MASSACHUSETTS
Department of Elementary
and Secondary Education

Release of Spring 2025 MCAS Test Items

from the

High School Introductory Physics Paper-Based Test

July 2025
Massachusetts Department of Elementary and Secondary Education

MASSACHUSETTS
Department of Elementary
and Secondary Education

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Overview of High School Introductory Physics Test

The spring 2025 high school Introductory Physics test was administered in two formats: a computer-based version and a paper-based version. Most students took the computer-based test. The paper-based test was offered as an accommodation for eligible students who were unable to use a computer. More information can be found on the MCAS Test Administration Resources page at www.doe.mass.edu/mcas/admin.html.

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

The introductory physics 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

Most items on the high school Introductory Physics test are also reported as aligning to one of three MCAS Science 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, science 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 document. Each student was also provided with a calculator.

During both high school Introductory Physics test sessions, the use of authorized bilingual word-to-word dictionaries and glossaries was allowed for students who are currently or were ever reported as English learners. No other reference tools or materials were allowed.

High School Introductory Physics

SESSION 1

This session contains 21 questions.

You may use your reference sheet in this session.

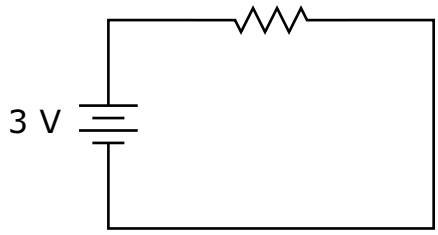
Directions

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 A circuit with a battery and resistor is shown.



Which of the following best describes what happens to the circuit when the voltage is increased to 12 V?

Ⓐ The current increases to four times the original value.

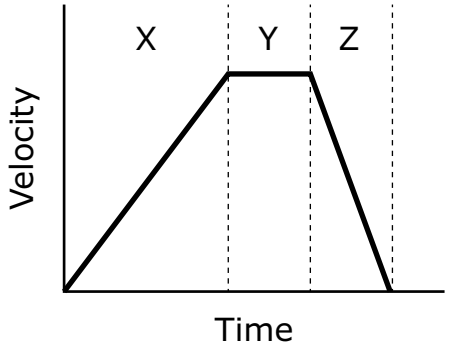
Ⓑ The current decreases to one-quarter the original value.

Ⓒ The resistance increases to four times the original value.

Ⓓ The resistance decreases to one-quarter the original value.

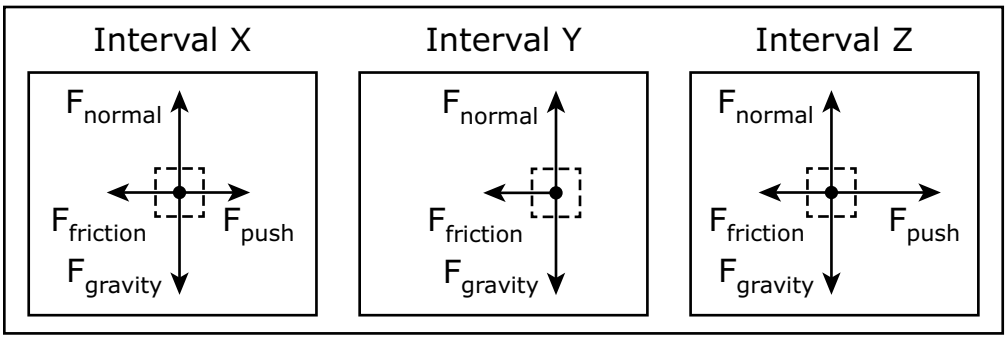
2 A student pushed an object across a table to the right. The graph shows the velocity of the object over time during three time intervals, X, Y, and Z.

Velocity vs. Time

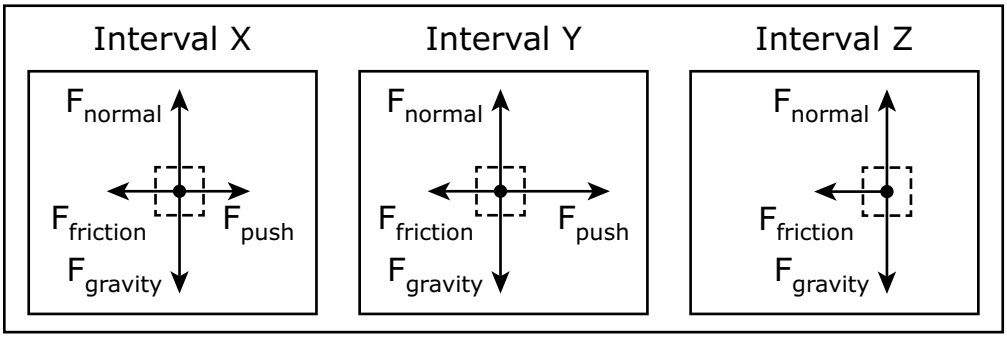


Which of the following sets of free-body force diagrams best represents the forces acting on the object during time intervals X, Y, and Z?

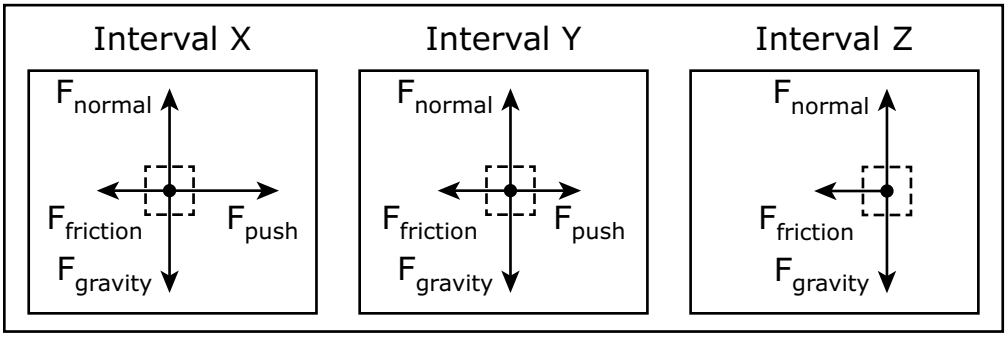
Ⓐ



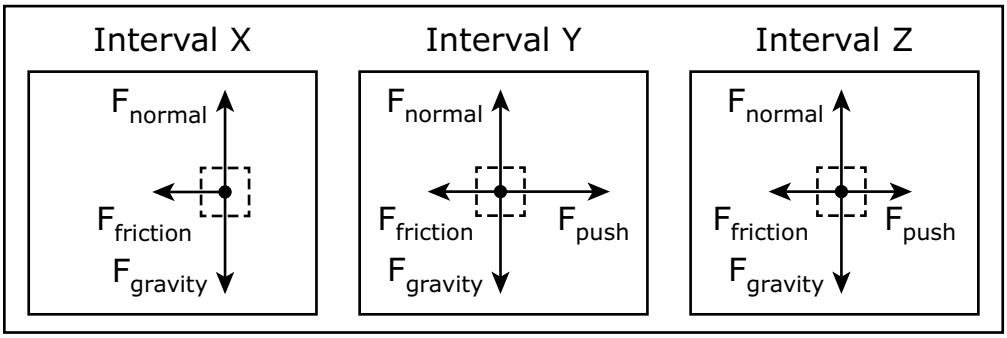
Ⓑ



Ⓒ



Ⓓ



3 Students are studying momentum using a baseball and a softball. The students measure the mass of each ball. Then the students roll the baseball toward the softball and measure the velocity of each ball after the balls collide.

Which of the following shows how the students can calculate the final momentum of the system after the balls collide?

Ⓐ

Step 1: Find the final momentum of the baseball by adding its mass and final velocity.
Step 2: Find the final momentum of the softball by adding its mass and final velocity.
Step 3: Add the final momentums of the two balls.

Ⓑ

Step 1: Find the final momentum of the baseball by adding its mass and final velocity.
Step 2: Find the final momentum of the softball by adding its mass and final velocity.
Step 3: Multiply the final momentums of the two balls.

Ⓒ

Step 1: Find the final momentum of the baseball by multiplying its mass and final velocity.
Step 2: Find the final momentum of the softball by multiplying its mass and final velocity.
Step 3: Add the final momentums of the two balls.

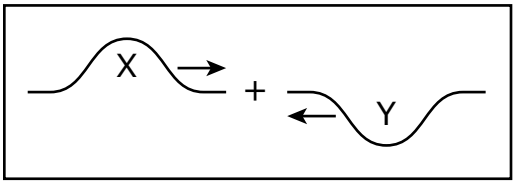
Ⓓ

Step 1: Find the final momentum of the baseball by multiplying its mass and final velocity.
Step 2: Find the final momentum of the softball by multiplying its mass and final velocity.
Step 3: Multiply the final momentums of the two balls.

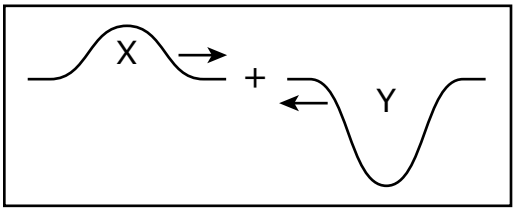
4 Two waves, X and Y, are traveling toward each other. The waves cancel each other out when they interact and completely overlap.

Which of the following diagrams **best** represents the two waves before they interact?

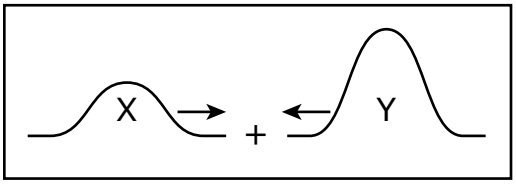
Ⓐ



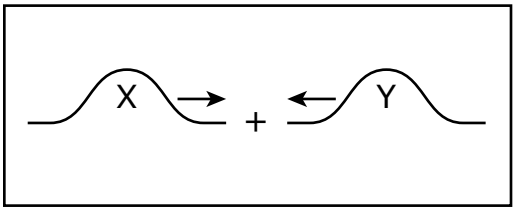
Ⓑ



Ⓒ



Ⓓ



5 Some older forms of computer technology used plastic discs coated with iron oxide to store information in magnetic fields. Which of the following **best** explains why one of these discs could be damaged if placed near a coil of wire that is carrying current?

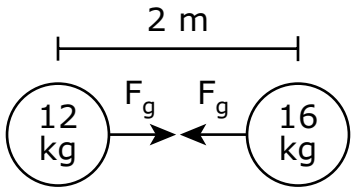
Ⓐ The coil of wire generates heat, which could charge the iron oxide coating.

Ⓑ The coil of wire uses energy, which could affect the energy stored in the iron oxide coating.

Ⓒ The current in the wire produces a gravitational field, which could pull the iron oxide coating off the disc.

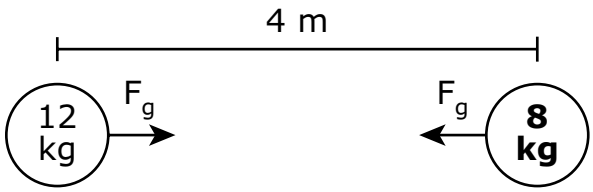
Ⓓ The current in the wire produces a magnetic field, which could alter the magnetic storage in the iron oxide coating.

6 A 12 kg object and a 16 kg object are located 2 m apart. Each exerts a gravitational force, F_g, on the other, as shown in the diagram.

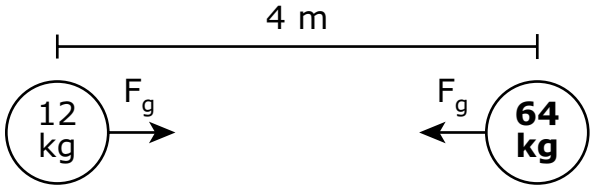


Which of the following pairs of objects placed 4 m apart will have these same gravitational forces?

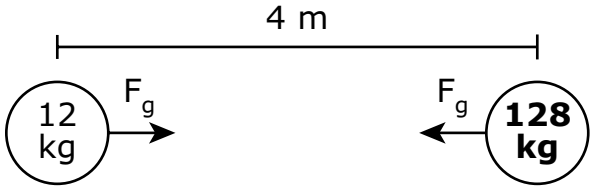
Ⓐ



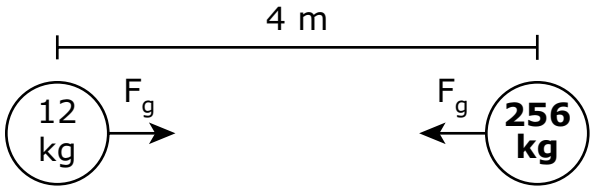
Ⓑ



Ⓒ

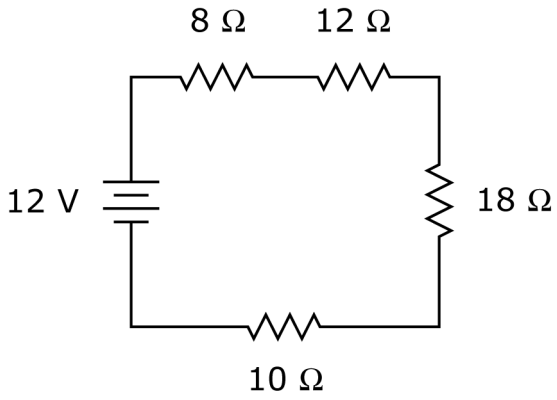


Ⓓ



This question has two parts.

7 A circuit with a battery and four resistors is shown.



Part A

Which resistor has the greatest voltage drop across it?

Ⓐ 8 Ω

Ⓑ 10 Ω

Ⓒ 12 Ω

Ⓓ 18 Ω

Part B

What is the current through the 10 Ω resistor?

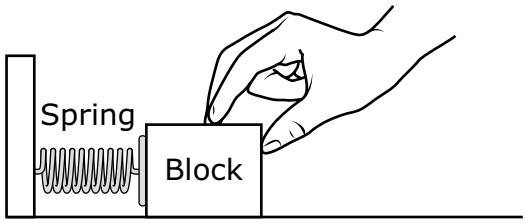
Ⓐ 0.25 A

Ⓑ 0.83 A

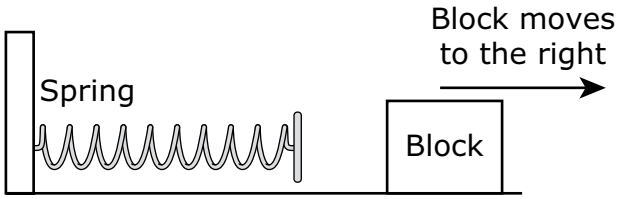
Ⓒ 1.2 A

Ⓓ 4 A

8 A student compresses a spring with a block, as shown in the diagram.



When the student lets go of the block, the block moves to the right, as shown in the diagram below.



Which of the following describes a change in energy that occurs when the student lets go of the block?

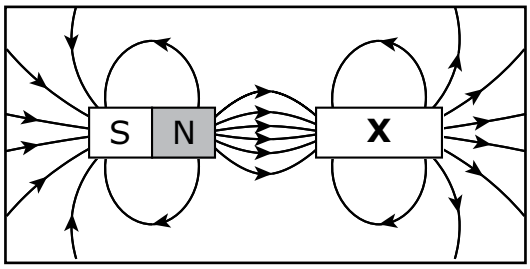
Ⓐ The total energy of the system increases as the moving block creates kinetic energy.

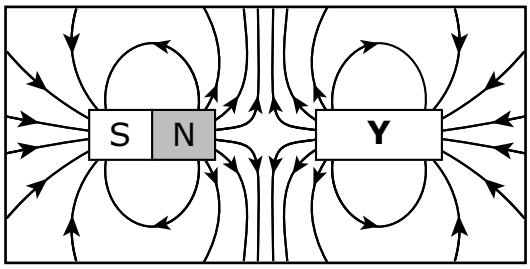
Ⓑ The total energy of the system decreases as kinetic energy changes into potential energy.

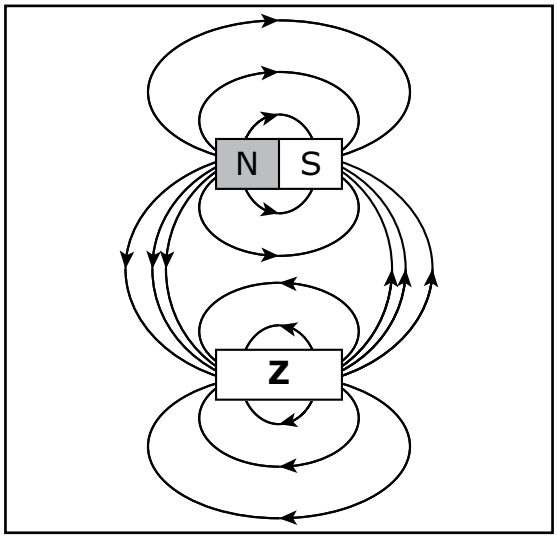
Ⓒ The potential energy of the block increases as the kinetic energy of the spring decreases.

Ⓓ The potential energy of the spring decreases as the kinetic energy of the block increases.

9 The magnetic fields between three pairs of magnets are shown. One magnet in each pair is labeled X, Y, or Z.







Which of the following shows the orientation of bar magnet **X**?

Ⓐ N S Ⓑ S N

Which of the following shows the orientation of bar magnet **Y**?

Ⓐ N S Ⓑ S N

Which of the following shows the orientation of bar magnet **Z**?

Ⓐ N S Ⓑ S N

This question has two parts.

10 A glass lens improves eyesight by changing how light travels from air into the glass lens.

Part A

As light travels from air into the glass lens, the frequency of the light remains the same.

As light moves from air into the glass lens, the light's period

Ⓐ changes.

Ⓑ does not change.

As light moves from air into the glass lens, the light's speed

Ⓐ changes.

Ⓑ does not change.

As light moves from air into the glass lens, the light's wavelength

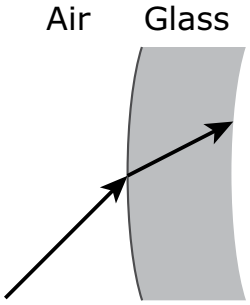
Ⓐ changes.

Ⓑ does not change.

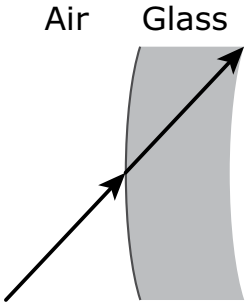
Part B

Which of the following models best shows how light travels from air into the glass lens?

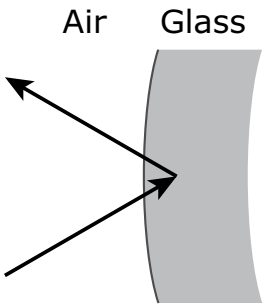
Ⓐ



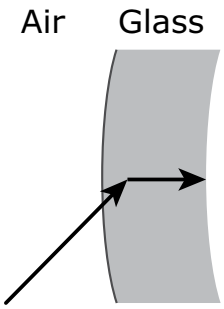
Ⓑ



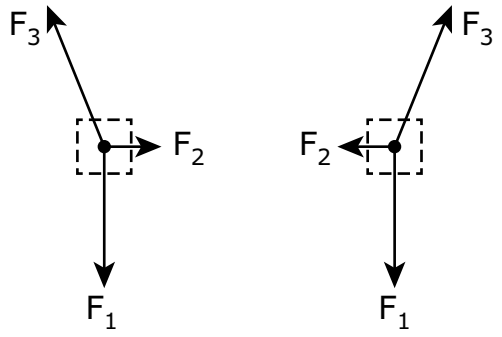
Ⓒ



Ⓓ



11 Two free-body force diagrams are shown.



Object 1 **Object 2**

Which of the following could be represented by these diagrams?

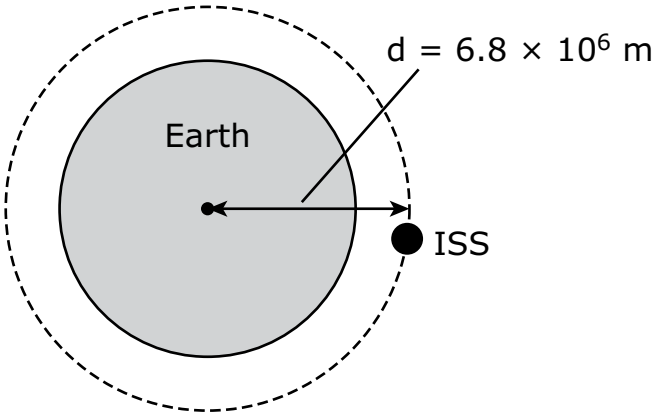
Ⓐ Two sleds are sliding down a hill together.

Ⓑ Two cars are parked in the same driveway.

Ⓒ Two large magnets on a table are repelling each other.

Ⓓ Two charged balloons hanging from strings are attracting each other.

12 The International Space Station (ISS) orbits Earth at an average distance of 6.8×10^6 m from the center of Earth, as shown in the diagram.



(not to scale)

The mass of the ISS is 4.2×10^5 kg, and the mass of Earth is 6.0×10^{24} kg. What is the magnitude of the average gravitational force that acts on the ISS?

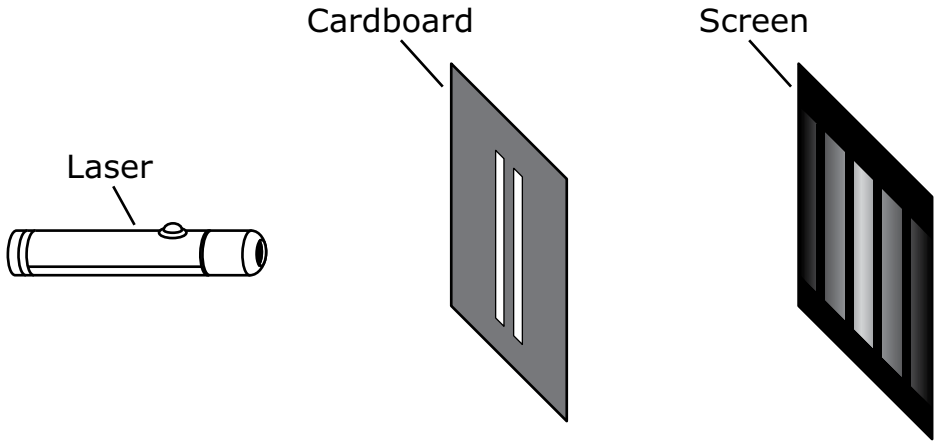
Ⓐ 4.0×10^{-14} N

Ⓑ 4.0×10^{-3} N

Ⓒ 3.7×10^6 N

Ⓓ 3.7×10^{23} N

13 A student shines a laser through a piece of cardboard that has two slits in it. The light travels through the slits, spreads out and overlaps, and produces a pattern on a screen, as shown.



Which of the following best describes what causes the pattern on the screen when a crest of a wave of light traveling through one slit overlaps with a crest of a wave of light traveling through the other slit?

Ⓐ The crests refract to form one of the dark lines in the pattern.

Ⓑ The crests reflect to form one of the dark lines in the pattern.

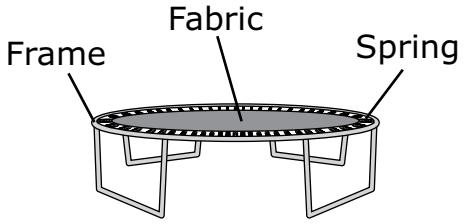
Ⓒ The crests destructively interfere to form one of the bright lines in the pattern.

Ⓓ The crests constructively interfere to form one of the bright lines in the pattern.

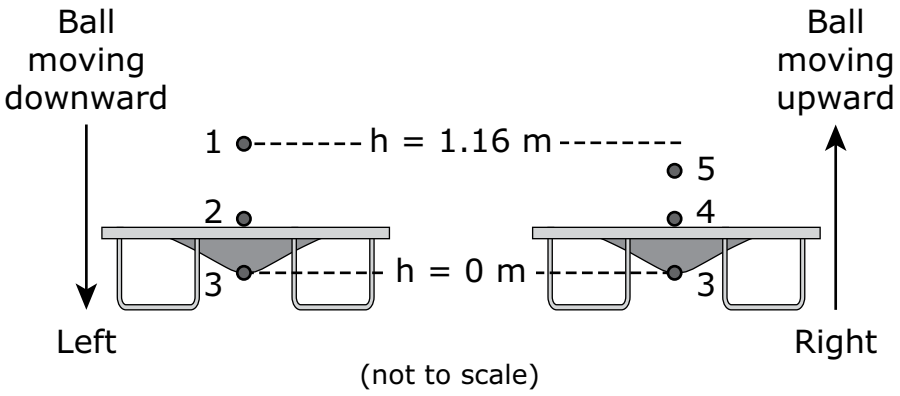
The following section focuses on energy conversions that occurred when a ball bounced on a trampoline.

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

Students used a trampoline and a ball to investigate energy conversions. The trampoline is shown in the diagram.



The students dropped a 5 kg metal ball onto the trampoline. The diagram below shows the positions of the ball during the investigation.



The ball was dropped from position 1 and was just above the trampoline at position 2. When the ball collided with the trampoline, both the fabric and springs stretched as the ball continued to move downward. The ball momentarily stopped at position 3, and then began moving upward as the fabric and springs returned to their original position. The ball was just above the trampoline at position 4 and continued to move upward to position 5.

The students recorded the ball's speed, height, and direction of motion at each position. The data are shown in the table.

Position	Speed (m/s)	Height (m)	Direction of Motion
1	0	1.16	no motion
2	3.2	0.65	downward
3	0	0	no motion
4	2.8	0.65	upward
5	0	1.04	no motion

14 In which of the following positions did the ball have the greatest momentum?

Ⓐ position 1

Ⓑ position 2

Ⓒ position 3

Ⓓ position 4

15 What was the gravitational potential energy of the 5 kg ball when it was at position 4?

Ⓐ 9.1 J

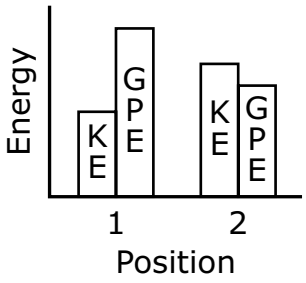
Ⓑ 19.6 J

Ⓒ 32.5 J

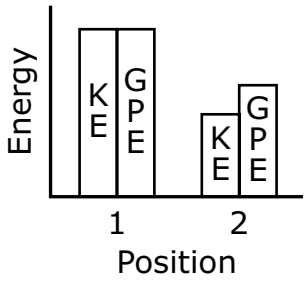
Ⓓ 50.0 J

16 Based on the data in the table, which of the following graphs best represents the gravitational potential energy (GPE) and kinetic energy (KE) of the ball at position 1 and at position 2?

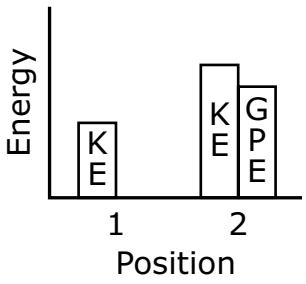
Ⓐ



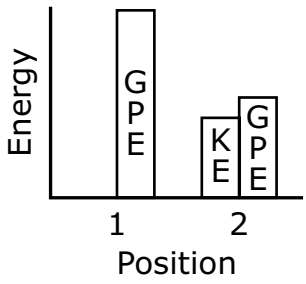
Ⓑ



Ⓒ



Ⓓ



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

17 The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

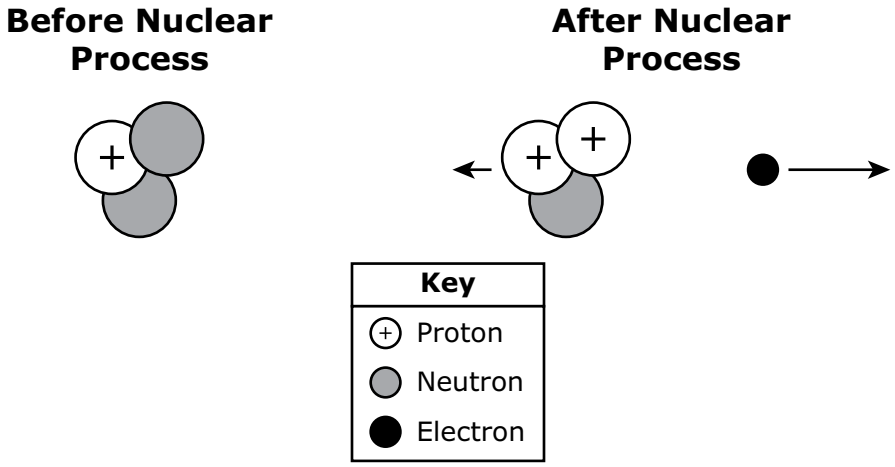
A. Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

B. Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

C. Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

17

18 Tritium is a form of hydrogen. The diagram shows a model of a tritium nucleus before and after it undergoes a nuclear process. The tritium nucleus is at rest before the nuclear process. The arrows represent the magnitude and direction of the velocity of the particles after the nuclear process.



Which of the following best describes the nuclear process shown in the model?

Ⓐ The nuclear process is fusion, and energy is released.

Ⓑ The nuclear process is fusion, and energy is absorbed.

Ⓒ The nuclear process is beta decay, and energy is released.

Ⓓ The nuclear process is beta decay, and energy is absorbed.

19 A musical instrument produces a sound with a frequency of 1318 Hz. The speed of the sound wave is 340 m/s.

What is the wavelength of the sound that the instrument produces?

Ⓐ 0.003 m

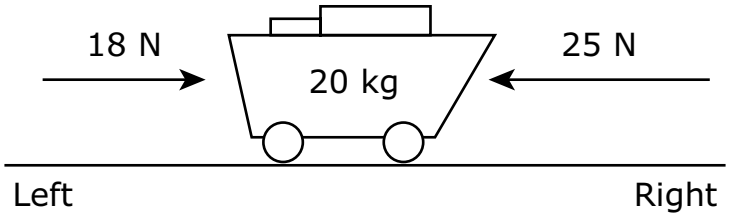
Ⓑ 0.258 m

Ⓒ 978.0 m

Ⓓ 1658 m

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

20 The diagram shows the horizontal forces on a cart. Assume friction is negligible and the cart is initially at rest.



A. Identify the direction the cart moves. Explain your reasoning.

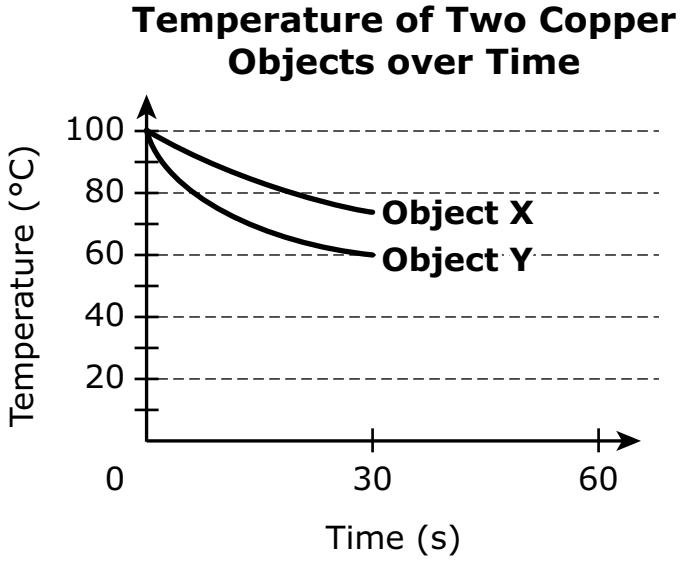
B. Calculate the cart's acceleration. Show your calculations and include units in your answer.

C. Determine the magnitude and direction of an additional force that will give the cart an acceleration of 1.5 m/s^2 to the right. Show your calculations and include units in your answer.

20

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

21 Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



A. Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

B. Describe when the copper objects will stop cooling.

C. The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

D. Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

21

High School Introductory Physics
SESSION 2

This session contains 22 questions.

You may use your reference sheet in this session.

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 A block of ice at −4°C and a cup of 80°C water are placed in a 23°C room. Which statement describes the flow of heat in this situation?

Ⓐ Heat flows into the ice and into the water.

Ⓑ Heat flows out of the ice and out of the water.

Ⓒ Heat flows out of the ice and into the water.

Ⓓ Heat flows into the ice and out of the water.

23 A student is 1 m away from two vending machines, R and S, in a school cafeteria. Vending machine R has twice the mass of vending machine S.

Which of the following best describes the gravitational forces that the vending machines exert on the student?

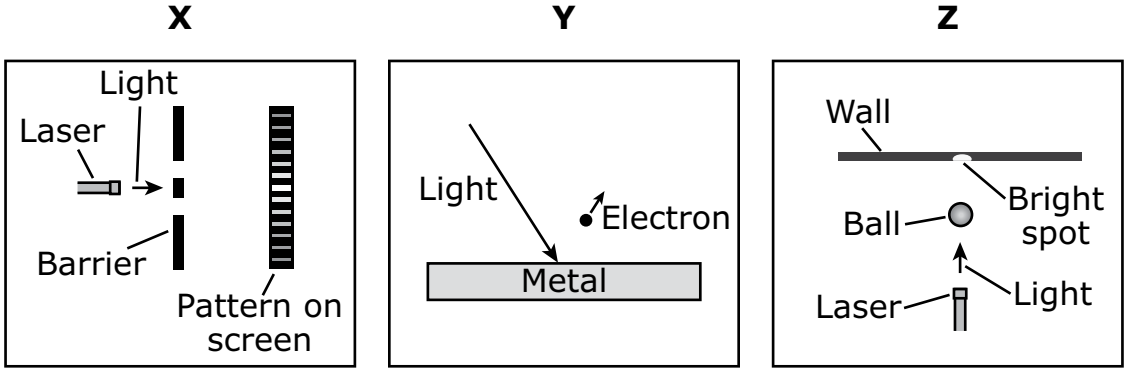
Ⓐ Vending machine R exerts half as much gravitational force on the student as vending machine S does.

Ⓑ Vending machine R exerts the same amount of gravitational force on the student as vending machine S does.

Ⓒ Vending machine R exerts twice as much gravitational force on the student as vending machine S does.

Ⓓ Vending machine R exerts four times as much gravitational force on the student as vending machine S does.

24 Students are analyzing the results of three investigations as they learn about the wave and particle models of light. The three investigations, X, Y, and Z, are represented in the diagrams.



In investigation **X**, light behaves like a

Ⓐ particle.

Ⓑ wave.

In investigation **Y**, light behaves like a

Ⓐ particle.

Ⓑ wave.

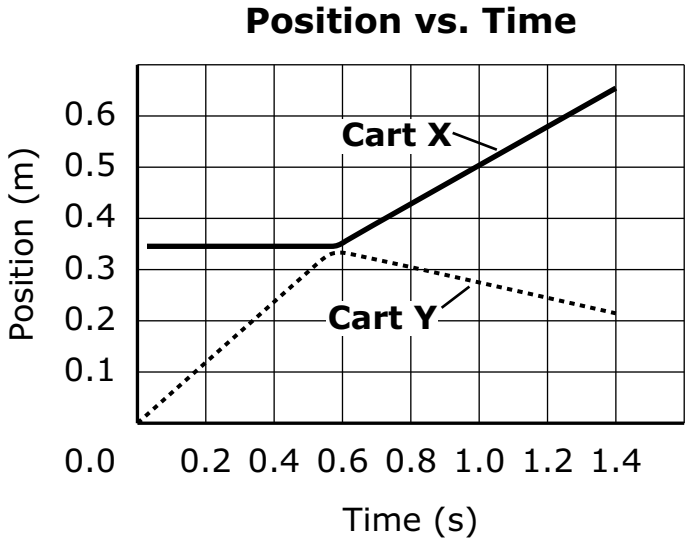
In investigation **Z**, light behaves like a

Ⓐ particle.

Ⓑ wave.

This question has two parts.

25 The graph shows the positions of two carts, cart X and cart Y, before and after they collided on a track. Assume friction was negligible and that the total momentum of the two-cart system was conserved during the collision.



Part A

Which cart was at rest before the collision?

Ⓐ cart X

Ⓑ cart Y

After the collision, the carts

Ⓐ were not moving.

Ⓑ moved in the same direction.

Ⓒ moved in opposite directions.

Part B

Which of the following best describes the two-cart system?

Ⓐ The net force on the system was zero during the collision.

Ⓑ The momentum of the system decreased during the collision.

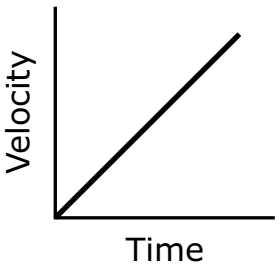
Ⓒ The velocity of the system was conserved during the collision.

Ⓓ The kinetic energy of the system increased during the collision.

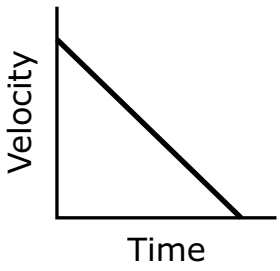
26 A 30 kg crate is being lifted upward with a rope. The rope applies a constant upward force of 360 N on the crate. Assume friction is negligible.

Which graph best shows the velocity of the crate over time?

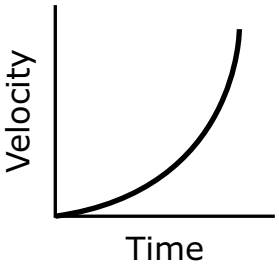
Ⓐ



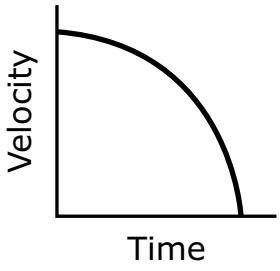
Ⓑ



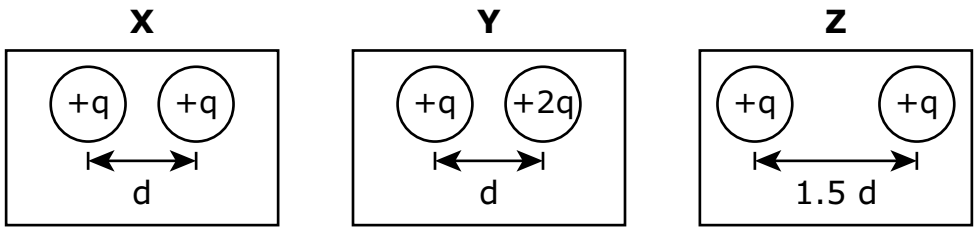
Ⓒ



Ⓓ



27 Three pairs of charges, X, Y, and Z, are shown.



Which of the following correctly orders the pairs of charges by the magnitude of the forces between the charges in each pair?

Ⓐ

X	Y	Z
Least force	⟶	Greatest force

Ⓑ

X	Z	Y
Least force	⟶	Greatest force

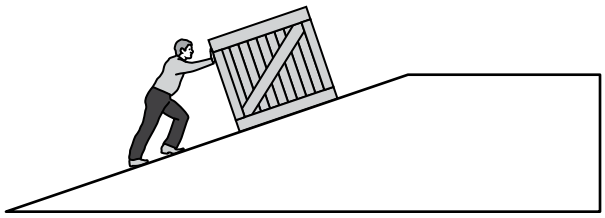
Ⓒ

Y	Z	X
Least force	⟶	Greatest force

Ⓓ

Z	X	Y
Least force	⟶	Greatest force

28 The diagram shows a worker pushing a crate from the bottom of a ramp to the top of the ramp.



The worker does 1900 J of work on the crate to push it to the top of the ramp. The crate has a gravitational potential energy of 1200 J at the top of the ramp.

What is the efficiency of the worker pushing the crate from the bottom to the top of the ramp?

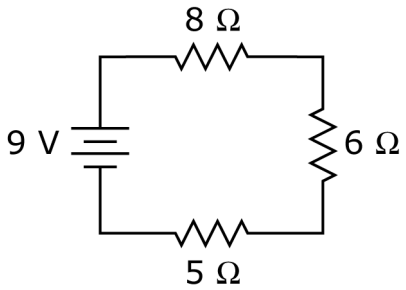
Ⓐ 0.23

Ⓑ 0.37

Ⓒ 0.58

Ⓓ 0.63

29 A circuit includes a battery and three resistors, as shown.



What is the total resistance of the circuit?

Ⓐ 2 Ω

Ⓑ 19 Ω

Ⓒ 28 Ω

Ⓓ 240 Ω

30 A car is traveling with an initial velocity of 30 m/s. Over 6 s, the car slows to a final velocity of 18 m/s.

What is the magnitude of the car's average acceleration during the 6 s?

Ⓐ 2 m/s^2

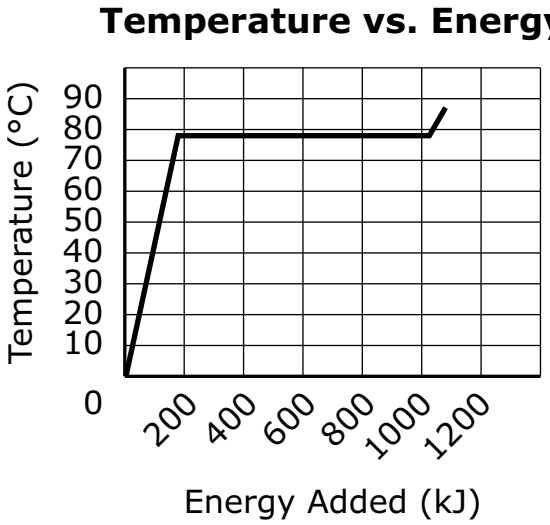
Ⓑ 3 m/s^2

Ⓒ 5 m/s^2

Ⓓ 8 m/s^2

This question has two parts.

31 In an investigation, the temperature of a 1 kg sample of liquid ethanol was initially 0°C. As energy was added to the sample, the temperature of the ethanol was recorded in a graph, as shown. Assume no energy was transferred to the surroundings.



Part A

Which of the following best describes the sample of ethanol?

Ⓐ The ethanol melted below 78°C.

Ⓑ The ethanol froze at about 78°C.

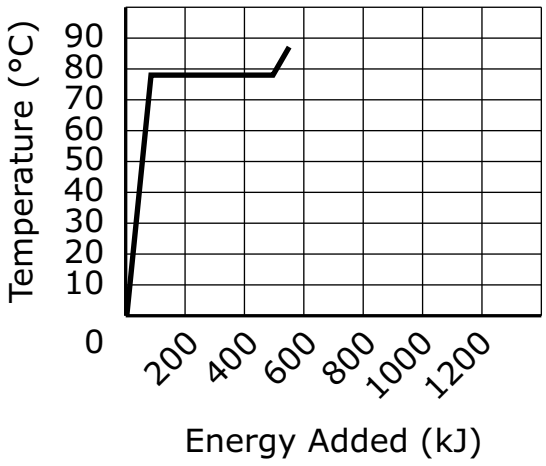
Ⓒ The ethanol remained a liquid above 78°C.

Ⓓ The ethanol began changing into a gas at about 78°C.

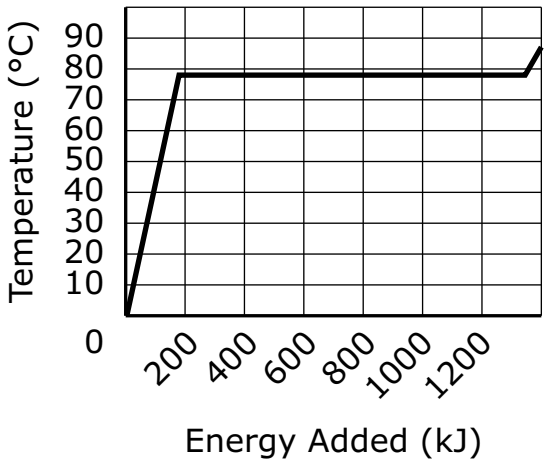
Part B

The investigation was repeated with a 0.5 kg sample of ethanol instead of a 1.0 kg sample. Which graph best represents the temperature of the 0.5 kg sample of ethanol as energy was added?

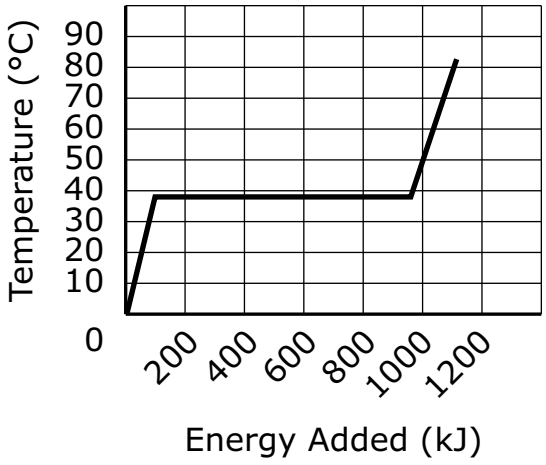
Ⓐ



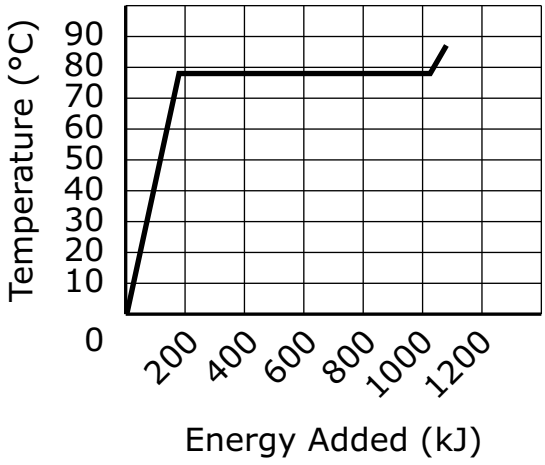
Ⓑ



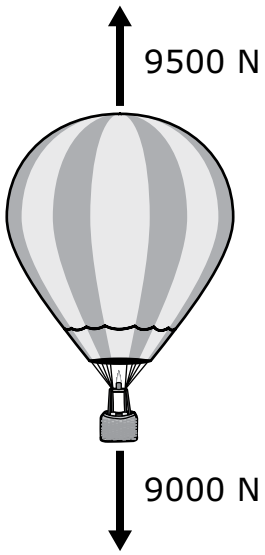
Ⓒ



Ⓓ



32 The diagram shows a 900 kg hot air balloon. Only two forces are acting on the balloon, a 9000 N gravitational force and a 9500 N lift force.



What is the acceleration of the balloon?

Ⓐ 0.21 m/s^2 upward

Ⓑ 0.21 m/s^2 downward

Ⓒ 0.56 m/s^2 upward

Ⓓ 0.56 m/s^2 downward

33 Which of the following has the **lowest** average molecular kinetic energy?

Ⓐ steam in a pipe

Ⓑ ice cubes in a cup

Ⓒ water boiling in a pan

Ⓓ water flowing in an aquarium

34 A 30 kg object moving at 10 m/s is used to test the strength of a material. The object collides with the material and comes to a stop. The average force on the object is 15,000 N.

What is the amount of time of the collision?

Ⓐ 0.0006 s

Ⓑ 0.001 s

Ⓒ 0.02 s

Ⓓ 0.33 s

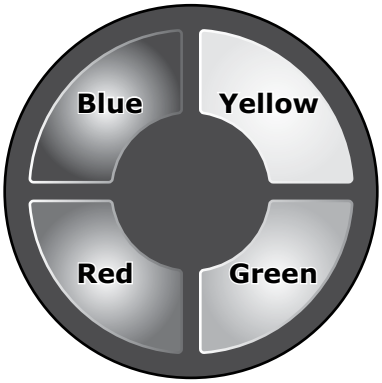
The following section focuses on sound and light waves produced by an electronic game.

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

One type of handheld electronic game is known as a random sequence game (RSG). The object of the game is to try to repeat a unique sequence of light and sound signals produced by the RSG. The player does this by pressing the game's four color buttons in the correct order.

The color buttons produce equally bright lights and equally loud sounds when pressed. Each color button, however, produces a different color of light and a different pitch of sound. The game is shown in the illustration.

Random Sequence Game



The table shows the frequency of the sound and the wavelength of the light that each button produces.

Sound Frequencies and Light Wavelengths Produced by RSG Buttons

Button Color	Sound Frequency (Hz)	Light Wavelength (m)
yellow	277	5.85×10^{-7}
green	165	5.70×10^{-7}
red	220	7.80×10^{-7}
blue	330	4.90×10^{-7}

35 A player presses the blue button on the RSG, which produces a blue light wave and a sound wave. The player's friend is standing 3 m away.

Which wave reaches the player's friend first?

Ⓐ the blue light wave

Ⓑ the sound wave

Which of the following best explains why this wave reaches the player's friend first?

Ⓐ The wave travels the same distance in more time than the other wave.

Ⓑ The wave travels the same distance in less time than the other wave.

36 If an astronaut tried to use the RSG while standing on the Moon, the astronaut would not be able to hear the game's sound but would be able to see the game's light. Which of the following best describes the sound and light waves?

Ⓐ Sound waves are transverse waves, and light waves are longitudinal waves.

Ⓑ Sound waves are mechanical waves, and light waves are longitudinal waves.

Ⓒ Sound waves are transverse waves, and light waves are electromagnetic waves.

Ⓓ Sound waves are mechanical waves, and light waves are electromagnetic waves.

37 Which of the following correctly compares a sound wave emitted by the green color button with a sound wave emitted by the blue color button?

Ⓐ The sound wave emitted by the green color button would have a larger amplitude.

Ⓑ The sound wave emitted by the green color button would have a smaller amplitude.

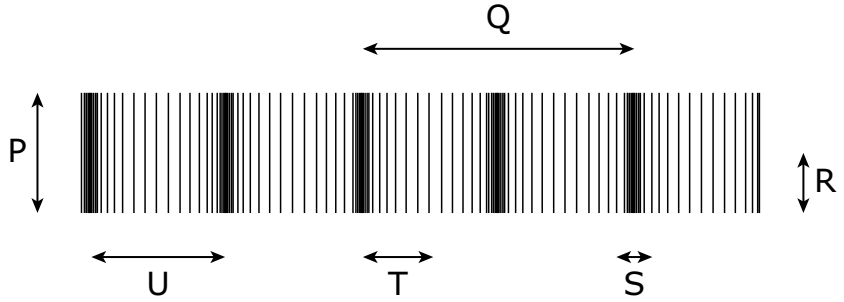
Ⓒ The sound wave emitted by the green color button would have a longer wavelength.

Ⓓ The sound wave emitted by the green color button would have a shorter wavelength.

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

38 A student pressed the red color button on the RSG, which produced a sound wave that traveled at 343 m/s through air.

A. The diagram shows the sound wave produced by the red button, with six arrows labeled P, Q, R, S, T, and U.



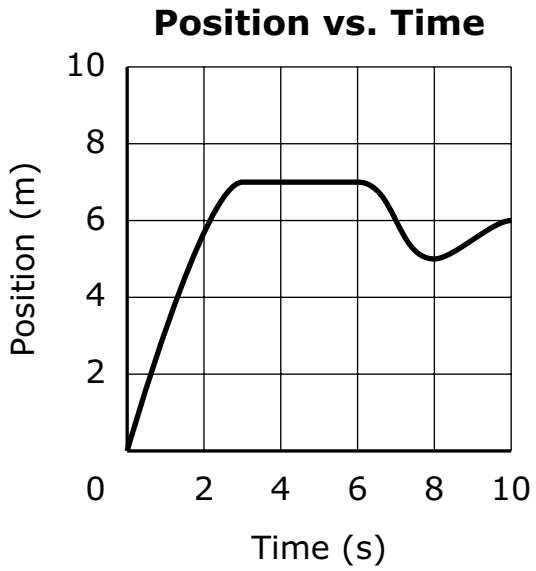
Identify the arrow (P, Q, R, S, T, or U) in the diagram that represents a wavelength of the sound.

B. Calculate the wavelength of the sound produced by the red button. Show your calculations and include units in your answer.

C. Calculate the period of the sound produced by the red button. Show your calculations and include units in your answer.

38

39 The graph shows the change in position of an object over time.



At which of the following times did the object have a velocity of 0 m/s?

Ⓐ 1 s

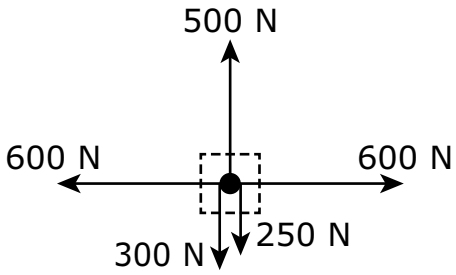
Ⓑ 4 s

Ⓒ 7 s

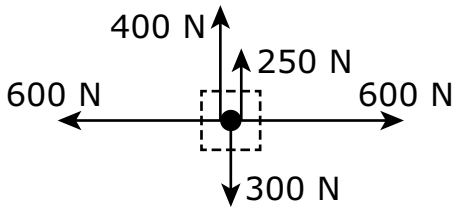
Ⓓ 9 s

40 Which of the following free-body force diagrams shows an object with zero net force?

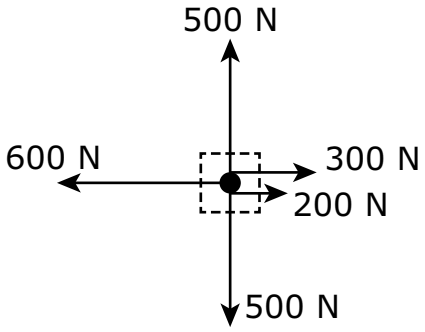
Ⓐ



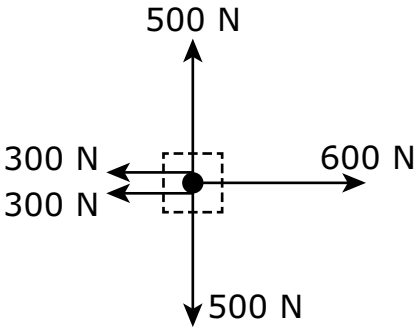
Ⓑ



Ⓒ



Ⓓ



41 A 25 Ω resistor and a 100 V battery are connected in a series circuit. What is the current through the resistor?

Ⓐ 0.3 A

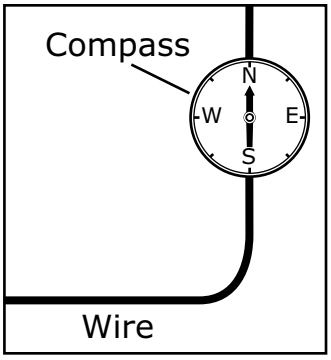
Ⓑ 2.0 A

Ⓒ 4.0 A

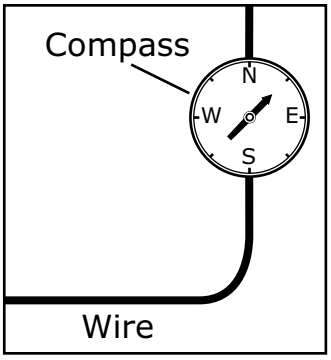
Ⓓ 75 A

42 A student placed a compass directly on top of a wire. The student then connected each end of the wire to a battery. The diagrams show the compass and wire before and after the battery was connected.

Battery Not Connected



Battery Connected



Which of the following best describes why the compass needle moved?

Ⓐ The metal of the wire generated a magnetic field strong enough to move the compass needle.

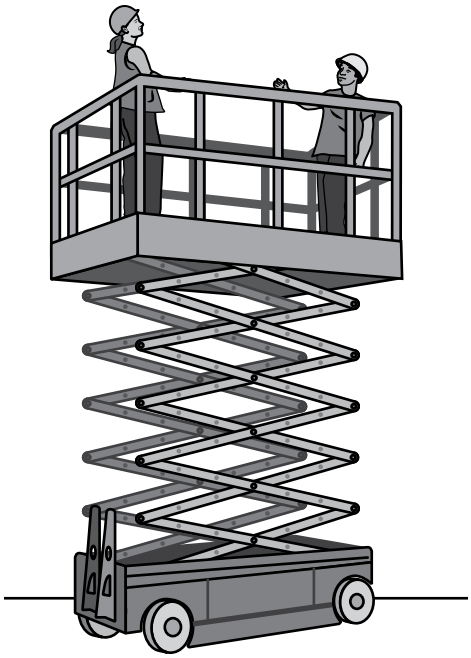
Ⓑ The current in the wire generated a magnetic field strong enough to move the compass needle.

Ⓒ The metal of the wire generated a gravitational field strong enough to move the compass needle.

Ⓓ The current in the wire generated a gravitational field strong enough to move the compass needle.

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

43 A material hoist is a device used to lift or lower heavy loads. The illustration shows a material hoist lifting two people whose combined mass is 160 kg.



A. Calculate the work done by the hoist to lift the two people 15 m. Show your calculations and include units in your answer.

B. Describe how the work done by the hoist to lift the two people 15 m compares to the change in gravitational potential energy of the two people. Support your answer by referring to variables in both the work and potential energy formulas.

C. The hoist is used to lift a 70 kg wooden beam to a height of 20 m. The beam then falls off the hoist.

Describe what happens to the beam's gravitational potential energy **and** the beam's kinetic energy as it falls to the ground.

D. Calculate the velocity of the 70 kg beam just before it hits the ground. Show your calculations and include units in your answer.

43

MASSACHUSETTS Department of Elementary and Secondary Education

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 = $6.7 \times 10^{-11} \frac{N \bullet m^2}{kg^2}$

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

g ≈ 10 m/s² at Earth's surface

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

1 J = 1 N • m

High School Introductory Physics
Spring 2025 Released Operational Items

PBT Item No.	Page No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description	Correct Answer (SR)**
1	3	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Describe how increasing the voltage of a battery in a series circuit affects the current through the circuit.	A
2	4–5	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a velocity vs. time graph to determine which free-body force diagram represents the forces acting on an object during each time interval of the graph.	C
3	6	*Motion, Forces, and Interactions*	HS.PHY.2.2	A. Investigations and Questioning	SR	Determine the steps a student should take to calculate the final momentum of a system of two colliding objects.	C
4	7	*Waves*	HS.PHY.4.5	C. Evidence, Reasoning, and Modeling	SR	Determine which model represents two waves that will cancel each other out when they interact.	A
5	8	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Explain why a disc that stores information in magnetic fields could be damaged by a nearby wire that carries a current.	D
6	9	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Analyze the effects of distance and mass on gravitational force to determine which pairs of objects have the same gravitational forces acting on them.	B
7	10	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Determine the resistor in a series circuit that has the greatest voltage drop across it and calculate the current through the circuit.	D;A
8	11	*Energy*	HS.PHY.3.3	C. Evidence, Reasoning, and Modeling	SR	Describe an energy conversion that takes place within a system.	D
9	12	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Interpret magnetic field lines to determine the orientation of a magnet.	B;A;B
10	13–14	*Waves*	HS.PHY.4.5	C. Evidence, Reasoning, and Modeling	SR	Identify whether light traveling from air into a glass lens changes given characteristics of light, and determine the model that shows how light travels from air into the glass lens.	B;A;A;A
11	15	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Identify a situation that two free-body force diagrams could represent.	D
12	16	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Calculate the magnitude of the gravitational force on an object orbiting Earth.	C
13	17	*Waves*	HS.PHY.4.3	C. Evidence, Reasoning, and Modeling	SR	Determine what wave interaction occurs and what pattern forms when a laser light shines through two slits.	D

PBT Item No.	Page No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description	Correct Answer (SR)**
14	20	*Motion, Forces, and Interactions*	HS.PHY.2.2	C. Evidence, Reasoning, and Modeling	SR	Interpret data to determine the position at which an object has the greatest momentum.	B
15	20	*Energy*	HS.PHY.3.2	B. Mathematics and Data	SR	Calculate the gravitational potential energy of an object.	C
16	21	*Energy*	HS.PHY.3.1	C. Evidence, Reasoning, and Modeling	SR	Determine which graph best represents an object's gravitational potential energy and kinetic energy.	D
17	22–23	*Motion, Forces, and Interactions*	HS.PHY.2.3	A. Investigations and Questioning	CR	Calculate the change in momentum of an object, calculate the average net force on the object, and explain why an identified change to the setup of the investigation would reduce the average net force on the object.	
18	24	*Energy*	HS.PHY.1.8	C. Evidence, Reasoning, and Modeling	SR	Interpret a model to determine the type of nuclear process shown and identify that energy is released during the process.	C
19	24	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Calculate the wavelength of a sound wave.	B
20	25–26	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	CR	Analyze the forces acting on an object to explain why the object moves to the left, calculate the acceleration of the object, and determine the magnitude and direction of an additional force that would result in a given acceleration.	
21	27–28	*Energy*	HS.PHY.3.4	C. Evidence, Reasoning, and Modeling	CR	Interpret a temperature vs. time graph of two objects in water to identify and explain the initial temperature of the water, describe when the objects will stop cooling, explain how more thermal energy was lost by one of the objects, and describe how the total heat transfer would be different if an object had a higher specific heat.	
22	30	*Energy*	HS.PHY.3.4	None	SR	Describe the flow of heat between ice and liquid water.	D
23	30	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Compare the gravitational forces that two objects exert on a person.	C
24	31	*Waves*	HS.PHY.4.3	C. Evidence, Reasoning, and Modeling	SR	Identify whether each investigation provides evidence that light behaves like a particle or like a wave.	B;A;B

PBT Item No.	Page No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description	Correct Answer (SR)**
25	32–33	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Interpret a position vs. time graph for two objects that collided to determine which object was at rest before the collision, the direction the objects moved after the collision, and the magnitude of the net force on the system during the collision.	A;C;A
26	34	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	SR	Analyze the forces acting on an object to determine which graph best represents the velocity of the object over time.	A
27	35	*Motion, Forces, and Interactions*	HS.PHY.2.4	C. Evidence, Reasoning, and Modeling	SR	Analyze the effect of distance and charge on electrostatic force to order three pairs of charges by the magnitude of the forces between the charges in each pair.	D
28	36	*Energy*	HS.PHY.3.3	B. Mathematics and Data	SR	Calculate the efficiency of a person pushing a crate up a ramp.	D
29	37	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	SR	Calculate the total resistance of a series circuit.	B
30	37	*Motion, Forces, and Interactions*	HS.PHY.2.10	B. Mathematics and Data	SR	Calculate the average acceleration of a car as it slows down.	A
31	38–39	*Energy*	HS.PHY.3.2	B. Mathematics and Data	SR	Interpret a temperature vs. energy graph to determine the temperature at which a substance changed state and how the graph would be different if a smaller mass of the substance were heated.	D;A
32	40	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	SR	Interpret a diagram of the forces acting on an object to determine the acceleration of the object.	C
33	41	*Energy*	HS.PHY.3.2	None	SR	Determine in which situation water has the lowest average molecular kinetic energy.	B
34	41	*Motion, Forces, and Interactions*	HS.PHY.2.3	B. Mathematics and Data	SR	Calculate the amount of time it takes an object to come to a stop after colliding with a material.	C
35	43	*Waves*	HS.PHY.4.1	None	SR	Explain why a light wave reaches an observer sooner than a sound wave.	A;B
36	43	*Waves*	HS.PHY.4.1	None	SR	Explain why sound cannot be heard and light can be seen when a device is used on the moon.	D
37	44	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Compare the wavelengths of two sound waves with different frequencies.	C

PBT Item No.	Page No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description	Correct Answer (SR)**
38	44–45	*Waves*	HS.PHY.4.1	B. Mathematics and Data	CR	Calculate the period and wavelength of a sound wave and identify the wavelength of the sound wave in a model.	
39	46	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a position vs. time graph to determine the velocity of an object.	B
40	47	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Determine which free-body force diagram shows an object with zero net force.	D
41	48	*Motion, Forces, and Interactions*	HS.PHY.2.9	B. Mathematics and Data	SR	Calculate the current through a resistor in a series circuit.	C
42	49	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Explain why a compass needle moves when it is near a wire that is connected to a battery.	B
43	50–51	*Energy*	HS.PHY.3.1	B. Mathematics and Data	CR	Calculate the work done to lift two people, describe how the work done on the people affects their gravitational potential energy, describe how the gravitational potential energy and kinetic energy of an object change as the object falls to the ground, and calculate the velocity of the object just before it hits the ground.	

* Science 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.