

---

## XX. Introductory Physics, High School

## *High School Introductory Physics Test*

The spring 2015 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](http://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

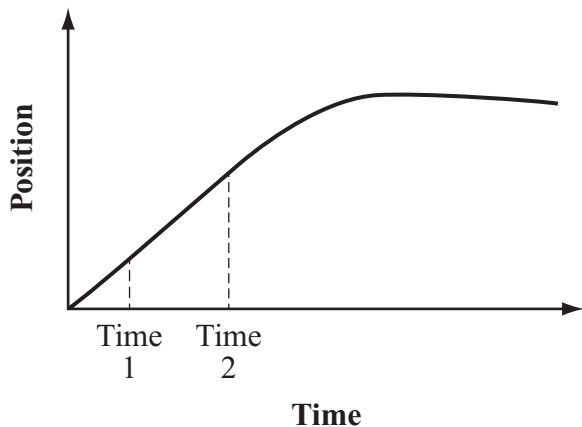
## SESSION 1

### 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 The graph below represents how a car's position changes over time.

Motion of Car



Which of the following statements best describes the motion of the car between time 1 and time 2?

- A. The car is stopped.
- B. The car's velocity is decreasing.
- C. The car's displacement stays the same.
- D. The car is traveling at a constant speed.

- 2 Object X is at rest on a horizontal sheet of ice. Object Y slides across the ice with an initial velocity of 10 m/s and collides with object X. Object Y stops and object X begins to move. Both objects have the same mass. Assume friction is negligible.

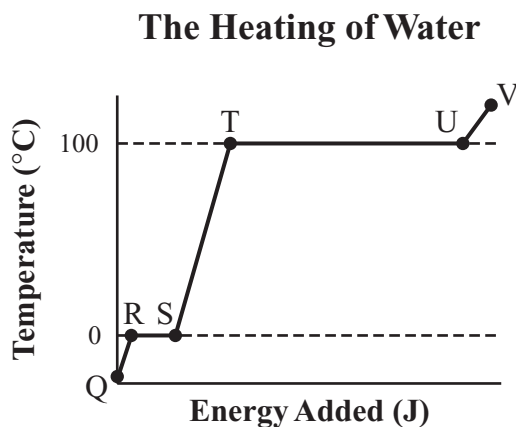
Which of the following conclusions can be drawn from this information?

- A. Object X moves away at 10 m/s, and momentum is conserved.
- B. Object X moves away at 10 m/s, and momentum is not conserved.
- C. Object X moves away at a velocity that is less than 10 m/s, and momentum is conserved.
- D. Object X moves away at a velocity that is less than 10 m/s, and momentum is not conserved.

3 Which of the following sets of charges has the greatest attractive force when the charges are equal in magnitude?

- A. two like charges placed 1 m apart
- B. two like charges placed 2 m apart
- C. two opposite charges placed 1 m apart
- D. two opposite charges placed 2 m apart

4 The graph below shows how the temperature of a sample of water changes as energy is added to the sample.



During which interval does a gas form?

- A. Q to R
- B. R to S
- C. S to T
- D. T to U

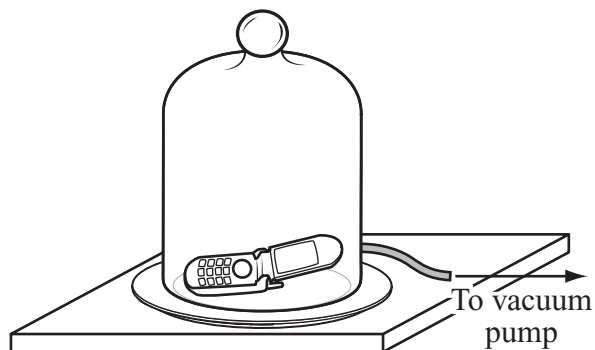
5 A clothes iron is designed to be used with a 220 V outlet. Which of the following will happen if the iron is plugged into a 110 V outlet instead of a 220 V outlet?

- A. The iron will exceed its maximum power rating.
- B. The internal resistance of the iron will increase.
- C. The iron will use the same energy for a given amount of time.
- D. The current delivered to the iron will be lower than the maximum amount.

6 Which statement describes what most likely occurs when a magnetic compass is placed next to a simple circuit made from a battery, a light bulb, and a wire?

- A. A magnetic field created by the compass causes the light bulb to stop working.
- B. A magnetic field created by the electric current causes the compass needle to move.
- C. A magnetic field created by the compass increases the current in the electrical circuit.
- D. A magnetic field created by the electric current places negative charges on the compass.

- 7 The diagram below shows a cell phone inside a glass jar that is sealed and connected to a vacuum pump.



The vacuum pump is turned on and removes the air from inside the jar.

Which of the following statements explains what happens when someone calls the cell phone?

- A. The signal does not reach the phone because sound needs a medium through which to travel.
  - B. The signal does not reach the phone because the signal needs a medium through which to travel.
  - C. The phone receives the signal and can be heard ringing because both the signal and sound can travel in a vacuum.
  - D. The phone receives the signal but cannot be heard ringing because the signal can travel in a vacuum but sound cannot.
- 8 Which of the following quantities is described by **both** a magnitude and a direction?
- A. acceleration
  - B. distance
  - C. mass
  - D. speed
- 9 An astronaut is making repairs on a satellite in space. The astronaut bumps against the satellite, causing a part to break off.
- Which statement describes the motion of the part after it breaks off the satellite?
- A. The part will immediately stop moving when a force is no longer acting on it.
  - B. The part will accelerate along a straight path until it is acted upon by another force.
  - C. The part will move at a constant speed along a straight path until it is acted upon by another force.
  - D. The part will move a short distance until it gradually comes to a stop as its inertia decreases.

10 When an uncharged balloon is rubbed against dry uncharged hair, electrons move from the hair onto the balloon's surface. Which table lists the charges of the balloon and the hair after they are moved apart?

A.

Balloon	Hair
positive	negative

B.

Balloon	Hair
negative	positive

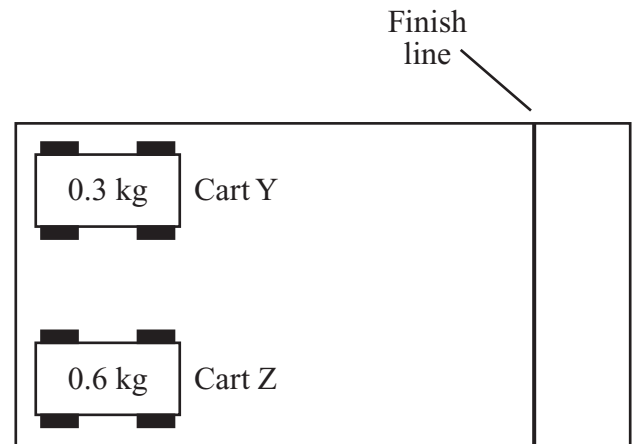
C.

Balloon	Hair
positive	no charge

D.

Balloon	Hair
negative	no charge

11 The diagram below shows the top view of two carts with different masses on a frictionless surface.



The carts are pushed from rest, and they reach the finish line at the same time. Which of the following statements describes and explains the forces applied to the carts?

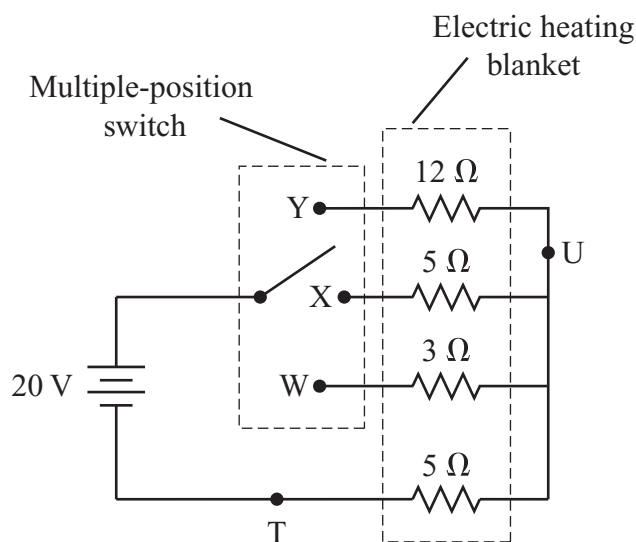
- A. Equal force is required to push the carts because they move on a frictionless surface.
- B. Equal force is required to push the carts because they reach the finish line at the same time.
- C. A greater force is applied to cart Y because it accelerates at the same rate as cart Z but has less mass.
- D. A greater force is applied to cart Z because it accelerates at the same rate as cart Y but has more mass.

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 simplified schematic for an adjustable electric heating blanket. The switch may be connected to point W, X, or Y depending on the desired level of warmth.



- Calculate the current generated in the blanket when the switch is connected to point X. Show your calculations and include units in your answer.
- Calculate the power generated in the blanket when the switch is connected to point X. Show your calculations and include units in your answer.
- Explain why a fuse at point T would be more effective in this circuit than a fuse at point U.
- Identify which point the switch should be connected to in order to generate the most warmth. Explain your answer.

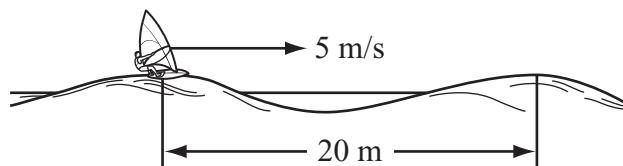
Mark your answers to multiple-choice questions 13 through 22 in the spaces provided in your Student Answer Booklet. Do not write your answers in this test booklet, but you may work out solutions to multiple-choice questions in the test booklet.

- 13 What is the momentum of a 4 kg bowling ball moving with a speed of 4 m/s?
- A.  $0 \text{ kg} \cdot \text{m/s}$
  - B.  $1 \text{ kg} \cdot \text{m/s}$
  - C.  $8 \text{ kg} \cdot \text{m/s}$
  - D.  $16 \text{ kg} \cdot \text{m/s}$
- 14 A train driver blows the train's horn as it moves away from a station. Which of the following statements describes how the sound of the horn heard by an observer standing at the station platform differs from the sound heard by the train driver?
- A. The observer hears the sound as having a greater velocity.
  - B. The observer hears the sound as having a lower frequency.
  - C. The observer hears the sound as having a greater amplitude.
  - D. The observer hears the sound as having a shorter wavelength.



- 15 Which of the following is an example of gravitational potential energy being converted to kinetic energy?
- A. A bike accelerates along a flat roadway.
  - B. A bike slows down while going up a hill.
  - C. A bike comes to a stop along a flat roadway.
  - D. A bike starts from rest and rolls down a hill.
- 16 What is the current flowing through a 60 W light bulb when it is connected to a 120 V source?
- A. 0.5 A
  - B. 2.0 A
  - C. 180 A
  - D. 7800 A

- 17 A windsurfer moves at 5 m/s while staying on the crest of a wave, as shown below.



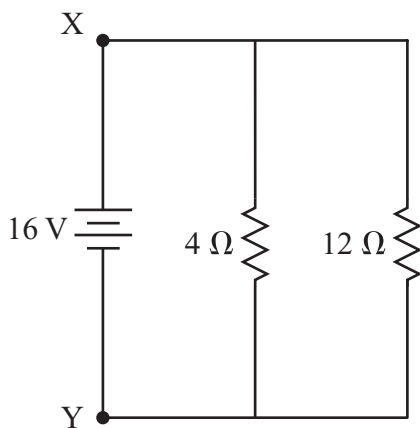
What is the frequency of the waves if the distance between the two wave crests is 20 m?

- A. 0.25 Hz
- B. 0.5 Hz
- C. 2.5 Hz
- D. 4 Hz

- 18 A motor exerts a force of 2,500 N to lift an elevator 12 m in 11 s. What is the average power generated by the motor?

A. 2,300 W  
B. 2,700 W  
C. 28,000 W  
D. 30,000 W

- 19 The diagram below shows a parallel circuit with a  $4\ \Omega$  resistor and a  $12\ \Omega$  resistor. The voltage between points X and Y is 16 V.



What is the voltage across the  $12\ \Omega$  resistor?

A. 12 V  
B. 16 V  
C. 36 V  
D. 64 V

- 20 A racecar completes 200 laps in 190 min on a circular path. The distance of each lap is 4.0 km. What is the racecar's average speed?

A. 0.0 km/min  
B. 1.1 km/min  
C. 1.3 km/min  
D. 4.2 km/min

- 21 Sunlight warms an area of Earth's surface. Winds then carry thermal energy from this area to another location.

Which two heat transfer processes are primarily involved in this situation?

A. radiation and convection  
B. radiation and evaporation  
C. conduction and convection  
D. conduction and evaporation

- 22 If the temperature of a gas in a closed container increases, which of the following also happens?

A. The mass of the molecules increases.  
B. The mass of the molecules decreases.  
C. The average molecular kinetic energy increases.  
D. The average molecular kinetic energy decreases.

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 student conducts an investigation to determine a ball's mass, displacement, velocity, and kinetic energy.

a. Identify **each** of the following as either a vector quantity or a scalar quantity:

- mass
- displacement
- velocity
- kinetic energy

b. Describe how vector quantities are different from scalar quantities.

The student measures the mass of the ball to be 0.25 kg. The ball is set in motion, and the student determines the magnitude of the ball's maximum velocity to be 11 m/s.

c. Calculate the maximum kinetic energy of the ball. Show your calculations and include units in your answer.

# Introductory Physics

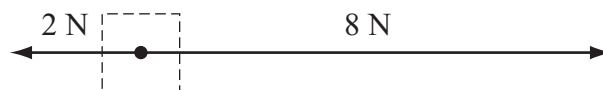
## SESSION 2

### 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 Frozen food is submerged in a small insulated container of  $95^{\circ}\text{C}$  water. Which statement best describes the temperature of the food after two hours, assuming no heat is lost outside of the insulated container?
- A. The temperature of the food will be  $95^{\circ}\text{C}$ .
  - B. The temperature of the food will be  $100^{\circ}\text{C}$ .
  - C. The temperature of the food will be the same as the temperature of the water.
  - D. The temperature of the food will be greater than the temperature of the water.

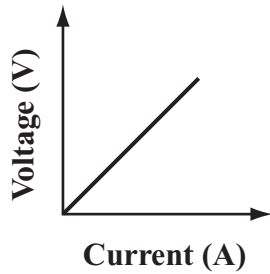
- 25 A free-body diagram is shown below.



What is the magnitude of the net force acting on this object?

- A. 4 N
- B. 6 N
- C. 10 N
- D. 16 N

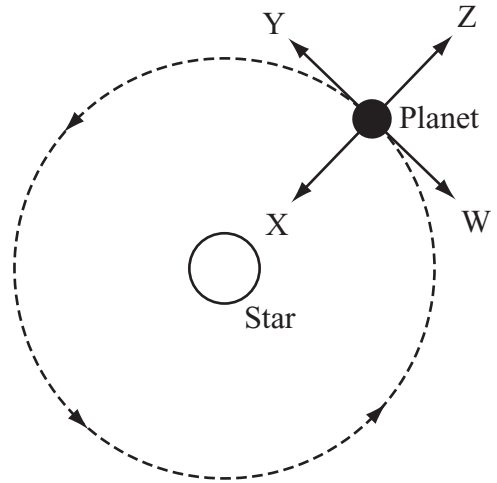
- 26 The graph below shows the relationship of voltage versus current for a circuit.



This graph represents the relationship described by which of the following laws?

- A. Coulomb's law
- B. Doppler's law
- C. Newton's law
- D. Ohm's law

- 27 The diagram below shows a planet moving in a circular orbit around a star. Four arrows are labeled W, X, Y, and Z.



Which arrow represents the direction of the force that keeps the planet in its orbit?

- A. arrow W
- B. arrow X
- C. arrow Y
- D. arrow Z

- 28 When astronauts landed on the Moon, radio signals helped them communicate with people on Earth. It took 1.3 s for a signal to travel from the Moon to Earth.

Which of the following is the **best** estimate of the distance between Earth and the Moon?

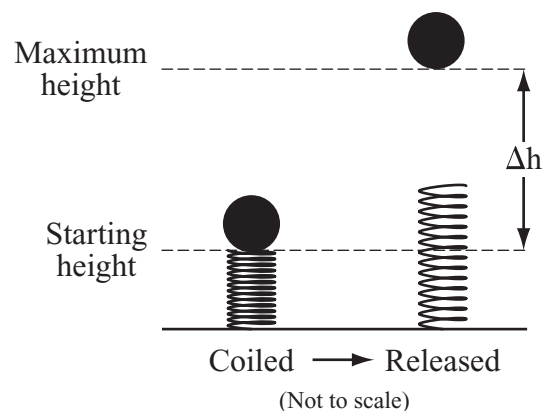
- A. 115,000,000 m
- B. 231,000,000 m
- C. 390,000,000 m
- D. 780,000,000 m

- 29 A seismic wave called a P-wave travels through the solid part of Earth. In a P-wave, the solid particles of Earth move parallel to the direction the P-wave travels.

P-waves are which of the following types of waves?

- A. electromagnetic
- B. longitudinal
- C. torsional
- D. transverse

- 30 A 0.5 kg sphere is placed on top of a coiled spring. The coiled spring has 30 J of elastic potential energy. When the spring is released, the sphere moves upward, as shown in the diagram below.



Neglecting friction and the mass of the spring, what is the change in height ( $\Delta h$ ) of the sphere?

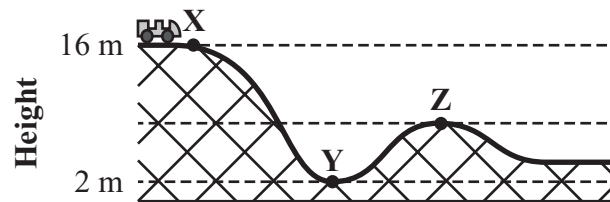
- A. 1.5 m
  - B. 5.0 m
  - C. 6.0 m
  - D. 15.0 m
- 31 A student heats 200 g of water from 20°C to 70°C. How much heat did the student add to the water if the specific heat for water is 4.2 J/g · °C?
- A. 10,000 J
  - B. 14,000 J
  - C. 42,000 J
  - D. 76,000 J

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** The diagram below shows three points on a roller coaster track. A car starts from rest at point **X** and travels along the track. Assume friction is negligible.



- Identify whether the car's gravitational potential energy increases, decreases, or stays the same as the car moves from point **X** to point **Y**.
- Identify whether the car's kinetic energy increases, decreases, or stays the same as the car moves from point **Y** to point **Z**.

The car has a mass of 600 kg.

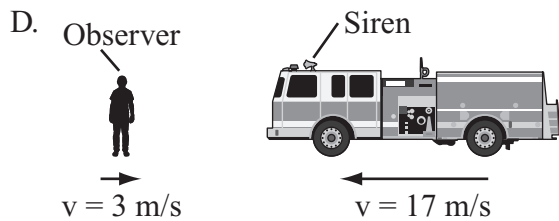
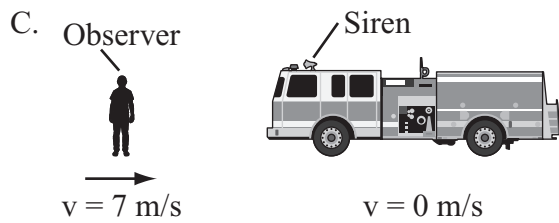
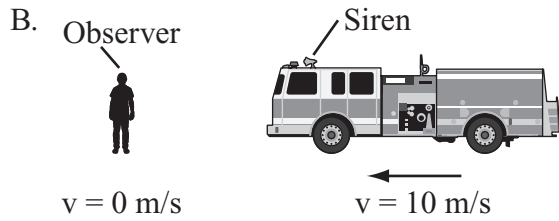
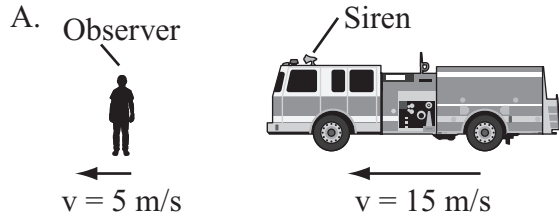
- Calculate the gravitational potential energy of the car at its maximum height. Show your calculations and include units in your answer.
- Calculate the maximum kinetic energy of the car. Show your calculations and include units in your answer.

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 Which of the following is an example of simple harmonic motion?
- A. a ball rolling down a hill
  - B. a book resting on a table
  - C. a bicyclist moving up a hill
  - D. a pendulum swinging back and forth
- 34 A planet with a radius equal to that of Earth has twice the mass of Earth. If an object weighs 800 N on Earth's surface, how much will it weigh on the other planet?
- A. 400 N
  - B. 800 N
  - C. 1600 N
  - D. 3200 N



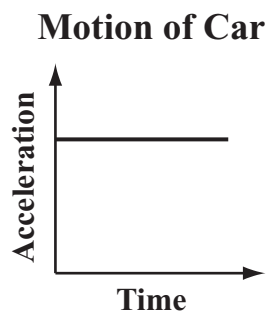
35 In which of the following situations will the observer perceive the highest frequency from the fire truck siren?



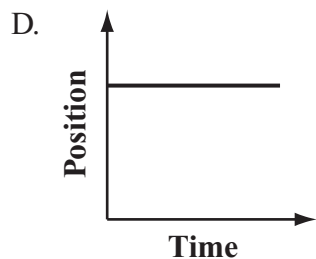
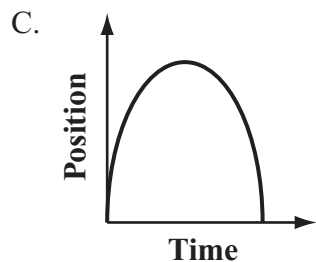
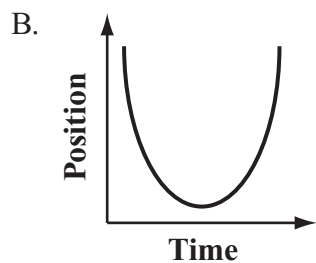
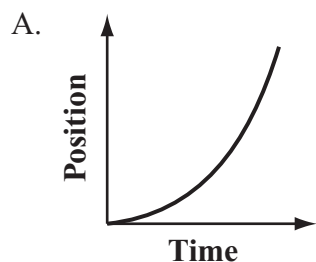
36 Which of the following statements describes electromagnetic waves?

- A. They have mass.
- B. They are transverse waves.
- C. They require a medium to propagate.
- D. They travel at varying speeds through a vacuum.

- 37 The graph below represents a car's motion as it accelerates from rest.



Which of the following graphs **best** represents the relationship between the accelerating car's position and time?



- 38 At a given temperature, a longitudinal mechanical wave will travel **fastest** through which of the following?

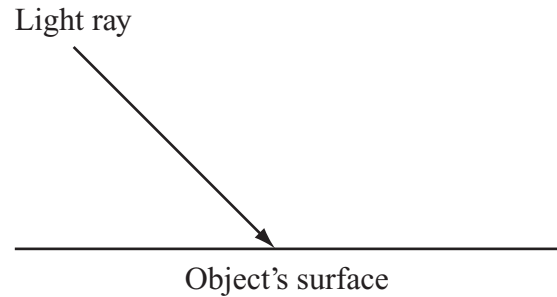
- A. a gas
- B. a liquid
- C. a solid
- D. a vacuum

- 39 Food can be sterilized by exposing it to high-frequency radiation. The higher the frequency of electromagnetic radiation used, the better it can penetrate thick layers of food.

Which part of the electromagnetic spectrum would be most effective for sterilizing food?

- A. gamma rays
- B. infrared waves
- C. radio waves
- D. visible light

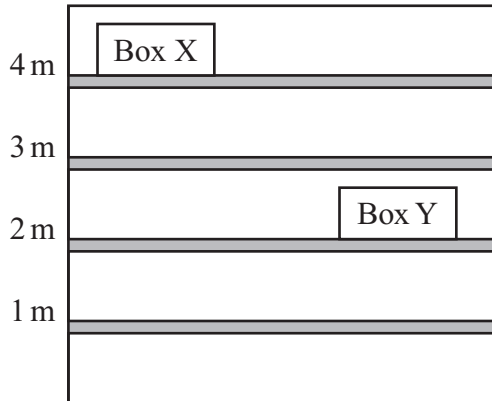
- 40 The diagram below represents a light ray striking the surface of a flat, shiny object.



What most likely happens to the light ray as it strikes the object's surface?

- A. It is completely absorbed by the object.
- B. It is reflected back in the direction it came from.
- C. It is reflected at an angle equal to the angle of incidence.
- D. It is reflected at an angle greater than the angle of incidence.

- 41 Two boxes with the same mass are placed on different shelves, as shown below.



Which of the following statements compares the amounts of work required to lift the boxes from the floor onto the different shelves?

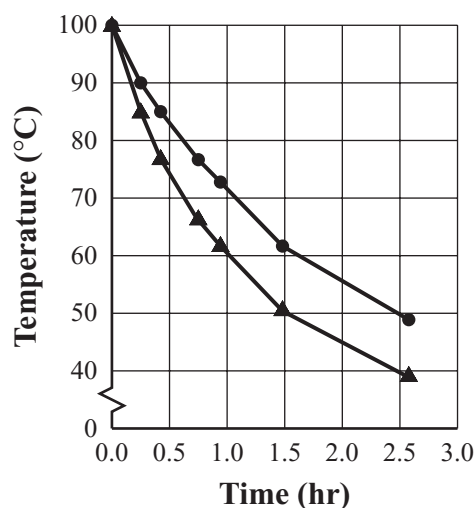
- A. Lifting box X required half as much work as lifting box Y.
- B. Lifting box X required twice as much work as lifting box Y.
- C. Lifting box X required four times as much work as lifting box Y.
- D. Lifting box X required the same amount of work as lifting box Y.
- 42 Which of the following statements describes a difference between kinetic friction and static friction?
- A. One type of friction applies to objects with large masses, and the other type applies to objects with small masses.
- B. One type of friction applies to objects on inclined surfaces, and the other type applies to objects on flat surfaces.
- C. One type of friction applies to accelerating objects, and the other type applies to objects moving with constant speed.
- D. One type of friction applies to objects in motion, and the other type applies to stationary objects resisting motion.
- 43 Which of the following is a purpose of a battery in a circuit?
- A. to provide voltage
- B. to provide resistance
- C. to turn the circuit on and off
- D. to protect the circuit from too much current

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 A student was investigating cooling times for two pots made of different materials. One pot was stainless steel and the other pot was iron. The pots were placed on a table in a  $25^{\circ}\text{C}$  room. The pots were roughly the same size and shape, and contained the same amount of water. The pots and water were originally at  $100^{\circ}\text{C}$ . The student recorded the temperature of the water in each pot over time. The graph below shows the results.



Key	
—●—	Stainless steel
—▲—	Iron

- Determine the amount of time it took the water in the iron pot to cool from  $100^{\circ}\text{C}$  to  $60^{\circ}\text{C}$ .
- Based on the graph, which pot, the iron pot or the stainless steel pot, was a better conductor of thermal energy? Explain your answer.
- Identify **two** methods of heat transfer that occurred as the water in the pots cooled, **and** describe how the transfer of heat occurred for **each** method.
- Describe when the pots no longer experienced a net loss of thermal energy.

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

- 45 A floating object moves up and down 15 times in 60 s because of ocean waves.
- Calculate the period of the ocean waves. Show your calculations and include units in your answer.
  - Calculate the frequency of the ocean waves. Show your calculations and include units in your answer.

An additional wave property must be known in order to calculate the velocity of the ocean waves.

- In your Student Answer Booklet, identify this additional wave property **and** draw a wave diagram showing how the property can be measured.
- Describe what will happen to the object if the amplitude of the ocean waves increases and all other wave characteristics stay the same.

### Formulas

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

$$F = ma$$

$$p = mv$$

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

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

$$V = IR$$

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

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

$$P = IV$$

$$v_f = v_i + a\Delta t$$

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

$$Q = mc\Delta T$$

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

$$PE = mg\Delta h$$

$$v = f\lambda$$

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

$$W = Fd$$

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

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

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

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

### Variables

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

### Definitions

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

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

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

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

**High School Introductory Physics**  
**Spring 2015 Released Items:**  
**Reporting Categories, Standards, and Correct Answers\***

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
1	331	<i>Motion and Forces</i>	1.3	D
2	331	<i>Motion and Forces</i>	2.5	A
3	332	<i>Electromagnetism</i>	5.4	C
4	332	<i>Heat and Heat Transfer</i>	3.3	D
5	332	<i>Electromagnetism</i>	5.2	D
6	332	<i>Electromagnetism</i>	5.6	B
7	333	<i>Waves and Radiation</i>	4.2	D
8	333	<i>Motion and Forces</i>	1.1	A
9	333	<i>Motion and Forces</i>	1.4	C
10	334	<i>Electromagnetism</i>	5.1	B
11	334	<i>Motion and Forces</i>	1.4	D
12	335	<i>Electromagnetism</i>	5.3	
13	336	<i>Motion and Forces</i>	2.5	D
14	336	<i>Waves and Radiation</i>	4.6	B
15	337	<i>Motion and Forces</i>	2.2	D
16	337	<i>Electromagnetism</i>	5.5	A
17	337	<i>Waves and Radiation</i>	4.1	A
18	338	<i>Motion and Forces</i>	2.4	B
19	338	<i>Electromagnetism</i>	5.3	B
20	338	<i>Motion and Forces</i>	1.2	D
21	338	<i>Heat and Heat Transfer</i>	3.1	A
22	338	<i>Heat and Heat Transfer</i>	3.3	C
23	339	<i>Motion and Forces</i>	1.1	
24	340	<i>Heat and Heat Transfer</i>	3.2	C
25	340	<i>Motion and Forces</i>	1.5	B
26	341	<i>Electromagnetism</i>	5.2	D
27	341	<i>Motion and Forces</i>	1.8	B
28	342	<i>Waves and Radiation</i>	6.1	C
29	342	<i>Waves and Radiation</i>	4.3	B
30	342	<i>Motion and Forces</i>	2.1	C
31	342	<i>Heat and Heat Transfer</i>	3.4	C
32	343	<i>Motion and Forces</i>	2.2	
33	344	<i>Waves and Radiation</i>	4.1	D
34	344	<i>Motion and Forces</i>	1.7	C
35	345	<i>Waves and Radiation</i>	4.6	D
36	345	<i>Waves and Radiation</i>	6.1	B
37	346	<i>Motion and Forces</i>	1.3	A
38	346	<i>Waves and Radiation</i>	4.5	C
39	347	<i>Waves and Radiation</i>	6.2	A



Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
40	347	<i>Waves and Radiation</i>	4.4	C
41	348	<i>Motion and Forces</i>	2.3	B
42	348	<i>Motion and Forces</i>	1.6	D
43	348	<i>Electromagnetism</i>	5.3	A
44	349	<i>Heat and Heat Transfer</i>	3.1	
45	350	<i>Waves and Radiation</i>	4.1	

\* 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.