XX. Introductory Physics, High School

High School Introductory Physics Test

The spring 2007 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-three 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.

1 A car is parked on the side of a hill. Which of the following **most likely** prevents the car from moving down the hill?

A. The car has too much mass to move easily.

B. There is friction in the door hinges of the car.

C. There is friction between the tires and the road.

D. The weight of the car is mostly on the front wheels.

2 Thermal energy is added to four identical 1.0 kg samples of water at room temperature.

Which of the following increases in each sample?

A. average charge of an electron

B. average density of a nucleus

C. average mass of a proton

D. average speed of a molecule

3 A current of 2 A passes through two resistors placed in series. The first resistor has a resistance of 10 Ω and the second resistor has a resistance of 20 Ω.

What is the total potential difference across the two resistors?

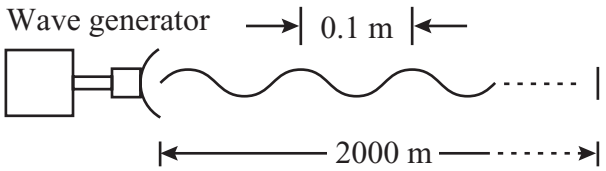
A. 13 V

B. 15 V

C. 30 V

D. 60 V

4 The diagram below shows a wave generator that emits a wave with a frequency of 500 Hz and a wavelength of 0.1 m.



How long does it take for the wave to travel a distance of 2000 m?

A. 20 s

B. 30 s

C. 40 s

D. 50 s

5 A hockey player swings her hockey stick and strikes a puck. According to Newton's third law of motion, which of the following is a reaction to the stick pushing on the puck?

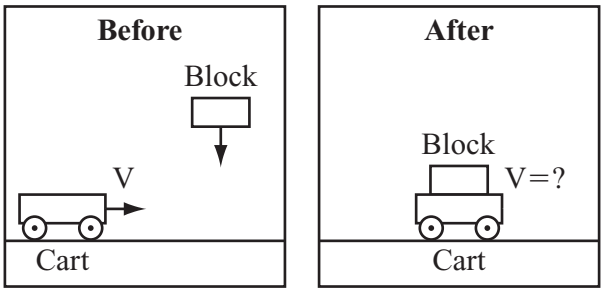
A. the puck pushing on the stick
B. the stick pushing on the player
C. the player pushing on the stick
D. the puck pushing on the player

6 To make ice, water must first be cooled. The specific heat of water is 4,186 J/kg • °C.

Approximately how much heat must be removed from 0.50 kg of water to change its temperature from 24°C to 5°C?

A. 0 J
B. 19,900 J
C. 39,800 J
D. 79,500 J

7 The diagrams below show a cart moving with a velocity, V, on a frictionless surface as a wooden block is being dropped. The block then falls straight down onto the moving cart.



Which of the following statements describes what will happen after the block lands on the moving cart?

A. The cart will move to the left at a velocity less than the original velocity of the cart.
B. The cart will move to the left at a velocity greater than the original velocity of the cart.
C. The cart will move to the right at a velocity less than the original velocity of the cart.
D. The cart will move to the right at a velocity greater than the original velocity of the cart.

8 A cart at the top of a hill is released and rolls down the hill. Which of the following describes the energy of the cart just as it reaches the bottom of the hill?

A. The cart has no energy.

B. The cart has maximum kinetic energy.

C. The cart has maximum gravitational potential energy.

D. The cart has equal gravitational potential and kinetic energy.

9 When one end of a short metal bar is heated, the opposite end will eventually become hot. Which of the following processes transfers the heat through the bar?

A. condensation

B. conduction

C. convection

D. radiation

10 Which of the following will definitely cause a change in the velocity of a parked car?

A. The car experiences an unbalanced force.

B. All forces acting on the car increase by 1 N.

C. All forces acting on the car decrease by 1 N.

D. The forces acting on the car are equal and balanced.

Question 11 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 11 in the space provided in your Student Answer Booklet.

11 A student rubs a balloon on her hair and the balloon acquires a negative charge.

a. Explain why the balloon acquires a negative charge.

b. After the balloon is rubbed on the student's head, the student's hair stands out from her head. Explain why this happens.

The student then brings the negatively charged balloon near another balloon that was charged in the same way.

c. Describe and explain what happens when the negatively charged balloon is brought near another negatively charged balloon.

Mark your answers to multiple-choice questions 12 through 24 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.

12 A rise in the temperature inside a kitchen means there is an increase in the

A. density of the air molecules.
B. number of the air molecules.
C. average size of the air molecules.
D. average kinetic energy of the air molecules.

13 Which of the following provides the **best** example of simple harmonic motion?

A. riding a regular bus route
B. sliding down a water slide
C. running a consistent daily jog
D. swinging on a playground swing

14 Jessica places 1000 g of water at 20.0°C in an insulated cup. The specific heat capacity of water is 4.20 J/g • °C.

What is the final temperature of the water if 5000 J of energy is added to the water in the insulated cup?

A. 20.1°C
B. 20.5°C
C. 21.2°C
D. 25.0°C

15 Which of the following is a vector quantity?

A. mass
B. force
C. temperature
D. kinetic energy

16 Two identical beakers each contain 250 mL of water. The temperature of the water is 85°C in one beaker and 15°C in the other beaker. A drop of red food coloring is placed in each beaker at the same time.

During the first minute, which of the following is **most likely** to happen?

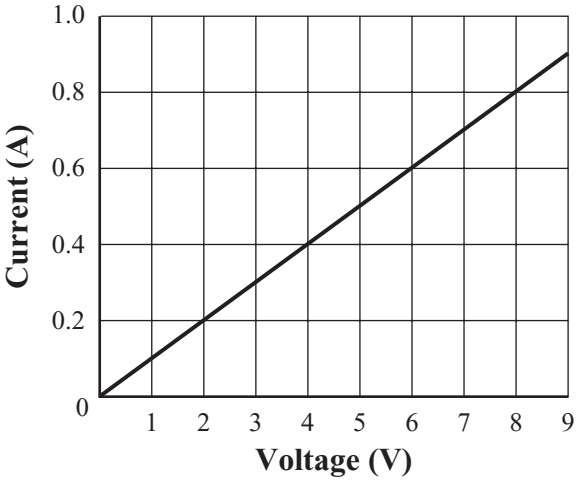
A. The food coloring will spread out faster in the 85°C water than in the 15°C water.

B. The food coloring will form a layer at the top of each beaker since it does not mix with water.

C. The food coloring will spread only halfway through the water in each beaker due to convection currents.

D. The food coloring will settle faster at the bottom of the beaker containing 85°C water than at the bottom of the beaker containing 15°C water.

17 The graph below relates the current to voltage data for a resistor.



Which of the following is the value of the resistor?

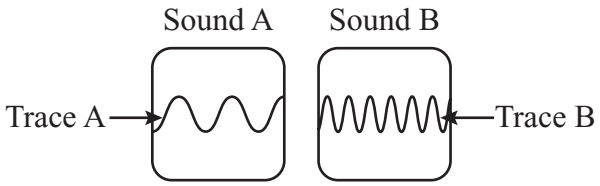
A. 0.2 Ω

B. 2 Ω

C. 4 Ω

D. 10 Ω

18 The illustration below shows wave traces of recorded sound waves on two computer screens.



Computer Screens

Traces A and B represent two different sounds with the same time scale horizontally.

From a comparison of the wave traces, which of the following **correctly** describes the relationship of sound B to sound A?

A. Sound B has a higher velocity.

B. Sound B has a higher amplitude.

C. Sound B has a higher frequency.

D. Sound B has a longer wavelength.

19 What is the mass of an object weighing 63 N on Earth?

A. 0.1 kg

B. 6.3 kg

C. 73 kg

D. 617 kg

20 Which of the following is **least likely** to result in the generation of static charge?

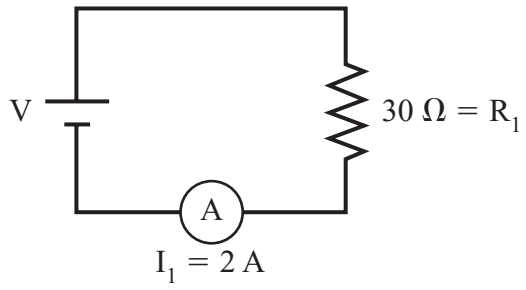
A. peeling plastic wrap off a CD case

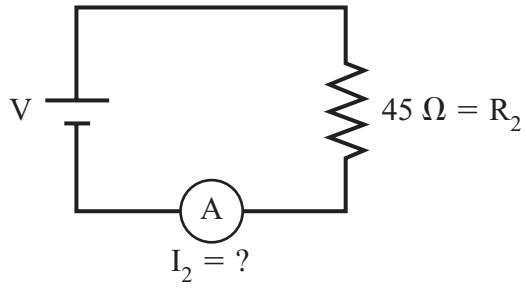
B. combing dry hair with a plastic comb

C. rubbing one's shoes on a synthetic carpet

D. drying one's body with a towel after a shower

21 The two resistors shown below are connected to identical power sources. Resistor 1 has a resistance of 30 Ω, and resistor 2 has a resistance of 45 Ω. The current in resistor 1 is 2 A.





What is the current in resistor 2?

A. 1.0 A

B. 1.3 A

C. 1.5 A

D. 3.0 A

22 The distance between Earth and the Moon was determined by measuring the time it took for light waves from Earth to travel to the Moon and back. Why was it **not** possible to use sound waves for this experiment?

A. Sound waves must move through a substance.

B. Sound waves would change frequency on the return to Earth.

C. Sound waves move too slowly for the technique to be accurate.

D. Sound waves move more slowly in Earth's atmosphere than in space.

23 Which of the following requires the greatest amount of heat?

A. increasing the temperature of 1 kg of water from 0°C to 30°C

B. increasing the temperature of 10 kg of water from 10°C to 20°C

C. increasing the temperature of 20 kg of water from 19°C to 21°C

D. increasing the temperature of 50 kg of water from 20°C to 21°C

24 If heat is added to a liquid, which of the following occurs?

A. The friction in the liquid increases.

B. The size of the liquid molecules expands.

C. The potential energy of the liquid changes.

D. The molecular motion in the liquid increases.

Questions 25 and 26 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 25 in the space provided in your Student Answer Booklet.

25 On a smooth, level surface, a red marble of mass 0.02 kg moving at 2.0 m/s collides with a stationary yellow marble of equal mass. After the collision, the red marble stops completely, and the yellow marble moves in the direction the red marble was moving.

a. Calculate the momentum of both marbles before the collision. Show your calculations and include units in your answer.

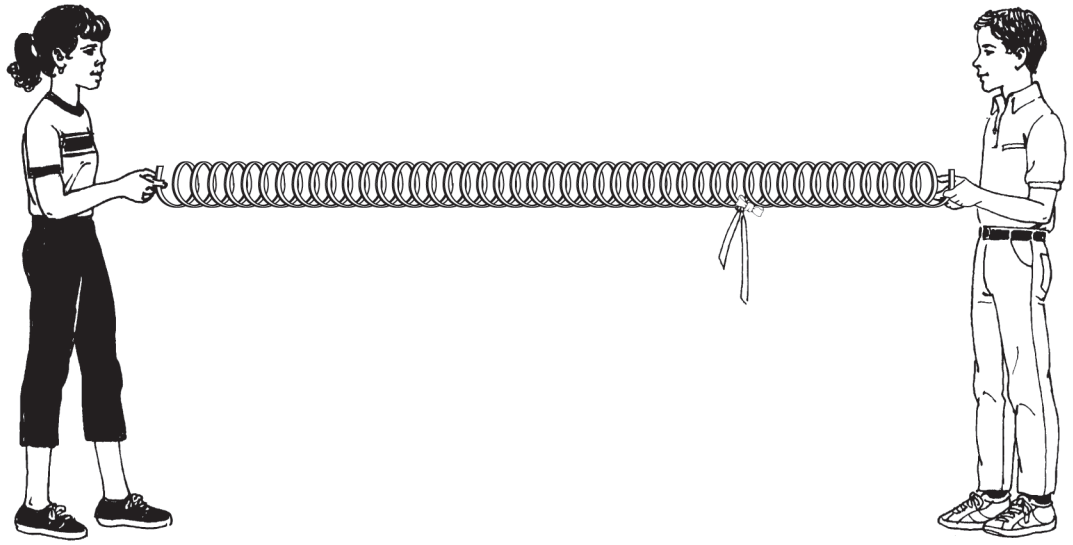
b. Calculate the momentum of both marbles after the collision. Show your calculations and include units in your answer.

c. If the velocity of the red marble doubles, how will the velocity of the yellow marble change after the collision?

d. If the red marble had **more** mass than the yellow marble, how would the momentum of the yellow marble change after the collision?

Write your answer to question 26 in the space provided in your Student Answer Booklet.

26 The drawing below shows two students holding the ends of a spring that has a ribbon attached to it.



In your Student Answer Booklet:

a. Draw and explain how a transverse wave will move along the spring.

b. Draw and explain how the ribbon will move when a transverse wave is sent along the spring.

c. Draw and explain how a longitudinal wave will move along the spring.

d. Draw and explain how the ribbon will move when a longitudinal wave is sent along the spring.

Introductory Physics

Session 2

DIRECTIONS

This session contains seventeen 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.

27 A 600 g basketball, a 57 g tennis ball, a 46 g golf ball, and a 2.7 g table tennis ball are moving with the same velocity. Which ball has the **greatest** momentum?

A. golf ball

B. basketball

C. tennis ball

D. table tennis ball

28 Which of the following is a **main** factor that affects the speed of a wave?

A. the pitch of sound

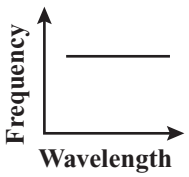
B. the loudness of sound

C. the amplitude of the wave

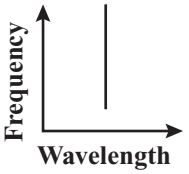
D. the properties of the medium

29 Which of the following graphs **best** represents the relationship of the frequency of an electromagnetic wave to its wavelength?

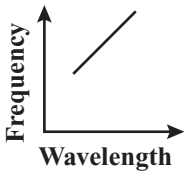
A.



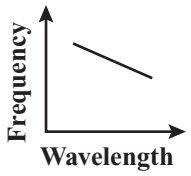
B.



C.



D.



30 The motor of one car is more powerful than the motor of another car. Which of the following must be true of the more powerful motor?

A. It can do work more quickly.

B. It can operate for a longer time.

C. It can burn fuel more efficiently.

D. It can store more potential energy.

31 Which of the following waves travels **fastest**?

A. water waves in oceans

B. seismic waves in rocks

C. sound waves from a violin string

D. electromagnetic waves from the Sun

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 In an experiment, the current is varied as it goes through the resistor in a circuit. An ammeter measures the current going through the resistor and a voltmeter measures the voltage across the resistor. The data are recorded and shown below.

Circuit Data

Current (A)	Voltage (V)
0.20	1.5
0.40	3.0
0.80	6.0
1.20	9.0
1.60	12.0
2.80	21.0

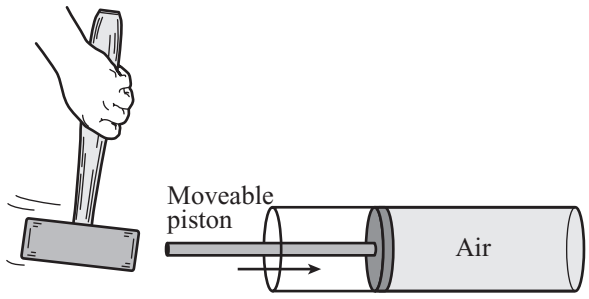
a. Using the data in the table, make a graph of the voltage versus the current in the circuit. Voltage should be on the *y*-axis. Make sure the graph has clearly labeled axes and a proper scale.

b. Find the slope of the graphed line. Show your calculations and include units in your answer.

c. Explain what the slope represents.

Mark your answers to multiple-choice questions 33 through 38 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 diagram below shows a hammer about to strike a moveable piston.



As the piston moves suddenly when struck, which type of wave pulse is generated in the air inside the cylinder?

A. electromagnetic
B. transverse
C. refracted
D. longitudinal

34 How long will it take a car to accelerate from 20 m/s to 26 m/s at a rate of 1.4 m/s^2?

A. 2.2 s
B. 2.7 s
C. 4.3 s
D. 4.6 s

35 Which of the following can carry light waves but not sound waves?

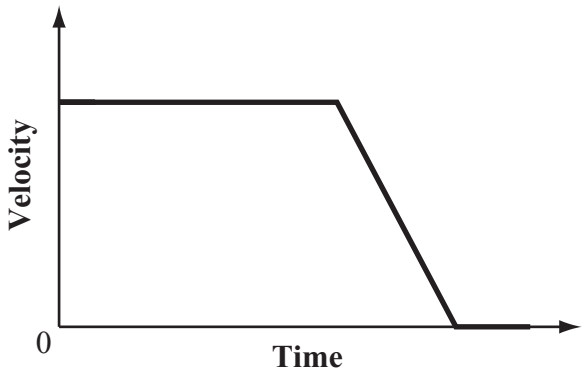
A. air
B. steel
C. water
D. vacuum

36 A crane lifts two 100 kg loads of building materials to the top of a building under construction. The first load is lifted in 10 s and the second load is lifted in 13 s.

Which of the following statements **best** compares the work and power expended by the crane lifting the two loads?

A. The crane does more work and expends more power for the first lift.
B. The crane does the same work and expends the same power for each lift.
C. The crane does the same work for each lift but expends more power for the first lift.
D. The crane does more work in the second lift but expends the same power for each lift.

37 The graph below relates velocity to time.



The graph would **most likely** apply to which of the following events?

A. A soccer ball that is at rest is suddenly kicked.

B. A ball is thrown upward and returns to the ground.

C. A person who is running at a constant speed decides to run faster.

D. A car traveling at a constant speed applies its brakes and comes to a stop.

38 Which of the following waves can travel at a speed of 3×10^8 m/s?

A. microwaves

B. seismic waves

C. ultrasonic waves

D. water waves

Question 39 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 39 in the space provided in your Student Answer Booklet.

39 A book is on a table. A student pushes it for a short time. Initially the book moves, but then it comes to a complete stop.

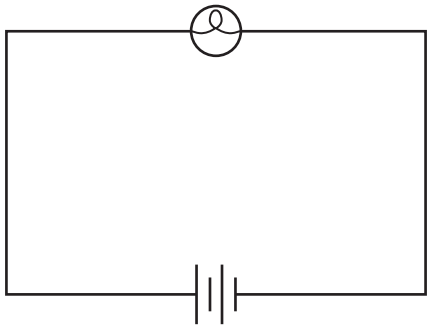
a. Identify the forces acting on the book before it is pushed. You may include a labeled diagram in your answer.

b. Explain why the book moves and then comes to a complete stop. Use the laws of physics in your answer.

c. The student wants the book to move at a constant speed in one direction. Describe the physical conditions needed for this to occur.

Mark your answers to multiple-choice questions 40 through 45 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.

40 The diagram below shows an electrical circuit.



Which of the following **best** explains why energy stored in the battery power source diminishes over time when this circuit is complete?

A. Energy is destroyed when the light bulb operates.

B. The light bulb transforms energy into light and heat.

C. The light bulb converts the negative charge of electrons into light and heat.

D. The power source generates energy more slowly than the light bulb consumes it.

41 A 9 kg model airplane flies horizontally at a constant speed. If the plane suddenly dives from its altitude of 50 m and levels off at 20 m, how much potential energy does it lose in the dive?

A. 450 J

B. 1800 J

C. 2700 J

D. 9000 J

42 Ultraviolet light has a shorter wavelength than visible light. Which of the following is another way ultraviolet light can be compared to visible light?

A. Ultraviolet light has a lower frequency than visible light.

B. Ultraviolet light has a higher frequency than visible light.

C. Ultraviolet light travels faster than visible light.

D. Ultraviolet light travels slower than visible light.

43 To calculate the momentum of a pickup truck with a velocity of 25 m/s east, it is also necessary to know which of the following?

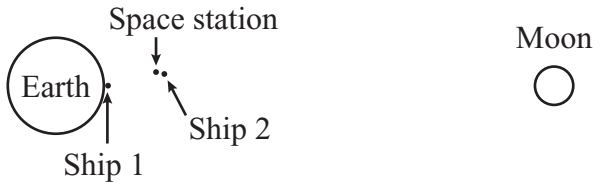
A. time elapsed

B. drive force of the motor

C. mass of the pickup truck

D. distance that the pickup travels

44 The diagram below represents two identical space ships, Earth, a space station, and the Moon.



The two ships are launched toward the Moon. Ship 1 is launched from Earth, and ship 2 is launched from the space station. It takes less force to launch ship 2.

Which of the following contributes **most** to the difference in the forces?

A. Ship 2 has less inertia in space than ship 1 does on Earth.

B. Earth exerts less gravitational force on ship 2 than on ship 1.

C. Ship 2 must travel a shorter distance than ship 1 before reaching the Moon.

D. The Moon exerts more gravitational force on ship 2 than on ship 1.

45 A sealed glass container holds molecules of nitrogen gas. The nitrogen molecules have increasing velocities.

Which of the following will make the molecules move faster?

A. bonding the molecules together

B. transferring heat to the molecules

C. expanding the volume of the container

D. decreasing the pressure in the container

Massachusetts Comprehensive Assessment System

Introductory Physics Formula Sheet

Formulas

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

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

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

$v_f = v_i + a\Delta t$

$\Delta d = v_i \Delta t + \frac{1}{2} a(\Delta t^2)$

$v_f{}^2 = v_i{}^2 + 2a\Delta d$

$F = ma$

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

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

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

$PE = mg\Delta h$

$W = F\Delta d$

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

$p = mv$

$V = IR$

$P = IV$

$Q = mc\Delta T$

$v = f\lambda$

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

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

Variables

a = acceleration	PE = gravitational potential energy
c = specific heat	q = charge of particle
d = distance	Q = heat
Δd = change in 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

Definitions

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

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

c = speed of electromagnetic waves = 3.00×10^8 m/s

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

High School Introductory Physics
Spring 2007 Released Items:
Reporting Categories, Standards, and Correct Answers

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
1	513	*Motion and Forces*	1.6	C
2	513	*Heat and Heat Transfer*	3.3	D
3	513	*Electromagnetism*	5.2	D
4	513	*Waves and Radiation*	4.1	C
5	514	*Motion and Forces*	1.4	A
6	514	*Heat and Heat Transfer*	3.4	C
7	514	*Motion and Forces*	2.5	C
8	515	*Motion and Forces*	2.2	B
9	515	*Heat and Heat Transfer*	3.1	B
10	515	*Motion and Forces*	1.4	A
11	516	*Electromagnetism*	5.1	
12	517	*Heat and Heat Transfer*	3.3	D
13	517	*Waves and Radiation*	4.1	D
14	517	*Heat and Heat Transfer*	3.4	C
15	517	*Motion and Forces*	1.1	B
16	518	*Heat and Heat Transfer*	3.3	A
17	518	*Electromagnetism*	5.2	D
18	519	*Waves and Radiation*	4.1	C
19	519	*Motion and Forces*	1.4	B
20	520	*Electromagnetism*	5.1	D
21	520	*Electromagnetism*	5.2	B
22	521	*Waves and Radiation*	4.2	A
23	521	*Heat and Heat Transfer*	3.4	B
24	521	*Heat and Heat Transfer*	3.3	D
25	522	*Motion and Forces*	2.5	
26	523	*Waves and Radiation*	4.3	
27	524	*Motion and Forces*	2.5	B
28	524	*Waves and Radiation*	4.1	D
29	524	*Waves and Radiation*	6.2	D
30	525	*Motion and Forces*	2.4	A
31	525	*Waves and Radiation*	4.2	D
32	526	*Electromagnetism*	5.2	
33	527	*Waves and Radiation*	4.3	D
34	527	*Motion and Forces*	1.2	C
35	527	*Waves and Radiation*	4.2	D
36	527	*Motion and Forces*	2.4	C
37	528	*Motion and Forces*	1.3	D
38	528	*Waves and Radiation*	6.1	A
39	529	*Motion and Forces*	1.4	
40	530	*Motion and Forces*	2.1	B
41	530	*Motion and Forces*	2.2	C
42	530	*Waves and Radiation*	6.2	B

Item No.	Page No.	Reporting Category	Standard	Correct Answer (MC)*
43	531	*Motion and Forces*	2.5	C
44	531	*Motion and Forces*	1.7	B
45	531	*Heat and Heat Transfer*	3.3	B

* 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.