XX. Introductory Physics, High School

High School Introductory Physics Test

The spring 2017 high school Introductory Physics test was based on learning standards in the Introductory Physics content strand of the October 2006 version of the *Massachusetts Science and Technology/Engineering Curriculum Framework*. These learning standards appear on pages 74–77 of the 2006 framework, which is available on the Department website at www.doe.mass.edu/frameworks/archive.html. Massachusetts adopted a new curriculum framework in science and technology/engineering in 2016. A plan for transitioning the MCAS assessments to the new framework is available at www.doe.mass.edu/mcas/tdd/sci.html?section=resources.

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 Which of the following describes a change in energy that occurs as an acorn falls from a tree toward the ground?

A. Kinetic energy decreases.

B. Gravitational potential energy increases.

C. Kinetic energy is converted into mechanical energy.

D. Gravitational potential energy is converted into kinetic energy.

2 The graph below represents the vertical displacement of an elevator during a 16 s period.

Vertical Displacement vs. Time for an Elevator
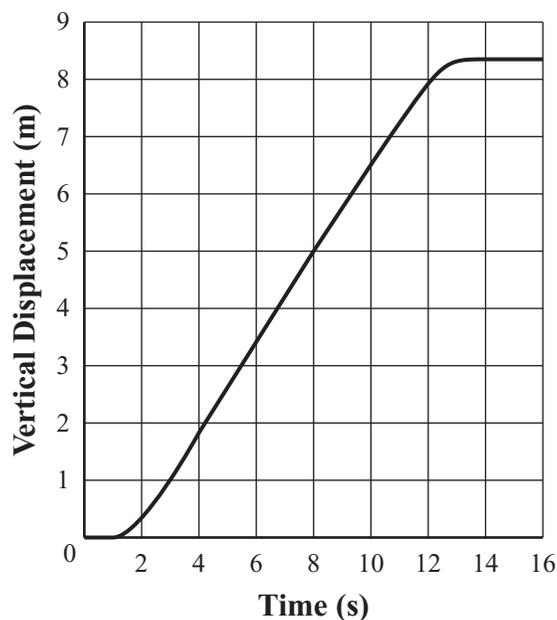
Which of the following can be concluded from the data in the graph?

A. Between 2 s and 6 s, the acceleration of the elevator is greatest.

B. Between 4 s and 12 s, the velocity of the elevator is constant.

C. Between 8 s and 14 s, the acceleration of the elevator is constant.

D. Between 14 s and 16 s, the velocity of the elevator is greatest.

3   A race begins with two signals: a loud beep and a bright light. Even though the signals are sent at the same time, the people watching the race see the light before they hear the beep.

Which of the following best explains the delay between seeing the light and hearing the beep?

A. Mechanical waves travel at a slower speed than electromagnetic waves.

B. Mechanical waves have a shorter frequency than electromagnetic waves.

C. Mechanical waves are greater in reflective strength than electromagnetic waves.

D. Mechanical waves are susceptible to more interference than electromagnetic waves.

4   Which of the following pairs of charges has the greatest attractive force?

A.

$+q$ $+q$

B.

$+q$ $+q$

C.

$+q$ $-q$

D.

$+q$ $-q$
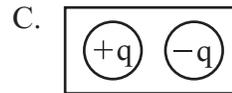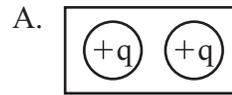
5   Which of the following circuit components represents a power source?

A.

B.

C.

D.
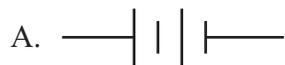
6   The diagram below shows a wave moving along a coiled spring.

What type of wave is shown in the diagram?

A. electromagnetic

B. longitudinal

C. refracted

D. transverse

7 Two students take turns lifting an object. Each student lifts the object from the ground to the same height. The first student lifts the object in one-third the time it takes the second student to lift the object.

Which of the following best compares the power of each student?

A. The first student uses one-third as much power as the second student.

B. The first student uses the same amount of power as the second student.

C. The first student uses three times as much power as the second student.

D. The first student uses nine times as much power as the second student.

8 The temperature of a small metal cube is 75°C. A student places the cube into an insulated container of water at a temperature of 40°C. The student then seals the container.

What is the temperature of the water inside the container 10 minutes later?

A. below 40°C

B. between 40°C and 75°C

C. exactly 75°C

D. between 75°C and 100°C

9 A student is investigating the motion of a block sliding down a ramp onto the floor. The diagram below shows the block at five points during the investigation.
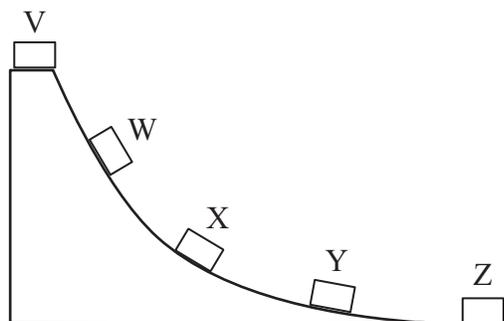
The block is at rest at point V. The student releases the block so that it slides down the ramp and stops at point Z.

Which of the following best explains where kinetic friction is acting on the block?

A. at point W only, because there is kinetic friction only when the block is speeding up

B. at point Y only, because there is kinetic friction only when the block is slowing down

C. at points W, X, and Y only, because there is kinetic friction anytime the block is moving on the ramp

D. at points V, W, X, and Y only, because kinetic friction is the force of gravity between the block and the ramp

10 A horse runs a distance of 240 m in 20 s. Which of the following is a scalar quantity that can be determined from this information?

A. the horse's speed

B. the horse's velocity

C. the horse's acceleration

D. the horse's displacement

11 A 500 Hz sound wave and a 400 Hz sound wave travel through the air. Which of the following characteristics **must** be different for the two waves?

A. amplitude

B. speed

C. velocity

D. wavelength

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 diagram below shows a circuit with four numbered electrical components.
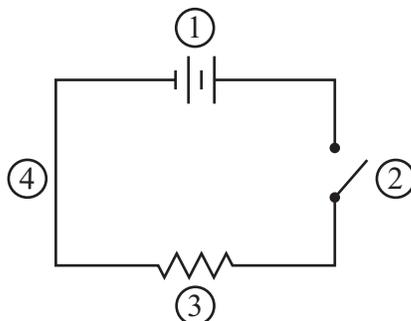
a. Identify each of the numbered components of the electric circuit **and** describe its function.

b. The current in the circuit is 0.5 A. Describe **two** changes to the circuit that would decrease the current in the circuit.

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 The diagram below represents two tug-of-war teams pulling on a rope and the forces for this situation. Group A applies a force of 420 N, and group B applies a force of 380 N.


Group A   **Group B**

420 N   380 N
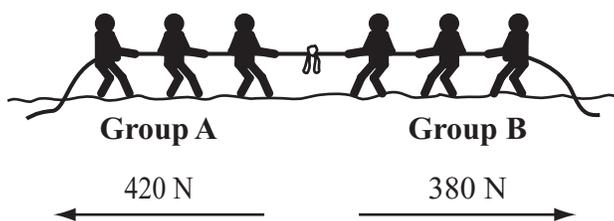
What is the net force on the rope?

A. 40 N to the right

B. 40 N to the left

C. 800 N upward

D. 800 N downward

14 Which of the following actions will increase the inertia of a shopping cart?

A. oiling the cart's wheels

B. adding items to the cart

C. removing the cart's wheels

D. rearranging items in the cart

15 The diagram below shows the path of a light ray as it travels from air into glass.
The dashed lines are normal to the surfaces of the glass.
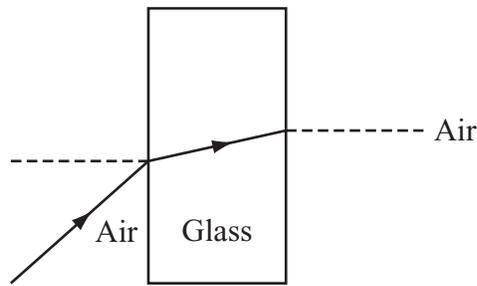
Which diagram shows how the light ray exits the glass?

A.

C.

B.

D.
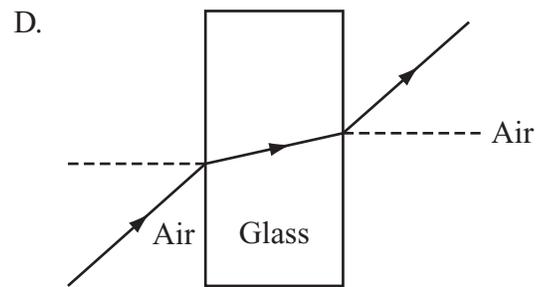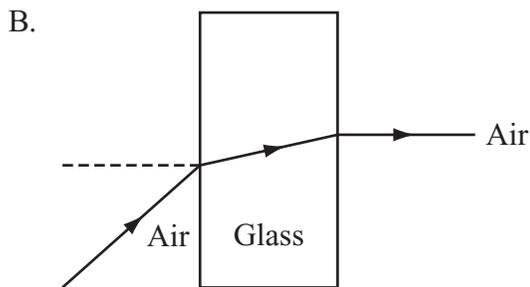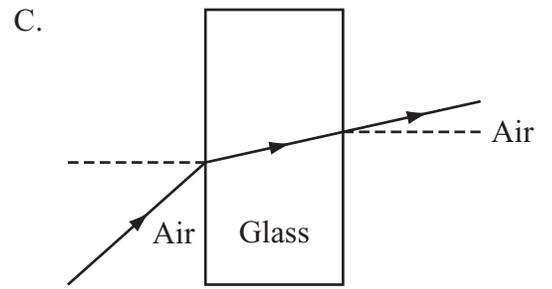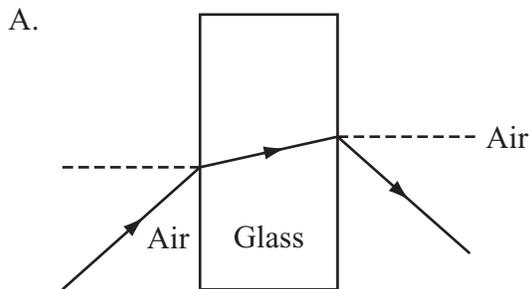
16 Which of the following describes a similarity between infrared radiation and radio waves?

A. They are both transverse waves.

B. They are both longitudinal waves.

C. They both require a vacuum to travel.

D. They both require a medium to travel.

17 A load uses a current of 5.0 A when it is attached to a 20 V source. What is the resistance of the load?

A. 0.25 Ω

B. 1.25 Ω

C. 4.0 Ω

D. 15.0 Ω

18 The masses of four objects, W, X, Y, and Z, are shown in the table below.

Object	Mass (kg)
W	100
X	200
Y	300
Z	400

In which of the following situations is the gravitational force the greatest?

A. when objects W and X are at a distance of 1 m from each other

B. when objects Y and Z are at a distance of 1 m from each other

C. when objects W and Y are at a distance of 2 m from each other

D. when objects X and Z are at a distance of 2 m from each other

19 Ultraviolet (UV) light kills a higher percentage of microorganisms in water than visible light does. Which of the following best compares UV light to visible light?

A. UV light moves more quickly than visible light.

B. UV light has a lower amplitude than visible light.

C. UV light has a higher frequency than visible light.

D. UV light has a longer wavelength than visible light.

20 The diagram below shows a ray of light striking a mirror at a 30° angle.
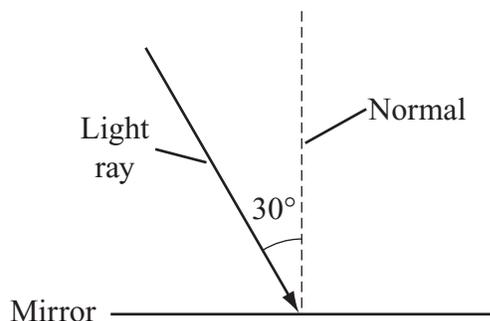
What angle will be formed by the reflected ray of light and the normal line?

A. 0°

B. 30°

C. 60°

D. 90°

21 Which of the following is the **best** example of increasing the potential energy of water?

A. pouring water into the ocean

B. freezing water into blocks of ice

C. directing water down onto a turbine blade

D. pumping water up into a tank high above the ground

22 The specific heat of water is 4.2 J/g • °C. How much heat is required to raise the temperature of 100 g of water by 5°C?

A. 84 J

B. 119 J

C. 500 J

D. 2100 J

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 A sample of ice is heated in a closed container. The sample melts and then evaporates. The container is then placed outside on a very cold day. The sample condenses and then freezes. The average molecular kinetic energy of the sample is measured during these changes.

a. Identify the tool used to measure the average molecular kinetic energy of the sample.

b. During which **two** phase changes does the sample absorb energy?

c. Describe the direction of heat flow between the sample and the air in the container as the sample condenses.

d. Does the sample ever release thermal energy without changing temperature? 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 A force of 20 N acted on a 5 kg object, moving it a distance of 4 m. How much work was done on the object?

- A. 5 J
- B. 20 J
- C. 80 J
- D. 400 J

25 Which of the following describes how a generator operates?

- A. It creates a large resistance to oppose the flow of electricity.
- B. It rotates a coil of wire through a magnetic field to produce a current.
- C. It uses side-by-side coils of wire to transform a voltage to a safe level.
- D. It transmits a signal to a circuit breaker to protect its components.

26 The diagram below shows two objects sliding toward each other on a level sheet of ice. Each object has a mass of 0.2 kg.
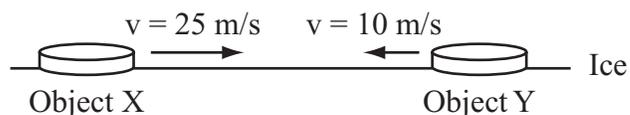
When the objects collide, object X moves to the left at 10 m/s. Neglecting friction, what is the velocity of object Y after the objects collide?

- A. 10 m/s left
- B. 10 m/s right
- C. 25 m/s left
- D. 25 m/s right

27 A radio speaker produces a loud sound that is heard by two people: a person sitting on a bench near the speaker, and a driver in a truck. The driver perceives the sound at a lower pitch than the person sitting on the bench.

Which of the following **best** explains why the driver perceives the pitch of the sound to be lower?

A. The driver is not close to the speaker.

B. The driver is not moving fast enough.

C. The driver is moving away from the speaker.

D. The driver has the windows of the truck closed.

28 Negatively charged plastic rods are brought near a plastic sphere and a metal sphere without touching the spheres. Which of the following diagrams best illustrates the resulting distribution of the negative charges on the two spheres?

A.

Plastic sphere   Metal sphere

B.

Plastic sphere   Metal sphere

C.

Plastic sphere   Metal sphere

D.

Plastic sphere   Metal sphere
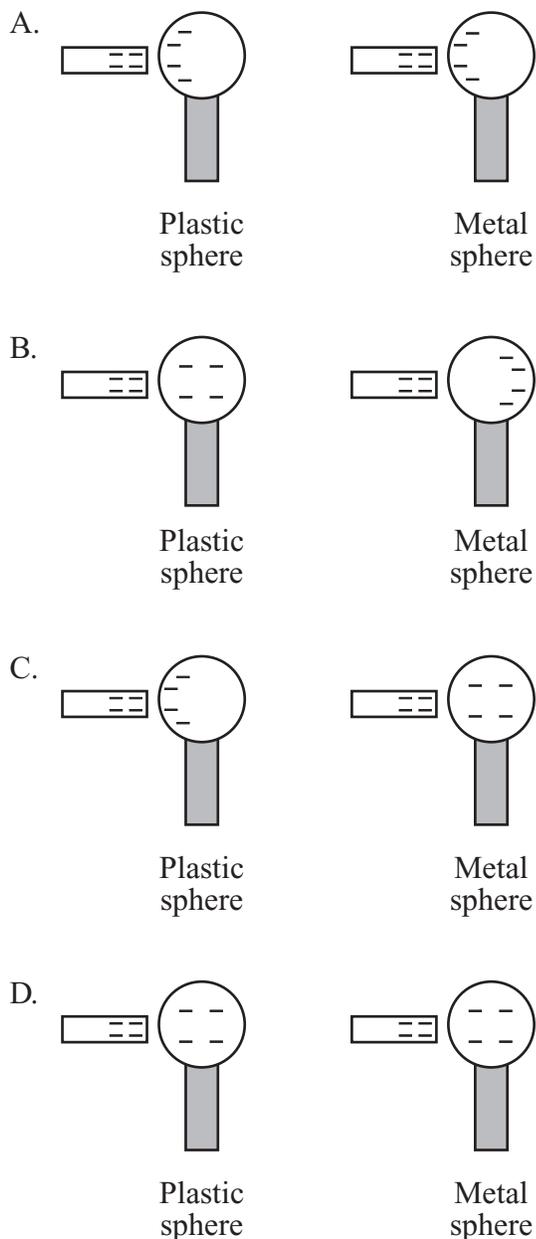
29 Which of the following describes a
vehicle moving at a constant velocity?

A. A go-cart races at 50 km/hr around a
   circular track.

B. A bicycle slows down as it approaches
   an intersection.

C. A truck travels north at 70 km/hr
   on a straight road.

D. A car steadily speeds up after a
   traffic light turns green.

30 The graph below shows the motion of
an object in one direction.

Motion of an Object
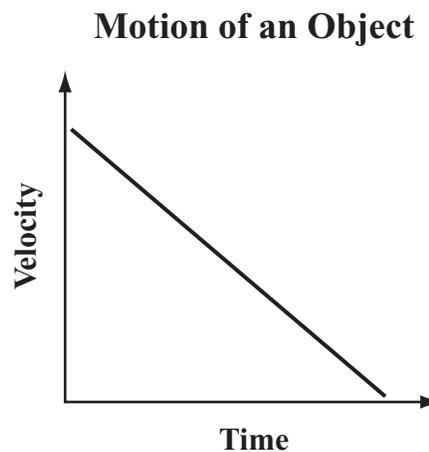
Which of the following describes the
object's motion?

A. The object has a constant
   speed.

B. The object has a positive
   acceleration.

C. The object has a negative
   acceleration.

D. The object has a negative
   displacement.

31 The table below shows characteristics of four sound waves.

Characteristics of Four Sound Waves

Sound Wave	Frequency (Hz)	Wavelength (m)	Intensity (dB)	Speed (m/s)
W	160	2.13	80	341
X	264	1.29	120	341
Y	396	0.86	100	341
Z	898	0.38	60	341

Based on the information in the table, which wave has the longest period?

A. wave W

B. wave X

C. wave Y

D. wave Z

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 An object is moving along a straight path. The graph below shows the object's distance from the starting point during a certain time interval.

Distance versus Time
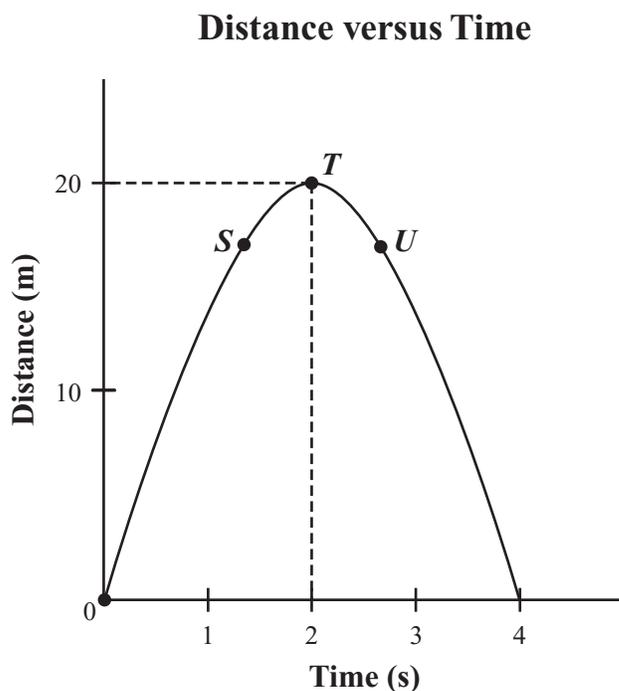
a. Determine the average speed of the object for the time interval 0–2 s. Show your calculations and include units in your answer.

b. Describe how the speed of the object is changing as it passes through point *S*. Explain your answer.

c. Identify the point (*S*, *T*, or *U*) at which the velocity of the object is equal to zero. Explain your answer.

d. Determine the distance moved **and** the displacement of the object for the time interval 0–4 s. Explain 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 The free-body force diagram below represents two forces, F_1 and F_2, acting on a hot air balloon as it rises through the air.

$F_1 = 1100$ N

F_2
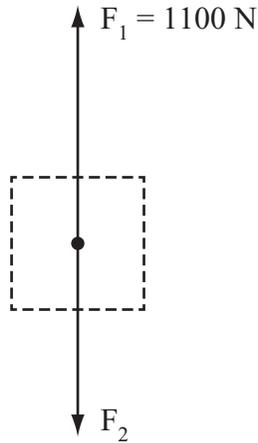
If the net force acting on the balloon is 120 N upward, what is the magnitude of F_2?

A.   980 N

B. 1100 N

C. 1200 N

D. 1220 N

34 A series circuit is constructed with a battery, a light bulb, and a resistor. What happens if the resistor is removed from the circuit?

A. The current increases and the bulb's light becomes dimmer.

B. The current increases and the bulb's light becomes brighter.

C. The current decreases and the bulb's light becomes dimmer.

D. The current decreases and the bulb's light becomes brighter.

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35 Vapor trails are created when water vapor is released from an airplane's engines. This water vapor turns into tiny ice crystals in the atmosphere. The diagram below shows vapor trails formed by an airplane.
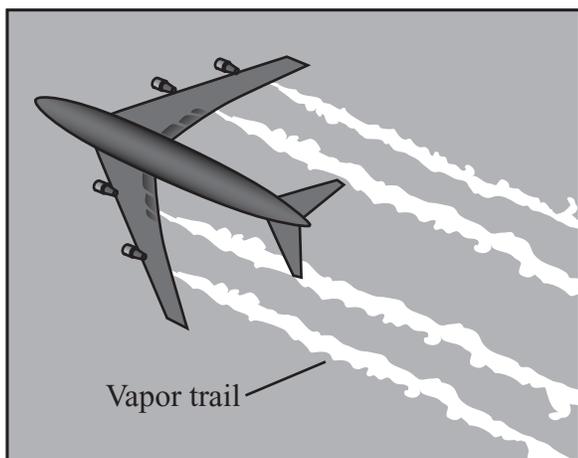
Vapor trail

Based on this information, which of the following **best** explains how vapor trails form from released water vapor?

A. Some of the water molecules have a lower specific heat than other molecules in the air.

B. Some of the mass of the water molecules decreases as the molecules fall toward the ground.

C. Some of the thermal energy of the water molecules is transferred to other molecules in the air.

D. Some of the water molecules gain gravitational potential energy while falling toward the ground.

36 A circuit has three different resistors and a battery. One of the resistors has a resistance of 10 Ω. A student wants to calculate the current flowing through this resistor.

Which of the following would provide the student with enough information to calculate the current in the 10 Ω resistor?

A. the arrangement of the circuit

B. the power rating of the battery

C. the voltage across this resistor

D. the values of the other two resistors

37 Which of the following best describes the kinds of waves that can be observed on Earth when a star explodes?

A. Light waves can be observed, but sound waves cannot be observed because sound waves are absorbed by Earth's atmosphere.

B. Light waves can be observed, but sound waves cannot be observed on Earth because sound waves cannot travel through space.

C. Neither light waves nor sound waves can be observed, because both types of waves are absorbed by matter before reaching Earth.

D. Both light waves and sound waves can be observed, but the sound waves take longer to reach Earth because light travels faster than sound.

38 The diagram below shows a negatively charged particle traveling toward two parallel charged plates.

Negatively charged particle

– – – – – – – – –

●———→

+ + + + + + + + +
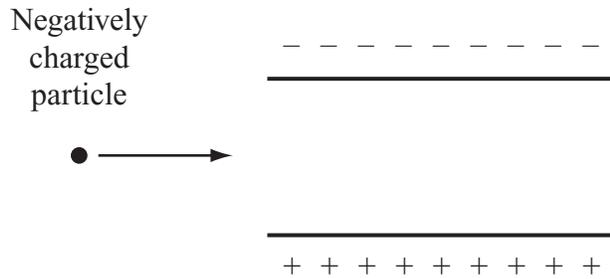
What will most likely happen to the negatively charged particle when it travels between the charged plates?

A. It will accelerate as it travels in a straight line.

B. Its path will bend upward toward the negatively charged plate.

C. It will maintain its original speed as it travels in a straight line.

D. Its path will bend downward toward the positively charged plate.

39 The diagram below shows the path a toy helicopter traveled. The path has four labeled intervals: W, X, Y, and Z.

Ground
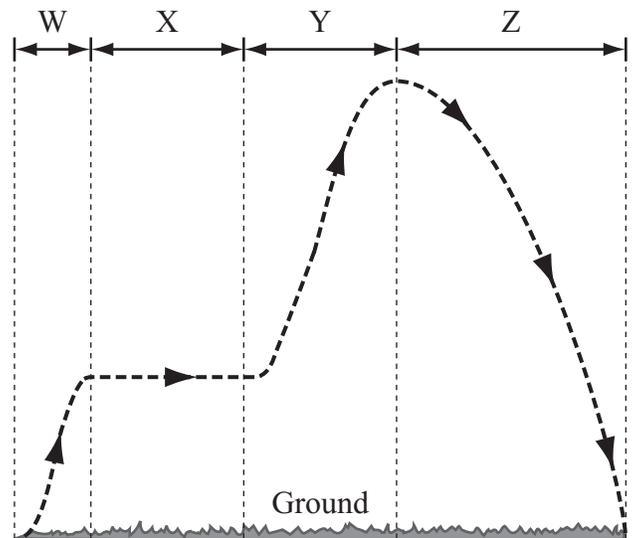
During which interval was gravitational potential energy converted into kinetic energy?

A. interval W

B. interval X

C. interval Y

D. interval Z

40 In radiation, heat is transferred by which of the following?

   A. electromagnetic waves

   B. fluid motion

   C. mechanical waves

   D. particle contact

41 During evaporation, molecules with higher-than-average kinetic energy escape from the surface of a liquid and enter the gas phase. As a result, the average kinetic energy of the remaining liquid molecules decreases.

Which of the following occurs because of the decrease in the liquid's average kinetic energy?

   A. The temperature of the liquid increases.

   B. The temperature of the liquid decreases.

   C. The specific heat of the liquid increases.

   D. The specific heat of the liquid decreases.

42 A car is traveling around a level, circular track. Which of the following forces causes the car to stay in a circular path?

    A. the force of air resistance acting on the car

    B. the force of inertia propelling the car forward

    C. the centripetal force from friction acting on the car's tires

    D. the applied force from the car's engine turning the wheels

43 Students are studying how sound travels in different media. The graph below shows the distance that sound travels over a period of time in four different media, W, X, Y, and Z. The media include all three states of matter.

Distance vs. Time for Sound in Different Media
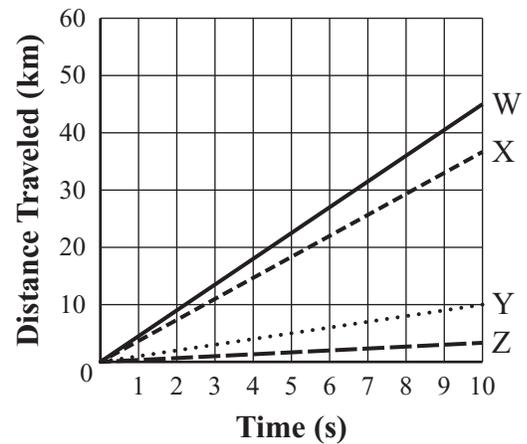
Based on the data in the graph, the students calculated the velocities of the sound in the four media.

Which of the following conclusions can the students make based on their calculations?

    A. Medium Z is most likely a gas.

    B. Medium Y is most likely a solid.

    C. Medium W and medium X are most likely liquids.

    D. Medium W is most likely a gas and medium X is most likely a liquid.

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 When a child presses a button on a toy car, the car produces a long "beep" sound with a frequency of 500 Hz.

   a. Calculate the period, T, of the beep. Show your calculations and include units in your answer.

   The sound of the beep travels through air at 340 m/s.

   b. Calculate the wavelength of the beep. Show your calculations and include units in your answer.

   The child presses the button and pushes the toy car away. The car moves 5 m before it stops. It continues to beep, even after it stops moving.

   c. Describe what happens to the amplitude of the beep observed by the child as the car moves away from the child.

   d. When does the child hear a beep with a frequency lower than 500 Hz? Explain your answer.

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

45 A winch is a device used to lift lobster traps out of the water and onto a lobster boat. The winch applies a force of 300 N to lift a trap a distance of 20 m in 12 s.

a. Calculate the work performed by the winch to lift the trap. Show your calculations and include units in your answer.

b. Calculate the power supplied by the winch to lift the trap. Show your calculations and include units in your answer.

The winch then lifts a second trap.

c. Explain how the winch could perform the same amount of work but supply a greater amount of power when lifting the second trap.

d. Explain how the winch could supply the same amount of power but perform a different amount of work when lifting the second trap.

Formulas

$\text{Average Speed} = \dfrac{d}{\Delta t}$

$F = ma$

$p = mv$

$\text{Average Acceleration} = \dfrac{\Delta v}{\Delta t}$

$F = G\dfrac{m_1 m_2}{d^2}$

$V = IR$

$\text{Average Velocity} = \dfrac{\Delta x}{\Delta t}$

$F = k\dfrac{q_1 q_2}{d^2}$

$P = IV$

$v_f = v_i + a\Delta t$

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

$Q = mc\Delta T$

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

$PE = mg\Delta h$

$v = f\lambda$

$v_f^2 = v_i^2 + 2a\Delta x$

$W = Fd$

$\lambda = \dfrac{c}{f}$

$\text{Average Velocity} = \dfrac{v_i + v_f}{2}$

$P = \dfrac{W}{\Delta t}$

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

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 = 3.00×10^8 m/s

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

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

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

High School Introductory Physics
Spring 2017 Released Items:
Reporting Categories, Standards, and Correct Answers*

Item No.	Page No.	Reporting Category	2006 Standard	Correct Answer (MC)*
1	291	Motion and Forces	2.1	D
2	291	Motion and Forces	1.3	B
3	292	Waves and Radiation	4.2	A
4	292	Electromagnetism	5.4	C
5	293	Electromagnetism	5.3	A
6	293	Waves and Radiation	4.3	B
7	294	Motion and Forces	2.4	C
8	294	Heat And Heat Transfer	3.2	B
9	295	Motion and Forces	1.6	C
10	295	Motion and Forces	1.1	A
11	295	Waves and Radiation	4.1	D
12	296	Electromagnetism	5.3	
13	297	Motion and Forces	1.4	B
14	297	Motion and Forces	1.4	B
15	298	Waves and Radiation	4.4	D
16	299	Waves and Radiation	6.1	A
17	299	Electromagnetism	5.2	C
18	300	Motion and Forces	1.7	B
19	300	Waves and Radiation	6.2	C
20	301	Waves and Radiation	4.4	B
21	301	Motion and Forces	2.2	D
22	301	Heat And Heat Transfer	3.4	D
23	302	Heat And Heat Transfer	3.3	
24	303	Motion and Forces	2.3	C
25	303	Electromagnetism	5.6	B
26	303	Motion and Forces	2.5	D
27	304	Waves and Radiation	4.6	C
28	304	Electromagnetism	5.1	B
29	305	Motion and Forces	1.2	C
30	305	Motion and Forces	1.3	C
31	306	Waves and Radiation	4.1	A
32	307	Motion and Forces	1.3	
33	308	Motion and Forces	1.5	A
34	308	Electromagnetism	5.5	B
35	309	Heat And Heat Transfer	3.3	C
36	309	Electromagnetism	5.2	C
37	309	Waves and Radiation	4.2	B
38	310	Electromagnetism	5.4	D
39	310	Motion and Forces	2.2	D

Item No.	Page No.	Reporting Category	2006 Standard	Correct Answer (MC)*
40	311	*Heat And Heat Transfer*	3.1	A
41	311	*Heat And Heat Transfer*	3.3	B
42	312	*Motion and Forces*	1.8	C
43	312	*Waves and Radiation*	4.5	A
44	313	*Waves and Radiation*	4.1	
45	314	*Motion and Forces*	2.4	

* 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.