XX. Introductory Physics, High School

High School Introductory Physics Test

The spring 2016 high school Introductory Physics test was based on learning standards in the Introductory Physics content strand of the *Massachusetts Science and Technology/Engineering Curriculum Framework* (2006). These learning standards appear on pages 74–77 of the *Framework*, which is available on the Department website at www.doe.mass.edu/frameworks/current.html.

Introductory Physics test results are reported under the following four MCAS reporting categories:

- Motion and Forces
- Heat and Heat Transfer
- Waves and Radiation
- Electromagnetism

The table at the conclusion of this chapter indicates each item's reporting category and the framework learning standard it assesses. The correct answers for multiple-choice questions are also displayed in the table.

Test Sessions

The high school Introductory Physics test included two separate test sessions, which were administered on consecutive days. Each session included multiple-choice and open-response questions.

Reference Materials and Tools

Each student taking the high school Introductory Physics test was provided with an Introductory Physics Formula Sheet. A copy of this formula sheet follows the final question in this chapter.

Each student also had sole access to a calculator with at least four functions and a square-root key.

During both Introductory Physics test sessions, the use of bilingual word-to-word dictionaries was allowed for current and former English language learner students only. No other reference tools or materials were allowed.

Introductory Physics

Session 1

DIRECTIONS

This session contains twenty-one multiple-choice questions and two open-response questions. Mark your answers to these questions in the spaces provided in your Student Answer Booklet. You may work out solutions to multiple-choice questions in the test booklet.

1 Four sleds are pulled up a hill. The table below shows the weight of each sled and its change in height after being pulled up the hill.

Sled	Weight of the Sled (N)	Change in Height (m)
W	350	40
X	400	30
Y	250	100
Z	200	60

Which pair of sleds have the same change in potential energy?

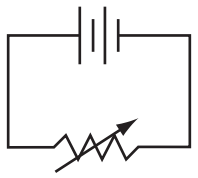
A. sleds W and Y

B. sleds W and Z

C. sleds X and Y

D. sleds X and Z

2 The circuit shown below has a variable resistor connected to a 6.0 V battery.



The value of the current at several settings of the variable resistor is recorded in the table below.

Trial	Resistance (Ω)	Current (A)
1	1.0	6.0
2	2.0	3.0
3	3.0	2.0
4	4.0	?

What amount of current flows through the battery when the variable resistor is set for 4 Ω?

A. 1.5 A

B. 1.0 A

C. 0.75 A

D. 0.50 A

3 Which of the following wave characteristics is the same for any electromagnetic wave traveling through empty space?

A. frequency
B. period
C. speed
D. wavelength

4 A 1 kg sample of liquid water and a 1 kg sample of ice are placed on a table. Which of the following statements best compares these two samples?

A. The liquid water has a larger volume than the ice.
B. The liquid water has a greater weight than the ice.
C. The liquid water has more thermal energy than the ice.
D. The liquid water has more gravitational potential energy than the ice.

5 Which of the following best compares average speed with average velocity?

A. Average speed is always less than average velocity.
B. Average speed has units of mph and average velocity has units of m/s.
C. Average speed is a vector quantity, but average velocity is a scalar quantity.
D. Average speed has only magnitude, but average velocity has both magnitude and direction.

6 Two U.S. quarters, initially at the same temperature, are heated with a flame. One of the quarters was made before 1965 and is composed of silver. The other quarter was made after 1965 and is composed mostly of copper.

What information is needed to determine which quarter will heat up faster?

A. the specific heats of the metals and the mass of each coin
B. the initial temperature of the coins and the mass of each coin
C. the temperature of the flame and the specific heats of the metals
D. the initial temperature of the coins and the temperature of the flame

7 Two particles with the same positive charge are 100 cm apart. What happens to the electric force between the two particles when the charge on each particle doubles?

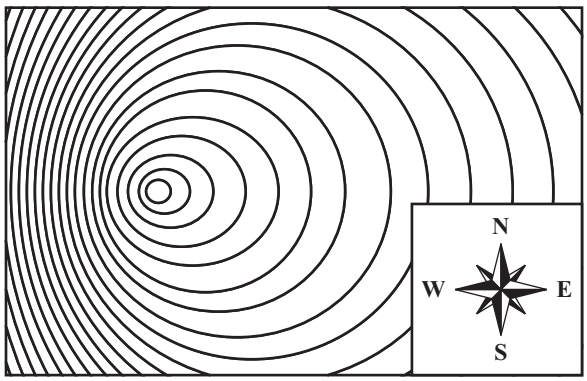
A. The electric force becomes attractive.

B. The magnitude of the electric force decreases.

C. The attractive electric force becomes two times as strong.

D. The repulsive electric force becomes four times as strong.

8 The diagram below represents a wave pattern made by an object moving in water, as seen from above the surface of the water.



Based on the wave pattern shown, in which direction is the object moving?

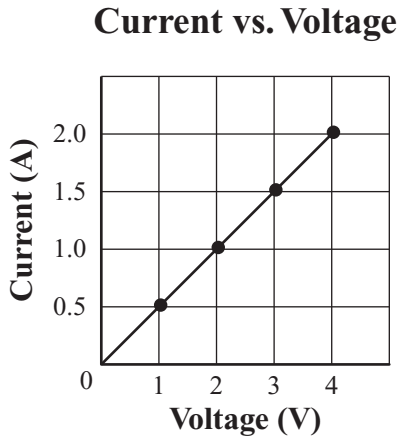
A. north

B. east

C. south

D. west

9 A student creates a circuit with a variable voltage supply and a 2 Ω resistor. The student varies the voltage and measures the current. The graph below shows the student's results.



What was the greatest power supplied by the battery?

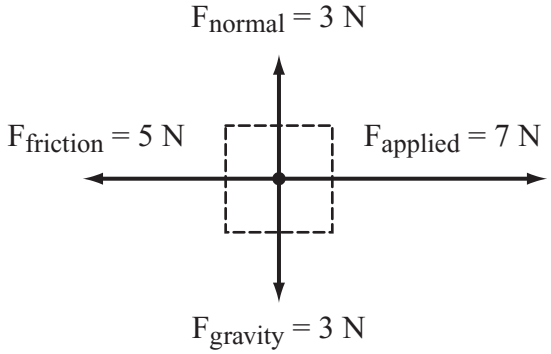
A. 2 W

B. 4 W

C. 8 W

D. 16 W

10 The free-body force diagram below represents four forces acting on an object.



What is the net force on the object?

A. 0 N

B. 2 N to the right

C. 6 N along the vertical axis

D. 18 N in all directions

11 The table below describes ball X and ball Y.

	Mass (kg)	**Velocity (m/s)**
Ball X	0.17	0.5
Ball Y	0.17	0.0

Which of the following best compares the momentum of the two balls?

A. Both balls have the same momentum because they have the same mass.

B. Both balls have the same momentum because they have the same inertia.

C. Ball Y has greater momentum than ball X because ball Y has no velocity.

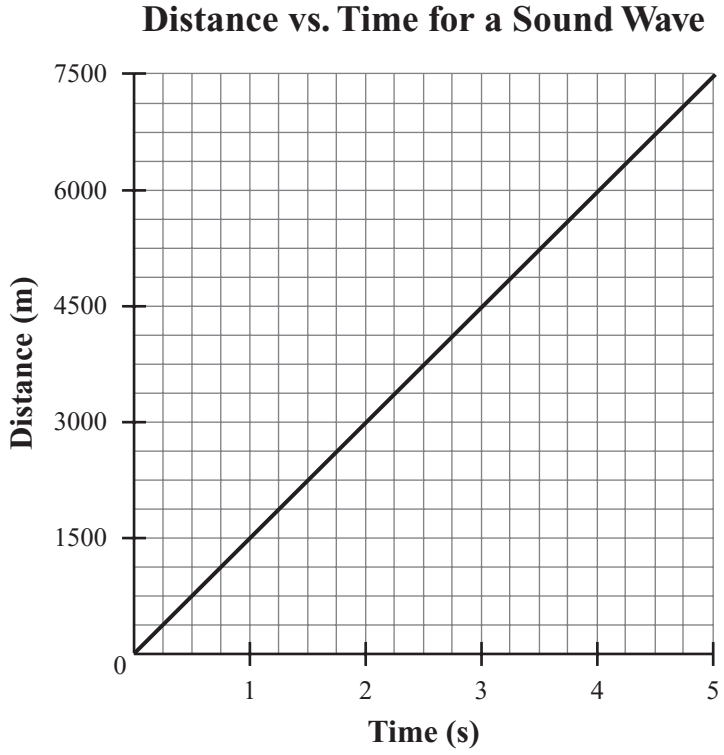
D. Ball X has greater momentum than ball Y because ball X has greater velocity.

Question 12 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 12 in the space provided in your Student Answer Booklet.

12 The graph below shows the relationship between distance and time for a sound wave moving through a liquid.



a. Calculate the speed of the sound wave. Show your calculations and include units in your answer.

b. Copy the graph onto the grid in your Student Answer Booklet. On your graph:

- Label the line you copied "liquid."
- Draw a line labeled "gas" to represent how this sound wave would travel through a typical gas.
- Draw a line labeled "solid" to represent how this sound wave would travel through a typical solid.

c. Explain your reasoning for the placement of the new lines (gas, solid) you drew in part (b).

d. Identify **one** property or characteristic of a sound wave that remains the same when it moves from a liquid into a gas or a solid.

Mark your answers to multiple-choice questions 13 through 22 in the spaces provided in your Student Answer Booklet. Do not write your answers in this test booklet, but you may work out solutions to multiple-choice questions in the test booklet.

13 What is the momentum of a 50 kg object traveling with a constant velocity of 20 m/s?

A. 2.5 kg • m/s

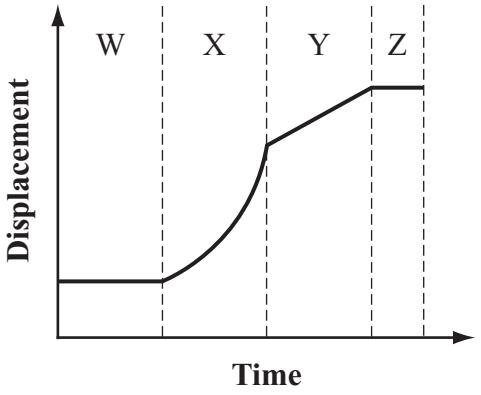
B. 1,000 kg • m/s

C. 10,000 kg • m/s

D. 20,000 kg • m/s

14 The graph below represents an object's motion over four time intervals: W, X, Y, and Z.

Displacement vs. Time



During which time interval does the object move with constant, positive velocity?

A. interval W

B. interval X

C. interval Y

D. interval Z

15 Two solid blocks with different masses are placed 1.0 m apart on a horizontal surface. Which of the following will occur if the two blocks are moved farther apart?

A. The gravitational force between the blocks will decrease.

B. The gravitational force between the blocks will remain the same.

C. The gravitational force of the more massive block will increase.

D. The gravitational force of the less massive block will increase.

16 A fan enables a computer's processor to run for long periods of time without overheating. Which of the following forms of heat energy transfer does this example **best** represent?

A. condensation
B. convection
C. evaporation
D. radiation

17 Which of the following is a function of a resistor in a circuit?

A. to disconnect the wires
B. to decrease the temperature
C. to limit the amount of current
D. to increase the amount of voltage

18 A small steel rod is placed in 5 L of water. The initial temperature of the steel rod is 120°C, and the initial temperature of the water is 10°C.

When does heat stop flowing between the steel rod and the water?

A. when the steel rod reaches 65°C
B. when the water reaches its boiling point
C. when the steel rod reaches 10°C and the water reaches 120°C
D. when the steel rod and the water reach the same temperature

19 The planet Mars has two moons, Phobos and Deimos. What is the direction of the force that keeps Phobos orbiting Mars?

A. toward the Sun
B. toward Deimos
C. toward the center of Mars
D. toward the north pole of Mars

20 A circuit has a light bulb connected to a constant voltage source. Which of the following changes must increase the power in the circuit?

A. using a light bulb that is more efficient

B. using a light bulb that draws more current

C. using a light bulb that is rated to last longer

D. using a light bulb that has a larger resistance

21 Which of the following describes properties that distinguish red light from violet light?

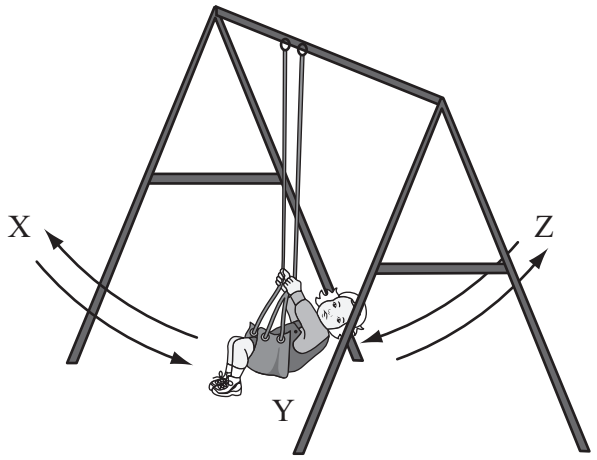
A. Red light has a longer wavelength and a lower frequency.

B. Red light has a longer wavelength and a higher frequency.

C. Red light has a shorter wavelength and a lower frequency.

D. Red light has a shorter wavelength and a higher frequency.

22 The diagram below shows a child on a swing. The child is swinging back and forth between points X and Z, through point Y. Points X and Z are at the same height.



Which of the following statements **best** describes the kinetic energy and the gravitational potential energy of the child?

A. The child has no potential energy and no kinetic energy at position X and position Y.

B. The child has the same kinetic energy and potential energy at position X and position Y.

C. The child has more potential energy and less kinetic energy at position X than at position Y.

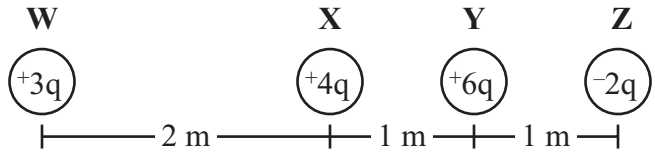
D. The child has more kinetic energy and less potential energy at position X than at position Y.

Question 23 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 23 in the space provided in your Student Answer Booklet.

23 Four charged objects, labeled W, X, Y, and Z, are arranged in a straight line, as shown below.



a. Identify the two objects that have the **greatest** magnitude of electric force between them.

b. Identify the two objects that have the **greatest** attractive force between them. Explain why these two charges have an attractive force.

c. Identify the two objects that have the **smallest** magnitude of electric force between them. Explain your answer.

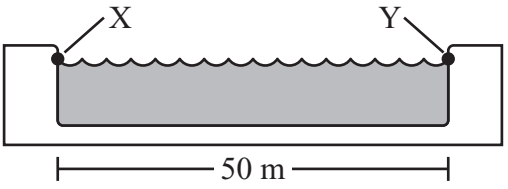
Introductory Physics

Session 2

DIRECTIONS

This session contains nineteen multiple-choice questions and three open-response questions. Mark your answers to these questions in the spaces provided in your Student Answer Booklet. You may work out solutions to multiple-choice questions in the test booklet.

24 The diagram below shows a pool with a length of 50 m.



A person swims three lengths of the pool: from point X to point Y, from point Y to point X, and then from point X to point Y again.

Which table shows the magnitudes of the distance the person traveled and the person's final displacement?

A.

Distance	Displacement
150 m	0 m

B.

Distance	Displacement
150 m	50 m

C.

Distance	Displacement
0 m	150 m

D.

Distance	Displacement
50 m	150 m

25 A television produces two types of waves: light and sound. Which of the following statements describes a property of both light and sound?

A. They can be reflected.

B. They require a medium.

C. They are mechanical waves.

D. They travel at the same speed.

26 What is the primary difference between insulators and conductors?

A. Electrons are present in insulators but not in conductors.

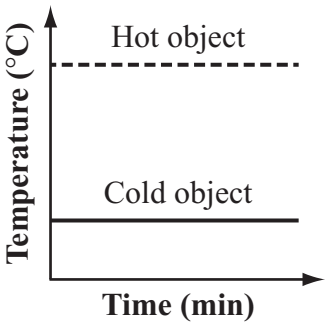
B. Electrons are present in conductors but not in insulators.

C. Electrons are free to move in insulators but not in conductors.

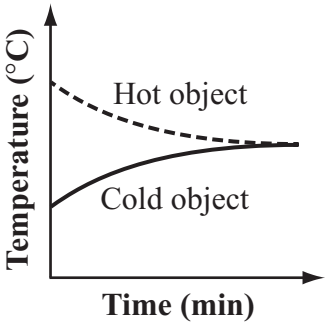
D. Electrons are free to move in conductors but not in insulators.

27 Two identical objects, one hot and one cold, are placed near each other in a closed system. Which of the following graphs shows what happens to the temperatures of the objects over time?

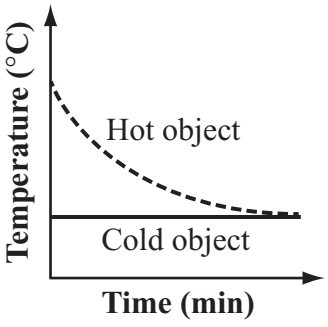
A.



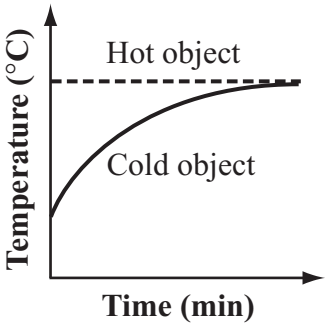
B.



C.



D.



28 A student rides a bicycle down a hill and then up another hill without pedaling. Which of the following statements **best** describes what happens to the energy of the student and the bicycle while they move up the hill?

A. Potential energy is lost and kinetic energy is gained.

B. Kinetic energy is lost and potential energy is gained.

C. The sum of potential and kinetic energy becomes less.

D. The sum of potential and kinetic energy becomes greater.

29 A trumpet makes a low-pitched note, while a flute makes a high-pitched note. The volume of both notes is the same.

What is different for the two sounds as they travel through the air?

A. the amplitude
B. the medium
C. the wavelength
D. the velocity

30 A book is dropped and falls to the floor. Which of the following describes the forces between the book and the floor when the book hits the floor?

A. The book exerts a force on the floor, but the floor does not exert a force on the book.
B. The book does not exert a force on the floor, but the floor exerts a force on the book.
C. The force exerted by the book on the floor is greater in magnitude than the force exerted by the floor on the book.
D. The force exerted by the book on the floor is equal in magnitude to the force exerted by the floor on the book.

31 Electromagnetic radiation is used in many forms of communication. Electromagnetic waves with relatively long wavelengths are often used to transmit signals because these waves travel easily around objects.

Which type of electromagnetic radiation is best for transmitting signals around objects?

A. gamma rays
B. radio waves
C. ultraviolet rays
D. x-rays

Question 32 is an open-response question.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 32 in the space provided in your Student Answer Booklet.

32 A car entering a highway stops on the entrance ramp. The car then accelerates uniformly along a straight line, reaching 28 m/s in 5.6 s.

a. What is the average acceleration of the car during the 5.6 s? Show your calculations and include units in your answer.

b. How far does the car travel in the 5.6 s? Show your calculations and include units in your answer.

c. Traveling in a straight line, the car slows down uniformly from 28 m/s, taking 3.5 s to come to a stop. What is the car's average acceleration during the 3.5 s? Show your calculations and include units in your answer.

d. How far does the car travel during the 3.5 s it takes to stop? Show your calculations and include units in your answer.

Mark your answers to multiple-choice questions 33 through 43 in the spaces provided in your Student Answer Booklet. Do not write your answers in this test booklet, but you may work out solutions to multiple-choice questions in the test booklet.

33 A student lifts a weight to a certain height. Which of the following requires the student to do more work?

A. lifting the same weight to a lower height

B. lifting a lighter weight to the same height

C. using more power to lift the same weight to a lower height

D. using the same power to lift the same weight to a greater height

34 Which of the following statements describes what happens when a sound wave moves from air into water?

A. The speed of the sound wave increases.

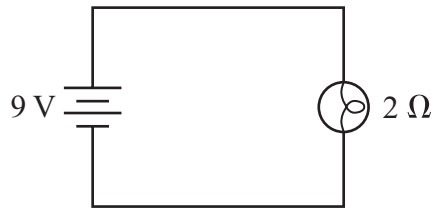
B. The speed of the sound wave decreases.

C. The frequency of the sound wave increases.

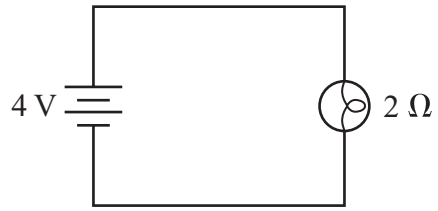
D. The wavelength of the sound wave decreases.

35 Which of the following circuits has the greatest current?

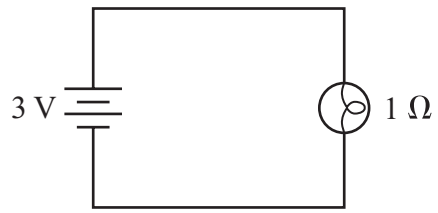
A.



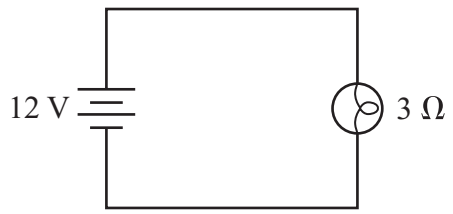
B.



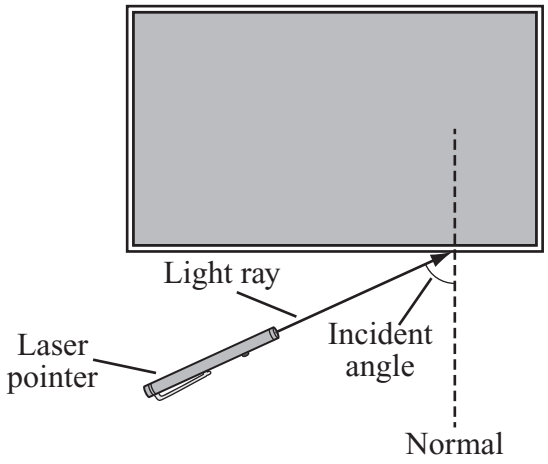
C.



D.



36 The diagram below shows a top view of a glass aquarium filled with water. A laser pointer is aimed at the front of the aquarium at an angle.



When the light from the laser initially hits the front of the aquarium, what is the **most likely** result?

A. All the light is absorbed by the glass.

B. All the light passes through the glass.

C. Some light reflects off the glass at an angle equal to the incident angle, and some light refracts into the water.

D. Some light reflects off the glass at an angle greater than the incident angle, and some light refracts into the water.

37 What is the net force that acts on a 5 kg object accelerating at 2 m/s^2 ?

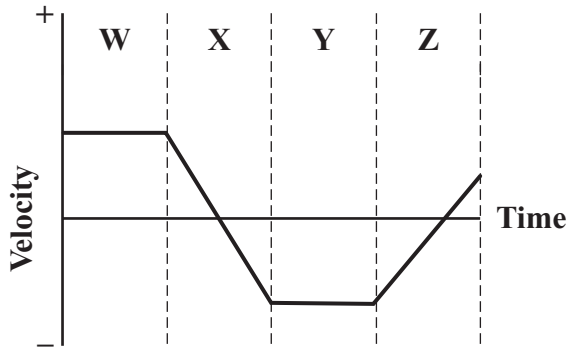
A. 2.5 N

B. 5 N

C. 10 N

D. 50 N

38 The graph below represents an object's velocity over four time intervals: W, X, Y, and Z.



During which time interval does the object have a positive acceleration?

A. interval W

B. interval X

C. interval Y

D. interval Z

39 Which of the following statements illustrates a difference between static friction and kinetic friction?

A. It is difficult to push a cart up a hill, but the cart moves easily on level ground.

B. A chair moves more easily on wheels than when it is slid across the floor.

C. It is difficult to start moving a sled, but the sled slides easily once it begins moving.

D. A coin slides more easily across a table when sawdust is spread over the table's surface.

40 Which of the following diagrams represents the motion of particles in a transverse wave?

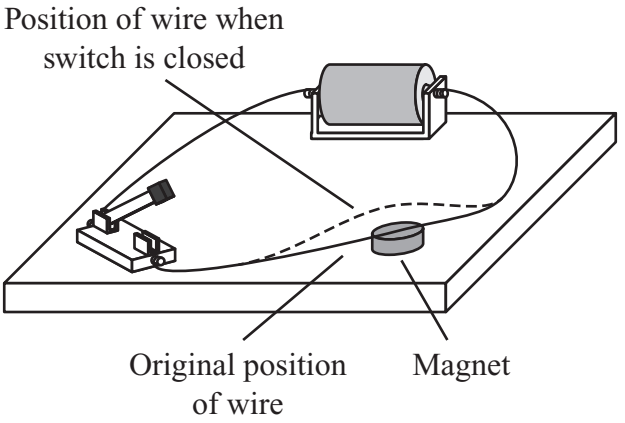
A. 

B. 

C. 

D. 

41 A student builds a simple circuit and places a magnet under one of the circuit's wires. When the switch is closed, charges flow in the circuit and the wire moves, as shown in the diagram below.



Which question is the student most likely trying to answer?

A. Does a positive charge build up in the wire?

B. Does a negative charge build up in the wire?

C. Does the current in the wire create a magnetic field?

D. Does the current in the wire cause the wire to heat up?

42 Which of the following describes a difference between electromagnetic waves and mechanical waves?

A. Only mechanical waves have long wavelengths.

B. Only mechanical waves require a medium to travel.

C. Only electromagnetic waves have a range of frequencies.

D. Only electromagnetic waves transfer energy from one place to another.

43 Which of the following phenomena best explains why light changes direction when it passes through an eyeglass lens?

A. conduction

B. diffraction

C. reflection

D. refraction

Questions 44 and 45 are open-response questions.

- **BE SURE TO ANSWER AND LABEL ALL PARTS OF EACH QUESTION.**
- **Show all your work (diagrams, tables, or computations) in your Student Answer Booklet.**
- **If you do the work in your head, explain in writing how you did the work.**

Write your answer to question 44 in the space provided in your Student Answer Booklet.

44 During cold periods, many orange growers repeatedly spray their trees with water to prevent the oranges from freezing. If the air is cold enough, the sprayed water freezes around the oranges, leaving the oranges themselves unfrozen.

a. Identify a measurement tool that orange growers use to measure the average kinetic energy of the air.

b. Describe what happens to the average molecular kinetic energy of the sprayed water as it cools **before** it freezes.

c. Describe what happens to the average molecular kinetic energy of the sprayed water as it freezes.

d. Explain how the phase change of the sprayed water may protect the oranges from freezing.

Write your answer to question 45 in the space provided in your Student Answer Booklet.

45 An astronaut and his space suit have a combined mass of 157 kg. The astronaut is using a 5.0 kg tool kit to repair a solar panel on the International Space Station. When the tether connecting the astronaut to the space station becomes unattached, the astronaut, still holding the tool kit, starts to float away at 0.2 m/s.

a. Calculate how far from the space station the astronaut will be after 1 minute. Show your calculations and include units in your answer.

b. Calculate the momentum of the astronaut holding the tool kit as the astronaut floats away. Show your calculations and include units in your answer.

The astronaut decides the only way to change his motion and move back toward the space station is to throw the tool kit.

c. Identify the direction the astronaut must throw the tool kit: toward the space station or away from it. Use the law of conservation of momentum to explain how throwing the tool kit may return the astronaut to the space station.

d. Calculate the velocity with which the astronaut must throw the tool kit in order to float back toward the space station at 0.1 m/s. Show your calculations and include units in your answer.

MASSACHUSETTS DEPARTMENT OF ELEMENTARY AND SECONDARY EDUCATION

Massachusetts Comprehensive Assessment System

Introductory Physics Formula Sheet

Formulas

Average Speed $= \frac{d}{\Delta t}$	$F = ma$	$p = mv$
Average Acceleration $= \frac{\Delta v}{\Delta t}$	$F = G\frac{m_1 m_2}{d^2}$	$V = IR$
Average Velocity $= \frac{\Delta x}{\Delta t}$	$F = k\frac{q_1 q_2}{d^2}$	$P = IV$
$v_f = v_i + a\Delta t$	$KE = \frac{1}{2}mv^2$	$Q = mc\Delta T$
$\Delta x = v_i \Delta t + \frac{1}{2}a\,\Delta t^2$	$PE = mg\Delta h$	$v = f\lambda$
$v_f^2 = v_i^2 + 2a\Delta x$	$W = Fd$	$\lambda = \frac{c}{f}$
Average Velocity $= \frac{v_i + v_f}{2}$	$P = \frac{W}{\Delta t}$	$T = \frac{1}{f}$

Variables

a = acceleration	q = charge of particle
c = specific heat	Q = heat
d = distance	R = resistance
f = frequency	Δt = change in time
F = force	ΔT = change in temperature
Δh = change in height	T = period
I = current	v = velocity
KE = kinetic energy	v_i = initial velocity
λ = wavelength	v_f = final velocity
m = mass	Δv = change in velocity
p = momentum	V = voltage
P = power	W = work
PE = gravitational potential energy	Δx = displacement

Definitions

c = speed of electromagnetic waves $= 3.00 \times 10^8$ m/s

G = Universal gravitational constant $= 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

k = Coulomb constant $= 8.99 \times 10^9 \frac{N \cdot m^2}{C^2}$

$g \approx 10\ m/s^2$ $\quad 1\ N = 1\frac{kg \cdot m}{s^2}$ $\quad 1\ J = 1\ N \cdot m$ $\quad 1\ W\ (watt) = 1\frac{J}{s}$

High School Introductory Physics
Spring 2016 Released Items:
Reporting Categories, Standards, and Correct Answers*

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
1	328	*Motion and Forces*	2.3	D
2	328	*Electromagnetism*	5.2	A
3	329	*Waves and Radiation*	6.1	C
4	329	*Heat and Heat Transfer*	3.3	C
5	329	*Motion and Forces*	1.1	D
6	329	*Heat and Heat Transfer*	3.4	A
7	330	*Electromagnetism*	5.4	D
8	330	*Waves and Radiation*	4.6	D
9	330	*Electromagnetism*	5.5	C
10	331	*Motion and Forces*	1.5	B
11	331	*Motion and Forces*	2.5	D
12	332	*Waves and Radiation*	4.5	
13	333	*Motion and Forces*	2.5	B
14	333	*Motion and Forces*	1.3	C
15	333	*Motion and Forces*	1.7	A
16	334	*Heat and Heat Transfer*	3.1	B
17	334	*Electromagnetism*	5.3	C
18	334	*Heat and Heat Transfer*	3.2	D
19	334	*Motion and Forces*	1.8	C
20	335	*Electromagnetism*	5.5	B
21	335	*Waves and Radiation*	6.2	A
22	335	*Motion and Forces*	2.2	C
23	336	*Electromagnetism*	5.4	
24	337	*Motion and Forces*	1.2	B
25	337	*Waves and Radiation*	4.2	A
26	337	*Electromagnetism*	5.1	D
27	338	*Heat and Heat Transfer*	3.2	B
28	338	*Motion and Forces*	2.1	B
29	339	*Waves and Radiation*	4.1	C
30	339	*Motion and Forces*	1.4	D
31	339	*Waves and Radiation*	6.2	B
32	340	*Motion and Forces*	1.2	
33	341	*Motion and Forces*	2.4	D
34	341	*Waves and Radiation*	4.5	A
35	341	*Electromagnetism*	5.2	A
36	342	*Waves and Radiation*	4.4	C
37	342	*Motion and Forces*	1.4	C
38	342	*Motion and Forces*	1.3	D
39	343	*Motion and Forces*	1.6	C

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
40	343	*Waves and Radiation*	4.3	A
41	343	*Electromagnetism*	5.6	C
42	344	*Waves and Radiation*	4.2	B
43	344	*Waves and Radiation*	4.4	D
44	345	*Heat and Heat Transfer*	3.3	
45	346	*Motion and Forces*	2.5	

***** Answers are provided here for multiple-choice items only. Sample responses and scoring guidelines for open-response items, which are indicated by the shaded cells, will be posted to the Department's website later this year.