XX. Introductory Physics, High School

High School Introductory Physics Test

The spring 2008 high school MCAS Introductory Physics test was based on learning standards in the Physics content strand of the Massachusetts *Science and Technology/Engineering Curriculum Framework* (2006). These learning standards appear on pages 74–77 of the *Framework*.

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

In *Test Item Analysis Reports* and on the Subject Area Subscore pages of the MCAS *School Reports* and *District Reports*, Introductory Physics test results are reported under the following four MCAS reporting categories:

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

Test Sessions

The MCAS 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 a 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.

The use of bilingual word-to-word dictionaries was allowed for current and former limited English proficient students only, during both Introductory Physics test sessions. No other reference tools or materials were allowed.

Cross-Reference Information

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.

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 Radio waves, visible light, and x-rays are examples of electromagnetic waves that **always** differ from each other in

A. amplitude.
B. intensity.
C. temperature.
D. wavelength.

2 Two oppositely charged objects are separated by a small distance. The objects are then moved three times farther apart from each other.

Which of the following statements best describes what happens to the electrical force between the objects?

A. The force of attraction increases.
B. The force of attraction decreases.
C. The force of attraction becomes zero.
D. The force of attraction stays the same.

3 A sound wave can be transmitted through all of the following **except**

A. a gas.
B. a liquid.
C. a solid.
D. a vacuum.

4 Three different boxes are lifted to different heights.

- Box X weighs 115 N and is lifted to 15 m.
- Box Y weighs 210 N and is lifted to 10 m.
- Box Z weighs 305 N and is lifted to 5 m.

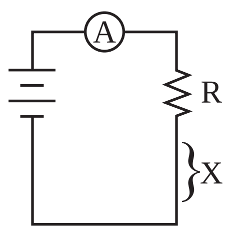
Which of the following statements best describes the boxes' change in mechanical energy?

A. Box X had the greatest change in mechanical energy.
B. Box Z had the smallest change in mechanical energy.
C. Boxes X and Y had the same change in mechanical energy.
D. Boxes Y and Z had the same change in mechanical energy.

5 Which of the following statements applies to a longitudinal wave?

A. The motion of the medium is random.
B. The motion of the medium is in a circular pattern.
C. The motion of the medium is parallel to the motion of the wave.
D. The motion of the medium is perpendicular to the motion of the wave.

6 An ammeter measures the current in the circuit shown below.



When the piece of wire labeled X is replaced by a second identical R, which of the following happens to the current?

A. It increases.
B. It decreases.
C. It goes to zero.
D. It remains unchanged.

7 A magnetic compass is placed near an insulated copper wire. When the wire is connected to a battery, the compass needle changes position.

Which of the following is the **best** explanation for the movement of the needle?

A. The copper wire magnetizes the needle to create a force.
B. The needle magnetizes the copper wire to create a force.
C. The current in the wire produces a magnetic field and exerts a force on the needle.
D. The insulation on the wire becomes energized and exerts a force on the needle.

8 Mike, who has a mass of 75 kg, is running north at 2.6 m/s. He accidentally collides with Tom, who has a mass of 125 kg and is not moving.

Which of the following statements describes how much momentum each person has **before** the collision?

A. Mike has a momentum of 130 kg • m/s north, and Tom has no momentum.
B. Mike has a momentum of 195 kg • m/s north, and Tom has no momentum.
C. Both Mike and Tom have a momentum of 130 kg • m/s north.
D. Both Mike and Tom have a momentum of 195 kg • m/s north.

9 X-ray waves and infrared waves are both electromagnetic waves. Which of the following describes another property x-ray waves and infrared waves share?

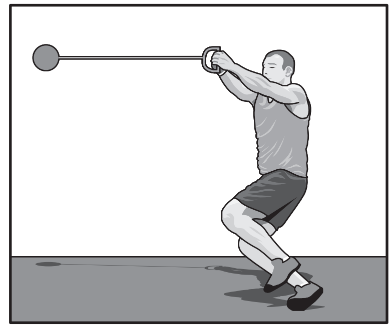
A. Both waves are longitudinal.
B. Both waves have the same frequency.
C. Both waves have the same wavelength.
D. Both waves travel at the same speed in a vacuum.

10 A recycling plant manager needs to melt 1500 kg of scrap copper to sell to a wire manufacturer. The copper is at 15°C and its melting point is 1083°C. The copper has a specific heat of 385 J/kg • K.

How much heat is required to raise the temperature of the copper to its melting point?

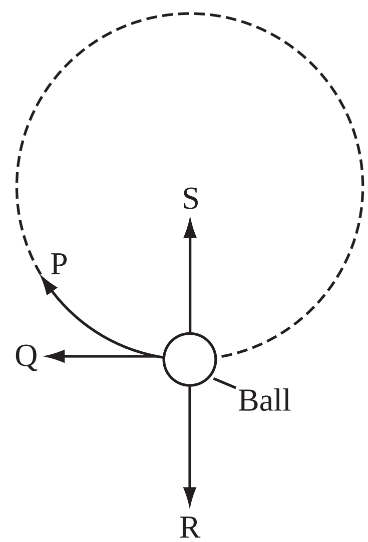
A. 6.2×10^8 J
B. 6.3×10^8 J
C. 7.7×10^8 J
D. 7.9×10^8 J

11 The illustration below shows an athlete participating in an Olympic hammer throw event.



The athlete twirls the hammer (a heavy steel ball attached to a wire) around several times before releasing it.

The diagram below shows the path of the ball as it is spun in a circle before its release.



Which arrow shows the direction of the centripetal force on the ball **before** the ball is released?

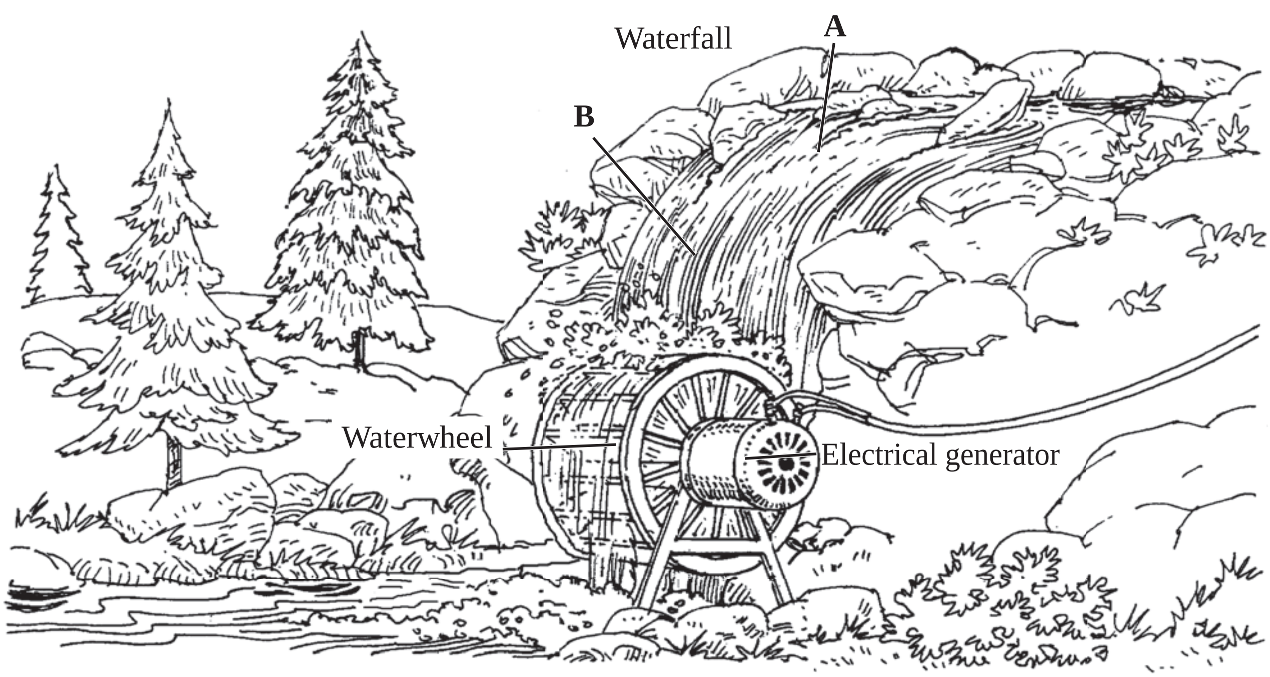
A. P
B. Q
C. R
D. S

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 In the diagram below, the falling water turns the waterwheel. The turning waterwheel generates electricity.



The water moves slowly at point A and then falls rapidly past point B.

a. Describe the changes in kinetic and gravitational potential energy of the water as it travels from point A to point B.

b. Explain why not all of the energy of the moving water available at point A is captured by the waterwheel to generate electricity.

c. Describe **two** ways the system can be changed so that more energy from the falling water is converted into electrical energy.

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 Suppose a scientist detects an electromagnetic wave with a frequency higher than those of gamma rays. The scientist labels this wave a Z-ray.

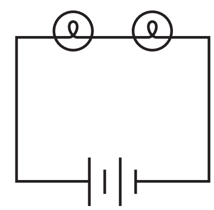
Which of the following would always be true of a Z-ray?

A. A Z-ray would have a lesser amplitude than gamma rays.
B. A Z-ray would have a greater amplitude than gamma rays.
C. A Z-ray would have a shorter wavelength than gamma rays.
D. A Z-ray would have a longer wavelength than gamma rays.

14 The power of a toaster can be determined if which of the following values are known?

A. the dimensions of the toaster
B. the resistance of the toaster's insulation
C. the voltage applied to the toaster and the toaster's temperature
D. the current through the circuit and the voltage applied to the toaster

15 In the diagram below, the circuit has one battery and two identical light bulbs.



If one light bulb is removed, which of the following could replace it so that the remaining light bulb is dimmer?

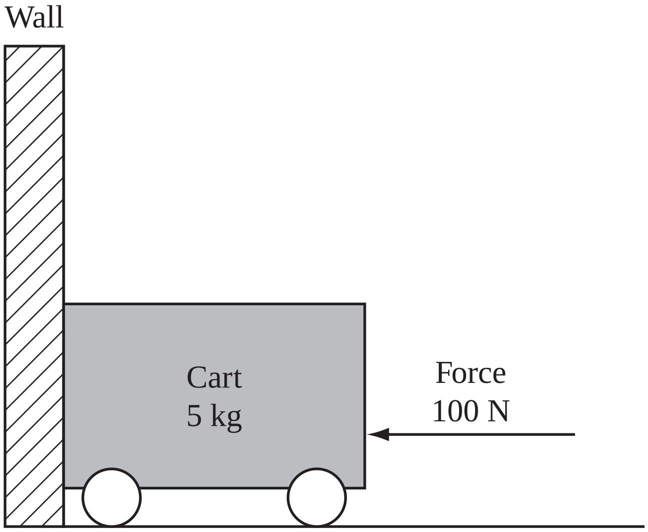
A. 

B. 

C. 

D. 

16 A cart with a mass of 5 kg rests on a floor next to a wall, as shown in the diagram below.



A person pushes on the cart to the left toward the wall with a force of 100 N. Which of the following statements is true in this situation?

A. The wall does not push on the cart.

B. The floor pushes 100 N up on the cart.

C. The cart pushes 100 N down on the floor.

D. The wall pushes 100 N to the right on the cart.

17 How much power is required to carry a 35 N package a vertical distance of 18 m if the work on the package is accomplished in 30 s?

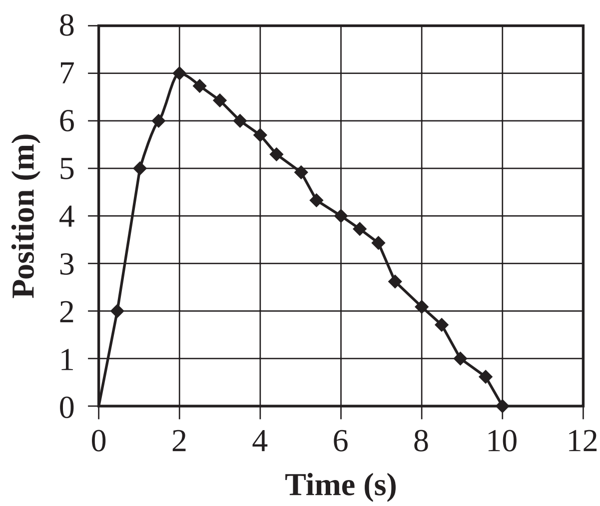
A. 16 W

B. 21 W

C. 58 W

D. 630 W

18 The graph below illustrates the position and time for a dog that runs to catch a stick and then returns with it.



The dog caught the stick after 2 s. What was the dog's average speed as he returned with the stick?

A. His average return speed was 0.7 m/s.

B. His average return speed was 0.9 m/s.

C. His average return speed was 2 m/s.

D. His average return speed was 4 m/s.

19 A heavy box is at rest on an inclined plane. The box begins to slide down the inclined plane when a small force is applied to the box. The force is removed as soon as the box begins to slide. The speed of the box increases as the box slides down the inclined plane.

Which of the following is the **most likely** cause of this increasing speed?

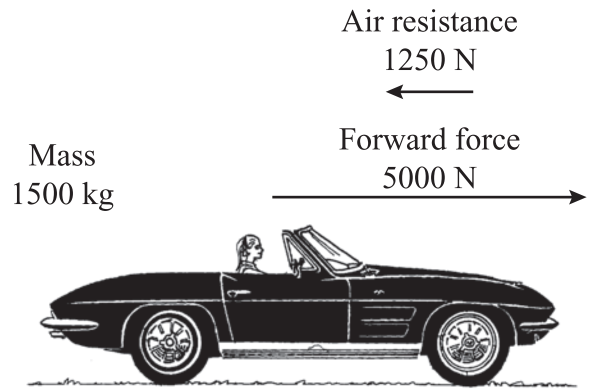
A. The force of gravity on the box is less when the box is not moving than when the box is moving.

B. The force of gravity on the box is greater when the box is not moving than when the box is moving.

C. The force of friction on the box is less when the box is not moving than when the box is moving.

D. The force of friction on the box is greater when the box is not moving than when the box is moving.

20 A 1500 kg car has an applied forward force of 5000 N and experiences an air resistance of 1250 N.



What is the car’s acceleration?

A. 2.5 m/s^2

B. 3.3 m/s^2

C. 4.2 m/s^2

D. 9.8 m/s^2

21 Measurements inside a sealed container show that the pressure exerted by a gas increases as the thermal energy of the gas increases.

Which of the following **best** explains this pressure increase?

A. The gas molecules stick to the walls of the container.

B. The gas molecules radiate energy in the form of nuclear particles.

C. The gas molecules begin to bond together into heavier molecules.

D. The gas molecules move faster and strike the container walls more frequently.

22 On the surface of the Moon, a ball is thrown straight up with an initial velocity. The ball has a constant acceleration due to the Moon's gravity.

On a graph of the ball's velocity versus time, which of the following would represent the ball at its highest point above the Moon's surface?

A. when the velocity is equal to 0 m/s

B. when the velocity is equal to 1.6 m/s

C. when the velocity has its greatest value

D. when the velocity has its most negative value

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 In an experiment, liquid 1 is at room temperature (21°C) and liquid 2 has been heated until it is warmer than room temperature. A student takes equal amounts of liquid 1 and liquid 2 and mixes them together in a beaker.

a. Compare the initial temperatures of liquid 1 and liquid 2 with the temperature of the mixture in the beaker at each of the following times:

- 5 minutes after mixing
- 2 hours after mixing

b. Describe the transfer of heat energy between the two liquids in the beaker.

c. Identify one other possible heat energy transfer in this experiment.

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 teenager removes the plastic wrapping from a CD. The pieces of wrap cling to her hand.

Which of the following forces causes the wrap to cling to her hand?

A. electrostatic

B. gravitational

C. magnetic

D. net

25 A bicycle rider is traveling at 7 m/s. During an 8 s period, the bicycle rider then slows down with a constant acceleration to a speed of 3 m/s.

How far does the bicycle rider travel during the 8 s?

A. 19 m

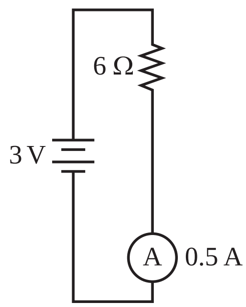
B. 32 m

C. 40 m

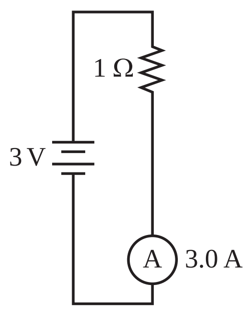
D. 80 m

26 Which of the following ammeters is shown with an **incorrect** reading?

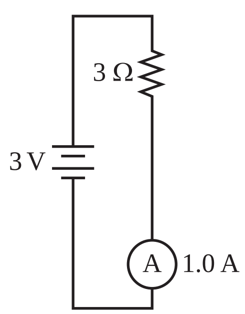
A.



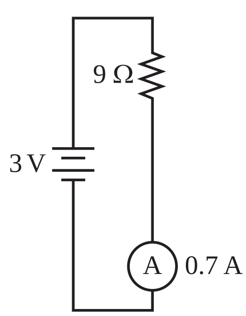
B.



C.



D.



27 Which of the following increases when a metal spring is stretched horizontally?

A. potential energy
B. kinetic energy
C. gravitational energy
D. electrical energy

28 Two students stretch a rope horizontally between them. One student moves one end of the rope up and down repeatedly for a short time.

Which of the following describes the frequency of the waves in the rope?

A. the height that the rope reaches when moved up

B. the amount of time it takes for one wave to travel the length of the rope

C. the number of times the rope is moved up and down in a time interval

D. the distance measured between the crest of one wave and the crest of the next wave in the rope

29 An engineering student is gathering data on the motion of a model car traveling down a ramp. If energy is conserved, the potential energy of the car at the top of the ramp should equal the kinetic energy of the car at the bottom of the ramp. After the first trial, the student calculates that the kinetic energy at the bottom of the ramp is less than the potential energy at the top of the ramp.

Which of the following can **best** explain this difference?

A. The car gained a small amount of mass as it moved down the ramp.

B. The student accidentally accelerated the car at the top of the ramp.

C. The measured height of the ramp was less than the actual height.

D. The student did not include the effect of frictional force in the calculation.

30 The distance of the star Vega from Earth is 1.6 million times greater than the distance of the Sun from Earth. Which of the following **best** describes the gravitational influence of Vega on Earth?

A. It is roughly equal to that of the Sun.

B. Its influence is greater than that of the Sun.

C. Its influence is small because of its distance.

D. It influences the magnitude of Earth’s mass.

31 What is the momentum of a metal disc with a mass of 1.5 kg sliding on a frictionless surface at 0.75 m/s?

A. 0.50 kg • m/s

B. 0.85 kg • m/s

C. 1.1 kg • m/s

D. 2.0 kg • m/s

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 elastic cord made for bungee jumping is being tested. A weight of 800 N is attached to one end of the bungee cord. Then the weight is released from a tall tower and it moves downward. When the elastic cord is fully extended, it exerts an opposing force of 900 N on the weight.

a. Draw and label a force diagram for this situation.

b. Calculate the net force on the weight. Show your calculations and include units in your answer.

c. Explain what would happen if the elastic cord exerted a maximum force of only 700 N on the weight.

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 heated rock is placed in a container of water that is cooler than room temperature. Which of the following statements best describes what happens?

A. Cold is removed from the container of water until the rock, the container, and the water all reach the same final temperature.
B. The heated rock loses heat to the container of water until the rock, the container, and the water all reach the same final temperature.
C. The heated rock loses heat to the container of water until the rock, the container, and the water each reach a different final temperature.
D. Cold is removed from the container of water until the rock, the container, and the water each reach a final temperature lower than their original temperatures.

34 Which of the following is possible due to longitudinal waves?

A. seeing the color red
B. getting a tan at the beach
C. hearing the sound of the ocean
D. riding a wave on a surfboard

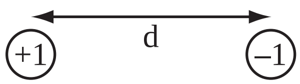
35 A student hypothesizes that the mass of a substance affects how the temperature of the substance changes when it is heated. The student uses the following procedure to test the hypothesis.

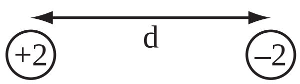
- Each sample is initially at room temperature before heating.
- Each sample is heated for the same amount of time with the same heat source.
- The final temperature is measured for each sample.

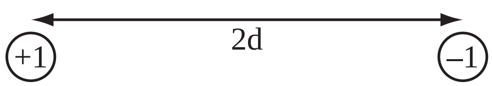
Which of the following would be the **best** way to select the samples for testing the student's hypothesis?

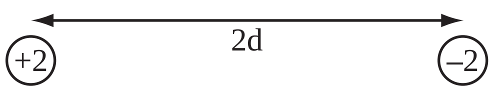
A. Obtain samples of one substance, each with the same mass.
B. Obtain samples of one substance, each with a different mass.
C. Obtain samples of different substances, each with the same mass.
D. Obtain samples of different substances, each with a different mass.

36 The distance between two charges is represented by d. In which of the following diagrams is the attractive force between the two charges the **greatest**?

A. 

B. 

C. 

D. 

37 A boat tied to a dock is stationary. Water waves constantly pass by the boat. The crests of the waves are 3 m apart and a crest passes the front of the boat every 4 s.

What is the velocity of the waves?

A. 0.75 m/s

B. 1.33 m/s

C. 3 m/s

D. 12 m/s

38 A window washer noticed that, from the same distance and with no breeze, the smell of ammonia glass cleaner reached him faster on a hot day (30°C) than on a cold day (5°C). Which of the following explains this observation?

A. Molecules expand at higher temperatures.

B. Molecules move more rapidly at higher temperatures.

C. The convection currents carry molecules at higher temperatures.

D. The chemical reaction of molecules increases at higher temperatures.

39 A student standing on the edge of a swimming pool sees a painted mark on the bottom of the pool. The mark appears to be at a shallower depth than the actual depth of the pool.

Which of the following descriptions of light waves **best** explains this observation?

A. Light from the mark travels through the water in a curved path.

B. Light from the mark is refracted as it travels from the water to the air.

C. Light from the mark is reflected as it travels from the water to the air.

D. Light from the mark bounces off the boundary between the water and the air.

40 Which of the following is a scalar quantity?

A. the mass of a brick

B. the velocity of a falling tennis ball

C. the force required to lift a 10 kg mass

D. the acceleration of a toy car over a 60 s period

41 A student is sitting in a large stadium far away from the starting line of a footrace, while listening to the footrace on the radio. As the race starts, the student hears the sound of the starting pistol on the radio. Shortly after that, the student hears the sound of the starting pistol from inside the stadium.

Which of the following best explains these observations?

A. Mechanical waves travel faster than electromagnetic waves.

B. Electromagnetic waves travel faster than mechanical waves.

C. The radio's signal traveled a shorter distance than the sound wave traveled.

D. The radio's microphone was farther away from the starting line than the student was.

42 People perceive sound differently in air than they do under water. Which of the following correctly compares the motion of sound waves in air and in water?

A. Sound waves travel faster in air than in water.

B. Sound waves travel slower in air than in water.

C. Sound waves travel in air but do not travel in water.

D. Sound waves travel at the same speed in air and in water.

43 A performer pulls a tablecloth out from under a complete set of dinnerware as shown in the illustration below.

Which of the following **best** explains the performer's success at leaving all the dinnerware on the table?

A. the inertia of the dinnerware

B. the large mass of the tablecloth

C. the placement of the dinnerware

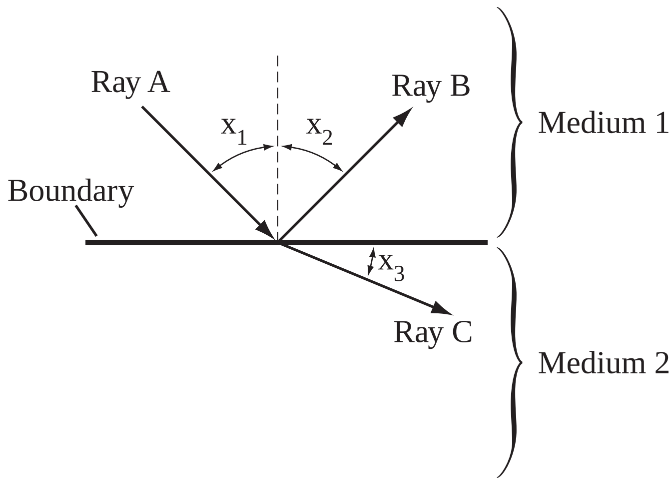
D. the rough material of the tablecloth

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 The diagram below shows what happens when a particular light wave strikes a boundary.



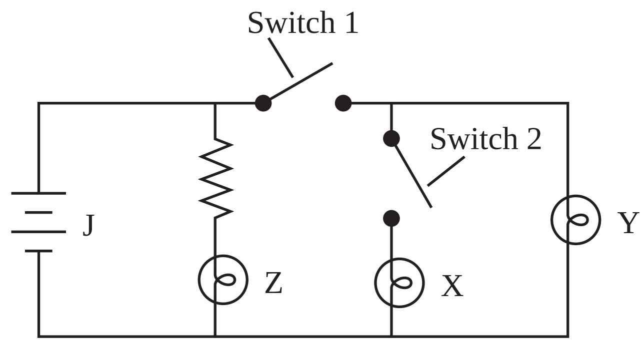
a. Identify each light ray, A, B, and C, as an incident, a refracted, or a reflected ray.

b. Describe the relationship between angles x_1 and x_2.

c. Describe how this setup could be changed so that the size of angle x_3 is different.

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

45 A circuit with three identical light bulbs is shown in the diagram below.



a. Identify the symbol labeled J in the circuit.

b. Describe what each light bulb does in each of the following situations:

- when switches 1 and 2 are open
- when switches 1 and 2 are closed
- when switch 1 is open and switch 2 is closed
- when switch 1 is closed and switch 2 is open

Massachusetts Comprehensive Assessment System
Introductory Physics Formula Sheet

Formulas

Average Speed $= \dfrac{d}{\Delta t}$	$F = ma$	$p = mv$
Average Acceleration $= \dfrac{\Delta v}{\Delta t}$	$F = G\dfrac{m_1 m_2}{d^2}$	$V = IR$
Average Velocity $= \dfrac{\Delta x}{\Delta t}$	$F = k\dfrac{q_1 q_2}{d^2}$	$P = IV$
$v_f = v_i + a\Delta t$	$KE = \frac{1}{2}mv^2$	$Q = mc\Delta T$
$\Delta x = v_i \Delta t + \frac{1}{2}a\,\Delta t^2$	$PE = mg\Delta h$	$v = f\lambda$
$v_f^2 = v_i^2 + 2a\Delta x$	$W = Fd$	$\lambda = \dfrac{c}{f}$
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 = $6.67 \times 10^{-11} \dfrac{N \bullet m^2}{kg^2}$

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

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

High School Introductory Physics
Spring 2008 Released Items:
Reporting Categories, Standards, and Correct Answers*

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
1	509	*Waves and Radiation*	6.2	D
2	509	*Electromagnetism*	5.4	B
3	509	*Waves and Radiation*	4.2	D
4	509	*Motion and Forces*	2.3	B
5	510	*Waves and Radiation*	4.3	C
6	510	*Electromagnetism*	5.2	B
7	510	*Electromagnetism*	5.6	C
8	510	*Motion and Forces*	2.5	B
9	511	*Waves and Radiation*	6.1	D
10	511	*Heat and Heat Transfer*	3.4	A
11	511	*Motion and Forces*	1.8	D
12	512	*Motion and Forces*	2.1	
13	513	*Waves and Radiation*	6.2	C
14	513	*Electromagnetism*	5.5	D
15	513	*Electromagnetism*	5.3	C
16	514	*Motion and Forces*	1.4	D
17	514	*Motion and Forces*	2.4	B
18	514	*Motion and Forces*	1.3	B
19	515	*Motion and Forces*	1.6	D
20	515	*Motion and Forces*	1.4	A
21	516	*Heat and Heat Transfer*	3.3	D
22	516	*Motion and Forces*	1.3	A
23	517	*Heat and Heat Transfer*	3.2	
24	518	*Electromagnetism*	5.1	A
25	518	*Motion and Forces*	1.2	C
26	519	*Electromagnetism*	5.2	D
27	519	*Motion and Forces*	2.2	A
28	520	*Waves and Radiation*	4.1	C
29	520	*Motion and Forces*	2.1	D
30	521	*Motion and Forces*	1.7	C
31	521	*Motion and Forces*	2.5	C
32	522	*Motion and Forces*	1.5	
33	523	*Heat and Heat Transfer*	3.2	B
34	523	*Waves and Radiation*	4.3	C
35	523	*Heat and Heat Transfer*	3.4	B
36	524	*Electromagnetism*	5.4	B
37	524	*Waves and Radiation*	4.1	A
38	524	*Heat and Heat Transfer*	3.3	B
39	525	*Waves and Radiation*	4.4	B
40	525	*Motion and Forces*	1.1	A
41	526	*Waves and Radiation*	4.2	B
42	526	*Waves and Radiation*	4.5	B

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
43	526	*Motion and Forces*	1.4	A
44	527	*Waves and Radiation*	4.4	
45	528	*Electromagnetism*	5.3	

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