

## PHYSICS B

## SECTION I

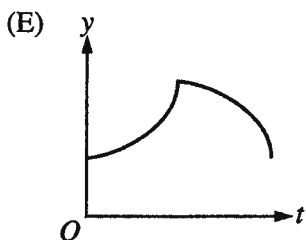
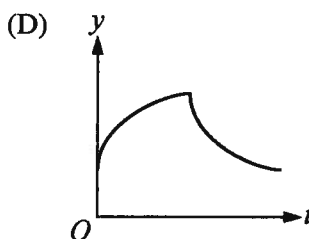
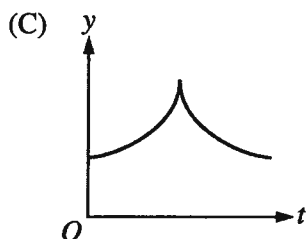
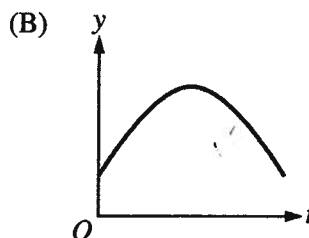
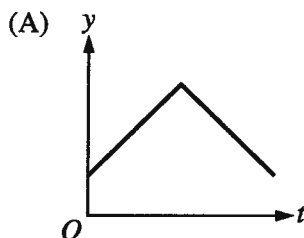
Time—90 minutes

70 Questions

**Directions:** Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

**Note:** To simplify calculations, you may use  $g = 10 \text{ m/s}^2$  in all problems.

1. A person throws a marble straight up into the air, releasing it a short height above the ground and catching it at that same height. If air resistance is negligible, which of the following graphs of position  $y$  versus time  $t$  is correct for the motion of the marble as it goes up and then comes down?



2. A rocket lifts a payload upward from the surface of Earth. The radius of Earth is  $R$ , and the weight of the payload on the surface of Earth is  $W$ . The force of Earth's gravity on the payload is  $\frac{W}{2}$  when the rocket's distance from the center of Earth is

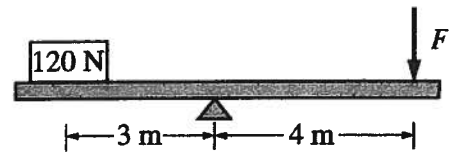
(A)  $R$   
(B)  $\sqrt{2}R$   
(C)  $2R$   
(D)  $2\sqrt{2}R$   
(E)  $4R$

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**Questions 3-4**

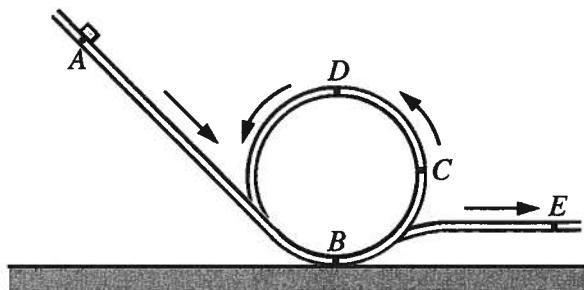
An object is thrown with an initial speed  $v$  near the surface of Earth. Assume that air resistance is negligible and the gravitational field is constant.

3. If the object is thrown vertically upward, the direction and magnitude of its acceleration while it is in the air is
- (A) upward and decreasing  
(B) upward and constant  
(C) downward and decreasing  
(D) downward and increasing  
(E) downward and constant
4. If the object is thrown horizontally, the direction and magnitude of its acceleration while it is in the air is
- (A) upward and decreasing  
(B) upward and constant  
(C) downward and decreasing  
(D) downward and increasing  
(E) downward and constant



5. An object weighing 120 N is set on a rigid beam of negligible mass at a distance of 3 m from a pivot, as shown above. A vertical force is to be applied to the other end of the beam a distance of 4 m from the pivot to keep the beam at rest and horizontal. What is the magnitude  $F$  of the force required?
- (A) 10 N  
(B) 30 N  
(C) 90 N  
(D) 120 N  
(E) 160 N
6. Inertia can be best described as the
- (A) force that keeps an object in motion with constant velocity  
(B) force that keeps an object at rest  
(C) force that overcomes friction  
(D) property responsible for an object's resistance to changes in motion  
(E) property responsible for slowing down an object

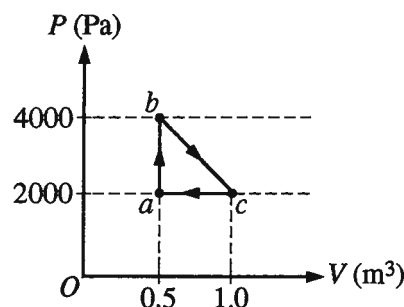
Questions 7-9



A block released from rest at position A slides with negligible friction down an inclined track, around a vertical loop, and then along a horizontal portion of the track, as shown above. The block never leaves the track.

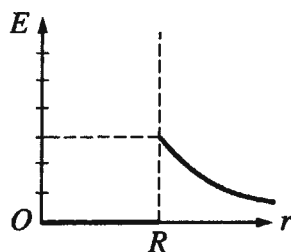
7. After the block is released, in which of the following sequences of positions is the speed of the block ordered from fastest to slowest?
  - (A) B C D E
  - (B) B E C D
  - (C) D C E B
  - (D) E B C D
  - (E) E D C B
8. Which of the following is true of the net force on the block when it is at position C?
  - (A) It is directed vertically downward only.
  - (B) It is directed vertically upward only.
  - (C) It is directed to the left only.
  - (D) It is directed to the right only.
  - (E) It has components both to the left and vertically downward.
9. The gravitational potential energy and the kinetic energy of the block are most nearly equal at which position? (Consider the potential energy to be zero at position B.)
  - (A) A
  - (B) B
  - (C) C
  - (D) D
  - (E) E

Questions 10-11

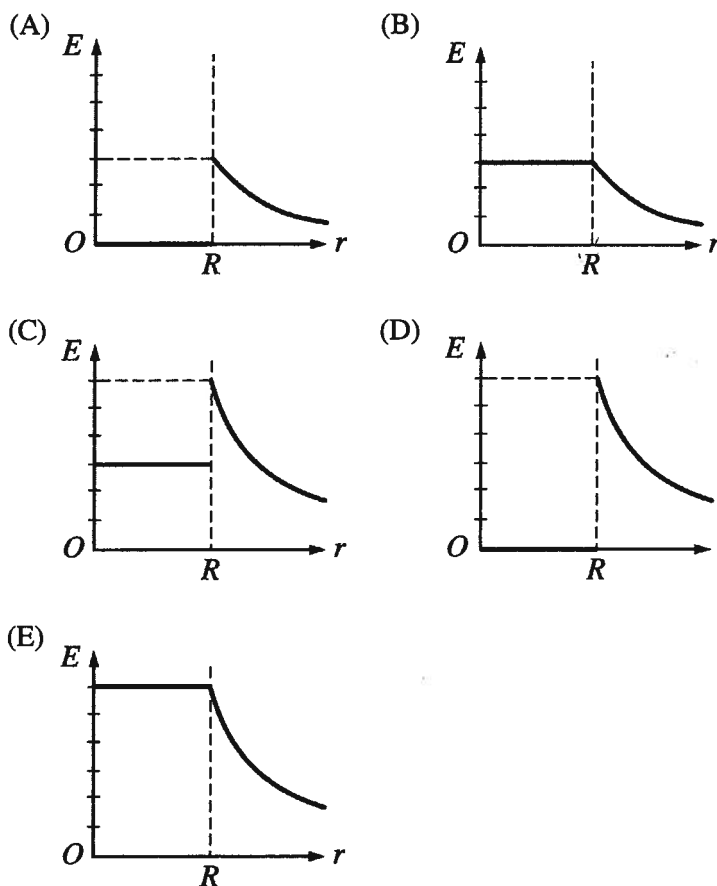


A sample of an ideal gas is taken through the cycle *abca*, as shown in the *PV* diagram above.

10. What is the change in internal energy of the gas for the process *bc*?
  - (A) -1500 J
  - (B) -500 J
  - (C) 0 J
  - (D) +500 J
  - (E) +1500 J
11. If 1000 J of heat is added to the gas during process *ab*, what is the change in internal energy of the gas for process *ab*?
  - (A) -2000 J
  - (B) -1000 J
  - (C) 0 J
  - (D) +1000 J
  - (E) +2000 J
12. At room temperature and one atmosphere of pressure, which of the following materials is the best conductor of heat?
  - (A) Air
  - (B) Helium
  - (C) Silver
  - (D) Water
  - (E) Wood
13. What is the acceleration of an object of mass  $4.5 \times 10^{-5}$  kg with a charge of  $9 \times 10^{-9}$  C under the influence of an electric field of magnitude 5000 V/m, assuming gravity is negligible?
  - (A) 0.05 m/s<sup>2</sup>
  - (B) 0.5 m/s<sup>2</sup>
  - (C) 0.9 m/s<sup>2</sup>
  - (D) 1.0 m/s<sup>2</sup>
  - (E) 5.0 m/s<sup>2</sup>



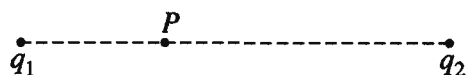
14. A conducting spherical shell of radius  $R$  has charge  $q$  uniformly distributed on its outer surface. The graph above represents electric field strength  $E$  versus distance  $r$  from the center of the spherical shell. Which of the following graphs best represents  $E$  versus  $r$  when the charge on the spherical shell is doubled to  $2q$ ?





15. A charged particle is in a region that contains both an electric and a magnetic field. The kinetic energy of the particle is  $9 \mu\text{J}$  at point  $X$  and  $11 \mu\text{J}$  at point  $Y$  in the figure above. If the only forces present are electromagnetic, what is the work done by the electric force on the particle as it moves from  $X$  to  $Y$  along the path shown?

- (A)  $0 \mu\text{J}$
- (B)  $1 \mu\text{J}$
- (C)  $2 \mu\text{J}$
- (D)  $11 \mu\text{J}$
- (E)  $20 \mu\text{J}$

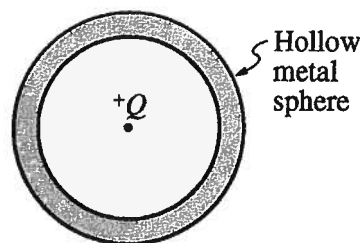


16. Two point charges of unknown magnitudes  $q_1$  and  $q_2$  are placed as shown above. The electric field intensity is zero at point  $P$ , which is closer to  $q_1$  than to  $q_2$ . Which of the following is true of the signs of the charges and their magnitudes?

<u>Signs</u>	<u>Magnitudes</u>
(A) Opposite	Equal
(B) Opposite	$q_1 > q_2$
(C) Same	Equal
(D) Same	$q_1 > q_2$
(E) Same	$q_1 < q_2$

17. A 60 W, 120 V lightbulb has a resistance of
- (A)  $0.5 \Omega$
  - (B)  $2.0 \Omega$
  - (C)  $120 \Omega$
  - (D)  $240 \Omega$
  - (E)  $480 \Omega$

Questions 18-19

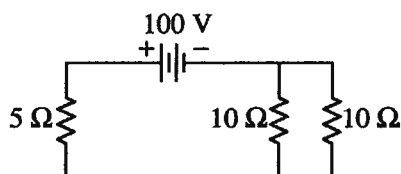


Charge  $+Q$  is located at the center of the hollow metal sphere shown in cross section above. The net charge on the sphere is zero.

18. What are the induced charges, if any, on the inner and outer surfaces of the sphere?

	<u>Inner Surface</u>	<u>Outer Surface</u>
(A)	Zero	Zero
(B)	$-Q$	Zero
(C)	$-Q$	$+Q$
(D)	$+Q$	$-Q$
(E)	$+Q$	$+Q$

19. If the potential of the inner surface is  $V$ , what is the potential of the outer surface?
- (A) Less than zero
  - (B) Zero
  - (C) Between zero and  $V$
  - (D)  $V$
  - (E) Greater than  $V$



20. In the circuit shown above, what is the current in the  $5\ \Omega$  resistor?

(A) 40 A  
(B) 25 A  
(C) 20 A  
(D) 10 A  
(E) 4 A

21. Balls 1 and 2 are each thrown horizontally from the same height above level ground, but ball 2 has a greater initial velocity after leaving the thrower's hand. If air resistance is negligible, how do the accelerations of the balls and the times it takes them to hit the ground compare?

<u>Acceleration <math>a</math></u>	<u>Time to Hit Ground</u>
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(A) Greater for ball 2	Greater for ball 2
(B) Greater for ball 2	Equal
(C) Equal	Greater for ball 2
(D) Equal	Less for ball 2
(E) Equal	Equal

22. Two objects, X and Y, accelerate from rest with the same constant acceleration. Object X accelerates for twice the time as object Y. Which of the following is true of these objects at the end of their respective periods of acceleration?

(A) Object X is moving at the same speed as object Y.  
(B) Object X is moving four times faster than object Y.  
(C) Object X has traveled the same distance as object Y.  
(D) Object X has traveled twice as far as object Y.  
(E) Object X has traveled four times as far as object Y.

23. A builder is replacing a concrete wall with a wooden one and wants the new wall to have the same area and rate of heat flow through it as the old wall. The thermal conductivities of wood and concrete are  $0.1\ \text{W/m}\cdot\text{K}$  and  $0.8\ \text{W/m}\cdot\text{K}$ , respectively. If the concrete wall is 40 cm thick and the temperature difference across the two walls is the same, what thickness of wooden wall is needed?

(A) 2 cm  
(B) 4 cm  
(C) 5 cm  
(D) 20 cm  
(E) 32 cm

24. A series of measurements are made of the pressure  $P$  and the volume  $V$  of a sample of nitrogen gas kept at a constant temperature. It is desired to represent the data graphically so that the graph will be a straight line if the behavior of the gas is ideal. Accordingly, which of the following should be plotted?

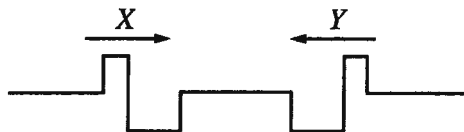
(A)  $P$  as a function of  $V$   
(B)  $V/P$  as a function of  $V$   
(C)  $P/V$  as a function of  $V$   
(D)  $P$  as a function of  $1/V$   
(E)  $1/P$  as a function of  $1/V$

25. An object is placed 12 cm in front of a concave mirror. The mirror forms a real inverted image that is the same size as the object, also at 12 cm in front of the mirror. The focal length of the mirror is

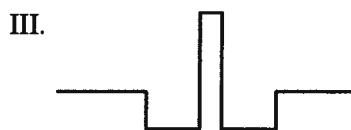
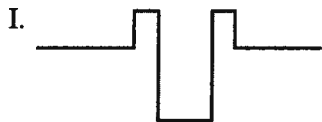
(A) 3.0 cm  
(B) 4.0 cm  
(C) 6.0 cm  
(D) 12 cm  
(E) 24 cm

26. At a point of observation, the time between successive crests of a passing wave is 0.2 s. Which of the following must be true of the wave?

(A) Its wavelength is 0.2 m.  
 (B) Its wavelength is 5 m.  
 (C) Its period is 5 s.  
 (D) Its frequency is 5 Hz.  
 (E) Its velocity of propagation is 5 m/s.



27. The two wave pulses, X and Y, shown above are moving toward each other in the same medium. Which of the following interference patterns could result at some instant as the pulses pass through each other?



(A) I only  
 (B) II only  
 (C) I and III only  
 (D) II and III only  
 (E) I, II, and III

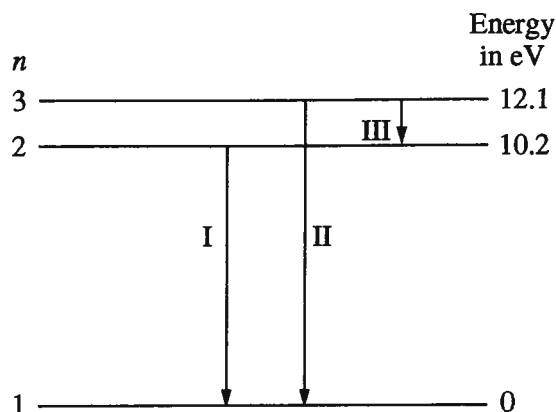
28. Which of the following experimental observations provides the best support for the statement, "Light behaves like a wave" ?

(A) Light can be reflected by a mirror.  
 (B) Light is scattered when passing through smoke.  
 (C) Monochromatic light forms bright and dark bands after passing through two narrow slits.  
 (D) White light can be broken into component colors by a prism.  
 (E) Light is bent by a gravitational field.

29. When a light wave passes from air into glass, quantities that remain constant include which of the following?

I. Frequency  
 II. Wavelength  
 III. Speed

(A) I only  
 (B) II only  
 (C) I and III only  
 (D) II and III only  
 (E) I, II, and III



30. The figure above shows a portion of the energy level diagram for hydrogen. Possible transitions among the energy levels are represented by arrows I, II, and III. Which of the following lists the transitions in order of their associated wavelengths of light, from shortest wavelength to longest wavelength?

(A) I, II, III  
 (B) I, III, II  
 (C) II, I, III  
 (D) II, III, I  
 (E) III, I, II

31.  $^{238}_{92}\text{U}$  undergoes a series of reactions in which it emits eight  $^4_2\text{He}$  nuclei and six electrons. What is the isotope that results from this series of reactions?

(A)  $^{222}_{66}\text{Dy}$   
 (B)  $^{206}_{81}\text{Tl}$   
 (C)  $^{206}_{82}\text{Pb}$   
 (D)  $^{207}_{82}\text{Pb}$   
 (E)  $^{214}_{88}\text{Ra}$

32. A deuterium nucleus  $^2_1\text{H}$  interacts with a lithium nucleus  $^7_3\text{Li}$ . Which of the following could NOT possibly occur as the end products of this reaction because of violation of conservation of charge or mass number?

(A)  $^4_2\text{He} + ^3_1\text{H} + ^2_1\text{H}$   
 (B)  $2\ ^3_1\text{H} + ^1_1\text{H} + 2\ ^1_0\text{n}$   
 (C)  $2\ ^4_2\text{He} + ^1_0\text{n}$   
 (D)  $^7_3\text{Li} + ^2_1\text{H}$   
 (E)  $^8_3\text{Li} + ^1_1\text{H}$



33. A railroad car of mass  $m$  is moving with speed  $v$  when it collides with and connects to a second railroad car of mass  $3m$ , initially at rest, as shown above. How do the speed and kinetic energy of the connected cars compare to those of the single car of mass  $m$  before the collision?

	<u>Speed</u>	<u>Kinetic Energy</u>
(A)	Less	Less
(B)	Less	The same
(C)	The same	Less
(D)	The same	The same
(E)	Greater	The same



34. A ball of mass  $m$  and momentum  $p$  has kinetic energy equal to which of the following?

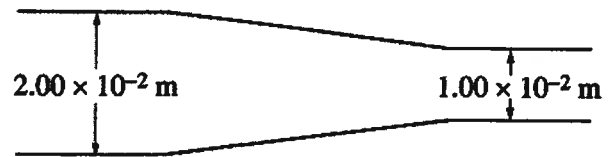
- (A)  $\frac{1}{2} \frac{p^2}{m}$   
 (B)  $\frac{p^2}{m}$   
 (C)  $2 \frac{p^2}{m}$   
 (D)  $\frac{1}{2} \frac{m}{p^2}$   
 (E)  $2 \frac{m}{p^2}$

35. A simple pendulum consisting of a small object of mass  $m$  attached to a string of length  $\ell$  has a period  $T$ . A pendulum with which of the following combinations of object mass and string length will also have period  $T$ ?

Object Mass	String Length
(A) $m/2$	$\ell$
(B) $m$	$\ell/4$
(C) $\sqrt{2}m$	$\ell/\sqrt{2}$
(D) $2m$	$4\ell$
(E) $4m$	$2\ell$

Item 36 was not scored.

### Questions 37-38



Helium gas is flowing steadily through the pipe shown above. The diameter of the pipe at the left end is  $2.00 \times 10^{-2}$  m and at the right is  $1.00 \times 10^{-2}$  m. The flow is slow enough that the density of the gas remains essentially constant. The volume flow rate is  $2.00 \times 10^{-3} \text{ m}^3/\text{s}$ .

37. The speed of the gas in the right end of the pipe is how many times the speed in the left end?
- (A)  $1/4$   
 (B)  $1/2$   
 (C)  $1$   
 (D)  $2$   
 (E)  $4$
38. What is the speed of the gas in the left end of the pipe?
- (A)  $4 \times 10^{-5} \text{ m/s}$   
 (B)  $0.10 \text{ m/s}$   
 (C)  $0.20 \text{ m/s}$   
 (D)  $\frac{5}{\pi} \text{ m/s}$   
 (E)  $\frac{20}{\pi} \text{ m/s}$

39. The pressure exerted on the bottom of a dam by the water in the reservoir created by the dam depends on the

(A) shape of the dam  
 (B) area of the dam  
 (C) depth of the water at the dam  
 (D) surface area of the reservoir  
 (E) shape of the bottom of the reservoir

40. A 3.0 kg block hanging from a spring scale is submerged in a beaker of water until the spring scale reads 20 N. What is the buoyant force on the block?

(A) 10 N  
 (B) 17 N  
 (C) 37 N  
 (D) 50 N  
 (E) It cannot be determined without knowing the dimensions of the block.

41. A planet of mass  $m$  orbits a star of mass  $M$ , where  $m \ll M$ . The orbit is circular, its radius is  $r$ , and its period is  $T$ . True statements about the planet's orbit include which of the following?

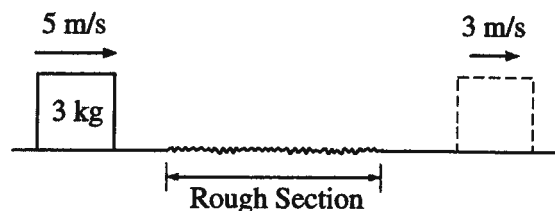
I. The orbital speed equals  $\frac{2\pi r}{T}$ .

II. The gravitational force equals  $\frac{GMm}{r^2}$ .

III. If the orbital radius  $r$  were greater,  $T$  would also be greater.

(A) I only  
 (B) II only  
 (C) I and III only  
 (D) II and III only  
 (E) I, II, and III

## Questions 42-43



A block of mass 3 kg slides along a horizontal surface that has negligible friction except for one section, as shown above. The block arrives at the rough section with a speed of 5 m/s and leaves it 0.5 s later with a speed of 3 m/s.

42. What is the magnitude of the work done by the frictional force exerted on the block by the rough section of the surface?

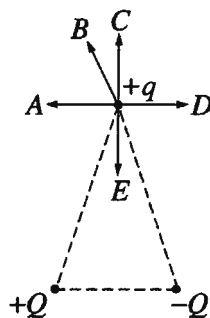
(A) 24 J  
 (B) 16 J  
 (C) 8 J  
 (D) 6 J  
 (E) 3 J

43. What is the magnitude of the average frictional force exerted on the block by the rough section of the surface?

(A) 30 N  
 (B) 12 N  
 (C) 4.5 N  
 (D) 4 N  
 (E) 3 N

44. An object attached to one end of a string moves in a circle at constant speed. Which of the following is correct?

- (A) The object is accelerating as it moves.
- (B) The object's velocity is the same as its speed.
- (C) The object does not require a force to keep its state of circular motion.
- (D) If the string breaks, the object will keep its circular motion.
- (E) If the string breaks, the object will move radially away from the center of the circle.

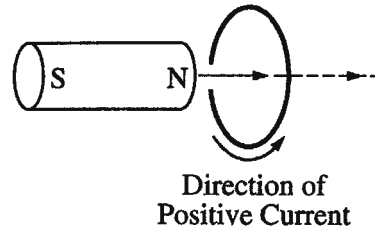


45. Three point charges,  $+q$ ,  $+Q$ , and  $-Q$ , are fixed at the corners of an isosceles triangle in the plane of the page, as shown above. Which arrow in the figure represents the direction of the net electrostatic force on charge  $+q$  due to the other two equal and opposite charges?

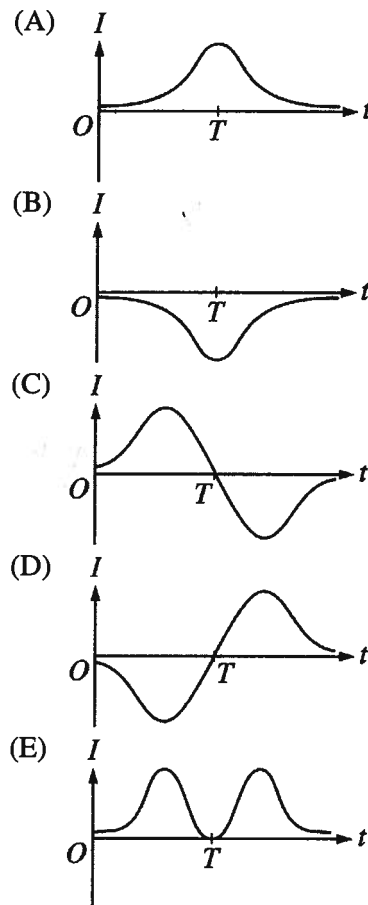
- (A) A
- (B) B
- (C) C
- (D) D
- (E) E

46. The magnetic flux for each turn of a 20-turn coil decreases from  $0.30 \text{ T} \cdot \text{m}^2$  to zero in 2 s. The emf induced in the coil is most nearly

- (A) 2 V
- (B) 3 V
- (C) 6 V
- (D) 9 V
- (E) 12 V



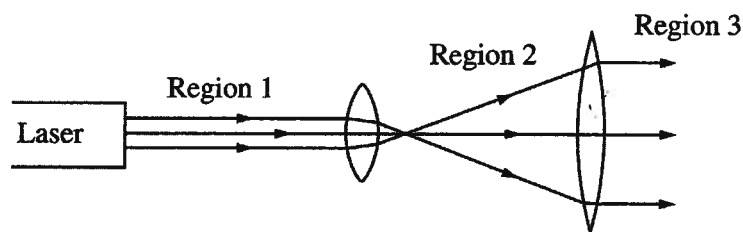
47. The magnet shown above is initially far away from the conducting loop and is moved at constant speed toward and completely through the loop. If  $T$  is the time at which the magnet is halfway through the loop, which of the following graphs best represents the induced current  $I$  in the loop as a function of time  $t$ ?



48. The index of refraction of air increases linearly with its density. A ray of light passes through an interface from vacuum into air. Statements that are true as the air is heated at constant pressure include which of the following?

- I. The frequency of refracted light in the air decreases.
- II. The wavelength of refracted light in the air decreases.
- III. The speed of light in the air increases.

- (A) II only
- (B) III only
- (C) I and II
- (D) II and III
- (E) I, II, and III



49. As shown above, two lenses are arranged so that a narrow laser beam of parallel rays spreads into a wider beam of parallel rays. If the lenses are interchanged, the light in region 3 will be a beam of

- (A) parallel rays narrower than the beam in region 1
- (B) parallel rays wider than the beam in region 1
- (C) parallel rays about the same width as in region 1
- (D) diverging rays
- (E) converging rays

50. Traveling waves are generated on a string fixed at both ends. The string has a length  $L$ , a linear mass density  $\mu$ , and a tension  $T$ . Which of the following will cause the wave speed to increase?

- I. Using the same string but increasing the tension
- II. Using a longer string with the same  $\mu$  and  $T$
- III. Using a string with the same  $L$  and  $T$  but a smaller  $\mu$

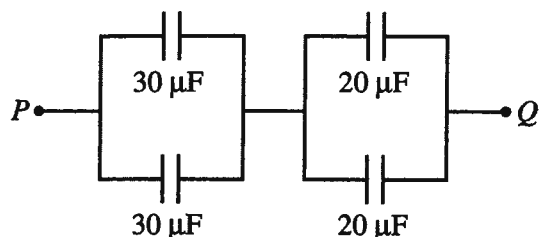
- (A) I only
- (B) II only
- (C) III only
- (D) I or II
- (E) I or III

51. The wavelength of yellow sodium light in vacuum is approximately  $6.0 \times 10^{-7}$  m. The frequency of the light is most nearly

- (A)  $2.0 \times 10^{-15}$  Hz
- (B) 1.8 Hz
- (C)  $1.8 \times 10^2$  Hz
- (D)  $1.7 \times 10^6$  Hz
- (E)  $5.0 \times 10^{14}$  Hz

52. When a voltage  $V$  is connected across a capacitor of capacitance  $C$ , charges of equal magnitude  $Q$  and opposite sign are on the plates, and the energy stored in the capacitor is  $U$ . If  $C$  is doubled and  $V$  is not changed, how are  $Q$  and  $U$  affected?

- | $Q$             | $U$         |
|-----------------|-------------|
| (A) Halved      | Halved      |
| (B) Halved      | Quartered   |
| (C) Not changed | Not changed |
| (D) Doubled     | Doubled     |
| (E) Doubled     | Quadrupled  |



53. In the diagram above, what is the equivalent capacitance between points  $P$  and  $Q$ ?

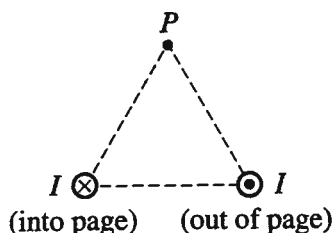
- (A)  $6\ \mu\text{F}$
- (B)  $24\ \mu\text{F}$
- (C)  $25\ \mu\text{F}$
- (D)  $50\ \mu\text{F}$
- (E)  $100\ \mu\text{F}$

54. Two skaters are initially at rest next to each other on frictionless ice. Skater A pushes on skater B. If skater A has greater mass than skater B, which of the following correctly relates the magnitudes of their momentums  $p$  and their kinetic energies  $K$  after the push?





- (A)  $p_A = p_B$  and  $K_A < K_B$
- (B)  $p_A = p_B$  and  $K_A = K_B$
- (C)  $p_A = p_B$  and  $K_A > K_B$
- (D)  $p_A < p_B$  and  $K_A < K_B$
- (E)  $p_A < p_B$  and  $K_A = K_B$

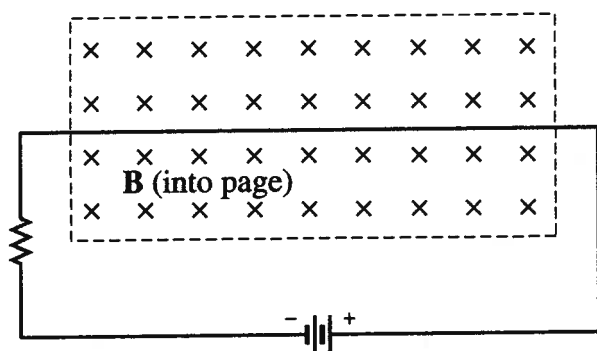
55. Which of the following is true of the conservation of momentum and kinetic energy?

- (A) Momentum is conserved only in elastic collisions.
- (B) Momentum is conserved only in inelastic collisions.
- (C) Kinetic energy is conserved only in elastic collisions.
- (D) Kinetic energy is conserved only in inelastic collisions.
- (E) Both require the same conditions in order to be conserved.



56. Current  $I$  flows into and out of the page in two parallel, long, straight wires that are fixed at two vertices of an equilateral triangle, as shown above. The net magnetic field at the third vertex (point  $P$ ) due to these currents is in which of the following directions?

- (A)   
 (B)   
 (C)   
 (D)   
 (E) None of the above



57. One section of wire in the circuit above lies in a region containing a magnetic field  $B$  directed into the page. The magnetic force on the section of wire is directed

- (A) into the page  
 (B) toward the right  
 (C) toward the left  
 (D) toward the top of the page  
 (E) toward the bottom of the page

58. A student wants to determine experimentally, without disconnecting any wires in the circuit, the DC current moving through a copper wire. Which of the following items of laboratory equipment would be sufficient to make the necessary measurements for this determination?

- (A) Magnetic field sensor only  
 (B) Magnetic field sensor and meterstick  
 (C) Bar magnet and meterstick  
 (D) Stopwatch and meterstick  
 (E) Voltmeter and ammeter

59. A force of constant magnitude  $F$  and fixed direction acts on an object of mass  $m$  that is initially at rest. If the force acts for a time interval  $\Delta t$  over a displacement  $\Delta x$ , what is the magnitude of the resultant change in the linear momentum of the object?

- (A)  $F \Delta t$   
 (B)  $F \Delta x$   
 (C)  $\frac{F \Delta t}{m}$   
 (D)  $\frac{F \Delta x}{m}$   
 (E)  $mF \Delta t$

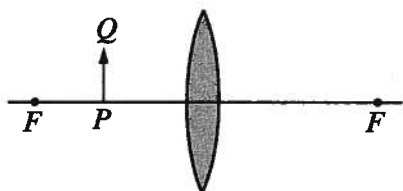
60. A ball is thrown with an initial speed of 20 m/s at an angle of  $60^\circ$  to the ground. If air resistance is negligible, what is the ball's speed at the instant it reaches its maximum height from the ground?

- (A) Zero  
 (B) 10 m/s  
 (C) 14 m/s  
 (D) 17 m/s  
 (E) 20 m/s

61. The maximum energy of photoelectrons emitted from a metal surface depends on which of the following?

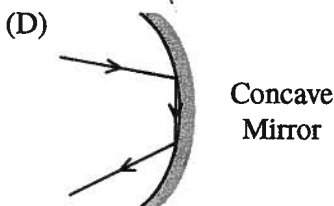
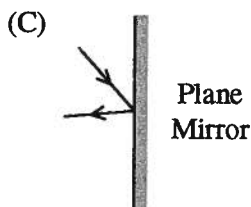
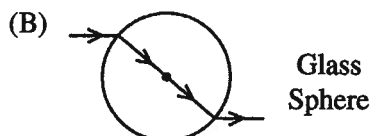
I. The intensity of the incident light  
 II. The frequency of the incident light  
 III. The work function of the metal

- (A) I only  
 (B) III only  
 (C) I and II only  
 (D) II and III only  
 (E) I, II, and III
62. For the hydrogen atom, how does the potential energy  $U$  of the atom change as the energy level  $n$  increases?
- (A) The potential energy always increases.  
 (B) The potential energy always decreases.  
 (C) The potential energy increases, then decreases.  
 (D) The potential energy decreases, then increases.  
 (E) The potential energy does not change.
63. The present theory of the nature of light suggests that it
- (A) is a wave only  
 (B) consists of particles only  
 (C) is a mixture of both waves and particles  
 (D) exhibits either wave or particle properties depending on the situation  
 (E) exhibits neither wave nor particle properties



64. An object  $PQ$  is located to the left of a converging lens having focal points  $F$ , as shown in the figure above. The image formed by the lens is
- (A) real, inverted, and smaller than the object  
 (B) real, inverted, and larger than the object  
 (C) real, upright, and larger than the object  
 (D) virtual, upright, and larger than the object  
 (E) virtual, upright, and smaller than the object

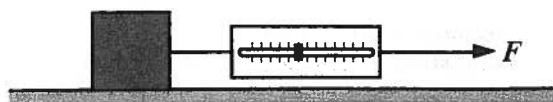
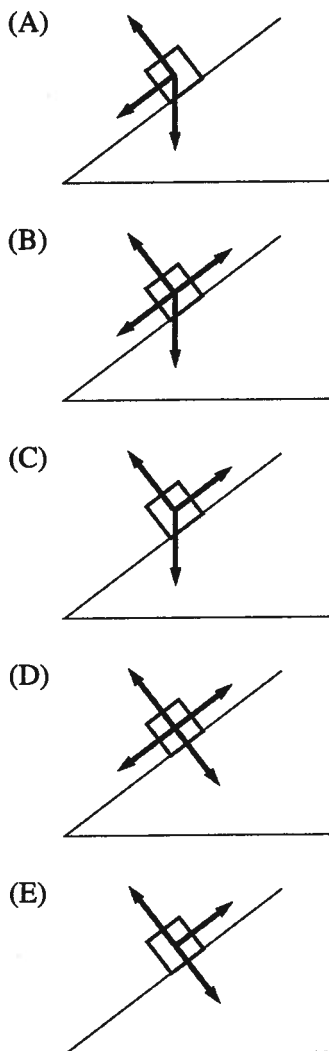
65. A student working with glass objects and silvered mirrors traces light rays in the laboratory. Which of the following ray tracings is drawn most correctly?



66. Young's double-slit experiment is performed with a pair of slits separated by a distance  $d$ . A screen is a distance  $L$  away from the slits, and the distance from the central maximum to the  $n$ th bright fringe is  $x$ . What is the wavelength of this light?

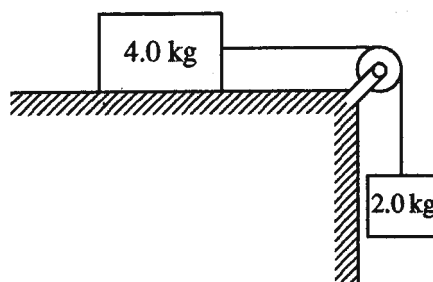
- (A)  $nxdL$   
 (B)  $\frac{xd}{nL}$   
 (C)  $\frac{nL}{xd}$   
 (D)  $\frac{L}{nxd}$   
 (E)  $\frac{nxd}{L}$

67. A box is given a sudden push up a ramp. Friction between the box and the ramp is not negligible. Which of the following diagrams best represents the directions of the actual forces acting on the box as it moves upward after the push?



68. In a lab, a block weighing 80 N is attached to a spring scale, and both are pulled to the right on a horizontal surface, as shown above. Friction between the block and the surface is negligible. What is the acceleration of the block when the scale reads 32 N?

- (A)  $2.0 \text{ m/s}^2$   
 (B)  $2.5 \text{ m/s}^2$   
 (C)  $4.0 \text{ m/s}^2$   
 (D)  $6.0 \text{ m/s}^2$   
 (E)  $8.0 \text{ m/s}^2$



69. The system shown above is released from rest. If friction is negligible, the acceleration of the 4.0 kg block sliding on the table shown above is most nearly

- (A) 0  
 (B)  $1.7 \text{ m/s}^2$   
 (C)  $3.3 \text{ m/s}^2$   
 (D)  $5.0 \text{ m/s}^2$   
 (E)  $10.0 \text{ m/s}^2$

70. A small car with mass  $m$  and speed  $2v$  and a large car with mass  $2m$  and speed  $v$  both travel the same circular section of an unbanked road. If the frictional force required to keep the small car on the road without skidding is  $F$ , then the frictional force required to keep the large car on the road without skidding is

- (A)  $4F$   
 (B)  $2F$   
 (C)  $F$   
 (D)  $F/2$   
 (E)  $F/4$



# Chapter III: Answers to the 2009 AP Physics B Exam

## ■ Section I: Multiple Choice

- Section I Answer Key and Percent Answering Correctly
- Analyzing Your Students' Performance on the Multiple-Choice Section
- Diagnostic Guide for the 2009 AP Physics B Exam

## ■ Section II: Free Response

- Comments from the Chief Reader
- Scoring Guidelines, Sample Student Responses, and Commentary

## Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions, the percent of AP students who answered each question correctly by AP score, and the total percent answering correctly.

### Section I Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
1	B	98	95	92	88	79	90
2	B	91	68	40	19	12	42
3	E	98	90	74	47	18	63
4	E	99	93	80	60	34	71
5	C	97	92	82	69	48	76
6	D	92	83	71	57	36	66
7	B	96	90	83	75	55	78
8	E	76	70	63	57	46	61
9	C	88	81	70	55	31	63
10	C	46	35	31	23	15	29
11	D	88	69	49	35	30	52
12	C	83	73	63	52	38	60
13	D	83	55	31	17	10	36
14	D	89	75	61	51	39	61
15	C	80	67	59	53	45	59
16	E	90	79	64	46	26	59
17	D	90	77	56	33	12	51
18	C	61	43	32	22	15	33
19	D	23	25	23	20	14	21
20	D	86	65	42	24	12	42
21	E	77	65	50	33	16	46
22	E	84	68	52	37	20	50
23	C	66	51	43	39	32	45
24	D	63	38	25	17	12	29
25	C	92	82	69	57	37	65

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
26	D	93	82	66	45	24	60
27	C	85	75	66	53	41	62
28	C	89	77	63	48	27	58
29	A	88	70	54	39	24	52
30	C	79	52	31	19	14	36
31	C	89	77	64	51	34	61
32	B	90	78	62	44	25	58
33	A	84	61	44	40	34	50
34	A	98	93	78	54	26	68
35	A	83	61	37	19	13	39
36*	—	—	—	—	—	—	—
37	E	72	49	32	19	10	33
38	E	59	34	16	7	5	21
39	C	86	75	64	55	42	63
40	A	96	89	76	56	26	66
41	E	81	65	50	38	21	49
42	A	82	62	38	19	10	39
43	B	87	68	47	28	18	47
44	A	91	80	64	43	21	58
45	D	94	85	70	49	22	62
46	B	79	50	29	19	13	35
47	C	40	28	24	23	22	27
48	B	41	23	17	15	14	20
49	A	38	26	20	15	11	21
50	E	60	49	43	35	21	40

\*Although 70 multiple-choice items were administered in Section I, item #36 was not used in scoring.

*continued on next page*

## Section I Answer Key and Percent Answering Correctly (continued)

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
51	E	94	75	49	23	9	47
52	D	75	54	37	24	15	38
53	B	89	71	47	24	11	45
54	A	77	57	40	26	16	41
55	C	81	58	37	23	16	40
56	A	68	46	31	23	17	35
57	E	79	60	41	26	13	41
58	B	45	23	13	9	12	18
59	A	85	63	36	18	9	39
60	B	75	52	31	19	15	35

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
61	D	83	57	33	18	11	37
62	A	53	39	30	24	18	31
63	D	83	74	62	49	29	58
64	D	69	49	35	24	16	36
65	E	35	19	14	13	12	17
66	B	68	40	22	14	12	28
67	A	69	53	38	24	18	38
68	C	89	78	65	48	27	59
69	C	51	27	15	10	12	21
70	D	68	43	25	17	15	31

### Analyzing Your Students' Performance on the Multiple-Choice Section

If you give your students the 2009 exam for practice, you may want to analyze the results to find overall strengths and weaknesses in their understanding of AP Physics B. The following diagnostic worksheet will help you do this. You are permitted to photocopy it and distribute it to your students for completion.

1. In each section, students should insert a check mark for each correct answer.
2. Add together the total number of correct answers for each section.

3. To compare the student's number of correct answers for each section with the average number correct for that section, copy the number of correct answers to the "Number Correct" table at the end of the Diagnostic Guide.

In addition, under each question, the percent of AP students who answered correctly is shown, so students can analyze their performance on individual questions. This information will be helpful in deciding how students should plan their study time.