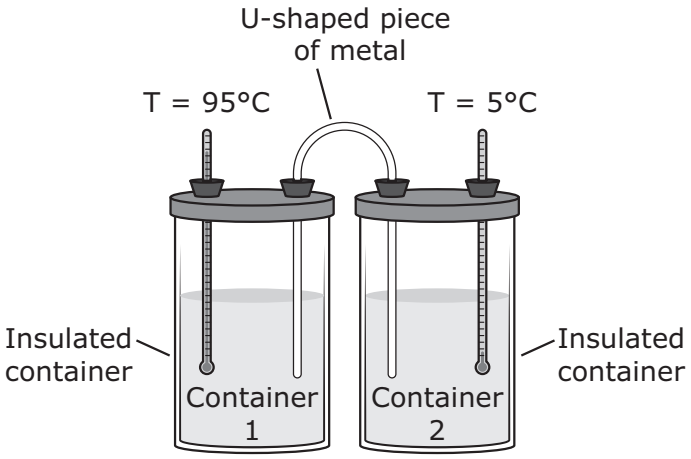
The following section focuses on thermal energy transfer.

Read the information below and use it to answer the selected-response questions and constructed-response question that follow.

A student conducted two investigations to learn about thermal energy transfer.

Investigation 1

During investigation 1, the student used two insulated containers, container 1 and container 2. The student added 500 g of 95ºC water to container 1 and 500 g of 5ºC water to container 2. The student closed the containers and placed a thermometer in each. The student then placed one end of a U-shaped piece of metal into the water in container 1 and the other end into the water in container 2, as shown.



Next, the student measured the water temperature in each container over time. The data are shown in Table 1.

Table 1: Temperature of Water over Time

Time (s)	Container 1 Temperature (°C)	Container 2 Temperature (°C)
0	95.0	5.0
100	77.3	22.7
200	66.6	33.4
300	60.0	40.0
400	56.1	43.9
500	53.7	46.3
600	52.2	47.8
700	50.0	50.0
800	50.0	50.0

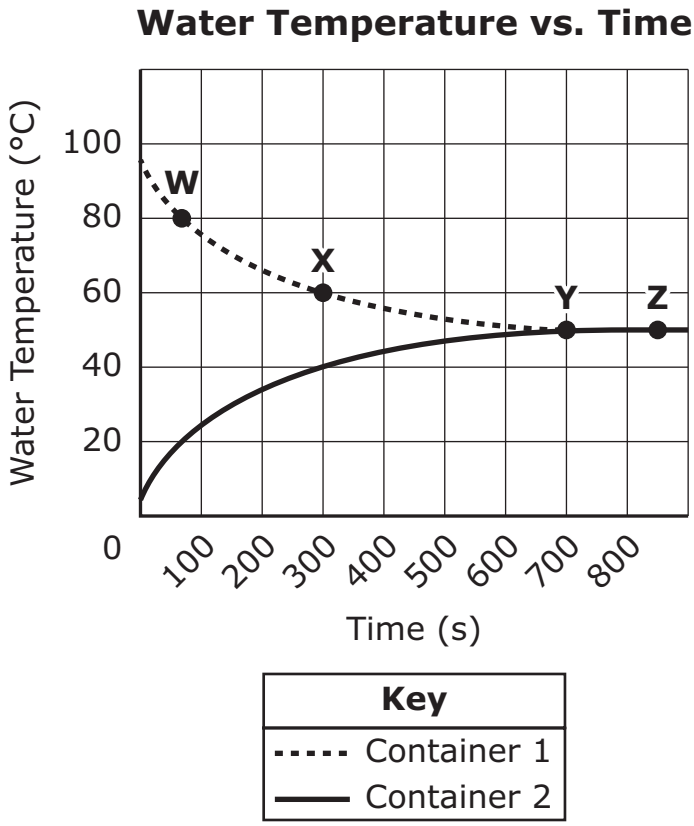
Investigation 2

The student investigated how the specific heat capacity of a substance affects the temperature change of the substance. During investigation 2, the student heated four liquids, W, X, Y, and Z. Each liquid had a mass of 200 g and was heated for the same amount of time using the same heat source. The specific heat capacities of the four liquids are shown in Table 2.

Table 2: Specific Heat Capacity of Liquids

Liquid	Specific Heat Capacity (J/g • °C)
W	4.18
X	1.97
Y	3.94
Z	3.67

33 The data from investigation 1 are represented in the graph. Four points on the graph are labeled W, X, Y, and Z.



At which point did container 1 and container 2 first reach thermal equilibrium?

Ⓐ point W

Ⓑ point X

Ⓒ point Y

Ⓓ point Z

34 Before beginning investigation 1, the student predicted that the direction of thermal energy transfer would be from container 1 to container 2.

Which of the following observations best supports the student's prediction?

Ⓐ The containers are good thermal insulators.

Ⓑ The U-shaped piece of metal is a good thermal conductor.

Ⓒ The water in container 1 is in thermal contact with the water in container 2.

Ⓓ The water in container 1 is at a higher temperature than the water in container 2.

35 In investigation 2, liquid Z had an initial temperature of 25°C before 54,316 J of thermal energy was added. What was the final temperature of liquid Z?

Ⓐ 49°C

Ⓑ 74°C

Ⓒ 99°C

Ⓓ 272°C

This question has two parts.

36 **Part A**

During the first 50 s of investigation 2, the temperature of 200 g of liquid W changed from 25°C to 31°C. How much thermal energy was transferred to liquid W in the first 50 s of investigation 2?

Ⓐ 5,016 J

Ⓑ 20,900 J

Ⓒ 25,916 J

Ⓓ 41,800 J

Part B

The student repeated investigation 2 with 400 g of liquid W instead of 200 g. The student used the same heat source and heated liquid W for the same amount of time.

How were the results of the investigation different when 400 g of liquid W were used instead of 200 g?

Ⓐ The change in temperature of liquid W was greater.

Ⓑ The change in temperature of liquid W was smaller.

Ⓒ The amount of thermal energy transferred to liquid W was greater.

Ⓓ The amount of thermal energy transferred to liquid W was smaller.

This question has three parts. Write your response on the next page. Be sure to label each part of your response.

37 The student analyzed the transfer of thermal energy that took place during investigation 1.

A. Identify whether the average molecular motion of the water molecules in container 1 **and** container 2 increased, decreased, or remained the same during the first 100 s of investigation 1. Be sure to label your answer for **each** container.

B. The student claimed that energy was conserved in the system during the transfer of thermal energy in investigation 1.

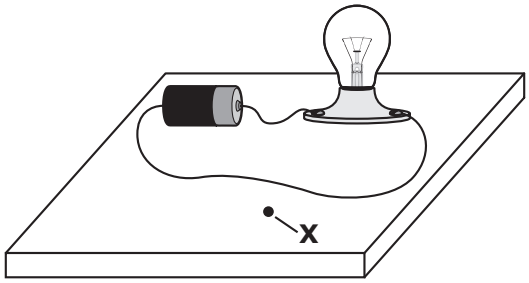
Describe how the student could use the data in Table 1 to support the claim.

C. Eventually thermal equilibrium was reached in investigation 1.

Compare the average molecular motion of the water molecules in both container 1 and container 2 after thermal equilibrium was reached. Explain your reasoning.

37

38 The diagram shows a simple circuit. A location near the circuit is labeled X.



Which of the following explains whether there is a magnetic field at point X?

Ⓐ There is no magnetic field at point X because wires are not magnets.

Ⓑ There is no magnetic field at point X because it is too far from the battery.

Ⓒ There is a magnetic field at point X because current flows through the wire.

Ⓓ There is a magnetic field at point X because the light has magnetic properties.

39 Elephants use sound for communication. The table shows the average frequencies of sound waves produced by adult elephants and their young.

Elephant	Frequency (Hz)
adult male	12
adult female	13
young male	22

What additional information is needed to determine the wavelengths of the sounds produced by the elephants?

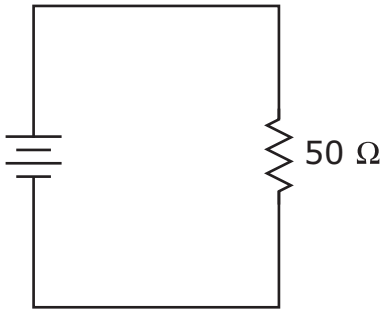
Ⓐ the speed of the sound waves

Ⓑ the period of the sound waves

Ⓒ the energy the sound waves carry

Ⓓ the distance the sound waves travel

40 The circuit shown has a current of 0.6 A.



What is the voltage of the battery?

Ⓐ 0.01 V

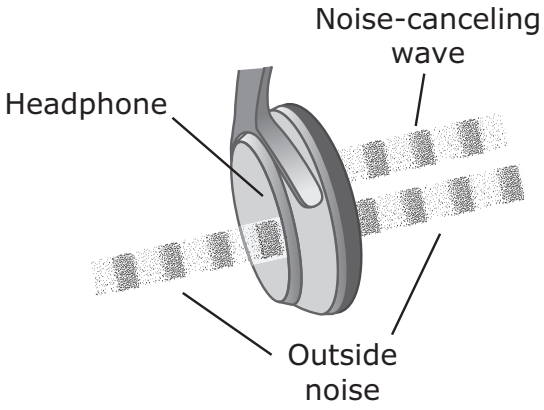
Ⓑ 30 V

Ⓒ 50.6 V

Ⓓ 83 V

This question has two parts.

41 A student listening to music uses noise-canceling headphones to reduce outside noise. The headphones create an inverted sound wave that interacts with the outside noise. The diagram represents how the headphones work.



Part A

Which wave behavior is used by the noise-canceling headphones to reduce outside noise for the student?

Ⓐ constructive interference

Ⓑ destructive interference

Ⓒ reflection

Ⓓ refraction

Part B

The student then uses the noise-canceling headphones in a location where the outside noise is louder and has a higher pitch. How would the noise-canceling wave produced by the headphones need to change for the headphones to be equally effective when the outside noise is louder and has a higher pitch?

Ⓐ The wave's velocity and wavelength would need to increase.

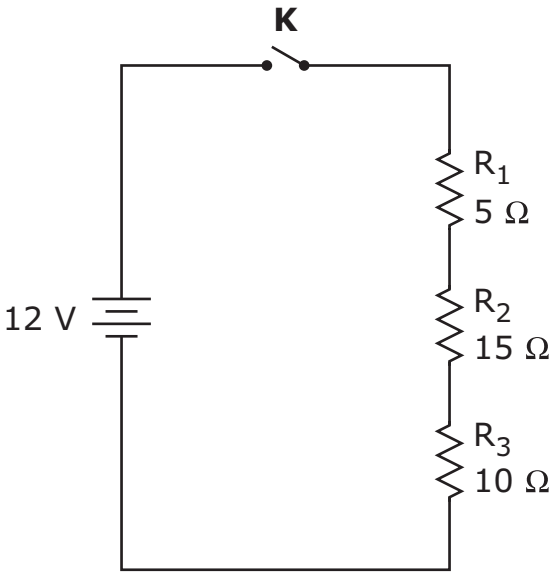
Ⓑ The wave's velocity and wavelength would need to decrease.

Ⓒ The wave's frequency and amplitude would need to increase.

Ⓓ The wave's frequency and amplitude would need to decrease.

This question has four parts. Write your response on the next page. Be sure to label each part of your response.

42 The diagram shows a circuit with a 12 V battery, three resistors, and component K.



A. Identify component K **and** explain its main function.

B. Component K is replaced with a piece of wire.

Calculate the total resistance of the circuit. Show your calculations and include units in your answer.

C. Is the amount of current flowing through R_1 the same as the amount of current flowing through R_2? Explain your reasoning.

D. Calculate the voltage drop across R_1. Show your calculations and include units in your answer.

42

Massachusetts Comprehensive Assessment System
Introductory Physics Reference Sheet

Formulas

$s_{average} = \frac{d}{\Delta t}$

$v_{average} = \frac{\Delta x}{\Delta t}$

$a_{average} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + a\Delta t$

$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$

$p = mv$

$F\Delta t = \Delta p$

$F_{net} = ma$

$F_g = mg$

$F_g = G\frac{m_1 m_2}{d^2}$

$F_e = k\frac{q_1 q_2}{d^2}$

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

$\Delta PE = mg\Delta h$

$W = \Delta E = Fd$

$eff = \frac{E_{out}}{E_{in}}$

$Q = mc\Delta T$

$v = \lambda f$

$T = \frac{1}{f}$

$V = IR$

Variables

a = acceleration
c = specific heat
d = distance
E = energy
eff = efficiency
f = frequency
F = force
g = acceleration due to gravity
Δh = change in height
I = current
KE = kinetic energy
λ = wavelength
m = mass
p = momentum
ΔPE = change in gravitational potential energy
q = charge of particle
Q = heat added or removed
R = resistance
s = speed
Δt = change in time
T = period
ΔT = change in temperature
v = velocity
V = potential difference (voltage)
W = work
Δx = change in position (displacement)

Unit Symbols

ampere, A
coulomb, C
degree Celsius, °C
hertz, Hz
joule, J
kilogram, kg
meter, m
newton, N
ohm, Ω
second, s
volt, V

Definitions

speed of electromagnetic waves in a vacuum = 3×10^8 m/s

G = Universal gravitational constant = $6.7 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

k = Coulomb's constant = $9 \times 10^9 \frac{N \cdot m^2}{C^2}$

$g \approx 10$ m/s^2 at Earth's surface

1 N = $1 \frac{kg \cdot m}{s^2}$

1 J = 1 N • m

Updated June 2018

High School Introductory Physics
Spring 2022 Released Operational Items

PBT Item No.	Page No.	Reporting Category	Standard	Science and Engineering Practice Category	Item Type*	Item Description	Correct Answer**
1	3	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a speed vs. time graph for an object to determine the position of the object at different times.	A
2	4	*Motion, Forces, and Interactions*	HS.PHY.2.4	C. Evidence, Reasoning, and Modeling	SR	Compare the electric forces between two pairs of charges.	A
3	4	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	SR	Determine which change to a circuit would reduce the total current in the circuit by half.	C
4	5	*Motion, Forces, and Interactions*	HS.PHY.2.1	C. Evidence, Reasoning, and Modeling	SR	Analyze a speed vs. time graph for an object and identify the free-body force diagram that represents the forces acting on the object.	C
5	5	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Calculate the final momentum of an object that is accelerated from rest.	B
6	6	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Describe how the energy between two charged objects changes when one of the objects moves and determine which model represents an electric field around two charged objects.	B;A;C
7	8	*Motion, Forces, and Interactions*	HS.PHY.2.5	C. Evidence, Reasoning, and Modeling	SR	Identify that an electric current produces a magnetic field, based on evidence from an investigation.	A
8	9	*Energy*	HS.PHY.3.3	B. Mathematics and Data	SR	Calculate the efficiency of a device.	B
9	10	*Waves*	HS.PHY.4.5	C. Evidence, Reasoning, and Modeling	SR	Interpret a diagram of light passing from air into glass and describe the angle of refraction.	C
10	11	*Waves*	HS.PHY.4.1	None	SR	Explain why some particles of light have more energy than other particles of light.	C
11	12	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	SR	Calculate the current in a series circuit with multiple resistors.	A
12	14	*Energy*	HS.PHY.3.1	None	SR	Describe how the energy of an object changes as it falls.	C
13	14	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Identify the magnitudes of a force acting on an object during multiple trials of an investigation.	B
14	15	*Energy*	HS.PHY.3.1	B. Mathematics and Data	SR	Calculate the kinetic energy of an object.	A
15	16	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Identify the free-body force diagram for an accelerating object and describe how the speed of the object changes as it accelerates.	C;A
16	17	*Motion, Forces, and Interactions*	HS.PHY.2.1	A. Investigations and Questioning	CR	Calculate an object's acceleration, describe how changing the distance over which a force is applied to the object affects its velocity, and describe one way to change the object's acceleration.	
17	19	*Motion, Forces, and Interactions*	HS.PHY.2.3	B. Mathematics and Data	SR	Calculate the change in momentum of an object.	A
18	19	*Motion, Forces, and Interactions*	HS.PHY.2.4	C. Evidence, Reasoning, and Modeling	SR	Describe a change to a pair of charges that would increase the distance between them.	A
19	20	*Motion, Forces, and Interactions*	HS.PHY.2.1	C. Evidence, Reasoning, and Modeling	SR	Determine which velocity vs. time graph represents the motion of an object with zero net force acting on it.	D
20	21	*Energy*	HS.PHY.3.1	B. Mathematics and Data	CR	Interpret a diagram to determine where an object has its greatest amount of gravitational potential energy (GPE), calculate the object's GPE, compare the object's kinetic energy (KE) at two positions, and determine the object's position when its KE and GPE are equal.	
21	23	*Waves*	HS.PHY.4.1	B. Mathematics and Data	CR	Calculate the speed of a sound wave and compare the characteristics of mechanical and electromagnetic waves.	

PBT Item No.	Page No.	Reporting Category	Standard	Science and Engineering Practice Category	Item Type*	Item Description	Correct Answer**
22	26	*Motion, Forces, and Interactions*	HS.PHY.2.10	B. Mathematics and Data	SR	Interpret a velocity vs. time graph to determine the distance a car travels.	B
23	27	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	SR	Using a model of the horizontal forces acting on an object, calculate the velocity of the object.	B
24	27	*Motion, Forces, and Interactions*	HS.PHY.2.2	None	SR	Describe how the momentum of a system is affected by a collision.	A
25	28	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a position vs. time graph to determine when a person was farthest from the starting position and to identify the time interval when the person had the greatest speed.	B;C
26	29	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Calculate the frequency of a wave.	C
27	30	*Energy*	HS.PHY.1.8	C. Evidence, Reasoning, and Modeling	SR	Describe how the mass and energy of a nucleus change during a radioactive decay process.	D
28	31	*Waves*	HS.PHY.4.5	C. Evidence, Reasoning, and Modeling	SR	Interpret a model of two wave pulses to determine the resulting destructive interference model.	B
29	32	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Interpret a data table to determine which pair of objects has the greatest gravitational attraction between them.	A
30	33	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Interpret a graph of the speed of sound in three media to determine which medium is a solid, which is a liquid, and which is a gas.	B
31	34	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Based on a model, identify the velocities of two spheres after a collision.	A
32	35	*Motion, Forces, and Interactions*	HS.PHY.2.3	C. Evidence, Reasoning, and Modeling	SR	Describe how extending the time interval over which a force acts on an object during a collision reduces the impact of the collision.	B
33	38	*Energy*	HS.PHY.3.4	B. Mathematics and Data	SR	Interpret a temperature vs. time graph for two objects in thermal contact to determine when the objects reached thermal equilibrium.	C
34	39	*Energy*	HS.PHY.3.4	C. Evidence, Reasoning, and Modeling	SR	Determine the observation that best supports a student's prediction about the direction of thermal energy transfer.	D
35	40	*Energy*	HS.PHY.3.4	B. Mathematics and Data	SR	Calculate the final temperature of an object after thermal energy is added.	C
36	41	*Energy*	HS.PHY.3.4	B. Mathematics and Data	SR	Calculate the amount of thermal energy transferred to a liquid and determine how the temperature change of the liquid would have been different if the mass of the liquid was greater.	A;B
37	42	*Energy*	HS.PHY.3.2	C. Evidence, Reasoning, and Modeling	CR	Describe how the average molecular motion of molecules changed in two containers, use data to support a claim that energy was conserved, and explain why the average molecular motion of molecules was the same when thermal equilibrium was reached.	
38	44	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Explain why a magnetic field is present near a wire.	C
39	45	*Waves*	HS.PHY.4.1	None	SR	Determine the additional information needed to calculate the wavelength of a sound.	A
40	46	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	SR	Calculate the voltage of the battery in a series circuit.	B
41	47	*Waves*	HS.PHY.4.5	C. Evidence, Reasoning, and Modeling	SR	Identify the wave behavior used by a device and explain how the wave produced by the device could be changed to be effective in a new situation.	B;C
42	48	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	CR	Identify a circuit component and describe its function, calculate the total resistance of a circuit, compare the current through two resistors, and calculate the voltage drop across a resistor.	

* Science and Technology/Engineering item types are: selected-response (SR) and constructed-response (CR).

** Answers are provided here for selected-response items only. Sample responses and scoring guidelines for constructed-response items will be posted to the Department's website later this year.