CollegeBoard
Advanced Placement
Program

AP® Physics B

Practice Exam

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TABLE OF INFORMATION FOR 2008 and 2009

CONSTANTS AND CONVERSION FACTORS

Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, 1 eV $= 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg·s^2
Universal gas constant, $R = 8.31$ J/(mol·K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}$ kg $= 931$ MeV/c^2
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s $= 4.14 \times 10^{-15}$ eV·s
	$hc = 1.99 \times 10^{-25}$ J·m $= 1.24 \times 10^{3}$ eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/N·m^2
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ N·m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}$ (T·m)/A
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^{5}$ N/m^2 $= 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron-volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan\theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

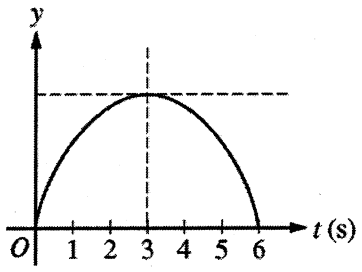
IV. For mechanics and thermodynamics equations, W represents the work done on a system.

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 place the letter of your choice in the corresponding box on the student answer sheet.

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

Questions 1-4



A ball is thrown straight up by a student at rest on the surface of Earth. A graph of the position y as a function of time t, in seconds, is shown above. Air resistance is negligible.

1. At which of the following times is the ball farthest from the student?

   (A) 1 s
   (B) 2 s
   (C) 3 s
   (D) 4 s
   (E) 5 s

2. At which of the following times is the speed of the ball the least?

   (A) 1 s
   (B) 2 s
   (C) 3 s
   (D) 4 s
   (E) 5 s

3. Which of the following best describes the acceleration of the ball?

   (A) It is downward and constant from 0 to 6 s.
   (B) It is downward and increases in magnitude from 0 to 3 s, then decreases.
   (C) It is downward and decreases in magnitude from 0 to 3 s, then increases.
   (D) It is upward and increases in magnitude from 0 to 3 s, then decreases.
   (E) It is upward and decreases in magnitude from 0 to 3 s, then increases.

4. What is the initial speed of the ball?

   (A) 30 m/s
   (B) 45 m/s
   (C) 60 m/s
   (D) 90 m/s
   (E) 180 m/s

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5. Two boxes of different masses in an orbiting space station appear to float at rest—one above the other—with respect to the station. An astronaut applies the same force to both boxes. Can the boxes have the same acceleration with respect to the space station?

   (A) No, because the boxes are moving in orbits of different radius.
   (B) No, because the box of greater mass requires more force to reach the same acceleration.
   (C) Yes, because both boxes appear weightless.
   (D) Yes, because both boxes are accelerating toward Earth at the same rate.
   (E) It cannot be determined without knowing whether the boxes are being pushed parallel or perpendicular to Earth's gravity.

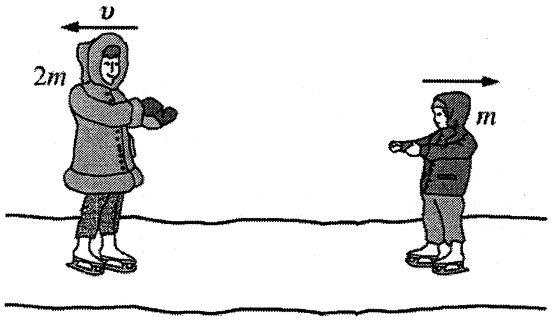
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6. An object is dropped from rest from a certain height. Air resistance is negligible. After falling a distance d, the object's kinetic energy is proportional to which of the following?

   (A) $1/d^2$
   (B) $1/d$
   (C) $\sqrt{d}$
   (D) d
   (E) d^2

7. An object is projected vertically upward from ground level. It rises to a maximum height H. If air resistance is negligible, which of the following must be true for the object when it is at a height $H/2$?

   (A) Its speed is half of its initial speed.
   (B) Its kinetic energy is half of its initial kinetic energy.
   (C) Its potential energy is half of its initial potential energy.
   (D) Its total mechanical energy is half of its initial value.
   (E) Its total mechanical energy is half of its value at the highest point.

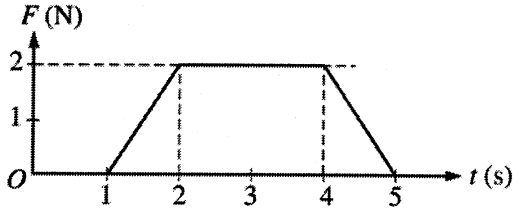


8. A boy of mass m and a girl of mass $2m$ are initially at rest at the center of a frozen pond. They push each other so that she slides to the left at speed v across the frictionless ice surface and he slides to the right as shown above. What is the total work done by the children?

   (A) Zero
   (B) mv
   (C) mv^2
   (D) $2mv^2$
   (E) $3mv^2$

9. An object of mass M travels along a horizontal air track at a constant speed v and collides elastically with an object of identical mass that is initially at rest on the track. Which of the following statements is true for the two objects after the impact?

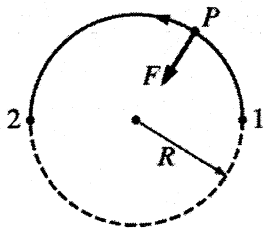
   (A) The total momentum is Mv and the total kinetic energy is $\frac{1}{2}Mv^2$.
   (B) The total momentum is Mv and the total kinetic energy is less than $\frac{1}{2}Mv^2$.
   (C) The total momentum is less than Mv and the total kinetic energy is $\frac{1}{2}Mv^2$.
   (D) The momentum of each object is $\frac{1}{2}Mv$.
   (E) The kinetic energy of each object is $\frac{1}{4}Mv^2$.



10. A 2 kg object initially moving with a constant velocity is subjected to a force of magnitude F in the direction of motion. A graph of F as a function of time t is shown above. What is the increase, if any, in the velocity of the object during the time the force is applied?

    (A) 0 m/s
    (B) 2.0 m/s
    (C) 3.0 m/s
    (D) 4.0 m/s
    (E) 6.0 m/s

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11. A particle P moves around the circle of radius R shown above under the influence of a radial force of magnitude F. What is the work done by the radial force as the particle moves from position 1 to position 2 halfway around the circle?

(A) Zero
(B) RF
(C) $2RF$
(D) πRF
(E) $2\pi RF$

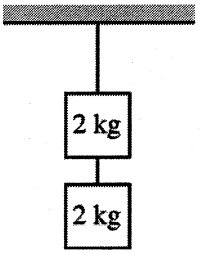
12. An object of mass m hanging from a spring of spring constant k oscillates with a certain frequency. What is the length of a simple pendulum that has the same frequency of oscillation?

(A) $\frac{mk}{g}$
(B) $\frac{mg}{k}$
(C) $\frac{kg}{m}$
(D) $\frac{k}{mg}$
(E) $\frac{g}{mk}$

13. A spherical planet has mass greater than that of Earth, but its density is unknown. The weight of an object on that planet compared with its weight on Earth is which of the following?

(A) Larger
(B) The same
(C) Smaller
(D) It cannot be determined without information about the planet's size.
(E) It cannot be determined without information about the planet's atmosphere.

Questions 14-15



Two blocks of wood, each of mass 2 kg, are suspended from the ceiling by strings of negligible mass, as shown above.

14. What is the tension in the upper string?

(A) 10 N
(B) 20 N
(C) 40 N
(D) 50 N
(E) 60 N

15. What is the force exerted on the upper block by the lower string?

(A) Zero
(B) 10 N upward
(C) 10 N downward
(D) 20 N upward
(E) 20 N downward

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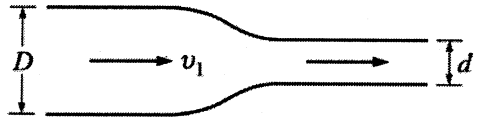
16. A vertical force of 30 N is applied uniformly to a flat button with a radius of 1 cm that is lying on a table. Which of the following is the best order of magnitude estimate for the pressure applied to the button?

(A) 10 Pa
(B) 10^2 Pa
(C) 10^3 Pa
(D) 10^4 Pa
(E) 10^5 Pa

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17. A ball that can float on water has mass 5.00 kg and volume 2.50×10^{-2} m^3. What is the magnitude of the downward force that must be applied to the ball to hold it motionless and completely submerged in freshwater of density 1.00×10^3 kg/m^3 ?

(A) 20.0 N
(B) 25.0 N
(C) 30.0 N
(D) 200 N
(E) 250 N



18. Water flows through the pipe shown above. At the larger end, the pipe has diameter D and the speed of the water is v_1. What is the speed of the water at the smaller end, where the pipe has diameter d?

(A) v_1
(B) $\left(\frac{d}{D}\right)v_1$
(C) $\left(\frac{D}{d}\right)v_1$
(D) $\left(\frac{d^2}{D^2}\right)v_1$
(E) $\left(\frac{D^2}{d^2}\right)v_1$

19. The floor of a building is made from a square, solid piece of concrete. When the temperature of the floor increases from 20°C to 28°C, each side of the square expands by 0.4 cm. If the temperature of the floor were to decrease from 20°C to 8°C, by how much would each side of the square contract?

(A) 0.2 cm
(B) 0.4 cm
(C) 0.6 cm
(D) 1.0 cm
(E) It cannot be determined without knowing the coefficient of linear expansion of the concrete.

20. The temperature of an ideal gas is directly proportional to which of the following?

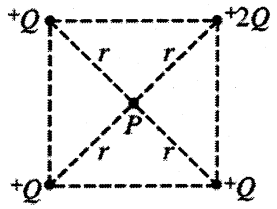
(A) Average translational kinetic energy of the molecules
(B) Average velocity of the molecules
(C) Average potential energy of the molecules
(D) Average momentum of the molecules
(E) None of the above

21. A heat engine operates in a cycle between temperatures 700 K and 400 K. The heat input to the engine during each cycle is 2800 J. What is the maximum possible work done by the engine in each cycle?

(A) 1200 J
(B) 1600 J
(C) 2100 J
(D) 2800 J
(E) 4400 J

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Questions 22-23



Four positive charges are fixed at the corners of a square, as shown above. Three of the charges have magnitude Q, and the fourth charge has a magnitude $2Q$. Point P is at the center of the square at a distance r from each charge.

22. What is the electric potential at point P ?

(A) Zero

(B) $\frac{kQ}{r}$

(C) $\frac{2kQ}{r}$

(D) $\frac{4kQ}{r}$

(E) $\frac{5kQ}{r}$

23. What is the magnitude of the electric field at point P ?

(A) Zero

(B) $\frac{kQ}{r^2}$

(C) $\frac{2kQ}{r^2}$

(D) $\frac{4kQ}{r^2}$

(E) $\frac{5kQ}{r^2}$

24. Conducting sphere X is initially uncharged. Conducting sphere Y has twice the diameter of sphere X and initially has charge q. If the spheres are connected by a long thin wire, which of the following is true once equilibrium has been reached?

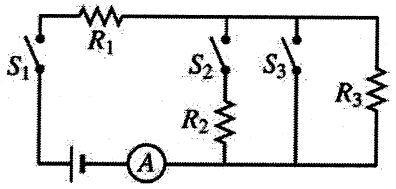
(A) Sphere Y has half the potential of sphere X.
(B) Spheres X and Y have the same potential.
(C) Sphere Y has twice the potential of sphere X.
(D) Sphere Y has half the charge of sphere X.
(E) Spheres X and Y have the same charge.

25. If the separation between the plates of an isolated charged parallel-plate capacitor is increased slightly, which of the following also increases?

(A) The capacitance
(B) The stored electrostatic energy
(C) The force of attraction between the plates
(D) The magnitude of the charge on each plate
(E) The magnitude of the electric field in the region between the plates

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Questions 26-28



In the circuit above, the resistors all have the same resistance. The battery, wires, and ammeter have negligible resistance. A closed switch also has negligible resistance.

26. Closing which of the switches will produce the greatest power dissipation in R_2 ?

(A) S_1 only
(B) S_2 only
(C) S_1 and S_2 only
(D) S_1 and S_3 only
(E) S_1, S_2, and S_3

27. Closing which of the switches will produce the greatest reading on the ammeter?

(A) S_1 only
(B) S_2 only
(C) S_3 only
(D) S_1 and S_2
(E) S_1 and S_3

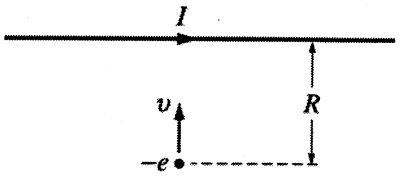
28. Closing which of the switches will produce the greatest voltage across R_3 ?

(A) S_1 only
(B) S_2 only
(C) S_1 and S_2 only
(D) S_1 and S_3 only
(E) S_1, S_2, and S_3

29. Two cables can be used to wire a circuit. Cable A has a lower resistivity, a larger diameter, and a different length than cable B. Which cable should be used to minimize heat loss if the same current is maintained in either cable?

(A) Cable A
(B) Cable B
(C) The heat loss is the same for both.
(D) It cannot be determined without knowing the length of each cable.
(E) It cannot be determined without knowing the materials contained in each cable.

Questions 30-31



An electron of charge $-e$ and a long straight wire carrying a current I to the right are both in the plane of the page, as shown above. In the position shown, the electron is a distance R from the wire and is moving directly toward it with speed v.

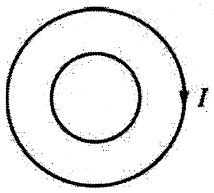
30. What is the direction of the magnetic force on the electron when it is in this position?

(A) Toward the bottom of the page
(B) Into the plane of the page
(C) Out of the plane of the page
(D) To the left
(E) To the right

31. What is the magnitude of the magnetic force on the electron when it is in this position?

(A) $\frac{\mu_0}{2\pi}\frac{Iev}{R}$
(B) $\frac{\mu_0}{2\pi}\frac{I^2ev}{R}$
(C) $\frac{\mu_0}{2\pi}\frac{Ie^2v}{R}$
(D) $\frac{\mu_0}{2\pi}\frac{Iev^2}{R}$
(E) $\frac{\mu_0}{2\pi}\frac{Iev}{R^2}$

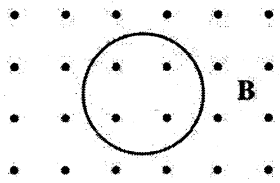
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32. Two concentric, circular wire loops lie in the same plane, as shown above. The current I in the outer loop is clockwise and increasing with time. The induced current in the inner loop is

(A) zero
(B) clockwise
(C) counterclockwise
(D) alternating between clockwise and counterclockwise
(E) either clockwise or counterclockwise, depending on the ratio of the radii of the loops

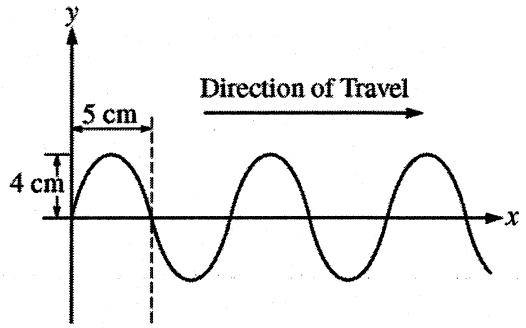
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33. A uniform magnetic field **B** is directed out of the page, as shown above. A loop of wire of area $0.40\ m^2$ is in the plane of the page. At a certain instant the field has a magnitude of 3.0 T and is decreasing at the rate of 0.50 T/s. The magnitude of the induced emf in the wire loop at this instant is most nearly

(A) 0.20 V
(B) 0.60 V
(C) 1.2 V
(D) 1.5 V
(E) 2.8 V

Questions 34-35



The figure above shows a transverse wave traveling to the right at a particular instant of time. The period of the wave is 0.2 s.

34. What is the amplitude of the wave?

(A) 4 cm
(B) 5 cm
(C) 8 cm
(D) 10 cm
(E) 16 cm

35. What is the speed of the wave?

(A) 4 cm/s
(B) 25 cm/s
(C) 50 cm/s
(D) 100 cm/s
(E) 200 cm/s

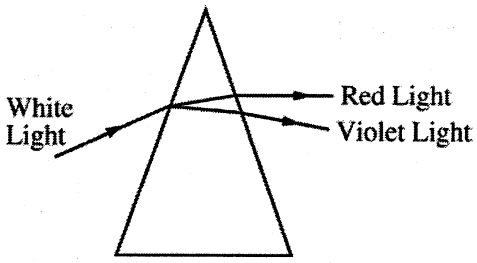
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36. Which of the following statements are true for both sound waves and electromagnetic waves?

I. They can undergo refraction.
II. They can undergo diffraction.
III. They can produce a two-slit interference pattern.
IV. They can produce standing waves.

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

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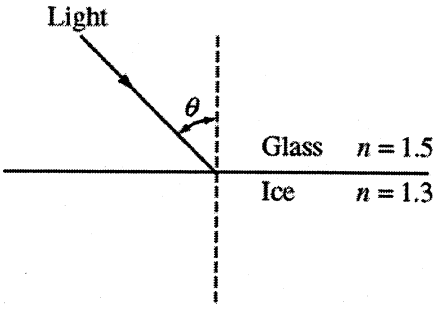


37. As shown above, a beam of white light is separated into separate colors when it passes through a glass prism. Red light is refracted through a smaller angle than violet light because red light has a

(A) slower speed in glass than violet light
(B) faster speed in glass than violet light
(C) slower speed in the incident beam than violet light
(D) faster speed in the incident beam than violet light
(E) greater intensity than violet light

38. If one of the two slits in a Young's double-slit demonstration of the interference of light is covered with a thin filter that transmits only half the light intensity, which of the following occurs?

(A) The fringe pattern disappears.
(B) The bright lines are brighter and the dark lines are darker.
(C) The bright lines and the dark lines are all darker.
(D) The bright lines and the dark lines are all brighter.
(E) The dark lines are brighter and the bright lines are darker.

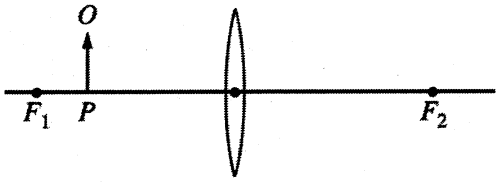


39. A ray of light in glass that is incident on an interface with ice, as shown above, is partially reflected and partially refracted. The index of refraction n for each of the two media is given in the figure. How do the angle of reflection and the angle of refraction compare with the angle of incidence θ?

	Angle of Reflection	Angle of Refraction
(A)	Same	Larger
(B)	Same	Smaller
(C)	Smaller	Same
(D)	Smaller	Smaller
(E)	Larger	Larger

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Questions 40-41



An object O is located at point P to the left of a converging lens, as shown in the figure above. F_1 and F_2 are the focal points of the lens.

40. If the focal length of the lens is 0.40 m and point P is 0.30 m to the left of the lens, where is the image of the object located?

(A) 1.2 m to the left of the lens
(B) 0.17 m to the left of the lens
(C) At the lens
(D) 0.17 m to the right of the lens
(E) 1.2 m to the right of the lens

41. Which of the following characterizes the image when the object is in the position shown?

(A) Real, inverted, and smaller than the object
(B) Real, upright, and larger than the object
(C) Real, inverted, and larger than the object
(D) Virtual, upright, and larger than the object
(E) Virtual, upright, and smaller than the object

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42. The work function for a metal is ϕ. What is the threshold frequency of incident light required for the emission of photoelectrons from a cathode made of that metal?

(A) $\frac{\phi}{h}$

(B) $\frac{h}{\phi}$

(C) ϕh

(D) $\frac{\phi}{hc}$

(E) $\frac{hc}{\phi}$

43. Two monochromatic light beams, one red and one green, have the same intensity and the same cross-sectional area. How does the energy of each photon and the number of photons crossing a unit area per second in the red beam compare with those of the green beam?

	Energy of Photon	Number of Photons Crossing Unit Area per Second
(A)	Same	Same
(B)	Greater for red	Less for red
(C)	Greater for red	Greater for red
(D)	Less for red	Less for red
(E)	Less for red	Greater for red

44. $^{226}_{88}\mathrm{Ra}$ decays into $^{222}_{86}\mathrm{Rn}$ plus

(A) a proton
(B) a neutron
(C) an electron
(D) a helium nucleus $\left(^{4}_{2}\mathrm{He}\right)$
(E) a deuteron $\left(^{2}_{1}\mathrm{H}\right)$

45. In any physically correct equation, the units of any two quantities must be the same whenever these quantities are

(A) added or multiplied only
(B) subtracted or divided only
(C) multiplied or divided only
(D) added or subtracted only
(E) added, subtracted, multiplied, or divided

46. On a day when the speed of sound is 340 m/s, a ship sounds its whistle. The echo of the sound from the shore is heard at the ship 6.0 s later. How far is the ship from the shore?

(A) 56.7 m
(B) 113 m
(C) 1020 m
(D) 2040 m
(E) 4080 m

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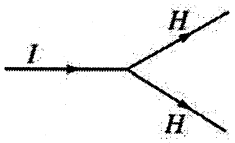
47. An isolated pair of charged particles X and Y, with masses m_X and $m_Y = 2m_X$, repel one another. The electrostatic force is the only force between them. If particle X accelerates at $2.2\ \text{m/s}^2$, what is the acceleration of particle Y?

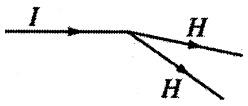
(A) $0\ \text{m/s}^2$
(B) $0.55\ \text{m/s}^2$
(C) $1.1\ \text{m/s}^2$
(D) $2.2\ \text{m/s}^2$
(E) $4.4\ \text{m/s}^2$

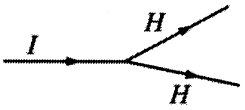
48. An object initially at rest is subjected to a constant net force. Measurements are taken of its velocity v at different distances d from the starting position. A graph of which of the following should exhibit a straight-line relationship?

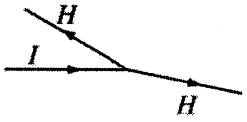
(A) d^2 versus v^{-2}
(B) d^2 versus v
(C) d versus v
(D) d versus v^{-1}
(E) d versus v^2

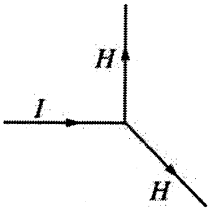
49. A disk slides to the right on a horizontal, frictionless air table and collides with another disk that was initially stationary. The figures below show a top view of the initial path I of the sliding disk and a hypothetical path H for each disk after the collision. Which figure shows an impossible situation?

(A)


(B)


(C)


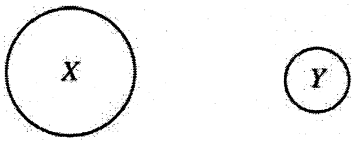
(D)


(E)


50. A meterstick of negligible mass is placed on a fulcrum at the 0.60 m mark, with a 2.0 kg mass hung at the 0 m mark and a 1.0 kg mass hung at the 1.0 m mark. The meterstick is released from rest in a horizontal position. Immediately after release, the magnitude of the net torque on the meterstick about the fulcrum is most nearly

(A) 2.0 N·m
(B) 8.0 N·m
(C) 10 N·m
(D) 14 N·m
(E) 16 N·m

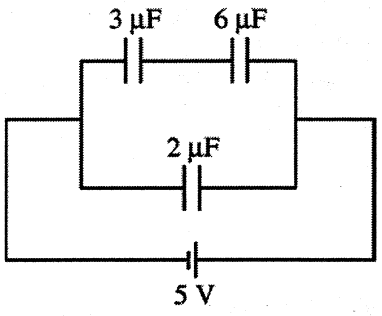
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51. The two charged metal spheres X and Y shown above are far apart, and each is isolated from all other charges. The radius of sphere X is greater than that of sphere Y, and the magnitudes of the electric fields just outside their surfaces are the same. How does the charge on sphere X compare with that on sphere Y?

(A) It is greater.
(B) It is less.
(C) It is the same.
(D) It cannot be determined without knowing the actual radii of the spheres.
(E) It cannot be determined without knowing the actual value of the electric field just outside the spheres.

Questions 52-53



Three capacitors are connected to a 5 V source, as shown in the circuit diagram above.

52. The equivalent capacitance for the circuit is

(A) $\frac{1}{11}$ μF
(B) $\frac{11}{18}$ μF
(C) 1 μF
(D) 4 μF
(E) 11 μF

53. How do the charge Q_3 stored in the 3 μF capacitor and the voltage V_3 across it compare with those of the 6 μF capacitor?

	Charge	Voltage
(A)	$Q_3 < Q_6$	$V_3 = V_6$
(B)	$Q_3 = Q_6$	$V_3 < V_6$
(C)	$Q_3 = Q_6$	$V_3 > V_6$
(D)	$Q_3 > Q_6$	$V_3 = V_6$
(E)	$Q_3 > Q_6$	$V_3 > V_6$

GO ON TO THE NEXT PAGE.

54. An ion with a charge $+Q$ moves with constant speed v in a circular path of radius R in a uniform magnetic field of magnitude B. What is the mass of the ion?

(A) $\frac{2QB}{v}$

(B) $\frac{QBR}{v}$

(C) $\frac{2QB}{v^2}$

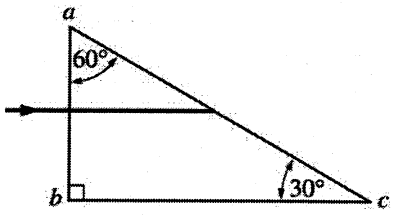
(D) $\frac{QBR}{v^2}$

(E) $\frac{2QBR}{v^2}$

55. A standing wave pattern is created on a guitar string as a person tunes the guitar by changing the tension in the string. Which of the following properties of the waves on the string will change as a result of adjusting only the tension in the string?

I. Speed of the traveling wave that creates the pattern
II. Frequency of the standing wave
III. Wavelength of the standing wave

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



56. A ray of light in air is incident on a 30°-60°-90° prism, perpendicular to face ab, as shown in the diagram above. The ray enters the prism and strikes face ac at the critical angle. What is the index of refraction of the prism?

(A) $\frac{1}{2}$

(B) $\sqrt{\frac{3}{2}}$

(C) $\frac{2\sqrt{3}}{3}$

(D) 2

(E) 3

57. Correct statements about the binding energy of a nucleus include which of the following?

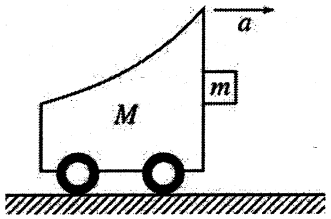
I. It is the energy needed to separate the nucleus into its individual protons and neutrons.
II. It is the energy liberated when the nucleus is formed from the original nucleons.
III. It is the energy equivalent of the apparent loss of mass of its nucleon constituents.

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

58. A car of mass 900 kg is traveling at 20 m/s when the brakes are applied. The car then comes to a complete stop in 5 s. What is the average power that the brakes produce in stopping the car?

(A) 1800 W
(B) 3600 W
(C) 7200 W
(D) 36,000 W
(E) 72,000 W

GO ON TO THE NEXT PAGE.



59. The figure above shows a cart of mass M accelerating to the right with a block of mass m held to the front surface only by friction. The coefficient of friction between the surfaces is μ. What is the minimum acceleration a of the cart such that the block will not fall?

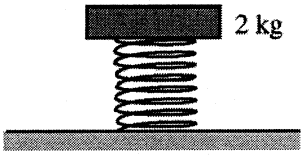
(A) μg

(B) $\frac{g}{\mu}$

(C) $\frac{gm}{\mu(M+m)}$

(D) $\frac{gM}{\mu(M+m)}$

(E) $\frac{\mu gM}{M+m}$



60. A platform of mass 2 kg is supported by a spring of negligible mass as shown above. The platform oscillates with a period of 3 s when the platform is pushed down and released. What must be the mass of a block that when placed on the platform doubles the period of oscillation to 6 s?

(A) 1 kg
(B) 2 kg
(C) 4 kg
(D) 6 kg
(E) 8 kg

61. The acceleration of a satellite of mass m in a circular orbit of radius R around a planet of mass M is equal to which of the following?

(A) $G\frac{M}{R^2}$

(B) $G\frac{m}{R^2}$

(C) $G\frac{mM}{R^2}$

(D) $G\frac{mM}{R}$

(E) $GmMR$

62. Two identical containers hold two different ideal gases, X and Y, at the same temperature. The number of moles of each gas is the same. The molecular mass of gas X is twice that of gas Y. The ratio of the pressure of X to that of Y is

(A) 1/2
(B) 1
(C) $\sqrt{2}$
(D) 2
(E) 4

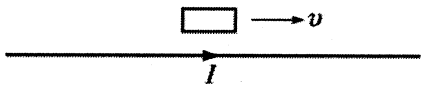
63. If three resistors with unequal resistance are connected in parallel in a DC circuit, which of the following is true of the total resistance?

(A) It is higher than the value of the highest resistance.
(B) It is equal to the middle resistance.
(C) It is equal to the average of the three resistances.
(D) It is lower than the value of the lowest resistance.
(E) It cannot be determined without knowing the emf applied across the combination.

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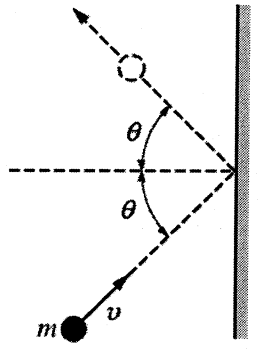
64. A tuning fork is used to create standing waves in a tube open at the top and partially filled with water. A resonance is heard when the water level is at a certain height. The next resonance is heard when the water level has been lowered by 0.5 m. If the speed of sound is equal to 340 m/s, the frequency of the tuning fork is

(A) 170 Hz
(B) 226 Hz
(C) 340 Hz
(D) 680 Hz
(E) 2450 Hz



65. A rectangular loop of wire moves at constant speed v parallel to a long wire carrying a current I, as shown above. Which of the following describes the current, if any, induced in the loop?

(A) A constant clockwise current
(B) A constant counterclockwise current
(C) An increasing current
(D) A decreasing current
(E) No current



66. A ball of mass m with speed v strikes a wall at an angle θ with the normal, as shown above. It then rebounds with the same speed and at the same angle. The impulse delivered by the ball to the wall is

(A) zero
(B) $mv\sin\theta$
(C) $mv\cos\theta$
(D) $2mv\sin\theta$
(E) $2mv\cos\theta$

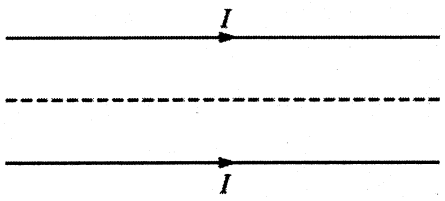
67. In an x-ray tube, electrons striking a target are brought to rest, causing x-rays to be emitted. In a particular x-ray tube, the maximum frequency of the emitted continuum x-ray spectrum is f_0. If the voltage across the tube is doubled, the maximum frequency is

(A) $\frac{f_0}{2}$
(B) $\frac{f_0}{\sqrt{2}}$
(C) f_0
(D) $\sqrt{2}f_0$
(E) $2f_0$

68. A diffraction grating is illuminated by light of wavelength 600 nm. On a screen 100 cm away is a series of bright spots spaced 10 cm apart. If the screen is now placed 30 cm from the diffraction grating, the new spacing between adjacent bright spots on the screen is most nearly

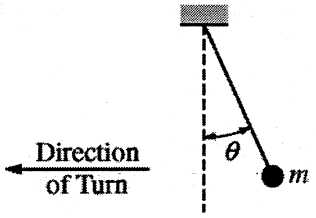
(A) 30 cm
(B) 10 cm
(C) 3 cm
(D) 1 cm
(E) 3 mm

GO ON TO THE NEXT PAGE.



69. Two long, straight, parallel wires in the plane of the page carry equal currents I in the same direction, as shown above. Which of the following correctly describes the forces acting on the wires and the resultant magnetic field at points along the dotted line midway between the wires?

Forces	Field
(A) Attractive	Not zero
(B) Attractive	Zero
(C) Zero	Zero
(D) Repulsive	Not zero
(E) Repulsive	Zero



70. An object of mass m hangs from a string that is fixed to the ceiling of a car. At the instant shown above, the car is moving into the plane of the page at constant speed v as it turns to the left around a horizontal curve of radius r. Which of the following is a correct expression for the angle θ of the string with respect to the vertical?

(A) $\cos\theta = \frac{mg}{r}$

(B) $\cos\theta = \frac{mv}{r}$

(C) $\sin\theta = \frac{mv^2}{r}$

(D) $\tan\theta = \frac{v^2}{gr}$

(E) $\tan\theta = \frac{gr}{v^2}$

STOP

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED
YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

TABLE OF INFORMATION FOR 2008 and 2009

CONSTANTS AND CONVERSION FACTORS

Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, 1 eV $= 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg·s^2
Universal gas constant, $R = 8.31$ J/(mol·K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}$ kg $= 931$ MeV/c^2
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s $= 4.14 \times 10^{-15}$ eV·s
	$hc = 1.99 \times 10^{-25}$ J·m $= 1.24 \times 10^{3}$ eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/N·m^2
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ N·m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}$ (T·m)/A
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^{5}$ N/m^2 $= 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron-volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan\theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

IV. For mechanics and thermodynamics equations, W represents the work done on a system.

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2008 and 2009

NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \leq \mu N$

$a_c = \frac{v^2}{r}$

$\tau = rF \sin\theta$

$\mathbf{p} = m\mathbf{v}$

$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$

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

$\Delta U_g = mgh$

$W = F\Delta r \cos\theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = Fv\cos\theta$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2}kx^2$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

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

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$

$E_{avg} = -\frac{V}{d}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$C = \frac{Q}{V}$

$C = \frac{\epsilon_0 A}{d}$

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

$R = \frac{\rho\ell}{A}$

$V = IR$

$P = IV$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$F_B = qvB\sin\theta$

$F_B = BI\ell\sin\theta$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

$\phi_m = BA\cos\theta$

$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$

$\mathcal{E} = B\ell v$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
v = velocity or speed
ρ = resistivity
θ = angle
ϕ_m = magnetic flux

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2008 and 2009

FLUID MECHANICS AND THERMAL PHYSICS

$P = P_0 + \rho gh$

$F_{buoy} = \rho V g$

$A_1 v_1 = A_2 v_2$

$P + \rho g y + \frac{1}{2}\rho v^2 = \text{const.}$

$\Delta \ell = \alpha \ell_0 \Delta T$

$H = \frac{kA\Delta T}{L}$

$P = \frac{F}{A}$

$PV = nRT = Nk_BT$

$K_{avg} = \frac{3}{2}k_BT$

$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_BT}{\mu}}$

$W = -P\Delta V$

$\Delta U = Q + W$

$e = \left|\frac{W}{Q_H}\right|$

$e_c = \frac{T_H - T_C}{T_H}$

A = area
e = efficiency
F = force
h = depth
H = rate of heat transfer
k = thermal conductivity
K_{avg} = average molecular kinetic energy
ℓ = length
L = thickness
M = molar mass
n = number of moles
N = number of molecules
P = pressure
Q = heat transferred to a system
T = temperature
U = internal energy
V = volume
v = velocity or speed
v_{rms} = root-mean-square velocity
W = work done on a system
y = height
α = coefficient of linear expansion
μ = mass of molecule
ρ = density

ATOMIC AND NUCLEAR PHYSICS

$E = hf = pc$

$K_{\max} = hf - \phi$

$\lambda = \frac{h}{p}$

$\Delta E = (\Delta m)c^2$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

WAVES AND OPTICS

$v = f\lambda$

$n = \frac{c}{v}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin\theta_c = \frac{n_2}{n_1}$

$\frac{1}{s_i} + \frac{1}{s_0} = \frac{1}{f}$

$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$

$f = \frac{R}{2}$

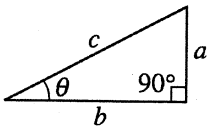
$d\sin\theta = m\lambda$

$x_m \sim \frac{m\lambda L}{d}$

d = separation
f = frequency or focal length
h = height
L = distance
M = magnification
m = an integer
n = index of refraction
R = radius of curvature
s = distance
v = speed
x = position
λ = wavelength
θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$
Triangle
$A = \frac{1}{2}bh$
Circle
$A = \pi r^2$
$C = 2\pi r$
Parallelepiped
$V = \ell w h$
Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r\ell + 2\pi r^2$
Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$
Right Triangle
$a^2 + b^2 = c^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$



A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

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PHYSICS B
SECTION II
Time—90 minutes
7 Questions

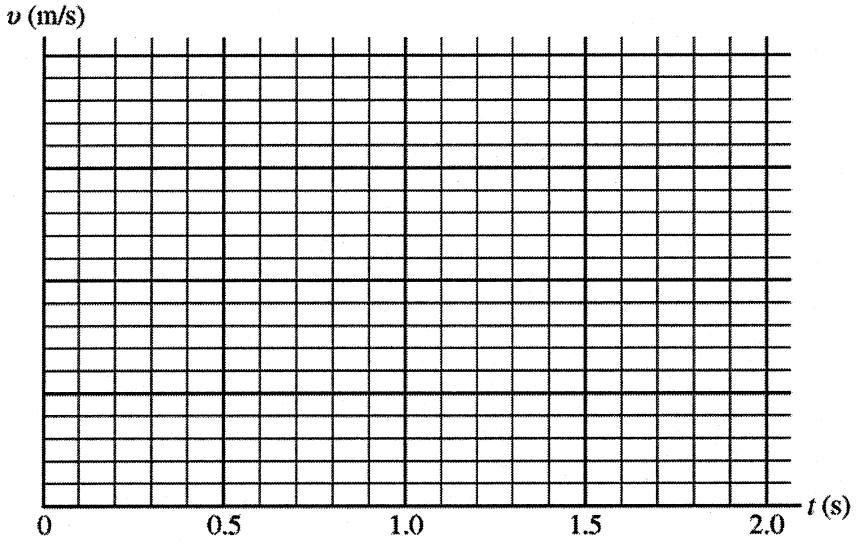
Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2-3. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. (10 points)
A toy cart of mass 0.50 kg moves across a horizontal table with constant acceleration. Its position x is measured for different times t, and the data are recorded in the table below.

Time t (s)	Position x (m)	Average Speed $\bar{v}$ (m/s)
0.00	0.20	
0.50	0.42	
1.00	0.90	
1.50	1.55	
2.00	2.30	

(a) Calculate the average speed of the cart during each 0.50 s time interval and fill in the blank spaces in the table above.

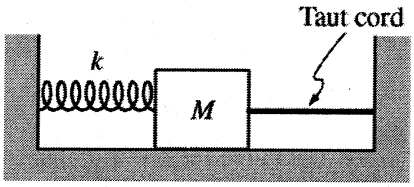
(b) On the axes below, label the vertical axis with appropriate numbers, plot the data, and draw a best-fit line to show a graph of velocity versus time for the cart.



(c) Using the best-fit line, calculate the acceleration of the cart.

(d) The cart continues with the constant acceleration calculated in (c) until it reaches the edge of the table at $t = 3.0$ s. It then falls to the floor, which is 1.2 m below the tabletop. Calculate the kinetic energy of the cart just before hitting the floor.

GO ON TO THE NEXT PAGE.



2. (15 points)
One end of a spring of spring constant k is attached to a wall, and the other end is attached to a block of mass M, as shown above. The block is pulled to the right, stretching the spring from its equilibrium position, and is then held in place by a taut cord, the other end of which is attached to the opposite wall. The spring and the cord have negligible mass, and the tension in the cord is F_T. Friction between the block and the surface is negligible. Express all algebraic answers in terms of M, k, F_T, and fundamental constants.

(a) On the dot below that represents the block, draw and label a free-body diagram for the block.

•

(b) Calculate the distance that the spring has been stretched from its equilibrium position.

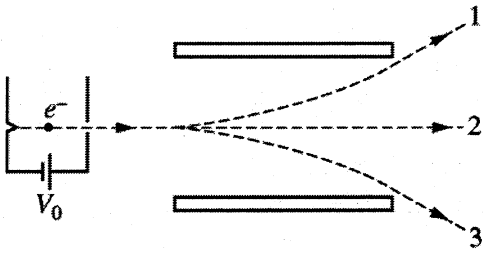
The cord suddenly breaks so that the block initially moves to the left and then oscillates back and forth.

(c) Calculate the speed of the block when it has moved half the distance from its release point to its equilibrium position.

(d) Calculate the time after the cord breaks until the block first reaches its position furthest to the left.

(e) Suppose instead that friction is not negligible and that the coefficient of kinetic friction between the block and the surface is μ_k. After the cord breaks, the block again initially moves to the left. Calculate the initial acceleration of the block just after the cord breaks.

GO ON TO THE NEXT PAGE.



3. (15 points)
Electrons are accelerated from rest through a potential difference V_0 and then pass through a region between two parallel metal plates, as shown above. The region between the plates can contain a uniform electric field **E** and a uniform magnetic field **B**. With only the electric field present, the electrons follow path 1. With only the magnetic field present, the electrons follow path 3. As drawn, the curved paths between the plates show the correct direction of deflection for each field, but not necessarily the correct path shape. With both fields present, the electrons pass undeflected along the straight path 2.

(a)
i. Which of the following describes the shape of the portion of path 1 between the plates?

____Circular ____Parabolic ____Hyperbolic ____Exponential

Justify your answer.

ii. What is the direction of the electric field?

____To the left ____To the top of the page ____Into the page
____To the right ____To the bottom of the page ____Out of the page

Justify your answer.

(b)
i. Which of the following describes the shape of the portion of path 3 between the plates?

____Circular ____Parabolic ____Hyperbolic ____Exponential

Justify your answer.

ii. What is the direction of the magnetic field?

____To the left ____To the top of the page ____Into the page
____To the right ____To the bottom of the page ____Out of the page

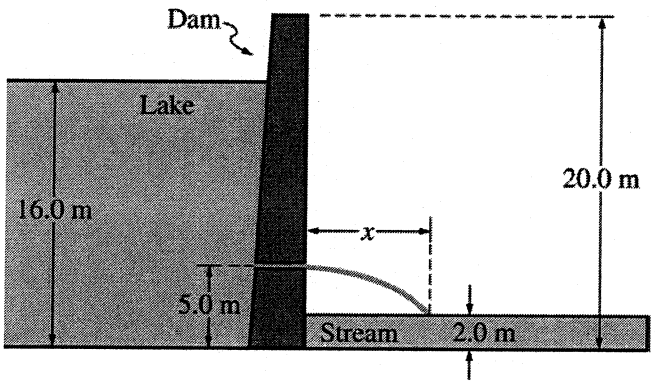
Justify your answer.

Between the plates the magnitude of the electric field is 3.4×10^4 V/m, and the magnitude of the magnetic field is 2.0×10^{-3} T.

(c) Calculate the speed of the electrons given that they are undeflected when both fields are present.

(d) Calculate the potential difference V_0 required to accelerate the electrons to the speed determined in part (c).

GO ON TO THE NEXT PAGE.



4. (10 points)
A 20 m high dam is used to create a large lake. The lake is filled to a depth of 16 m as shown above. The density of water is 1000 kg/m^3 .

(a) Calculate the absolute pressure at the bottom of the lake next to the dam.

A release valve is opened 5.0 m above the base of the dam, and water exits horizontally from the valve.

(b) Use Bernoulli's equation to calculate the initial speed of the water as it exits the valve.

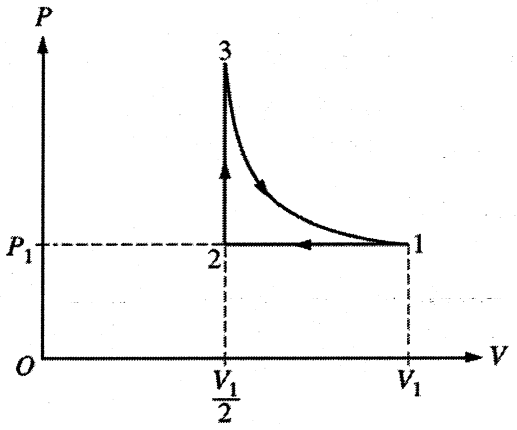
(c) The stream below the surface of the dam is 2.0 m deep. Assuming that air resistance is negligible, calculate the horizontal distance x from the dam at which the water exiting the valve strikes the surface of the stream.

(d) Suppose that the atmospheric pressure in the vicinity of the dam increased. How would this affect the initial speed of the water as it exits the valve?

___It would increase. ____It would decrease. ____It would remain the same.

Justify your answer.

GO ON TO THE NEXT PAGE.



5. (10 points)
A sample of n moles of an ideal gas, originally at a pressure P_1 and volume V_1, undergoes the three processes shown on the PV diagram above:

Process $1 \rightarrow 2$: The volume is halved while the pressure remains constant.
Process $2 \rightarrow 3$: The pressure is increased while the volume remains constant until the temperature reaches its original value.
Process $3 \rightarrow 1$: The volume is increased while the temperature remains constant until the volume reaches its original value.

(a) Determine expressions for each of the following in terms of P_1, V_1, n, and fundamental constants.

i. The temperature of the gas in state 1

ii. The pressure of the gas in state 3

iii. The total work done on the gas during processes $1 \rightarrow 2$ and $2 \rightarrow 3$

(b) Indicate below whether heat is added to the gas, removed from the gas, or neither during the process $2 \rightarrow 3$.

____ Added to ____ Removed from ____ Neither added to nor removed from

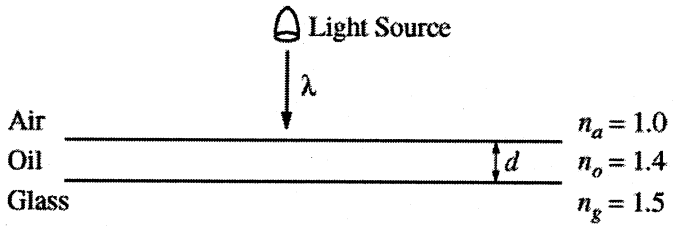
Justify your answer.

(c) Indicate below whether heat is added to the gas, removed from the gas, or neither during the process $3 \rightarrow 1$.

____ Added to ____ Removed from ____ Neither added to nor removed from

Justify your answer.

GO ON TO THE NEXT PAGE.



6. (10 points)

In a classroom demonstration of thin films, your physics teacher takes a glass plate and places a thin layer of transparent oil on top of it. The oil film is then illuminated by shining a narrow beam of white light perpendicularly onto the oil's surface, as shown above. The indices of refraction of air, the oil, and the glass plate are given in the diagram. Standing near the light source, you observe that the film appears green. This corresponds to a wavelength of 520 nm.

(a) Determine each of the following for the green light.

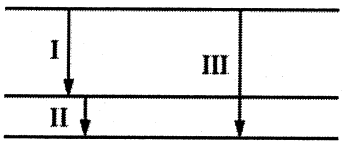
i. The frequency of the light in air

ii. The frequency of the light in the oil film

iii. The wavelength of the light in the oil film

(b) Calculate the minimum thickness of the oil film (other than zero) such that the observed green light is the most intense.

(c) As your teacher changes the angle of the light source, the light you observe from the film changes color. Give an explanation for this phenomenon.



7. (10 points)

The diagram above shows a portion of the energy-level diagram for a particular atom. When the atom undergoes transition I, the wavelength of the emitted radiation is 400 nm, and when it undergoes transition II, the wavelength is 700 nm.

(a) Calculate the wavelength of the emitted radiation when the atom undergoes transition III.

A photon emitted during transition III is then incident on a metal surface of work function 2.1 eV.

(b) Calculate the maximum kinetic energy of the electron ejected from the metal by the photon.

(c) Calculate the de Broglie wavelength of the ejected electron.

STOP

END OF EXAM

Name: _____

AP® Physics B
Student Answer Sheet for Multiple-Choice Section

No.	Answer
1	
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3	
4	
5	
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7	
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No.	Answer
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No.	Answer
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70	

AP® Physics B
Multiple-Choice Answer Key

No.	Correct Answer
1	C
2	C
3	A
4	A
5	B
6	D
7	B
8	E
9	A
10	C
11	A
12	B
13	D
14	C
15	E
16	E
17	D
18	E
19	C
20	A
21	A
22	E
23	B
24	B
25	B
26	C
27	E
28	A
29	D
30	E

No.	Correct Answer
31	A
32	C
33	A
34	A
35	C
36	E
37	B
38	E
39	A
40	A
41	D
42	A
43	E
44	D
45	D
46	C
47	C
48	E
49	B
50	B
51	A
52	D
53	C
54	B
55	C
56	C
57	E
58	D
59	B
60	D

No.	Correct Answer
61	A
62	B
63	D
64	C
65	E
66	E
67	E
68	C
69	B
70	D

AP® Physics B
Free-Response Scoring Guidelines

General Notes about AP Physics Practice Exam Scoring Guidelines

1. The solutions contain a common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. They are typical of draft guidelines developed before student solutions are available. Teachers should feel free to make modifications based on their students' responses.

2. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

The following rules apply to the official scoring of AP Physics Exams.

3. All correct methods of solution receive appropriate credit for correct work.

4. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

5. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description.*

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

AP® Physics B
Free-Response Scoring Guidelines

Question 1

10 points total

Distribution of points

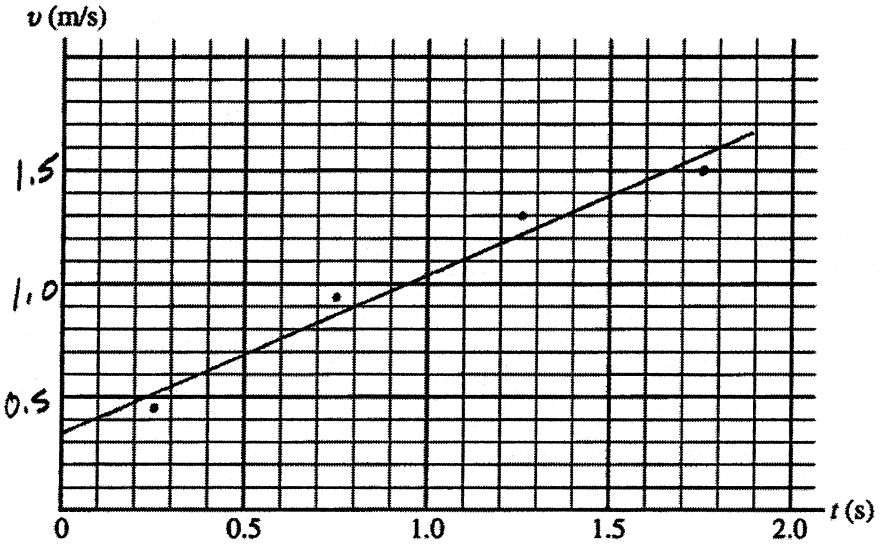
(a) 2 points

Time t (s)	Position x (m)	Average Speed $\bar{v}$ (m/s)
0.00	0.20	
		0.44
0.50	0.42	
		0.96
1.00	0.90	
		1.30
1.50	1.55	
		1.50
2.00	2.30	

For all values for average speed correct in the table — 2 points

Note: 1 point partial credit may be given if one value is incorrect but evidence is shown that $\bar{v} = \Delta x/t$ was used in calculating the average speed.

(b) 3 points



For labeling the vertical axis with numbers appropriate for the range of values of average speed obtained in (a) — 1 point

For at least three data points plotted correctly using the midpoint of each time interval rather than either end point (For constant acceleration, the average speed during an interval is equal to the speed at the midpoint.) — 1 point

For drawing a reasonable straight line fit that has two data points above the line and two data points below the line — 1 point

AP® Physics B
Free-Response Scoring Guidelines

Question 1 (continued)

Distribution of points

(c) 2 points

For an indication that the acceleration is the slope of the best-fit line — 1 point

$a = \Delta v/\Delta t$ = slope

For correctly choosing two points on the line to calculate the slope — 1 point

For example, using the graph shown above and selecting points (1.8, 1.6) and (0.1, 0.4)

$$a = \frac{1.6 \text{ m/s} - 0.40 \text{ m/s}}{1.8 \text{ s} - 0.10 \text{ s}}$$

$$a = 0.71 \text{ m/s}^2$$

(d) 3 points

For a correct calculation of the speed at $t = 3.0$ s — 1 point

$v = v_0 + at$

Using the intercept $v_0 = 0.35$ m/s from the graph, and $a = 0.71 \text{ m/s}^2$ from part (c)

$v = 0.35 \text{ m/s} + (0.71 \text{ m/s}^2)(3.0 \text{ s}) = 2.5 \text{ m/s}$

For a correct expression for the final kinetic energy that includes both potential and kinetic energy terms — 1 point

$$K = mgh + \frac{1}{2}mv^2$$

For correct substitutions — 1 point

$$K = (0.50 \text{ kg})(9.8 \text{ m/s}^2)(1.2 \text{ m}) + \frac{1}{2}(0.50 \text{ kg})(2.5 \text{ m/s})^2$$

$K = 7.4$ J

Note: Answers ranging from 7.2 to 7.8 may be obtained, depending on the value of g used and the values of v_0 and a obtained from the graph.

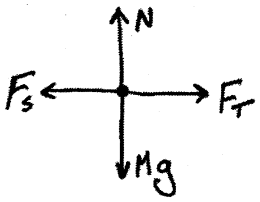
AP® Physics B
Free-Response Scoring Guidelines

Question 2

15 points total

Distribution of points

(a) 4 points



For each correctly drawn and labeled force, award 1 point — 4 points
Note: 1 point is deducted for each incorrect force vector shown, up to 4 points.

(b) 2 points

For indicating that the forces exerted by the spring and the cord are equal in magnitude — 1 point
$F_T = F_S = kx_0$

For the correct expression for x_0 — 1 point
$x_0 = F_T/k$

(c) 4 points

For a correct expression of conservation of energy relating both kinetic and potential energies — 1 point
$U_{S\,final} + K = U_{S\,initial}$

For a correct equation relating v and x_0 — 1 point

$$\frac{1}{2}k\left(\frac{x_0}{2}\right)^2 + \frac{1}{2}Mv^2 = \frac{1}{2}kx_0^2$$

$$\frac{1}{8}kx_0^2 + \frac{1}{2}Mv^2 = \frac{1}{2}kx_0^2$$

$$\frac{1}{2}Mv^2 = \frac{3}{8}kx_0^2$$

$$v = \frac{x_0}{2}\sqrt{\frac{3k}{M}}$$

For the correct substitution of $x_0 = F_T/k$ from part (b) — 1 point

$$v = \frac{F_T}{2k}\sqrt{\frac{3k}{M}}$$

For the correct expression for v — 1 point

$$v = \frac{F_T}{2}\sqrt{\frac{3}{kM}}$$

AP® Physics B
Free-Response Scoring Guidelines

Question 2 (continued)

Distribution of points

(d) 2 points

For an indication that the time desired is one-half of the period of oscillation of the block — 1 point

$t = \frac{T}{2}$

The period of oscillation of the block is given by

$T = 2\pi\sqrt{\frac{M}{k}}$

For the correct expression for the time — 1 point

$t = \pi\sqrt{\frac{M}{k}}$

(e) 3 points

For a correct expression of Newton's second law involving both the forces exerted by the spring and by friction — 1 point

$Ma = F_S - F_{friction}$

For correctly substituting $F_S = kx_0$ and $F_{friction} = \mu_k Mg$ — 1 point

$Ma = kx_0 - \mu_k Mg$

$a = \frac{kx_0}{M} - \mu_k g$

Substituting $x_0 = F_T/k$ from (b)

$a = \frac{kF_T}{Mk} - \mu_k g$

For the correct expression for the acceleration — 1 point

$a = \frac{F_T}{M} - \mu_k g$

AP® Physics B
Free-Response Scoring Guidelines

Question 3

15 points total | **Distribution of points**

(a)

(i) 3 points

For indicating that the path is parabolic — 1 point
For a correct justification that includes descriptions of the motion of the electrons in both the horizontal and vertical directions — 2 points
For example: The electrons have constant speed to the right. The constant electric force provides a constant acceleration toward the top of the page. This is similar to a projectile under the influence of gravity, so the shape is parabolic.
Note: 1 point partial credit may be awarded for a partially complete justification.

(ii) 2 points

For indicating that the electric field points toward the bottom of the page — 1 point
For a correct justification — 1 point
For example: To create path 1, the electric force must be toward the top of the page. The electron is negatively charged, so the field must point in the opposite direction to the electric force.

(b)

(i) 2 points

For indicating that the path is circular — 1 point
For a correct justification — 1 point
For example: The magnetic force is always perpendicular to the velocity of the electrons and has constant magnitude. Thus it acts as a centripetal force making the electrons follow a circular path.

(ii) 2 points

For indicating that the magnetic field points into the page — 1 point
For a correct justification — 1 point
For example: To create path 3, the initial magnetic force must be toward the bottom of the page. With the initial velocity to the right, the right-hand rule gives a field pointing out of the page. But the electron is negatively charged, so the field must point in the opposite direction.

AP® Physics B
Free-Response Scoring Guidelines

Question 3 (continued)

Distribution of points

(c) 3 points

For an indication that the electric and magnetic forces are equal in magnitude — 1 point

$F_E = F_B$

For substitutions of the correct expressions for these forces in terms of the fields — 1 point

$evB = eE$

$v = E/B$

Substituting the numerical values given for E and B

$v = \left(3.4 \times 10^4 \text{ V/m}\right)/\left(2.0 \times 10^{-3} \text{ T}\right)$

For the correct numerical answer with units — 1 point

$v = 1.7 \times 10^7 \text{ m/s}$

(d) 3 points

For an indication that the change in potential energy of the electrons is equal to their kinetic energy — 1 point

$\Delta U_E = K$

For substitutions of the correct expressions for these quantities — 1 point

$eV_0 = \frac{1}{2} m_e v^2$

$V_0 = \frac{m_e v^2}{2e}$

Substituting the numerical values of m_e, e, and the value of v from part (c)

$$V_0 = \frac{\left(9.11 \times 10^{-31} \text{ kg}\right)\left(1.7 \times 10^7 \text{ m/s}\right)^2}{2\left(1.6 \times 10^{-19} \text{ C}\right)}$$

For the correct numerical answer with units — 1 point

$V_0 = 823 \text{ V}$

AP® Physics B
Free-Response Scoring Guidelines

Question 4

10 points total

Distribution of points

(a) 2 points

For an indication that the absolute pressure is the sum of the atmospheric pressure and the gauge pressure — 1 point

$P_{abs} = P_{atm} + \rho gh$

$P = 1 \times 10^5 \text{ Pa} + \left(1000 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(16 \text{ m})$

For the correct answer with units — 1 point

$P = 2.6 \times 10^5 \text{ Pa}$

(b) 3 points

Bernoulli's equation is given in the equation tables as

$P + \rho gy + \frac{1}{2}\rho v^2 = \text{ const.}$

For correctly applying Bernoulli's equation to this situation — 1 point

$P_{valve} + \rho g y_{valve} + \frac{1}{2}\rho v_{valve}^2 = P_{lake} + \rho g y_{lake} + \frac{1}{2}\rho v_{lake}^2$

For recognizing that the pressure at the exit point of the valve is essentially the same as at the top of the lake, and that the speed of the water at the top of the lake is essentially equal to zero — 1 point

$\frac{1}{2}\rho v_{valve}^2 = \rho g(y_{lake} - y_{valve})$

$v_{valve} = \sqrt{2g(y_{lake} - y_{valve})}$

For correct substitutions — 1 point

$v_{valve} = \sqrt{2\left(9.8 \text{ m/s}^2\right)(16.0 \text{ m} - 5.0 \text{ m})}$

$v_{valve} = 14.7 \text{ m/s}$ (or 14.8 m/s using $g = 10 \text{ m/s}^2$)

(c) 3 points

For the correct calculation of the time for the water to fall to the surface — 1 point

$y = \frac{1}{2}gt^2$

$t = \sqrt{2y/g} = \sqrt{2(5.0 \text{ m} - 2.0 \text{ m})/\left(9.8 \text{ m/s}^2\right)} = 0.78 \text{ s}$ (or 0.77 s using $g = 10 \text{ m/s}^2$)

For the correct substitutions of v and t into the correct expression for the horizontal distance — 1 point

$x = vt = (14.7 \text{ m/s})(0.78 \text{ s})$

For the correct answer with units — 1 point

$x = 11.5 \text{ m}$ (or 11.4 m using $g = 10 \text{ m/s}^2$ in the calculations for the speed and time)

AP® Physics B
Free-Response Scoring Guidelines

Question 4 (continued)

Distribution of points

(d) 2 points

For indicating that the initial speed of the water would remain the same — 1 point
For a correct justification — 1 point
For example: When Bernoulli's equation is applied to this situation, atmospheric pressure appears on both sides of the equation and cancels out. So it has no effect on the speed of the exiting water.

AP® Physics B
Free-Response Scoring Guidelines

Question 5

10 points total | **Distribution of points**

(a)

(i) 1 point

For the correct use of the ideal gas law to find the temperature of the gas in state 1 — 1 point

$P_1V_1 = nRT_1$

$T_1 = P_1V_1/nR$

(ii) 2 points

For the correct application of the ideal gas law at states 3 and 1 — 1 point

$\frac{PV}{T} = nR = \text{ const}, \text{ so } \frac{P_3V_3}{T_3} = \frac{P_1V_1}{T_1}$

For correct substitutions of $T_3 = T_1$ and $V_3 = \frac{V_1}{2}$ to arrive at the correct answer — 1 point

$P_3\frac{V_1}{2} = P_1V_1$

$P_3 = 2P_1$

(iii) 2 points

$W = -P\Delta V$

For recognition that for process $2 \rightarrow 3$, $\Delta V = 0$, so $W_{2\rightarrow 3} = 0$ — 1 point

For the correct expression for the work done on the gas during process $1 \rightarrow 2$ — 1 point

$W_{1\rightarrow 2} = -P_1\left(\frac{V_1}{2} - V_1\right) = \frac{P_1V_1}{2}$

$W_{tot} = W_{1\rightarrow 2} + W_{2\rightarrow 3} = \frac{P_1V_1}{2} + 0$

$W_{tot} = \frac{P_1V_1}{2}$

(b) 3 points

For indicating that heat is added to the gas — 1 point

For a correct justification — 2 points

For example: From the first law of thermodynamics, $\Delta U = Q + W$, it follows that $Q = \Delta U - W$. During process $2 \rightarrow 3$ the volume is constant, so $W = -p\Delta V = 0$. The temperature increases and the internal energy is proportional to temperature, so ΔU is positive. Therefore Q is positive. Heat must be added to increase the internal energy.

Note: 1 point partial credit may be given for a partially correct answer.

AP® Physics B
Free-Response Scoring Guidelines

Question 5 (continued)

Distribution of points

(c) 2 points

For indicating that heat is added to the gas — 1 point
For a correct justification — 1 point
For example: From the first law of thermodynamics it follows that $Q = \Delta U - W$.
Process $3 \rightarrow 1$ is isothermal and since the internal energy is proportional to temperature, $\Delta U = 0$. Therefore $Q = -W = -(-p\Delta V) = p\Delta V$. Since V increases, ΔV is positive. Therefore Q is positive. Heat must be added to maintain the internal energy.

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Question 6

10 points total | **Distribution of points**

(a)

(i) 2 points

For a correct expression relating the frequency to the speed and wavelength, with correct substitutions — 1 point

$v = f\lambda$

$f = v/\lambda$

$f_a = \left(3.00 \times 10^8 \text{ m/s}\right)/\left(520 \times 10^{-9} \text{ m}\right)$

For the correct answer with units — 1 point

$f_a = 5.77 \times 10^{14}$ Hz

(ii) 1 point

For an indication that the frequency in the oil film is the same as the frequency in air — 1 point

$f_o = 5.77 \times 10^{14}$ Hz

(iii) 2 points

For a correct expression relating the wavelengths in air and oil to the index of refraction, with correct substitutions — 1 point

$n = \dfrac{c}{v_o} = \dfrac{f_a\lambda_a}{f_o\lambda_o} = \dfrac{\lambda_a}{\lambda_o}$

$\lambda_o = \lambda_a/n_o$

$\lambda_o = \left(520 \times 10^{-9} \text{ m}\right)/1.4$

For the correct answer with units — 1 point

$\lambda_o = 3.71 \times 10^{-7}$ m $= 371$ nm

(b) 3 points

There are two 180° phase changes as the light is reflected, one as the light reaches the surface of the oil and one at the surface of the glass, so the condition for maximum constructive interference is a path length difference of one wavelength.

For using $2t$ as the path length difference, where t is the thickness of the oil film — 1 point

For the correct relationship between path length difference and the wavelength in oil — 1 point

$2t = m\lambda_o$, for any integer m, but $m = 1$ for minimum thickness

$t = \lambda_o/2$

For the correct answer including units — 1 point

$t = 1.86 \times 10^{-7}$ m $= 186$ nm

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Question 6 (continued)

Distribution of points

(c) 2 points

For a correct explanation — 2 points

For example: Light viewed at different angles corresponds to different path lengths in the oil. Each color has a different wavelength, and thus requires a different path length difference for constructive interference.

Note: Partial credit of 1 point may be given for an incomplete answer that, for example, mentions only that the different angles correspond to different path lengths or that each color has a different wavelength.

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Question 7

10 points total

Distribution of points

(a) 3 points

For an indication that the energy of transition III is the sum of the energies of the other two transitions — 1 point

$E_{III} = E_I + E_{II}$

For using the correct expression relating the energy of each transition to its wavelength — 1 point

$E = hf = hc/\lambda$

$$\frac{hc}{\lambda_{III}} = \frac{hc}{\lambda_I} + \frac{hc}{\lambda_{II}}$$

$$\frac{1}{\lambda_{III}} = \frac{1}{\lambda_I} + \frac{1}{\lambda_{II}}$$

$$\frac{1}{\lambda_{III}} = \frac{1}{400\text{ nm}} + \frac{1}{700\text{ nm}} = \frac{11}{2800\text{ nm}}$$

For the correct answer including units — 1 point

$\lambda_{III} = 255$ nm

(b) 3 points

For a correct expression for the kinetic energy of the photon emitted during transition III — 1 point

$$E_{III} = hf_{III} = \frac{hc}{\lambda_{III}}$$

For an indication that the maximum kinetic energy is equal to the transition energy minus the work function — 1 point

$$K_{max} = E_{III} - \phi = \frac{hc}{\lambda_{III}} - \phi$$

$$K_{max} = \frac{1.24 \times 10^3\ \text{eV•nm}}{255\text{ nm}} - 2.1\text{ eV}$$

For the correct answer including units — 1 point

$K_{max} = 2.80$ eV (or 4.5×10^{-19} J)

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Question 7 (continued)

Distribution of points

(c) 4 points

For using a correct relationship relating the de Broglie wavelength of the electron to its speed — 1 point

$\lambda = h/p = h/mv$

For correctly determining the speed of the electron and substituting into the equation above — 1 point

$K_{max} = \frac{1}{2}mv^2$

$v = \sqrt{2K_{max}/m}$

$\lambda = h/m\sqrt{2K_{max}/m}$

$\lambda = h/\sqrt{2mK_{max}}$

For correct substitutions — 1 point

$\lambda = \left(6.63 \times 10^{-34}\ \text{J•s}\right)\Big/\sqrt{2\left(9.11 \times 10^{-31}\ \text{kg}\right)(2.80\ \text{eV})\left(1.6 \times 10^{-19}\ \text{J/eV}\right)}$

For the correct answer including units — 1 point

$\lambda = 7.34 \times 10^{-10}\ \text{m} = 0.734\ \text{nm}$

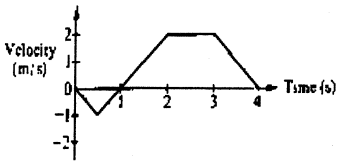
1984 AP Physics B Multiple Choice Exam

1984 B Physics Multiple-Choice

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 blacken the corresponding space on the answer sheet.

1. If the mass of a simple pendulum is doubled but its length remains constant, its period is multiplied by a factor of
   (A) $\frac{1}{2}$
   (B) $\frac{1}{\sqrt{2}}$
   (C) 1
   (D) $\sqrt{2}$
   (E) 2

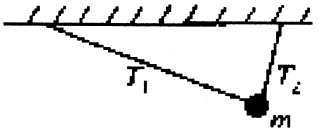
2. A railroad flatcar of mass 2,000 kilograms rolls to the right at 10 meters per second and collides with a flatcar of mass 3,000 kilograms that is rolling to the left at 5 meters per second. The flatcars couple together. Their speed after the collision is
   (A) 1m/s
   (B) 2.5m/s
   (C) 5 m/s
   (D) 7 m/s
   (E) 7.5m/s



3. The graph above shows the velocity versus time for an object moving in a straight line. At what time after time = 0 does the abject again pass through its initial position?
   (A) Between O and 1 s
   (B) 1 s
   (C) Between 1 and 2 s
   (D) 2 s
   (E) Between 2 and 3 s

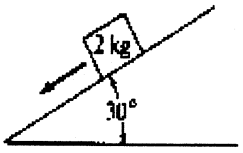
4. Which of the following is true for a system consisting of a mass oscillating on the end of an ideal spring?
   (A) The kinetic and potential energies are equal at all times.
   (B) The kinetic and potential energies are both constant.
   (C) The maximum potential energy is achieved when the mass passes through its equilibrium position.
   (D) The maximum kinetic energy and maximum potential energy are equal, but occur at different times.
   (E) The maximum kinetic energy occurs at maximum displacement of the mass from its equilibrium position.

5. A hall of mass m is suspended from two strings of unequal length as shown above. The tensions T_1 and T_2 in the strings must satisfy which of the following relations?
   (A) $T_1 = T_2$
   (B) $T_1 > T_2$
   (C) $T_1 < T_2$
   (D) $T_1 + T_2 = mg$
   (E) $T_1 - T_2 = mg$



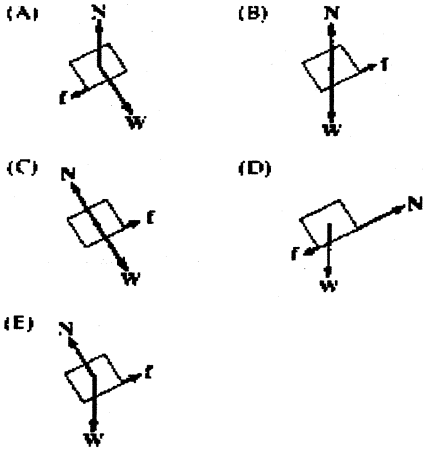
Questions 6-7

A 2-kilogram block slides down a 30° incline as shown above with an acceleration of 2 meters per second squared.



6. Which of the following diagrams best represents the gravitational force **W**, the frictional force **f**, and the normal force **N** that act on the block?

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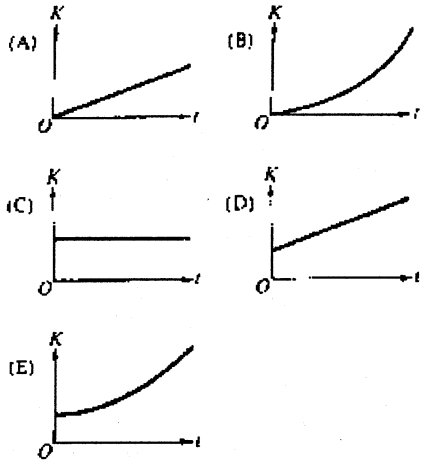
7. The magnitude of the frictional force along the plane is most nearly
   (A) 2.5 N
   (B) 5 N
   (C) 6 N
   (D) 10 N
   (E) 16 N

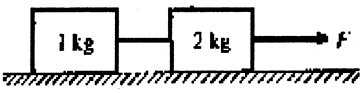
8. When a person stands on a rotating merry-go-round, the frictional force exerted on the person by the merry-go-round is
   (A) greater in magnitude than the frictional force exerted on the person by the merry-go-round
   (B) opposite in direction to the frictional force exerted on the merry-go-round by the person
   (C) directed away from the center of the merry-go-round
   (D) zero if the rate of rotation is constant
   (E) independent of the person's mass

9. Each of five satellites makes a circular orbit about an object that is much more massive than any of the satellites. The mass and orbital radius of each satellite are given below. Which satellite has the greatest speed?

	Mass	Radius
(A)	$\frac{1}{2}m$	R
(B)	m	$\frac{1}{2}R$
(C)	m	R
(D)	m	$2R$
(E)	$2m$	R

10. From the top of a high cliff, a ball is thrown horizontally with initial speed v_0. Which of the following graphs best represents the ball's kinetic energy K as a function of time t?

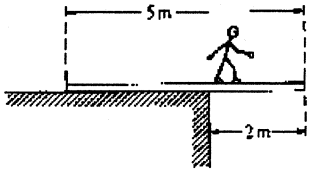




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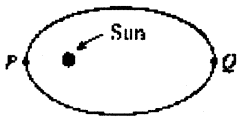
11. When the frictionless system shown above is accelerated by an applied force of magnitude F, the tension in the string between the blocks is
(A) $2F$
(B) F
(C) $\frac{2}{3}F$
(D) $\frac{1}{2}F$
(E) $\frac{1}{3}F$

12. When a mass is attached to a spring, the period of oscillation is approximately 2.0 seconds. When the mass attached to the spring is doubled, the period of oscillation is most nearly
(A) 0.5 s
(B) 1.0 s
(C) 1.4 s
(D) 2.0 s
(E) 2.8 s



13. A 5-meter uniform plank of mass 100 kilograms rests on the top of a building with 2 meters extended over the edge as shown above. How far can a 50-kilogram person venture past the edge of the building on the plank before the plank just begins to tip?
(A) $\frac{1}{2}m$
(B) 1 m
(C) $\frac{2}{3}m$
(D) 2 m
(E) It is impossible to make the plank tip since the person would have to he more than 2 meters from the edge of the building.

14. An asteroid moves in an elliptic orbit with the Sun at one focus as shown above. Which of the following quantities increases as the asteroid moves from point P in its orbit to point Q?
(A) Speed
(B) Angular momentum
(C) Total energy
(D) Kinetic energy
(E) Potential energy



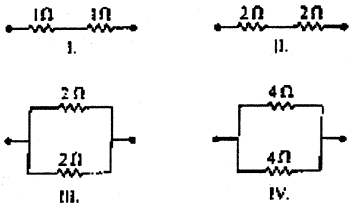
15. The electron volt is a measure of
(A) charge
(B) energy
(C) impulse
(D) momentum
(E) velocity

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16. A solid conducting sphere is given a positive charge Q. How is the charge Q distributed in or on the sphere?
(A) It is concentrated at the center of the sphere.
(B) It is uniformly distributed throughout the sphere.
(C) Its density decreases radially outward from the center.
(D) Its density increases radially outward from the center.
(E) It is uniformly distributed on the surface of the sphere only.

17. A parallel-plate capacitor is charged by connection to a battery. If the battery is disconnected and the separation between the plates is increased, what will happen to the charge on the capacitor and the voltage across it?
(A) Both remain fixed.
(B) Both increase.
(C) Both decrease.
(D) The charge increases and the voltage decreases.
(E) The charge remains fixed and the voltage increases.

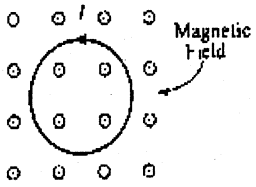
18. Which two arrangements of resistors shown above have the same resistance between the terminals?
(A) I and II
(B) I and IV
(C) II and III
(D) II and IV
(E) III and IV



Questions 19-20. A point P is 0.50 meter from a point charge of 5.0×10^{-8} coulomb.

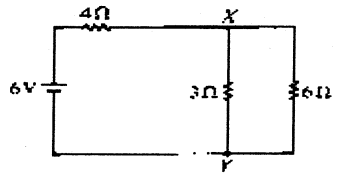
19. The intensity of the electric field at point P is most nearly
(A) 2.5×10^{-8} N/C
(B) 2.5×10^{1} N/C
(C) 9.0×10^{2} N/C
(D) 1.8×10^{3} N/C
(E) 7.5×10^{8} N/C

20. The electric potential at point P is most nearly
(A) 2.5×10^{-8} V
(B) 2.5×10^{1} V
(C) 9.0×10^{2} V
(D) 1.8×10^{3} V
(E) 7.5×10^{8} V



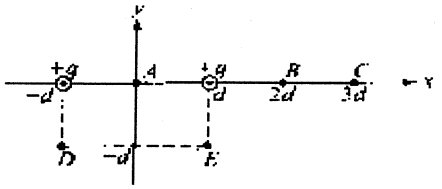
21. There is a counterclockwise current I in a circular loop of wire situated in an external magnetic field directed out of the page as shown above. The effect of the forces that act on this current is to make the loop
(A) expand in size
(B) contract in size
(C) rotate about an axis perpendicular to the page
(D) rotate about an axis in the plane of the page
(E) accelerate into the page

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22. In the circuit shown above, what is the value of the potential difference between points *X* and *Y* if the 6-volt battery has no internal resistance?
    (A) 1 V
    (B) 2 V
    (C) 3 V
    (D) 4 V
    (E) 6 V
23. One joule of work is needed to move one coulomb of charge from one point to another with no change in velocity. Which of the following is true between the two points?
    (A) The resistance is one ohm.
    (B) The current is one ampere.
    (C) The potential difference is one volt.
    (D) The electric field strength is one newton per coulomb.
    (E) The electric field strength is one joule per electron.

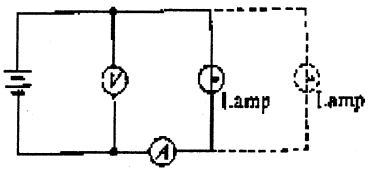
Questions 24-25



Two positive charges of magnitude q are each a distance *d* from the origin *A* of a coordinate system as shown above.

24. At which of the following points is the electric field least in magnitude?
    (A) *A*
    (B) *B*
    (C) *C*
    (D) *D*
    (E) *E*

25. At which of the following points is the electric potential greatest in magnitude?
    (A) *A*
    (B) *B*
    (C) *C*
    (D) *D*
    (E) *E*

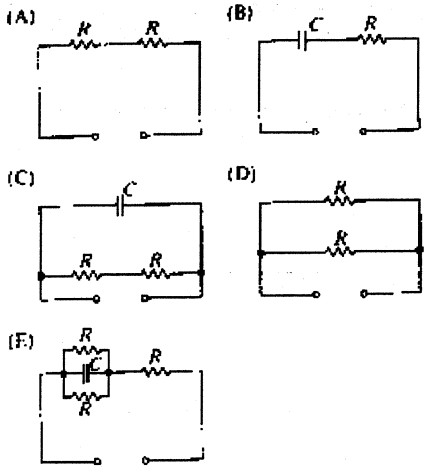


26. A lamp, a voltmeter *V*, an ammeter *A*, and a battery with zero internal resistance are connected as shown above. Connecting another lamp in parallel with the first lamp as shown by the dashed lines would

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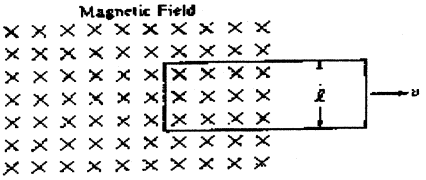
(A) increase the ammeter reading
(B) decrease the ammeter reading
(C) increase the voltmeter reading
(D) decrease the voltmeter reading
(E) produce no change in either meter reading

Questions 27-28 relate to the five incomplete circuits below composed of resistors R, all of equal resistance, and capacitors *C*, all of equal capacitance. A battery that can be used to complete any of the circuits is available.



27. Into which circuit should the battery be connected to obtain the greatest steady power dissipation?

28. Which circuit will retain stored energy if the battery is connected to it and then disconnected?



29. The figure above shows a rectangular loop of wire of width ℓ and resistance R. One end of the loop is in a uniform magnetic field of strength B at right angles to the plane of the loop. The loop is pulled to the right at a constant speed v. What are the magnitude and direction of the induced current in the loop?

	Magnitude	Direction
(A)	$B\ell vR$	Clockwise
(B)	$B\ell vR$	Counterclockwise
(C)	$B\ell v/R$	Clockwise
(D)	$B\ell v/R$	Counterclockwise
(E)	0	Undefined

30. A 2-kilogram block of metal with a specific heat of 100 joules per kilogram • Kelvin falls from rest through a distance of 100 meters to the Earth's surface. If half of the potential energy lost by the fallen block is converted to internal energy of the block, the temperature change of the block is most nearly
(A) 1 K
(B) 5 K
(C) 10 K
(D) 25 K
(E) 45 K

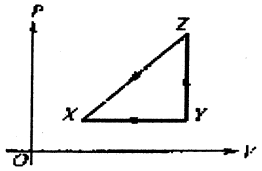
31. The maximum efficiency of a heat engine that operates between temperatures of 1500 K in the firing chamber and 600 K in the exhaust chamber is most nearly

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(A) 33%
(B) 40%
(C) 60%
(D) 67%
(E) 100%

32. An ideal gas is made up of N diatomic molecules, each of mass M. All of the following statements about this gas are true EXCEPT:
(A) The temperature of the gas is proportional to the average translational kinetic energy of the molecules.
(B) All of the molecules have the same speed.
(C) The molecules make elastic collisions with the walls of the container.
(D) The molecules make elastic collisions with each other.
(E) The average number of collisions per unit time that the molecules make with the walls of the container depends on the temperature
of the gas.

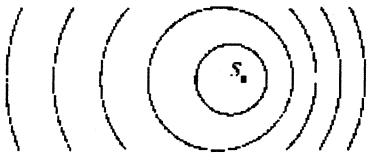
Questions 33-34



A thermodynamic system is taken form an initial state X along the path $XYZX$ as shown in the PV-diagram above.

33. For the process $X \rightarrow Y$, ΔU is greater than zero and
(A) Q<0 and W=0
(B) Q<0 and W>0
(C) Q>0 and W<0
(D) Q>0 and W=0
(E) Q>0 and W>0

34. For the process Y→Z, Q is greater than zero and
(A) W<0 and ΔU=0
(B) W=0 and ΔU<0
(C) W=0 and ΔU>0
(D) W>0 and ΔU=0
(E) W>0 and ΔU>0



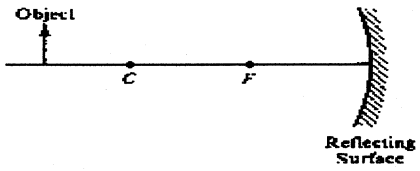
35. A small vibrating object S moves across the surface of a ripple tank producing the wave fronts shown above. The wave fronts move with speed v. The object is traveling in what direction and with what speed relative to the speed of the wave fronts produced?

	Direction	Speed
(A)	To the right	Equal to v
(B)	To the right	Less than v
(C)	To the right	Greater than v
(D)	To the left	Less than v

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(E) To the left Greater than v

36. The critical angle for a transparent material in air is 30°. The index of refraction of the material is most nearly
(A) 0.33
(B) 0.50
(C) 1.0
(D) 1.5
(E) 2.0



37. An object is placed as shown in the figure above. The center of curvature C and the focal point F of the reflecting surface are marked. As compared with the object, the image formed by the reflecting surface is
(A) erect and larger
(B) erect and the same size
(C) erect and smaller
(D) inverted and larger
(E) inverted and smaller

38. When one uses a magnifying glass to read fine print, one uses a
(A) converging lens to produce a virtual image of the print
(B) converging lens to produce a real image of the print
(C) mirror to produce a virtual image of the print
(D) diverging lens to produce a real image of the print
(E) diverging lens to produce a virtual image of the print

39. Two point sources in a ripple tank radiate waves in phase with a constant wavelength of 0.02 meter. The first-order interference maximum appears at 6° (use sin 6° = 0.1). The separation of the sources is most nearly
(A) 0.001 m
(B) 0.002 m
(C) 0.06 m
(D) 0.1 m
(E) 0.2 m

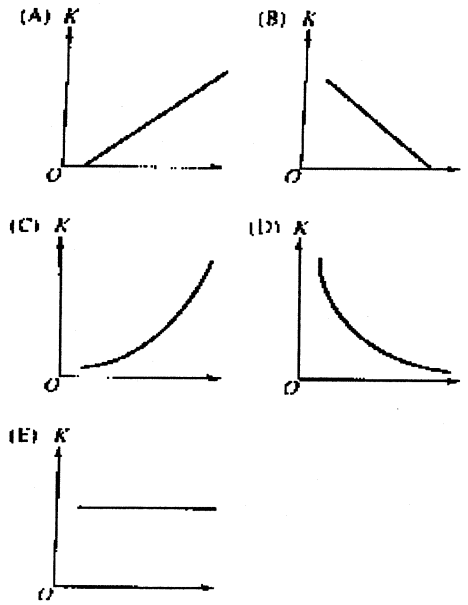
40. A cord of fixed length and uniform density, when held between two fixed points under tension T, vibrates with a fundamental frequency f. If the tension is doubled, the fundamental frequency is
(A) $2f$
(B) $\sqrt{2f}$
(C) f
(D) $\frac{f}{\sqrt{2}}$
(E) $\frac{f}{2}$

41. Which color of light emitted from an atom would be associated with the greatest change in energy of the atom?
(A) Blue
(B) Green
(C) Red

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(D) Violet
(E) Yellow

Questions 42-43 relate to photoelectric effect and the five graphs below.



42. Which graph best shows the maximum kinetic energy K of the photoelectrons as a function of the frequency of incident light?

43. Which graph best shows the maximum kinetic energy K of the photoelectrons as a function of the intensity of incident light?

44. ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow 3\ {}^{1}_{0}n + {}^{142}_{56}Ba +$ _____

The additional product of the nuclear fission reaction shown above is

(A) ${}^{91}_{36}Kr$
(B) ${}^{92}_{35}Br$
(C) ${}^{93}_{36}Kr$
(D) ${}^{93}_{37}Rb$
(E) ${}^{94}_{37}Rb$

45. The deuteron mass m_d is related to the neutron mass m_n and the proton mass m_p by which of the following expressions?
(A) $m_d = m_n - m_p$
(B) $m_d = m_n + m_p$
(C) $m_d = 2(m_n + m_p)$
(D) $m_d = m_n + m_p$ – (mass equivalent to deuteron binding energy)
(E) $m_d = m_n + m_p$ + (mass equivalent to deuteron binding energy)

46. Electrons that have been accelerated from rest through a potential difference of 150 volts have a de Broglie wavelength of approximately 1 Ångstrom (10^{-10} meter). In order to obtain electrons whose de Broglie wavelength is 0.5 Ångstrom (5 X 10^{-11}~ meter), what accelerating potential is required?
(A) 37.5 V
(B) 75 V

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(C) 300 V
(D) 600 V
(E) 22,590 V

Questions 47-49

A 1.0-meter stick and a clock move with speed 0.8 c relative to an observer.

47. If the stick is aligned parallel to the direction of motion, its observed length is most nearly
(A) $0.6m$
(B) $0.8m$
(C) $1.0m$
(D) $\frac{1}{0.8}m$
(E) $\frac{1}{0.6}m$

48. If the stick is aligned perpendicularly to the direction of motion, its observed length is most nearly
(A) $0.6\ m$
(B) $0.8\ m$
(C) $1.0m$
(D) $\frac{1}{0.8}m$
(E) $\frac{1}{0.6}m$

49. Compared to clocks at rest relative to the observer, the moving clock will seem to the observer to run
(A) slower, at about 0.6 times the rate of the clocks at rest
(B) slower, at about 0.8 times the rate of the clocks at rest
(C) at the same rate as the clocks at Pest
(D) faster, at about $\frac{1}{0.8}$ times the rate of the clacks at rest
(E) faster, at about $\frac{1}{0.6}$ times the rate of the clocks at rest

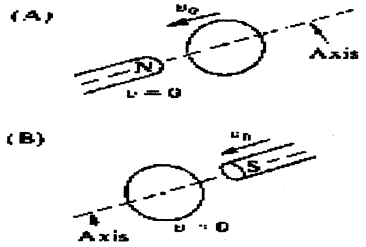
50. An ideal gas confined in a box initially has pressure p. If the absolute temperature of the gas is doubled and the volume of the box is quadrupled, the pressure is
(A) $\frac{1}{8}p$
(B) $\frac{1}{4}p$
(C) $\frac{1}{2}p$
(D) p
(E) $2p$

51. A ball attached to a string is whirled around in a horizontal circle having a radius r. If the radius of the circle is changed to $4r$ and the same centripetal force is applied by the string, the new speed of the ball is which of the following?
(A) One-quarter the original speed
(B) One-half the original speed
(C) The same as the original speed
(D) Twice the original speed
(E) Four times the original speed

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52. A person pushes a box across a horizontal surface at a constant speed of 0.5 meter per second. The box has a mass of 40 kilograms, and the coefficient of sliding friction is 0.25. The power supplied to the box by the person is
(A) 0.2 W
(B) 5 W
(C) 50 W
(D) 100 W
(E) 200 W

53. In each of the following situations, a bar magnet is aligned along the axis of a conducting loop. The magnet and the loop move with the indicated velocities. In which situation will the bar magnet NOT induce a current in the conducting loop?



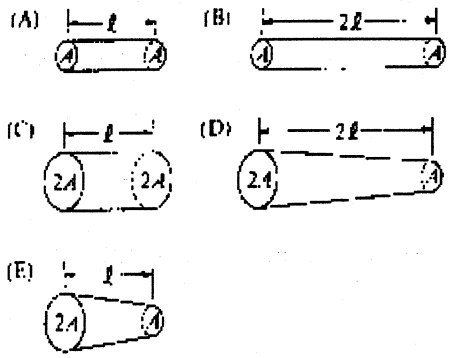
54. A parallel-plate capacitor has a capacitance C_0. A second parallel-plate capacitor has plates with twice the area and twice the separation. The capacitance of the second capacitor is most nearly
(A) $\frac{1}{4}C_0$
(B) $\frac{1}{2}C_0$
(C) C_0
(D) $2C_0$
(E) $4C_0$

55. A vibrating tuning fork sends sound waves into the air surrounding it. During the time in which the tuning fork makes one complete vibration, the emitted wave travels
(A) one wavelength
(B) about 340 meters
(C) a distance directly proportional to the frequency of the vibration
(D) a distance directly proportional to the square root of the air density
(E) a distance inversely proportional to the square root of the pressure

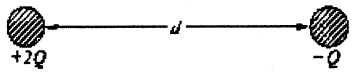
56. Two planets have the same size, but different masses, and no atmospheres. Which of the following would be the same for objects with equal mass on the surfaces of the two planets?
I. The rate at which each would fall freely
II. The amount of mass each would balance on an equal-arm balance
III. The amount of momentum each would acquire when given a certain impulse
(A) I only
(B) III only
(C) I and II only
(D) II and II1 only
(E) I, II, and III

57. The five resistors shown below have the lengths and cross-sectional areas indicated and are made of material with the same resistively. Which has the greatest resistance?

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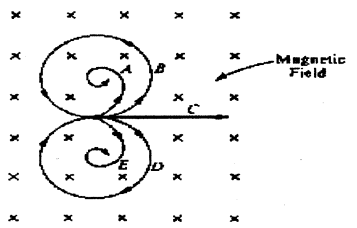


58. According to the Bohr model of the atom, electrons orbit the nucleus in definite orbits. According to the laws of classical physics, this model would be impossible because electrons
(A) the positively charged nucleus attracts the electrons
(B) Coulomb's law applies
(C) accelerating electrons radiate energy
(D) there is a centripetal force on the electrons
(E) angular momentum is conserved



59. Two identical conducting spheres are charged to $+2Q$ and $-Q$, respectively, and are separated by a distance d (much greater than the radii of the spheres) as shown above. The magnitude of the force of attraction on the left sphere is F_1. After the two spheres are made to touch and then are reseparated by distance d, the magnitude of the force on the left sphere is F_1. Which of the following relationships is correct?
(A) $2F_1 = F_2$
(B) $F_1 = F_2$
(C) $F_1 = 2F_2$
(D) $F_1 = 4F_2$
(E) $F_1 = 8F_2$

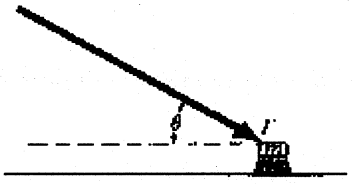
60. Which of the paths above represents the path of an electron traveling without any loss of energy through a uniform magnetic field directed into the page?
(A) A
(B) B
(C) C
(D) D
(E) E

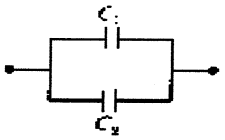


61. A push broom of mass m is pushed across a rough horizontal floor by a force of magnitude T directed at angle θ as shown above. The coefficient of friction between the broom and the floor is It. The frictional force on the broom has magnitude
(A) $\mu(mg + T\sin\theta)$
(B) $\mu(mg + T\sin\theta)$
(C) $\mu(mg + T\cos\theta)$
(D) $\mu(mg - T\cos\theta)$
(E) μmg

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ide available for





62. Two capacitors are connected in parallel as shown above. A voltage V is applied to the pair. What is the ratio of charge stored on C_2 to the charge stored on C_1, when $C_1 = 1.5C_2$?

(A) $\frac{4}{9}$

(B) $\frac{2}{3}$

(C) 1

(D) $\frac{3}{2}$

(E) $\frac{9}{4}$

63. Two long, parallel wires, fixed in space, carry currents I, and 12. The force of attraction has magnitude F. What currents will give an attractive force of magnitude 4F?

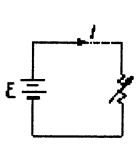
(A) $2I_1$ *and* $\frac{1}{2}I_2$

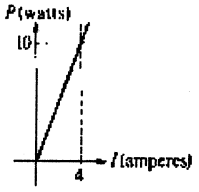
(B) I_1 *and* $\frac{1}{4}I_2$

(C) $\frac{1}{2}I_1$ *and* $\frac{1}{2}I_2$

(D) $2I_1$ *and* $2I_2$

(E) $4I_1$ *and* $4I_2$





64. The circuit shown above left is made up of a variable resistor and a battery with negligible internal resistance. A graph of the power P dissipated in the resistor as a function of the current I supplied by the battery is given above right. What is the emf of the battery?

(A) 0.025 V
(B) 0.67 V
(C) 2.5 V
(D) 6.25 V
(E) 40 V

65. A body moving in the positive x direction passes the origin at time $t = 0$. Between t = 0 and t = 1 second, the body has a constant speed of 24 meters per second. At $t = 1$ second, the body is given a constant acceleration of 6 meters per second squared in the negative x direction. The position x of the body at $t = 11$ seconds is

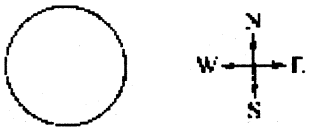
(A) +99 m
(B) +36 m
(C) -36 m
(D) -75 m
(E) -99 m

66. A person weighing 800 newtons on Earth travels to another planet with twice the mass and twice the radius of Earth. The person's weight on this other planet is most nearly

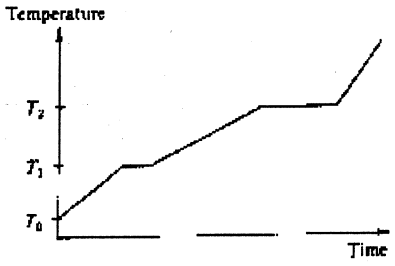
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(A) 400 N
(B) $\frac{800}{\sqrt{2}}N$
(C) 800 N
(D) $800\sqrt{2}N$
(E) 1,600 N

67. A racing car is moving around the circular track of radius 300 meters shown above. At the instant when the car's velocity is directed due east, its acceleration is directed due south and has a magnitude of 3 meters per second squared. When viewed from above, the car is moving
(A) clockwise at 30 m/s
(B) clockwise at 10 m/s
(C) counterclockwise at 30 m/s
(D) counterclockwise at 10 m/s
(E) with constant velocity



View of Track from Above



68. Heat is added at a constant rate to a sample of pure substance that is initially a solid at temperature To. The temperature of the sample as a function of time is shown in the graph above. From the graph, one can conclude that the
(A) substance sublimes directly from the solid phase to the vapor phase
(B) melting point is T2
(C) specific heat is greater for the liquid phase than for the solid phase
(D) heat of fusion and heat of vaporization are equal
(E) specific heat of the solid increases linearly with temperature

69. An illuminated object is placed 0.30 meter from a lens whose focal length is -0.15. meter. The image is
(A) inverted, real, and 0,30 meter from the lens on the opposite side from the object
(B) upright, virtual, and 0.30 meter from the lens on the opposite side, from the object
(C) upright, real, and 0110 meter from the lens on the same side as the object
(D) upright, virtual, and 0. 10 meter from the lens on the same side as the object
(E) inverted, real, and 0. 10 meter from the lens on the same side as the object

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1993 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.

1. In which of the following situations would an object be accelerated?

I. It moves in a straight line at constant speed.
II. It moves with uniform circular motion.
III. It travels as a projectile in a gravitational field with negligible air resistance.

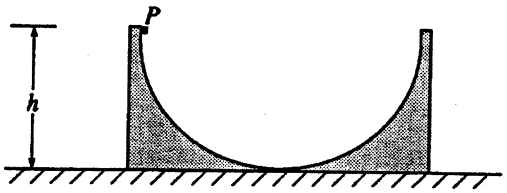
(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

2. A ball falls straight down through the air under the influence of gravity. There is a retarding force F on the ball with magnitude given by F = bv, where t is the speed of the ball and b is a positive constant. The magnitude of the acceleration a of the ball at any time is equal to which of the following?

(A) $g-b$
(B) $g-\frac{bv}{m}$
(C) $g+\frac{bv}{m}$
(D) $\frac{g}{b}$
(E) $\frac{bv}{m}$

3. An ideal spring obeys Hooke's law, F = - kx. A mass of 0.50 kilogram hung vertically from this spring stretches the spring 0.075 meter. The value or the force constant for the spring is most nearly

(A) 0.33 N/m
(B) 0.66 N/m
(C) 6.6 N/m
(D) 33 N/m
(E) 66 N/m



4. The figure above shows a rough semicircular track whose ends are at a vertical height h. A block placed at point P at one end of the track is released from rest and slides past the bottom of the track. Which of the following is true of the height to which the block rises on the other side of the track?

(A) It is equal to h/2 π.

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(B) It is equal to h/4.
(C) It is equal to h/2.
(D) It is equal to h.
(E) It is between zero and h; the exact height depends on how much energy is lost to friction.

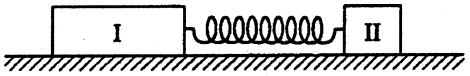
5. An object is released from rest on a planet that has no atmosphere. The object falls freely for 3.0 meters in the first second. What is the magnitude of the acceleration due to gravity on the planet?

(A) 1.5 m/s^2
(B) 3.0 m/s^2
(C) 6.0 m/s^2
(D) 10.0 m/s^2
(E) 12.0 m/s^2

6. If Spacecraft X has twice the mass of Spacecraft Y. then true statements about X and Y include which of the following?

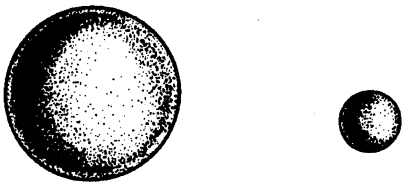
I. On Earth, X experiences twice the gravitational force that Y experiences.
II. On the Moon, X has twice the weight of Y.
III. When both are in the same circular orbit, X has twice the centripetal acceleration of Y.

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



7. Two pucks are attached by a stretched spring and are initially held at rest on a frictionless surface, as shown above. The pucks are then released simultaneously. If puck I has three times the mass of puck II, which of the following quantities is the same for both pucks as the spring pulls the two pucks toward each other?

(A) Speed
(B) Velocity
(C) Acceleration
(D) Kinetic energy
(E) Magnitude of momentum



8. The two spheres pictured above have equal densities and are subject only to their mutual gravitational attraction. Which of the following quantities must have the same magnitude for both spheres?

(A) Acceleration
(B) Velocity
(C) Kinetic energy
(D) Displacement from the center of mass
(E) Gravitational force

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9. When an object oscillating in simple harmonic motion is at its maximum displacement from the equilibrium position, which of the following is true of the values of its speed and the magnitude of the restoring force?

Speed	Restoring Force
(A) Zero	Maximum
(B) Zero	Zero
(C) ½ maximum	½ maximum
(D) Maximum	½ maximum
(E) Maximum	Zero

10. Which of the following is true when an object of mass m moving on a horizontal frictionless surface hits and sticks to an object of mass M > m, which is initially at rest on the surface?

(A) The collision is elastic.
(B) All of the initial kinetic energy of the less-massive object is lost.
(C) The momentum of the objects that are stuck together has a smaller magnitude than the initial momentum of the less-massive object.
(D) The speed of the objects that are stuck together will be less than the initial speed of the less-massive object.
(E) The direction of motion of the objects that are stuck together depends on whether the hit is a head-on collision.

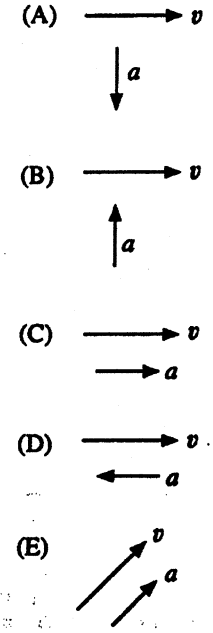
11. Two objects having the same mass travel toward each other on a flat surface, each with a speed of 10 meter per second relative to the surface. The objects collide head-on and are reported to rebound after the collision, each with a speed of 20 meters per second relative to the surface. Which of the following assessments of this report is most accurate?

(A) Momentum was not conserved, therefore the report is false.
(B) If potential energy was released to the objects during the collision, the report could be true.
(C) If the objects had different masses, the report could be true.
(D) If the surface was inclined, the report could be true.
(E) If there was no friction between the objects and the surface, the report could be true.



12. An automobile moves at constant speed down one hill and up another hill along the smoothly curved surface shown above. Which of the following diagrams best represents the directions of the velocity and the acceleration of the automobile at the instant that it is at the lowest position, as shown.

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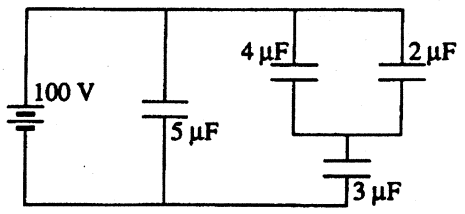
13. Which of the following will cause the electrical resistance of certain materials known as superconductors to suddenly decrease to essentially zero?

(A) Increasing the voltage applied to the material beyond a certain threshold voltage
(B) Increasing the pressure applied to the material beyond a certain threshold pressure
(C) Cooling the material below a certain threshold temperature
(D) Stretching the material to a wire of sufficiently small diameter
(E) Placing the material in a sufficiently large magnetic field

14. Kirchhoff's loop rule for circuit analysis is an expression of which of the following?

(A) Conservation of charge
(B) Conservation of energy
(C) Ampere's law
(D) Faraday's law
(E) Ohm's law

Questions 15-16 refer to the circuit shown below.



15. The equivalent capacitance for this network is most nearly

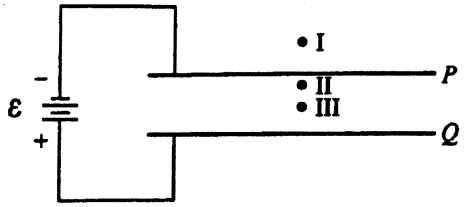
(A) 10/7 *u*F

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(B) 3/2 *u*F
(C) 7/3 *u*F
(D) 7 *u*F
(E) 14 *u*F

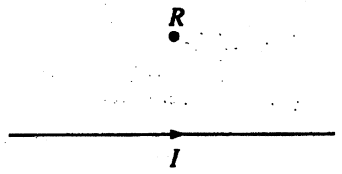
16. The charge stored in the 5-microfarad capacitor is most nearly

(A) 360 *u*C
(B) 500 *u*C
(C) 710 *u*C
(D) 1,100 *u*C
(E) 1,800 *u*C



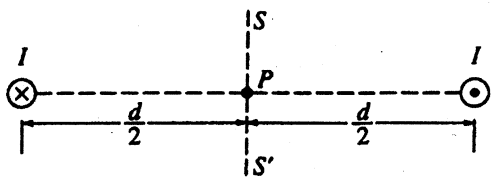
17. Two large parallel conducting plates P and Q are connected to a battery of emf C, as shown above. A test charge is placed successively at points I, II, and III. If edge effects are negligible, the force on the charge when it is at point III is

(A) of equal magnitude and in the same direction as the force on the charge when it is at point I
(B) of equal magnitude and in the same direction as the force on the charge when it is at point II
(C) equal in magnitude to the force on the charge when it is at point I, but in the opposite direction
(D) much greater in magnitude than the force on the charge when it is at point II, but in the same direction
(E) much less in magnitude than the force on the charge when it is at point II, but in the same direction



18. The direction of the magnetic field at point R caused by the current I in the wire shown above is

(A) to the left
(B) to the right
(C) toward the wire
(D) into the page
(E) out of the page

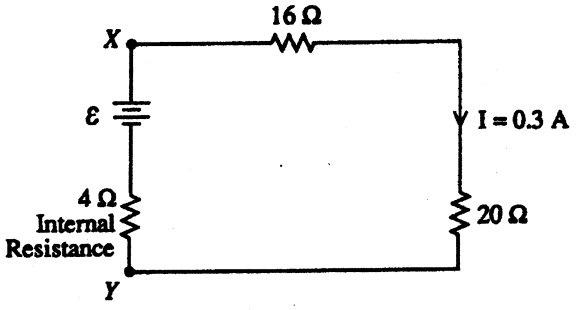


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19. Two long, parallel wires are separated by a distance a as shown above. One wire carries a steady current I into the plane of the page while the other wire carries a steady current I out of the page. At what points in the plane of the page and outside the wires, besides points at infinity, is the magnetic field due to the currents zero?

(A) Only at point P
(B) At all points on the line *SS'*
(C) At all points on the line connecting the two wires
(D) At all points on a circle of radius 2d centered on point P
(E) At no points

Questions 20-22 relate to the following circuit diagram, which shows a battery with an internal resistance of 4.0 ohms connected to a 16-ohm and a 20-ohm resistor in series. The current in the 20-ohm resistor is 0.3 amperes.



20. What is the emf of the battery?
(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

21. What is the potential difference across the terminals X and Y of the battery?

(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

22. What power is dissipated by the 4-ohm internal resistance of the battery?

A) 0.36 W
(B) 1.2 W
(C) 3.2 W
(D) 3.6 W
(E) 4.8 W

23. If the gas in a container absorbs 275 joules of heat has 125 joules of work done on it, and then does 50 joules of work, what is the increase in the internal energy of the gas?

(A) 100 J
(B) 200 J
(C) 350 J
(D) 400 J
(E) 450 J

Questions 24-25

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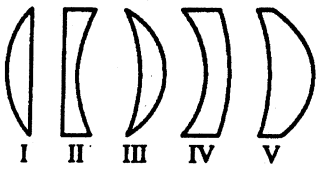
A piece of metal with a mass of 1.50 kilograms, specific heat of 200 J/kg / C°, and initial temperature of 100° C is dropped into an insulated jar that contains liquid with a mass of 3.00 kilograms, specific heat of 1,000 J/kg · C°, and initial temperature of 0° C. The piece of metal is removed after 5 seconds, at which time its temperature is 20° C. Neglect any effects of heat transfer to the air or to the insulated jar.

24. The temperature of the liquid after the metal is removed is

(A) 0° C
(B) 4° C
(C) 8° C
(D) 10° C
(E) 20° C

25. The average rate at which heat is transferred while the piece of metal is in the liquid is

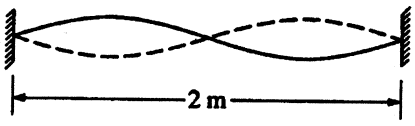
(A) 4,000 J/s
(B) 4,800 J/s
(C) 6,000 J/s
(D) 9,600 J/s
(E) 16,000 J/s



26. Which three of the glass lenses above, when placed in air, will cause parallel rays of light to converge?

(A) I, II, and III
(B) I, III, and V
(C) l, IV, and V
(D) II, III, and IV
(E) II, IV, and V

Questions 27-28



A standing wave of frequency 5 hertz is set up on a string 2 meters long with nodes at both ends and in the center, as shown above.

27. The speed at which waves propagate on the string is

(A) 0.4 m/s
(B) 2.5 m/s
(C) 5 m/s
(D) 10 m/s
(E) 20 m/s

28. The fundamental frequency of vibration of the string is

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(A) I Hz
(B) 2.5 Hz
(C) 5 Hz
(D) 7.5 Hz
(E) 10 Hz

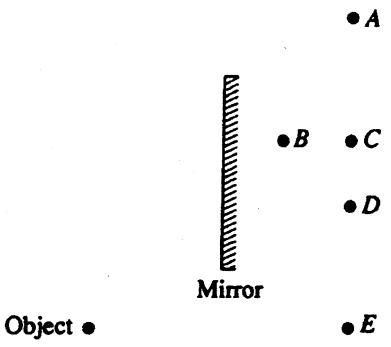
Radio waves
Infrared radiation
Visible light
Ultraviolet radiation
Gamma radiation

29. For the five types of electromagnetic radiation listed above, which of the following correctly describes the way in which wavelength, frequency, and photon energy change as one goes from the top of the list to the bottom?

Wavelength	Frequency	Photon Energy
(A) Decreases	Decreases	Increases
(B) Decreases	Increases	Increases
(C) Increases	Decreases	Decreases
(D) Increases	Decreases	Increases
(E) Increases	Increases	Increases

30. Sound in air can best be described as which of the following types of waves?

(A) Longitudinal
(B) Transverse
(C) Torsional
(D) Electromagnetic
(E) Polarized



31. An object is placed near a plane mirror, as shown above. Which of the labeled points is the position of the image?

(A) A
(B) B
(C) C
(D) D

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(E) E

Questions 32-33 deal with nuclear fission for which the following reaction is a good example.

$$\frac{235}{92}\text{U} + \frac{1}{0}\text{n} \rightarrow \frac{138}{56}\text{Ba} + \frac{95}{36}\text{Kr} + \text{neutrons} + \text{released energy}$$

32. The total number of free neutrons in the products of this reaction is

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

33. Which of the following statements is always true for neutron-induced fission reactions involving $\frac{235}{92}\text{U}$?

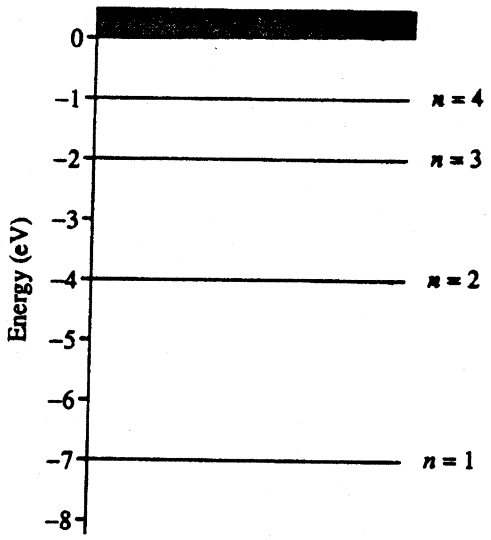
I. The end products always include Ba and Kr.

II. The rest mass of the end products is less than that of $\frac{235}{92}\text{U} + \frac{1}{0}\text{n}$.

III The total number of nucleons (protons plus neutrons) in the end products is less than that in $\frac{235}{92}\text{U} + \frac{1}{0}\text{n}$.

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

Questions 34-35



A hypothetical atom has four energy states as shown above.

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34. Which of the following photon energies could NOT be found in the emission spectra of this atom after it has been excited to the $n = 4$ state?

(A) l eV
(B) 2 eV
(C) 3 eV
(D) 4 eV
(E) 5 eV

35. Which of the following transitions will produce the photon with the longest wavelength?

(A) $n = 2$ to $n = l$
(B) $n = 3$ to $n = l$
(C) $n = 3$ to $n = 2$
(D) $n = 4$ to $n = l$
(E) $n = 4$ to $n = 3$

36. Cobalt 60 is a radioactive source with a half-life of about 5 years. After how many years will the activity of a new sample of cobalt 60 be decreased to 1/8 its original value?

(A) 2.5 years
(B) 5 years
(C) 10 years
(D) 15 years
(E) It depends on the original amount of cobalt 60.

37. Of the following phenomena, which provides the best evidence that light can have particle properties?

(A) Interference of light in thin films
(B) Electromagnetic radiation
(C) Photoelectric effect
(D) Electron diffraction
(E) X-ray diffraction

38. Of the following phenomena, which provides the best evidence that particles can have wave properties?

(A) The absorption of photons by electrons in an atom
(B) The a-decay of radioactive nuclei
(C) The interference pattern produced by neutrons incident on a crystal
(D) The production of x-rays by electrons striking a metal target
(E) The scattering of photons by electrons at rest

39. A muon, with a lifetime of 2×10^{-6} second in its frame of reference, is created in the upper atmosphere with a velocity of 0.998c toward the Earth. The lifetime of the muon, as measured by an observer on the Earth, is most nearly

(A) 3 x l0-2s
(B) 3 x 10-3 S
(C) 3 x l0-4s
(D) 3 x 10-5 S
(E) 3 x l0-h S

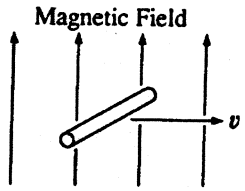
40. The operator of a space station observes a space vehicle approaching at a constant speed v. The operator sends a light signal at speed c toward the space vehicle. The speed of the light signal relative to the space vehicle is

(A) c + v
(B) c - v
(C) c

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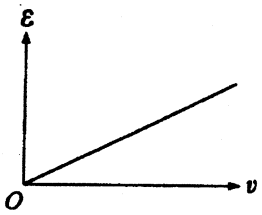
(D) $v/\sqrt{1-v^2/c^2}$

(E) $c\sqrt{1-v^2/c^2}$

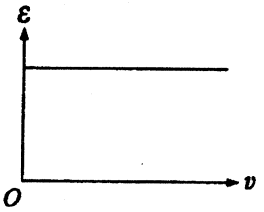


41. A wire of constant length is moving in a constant magnetic field, as shown above. The wire and the velocity vector are perpendicular to each other and are both perpendicular to the field. Which of the following graphs best represents the potential difference ε between the ends of the wire as a function of the speed v of the wire?

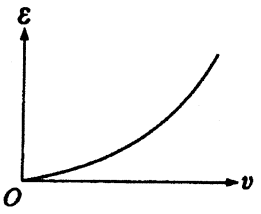
(A)



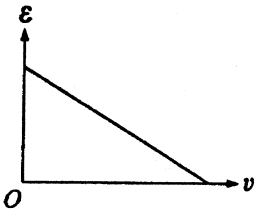
(B)



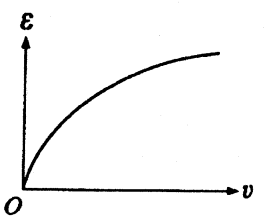
(C)



(D)



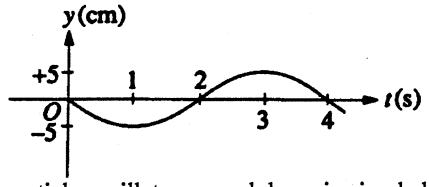
(E)



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42. Forces between two objects which are inversely proportional to the square of the distance between the objects include which of the following?
I. Gravitational force between two celestial bodies
II. Electrostatic force between two electrons
III. Nuclear force between two neutrons

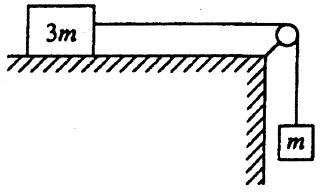
(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III



43. A particle oscillates up and down in simple harmonic motion. Its height y as a function of time t is shown in the diagram above. At what time t does the particle achieve its maximum positive acceleration?
(A) 1s
(B) 2s
(C) 3s
(D) 4s
(E) None of the above, because the acceleration is constant

44. A weight lifter lifts a mass m at constant speed to a height *h* in time *t*. What is the average power output of the weight lifter?

(A) *mg*
(B) *mh*
(C) *mgh*
(D) *mght*
(E) *mgh/t*



45. A block of mass 3m can move without friction on a horizontal table. This block is attached to another block of mass m by a cord that passes over a frictionless pulley, as shown above. If the masses of the cord and the pulley are negligible, what is the magnitude of the acceleration of the descending block?

(A) Zero
(B) g/4
(C) g/3
(D) 2g/3
(E) g

46. A car initially travels north and then turns to the left along a circular curve. This causes a package on the seat of the car to slide toward the right side of the car. Which of the following is true of the net force on the package while it is sliding?

(A) The force is directed away from the center of the circle.

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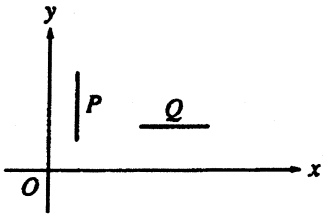
(B) The force is directed north.
(C) There is not enough force directed north to keep the package from sliding.
(D) There is not enough force tangential to the car's path to keep the package from sliding.
(E) There is not enough force directed toward the center of the circle to keep the package from sliding.

47. A block of mass m slides on a horizontal frictionless table with an initial speed v_0. It then compresses a spring of force constant k and is brought to rest. How much is the spring compressed from its natural length?

(A) $\frac{v_0^2}{2g}$
(B) $\frac{mg}{k}$
(C) $\frac{m}{k}v_0$
(D) $\sqrt{\frac{m}{k}}v_0$
(E) $\sqrt{\frac{k}{m}}v_0$

48. The planet Mars has mass 6.4×10^{23} kilograms and radius 3.4×10^{6} meters. The acceleration of an object in free-fall near the surface of Mars is most nearly

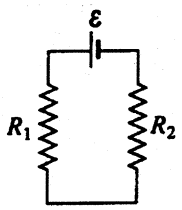
(A) zero
(B) l.0 m/s2
(C) 1.9 m/s2
(D) 3.7 m/s2
(E) 9.8 m/s2



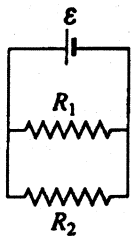
49. Rods P and Q are at rest in an inertial reference frame and oriented as shown above. Both rods have length L in this reference frame. A person moves at a relativistic speed in the y direction. Which of the following would be the lengths, as compared to L, observed for these rods by the person?

P	Q
(A) Less than L	Less than L
(B) Less than L	L
(C) Less than L	Greater than L
(D) L	Less than L
(E) L	L

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Series Connection



Parallel Connection

50. In the diagrams above, resistors R_1. and R_2 are shown in two different connections to the same source of emf ε that has no internal resistance. How does the power dissipated by the resistors in these two cases compare?

(A) It is greater for the series connection.
(B) It is greater for the parallel connection.
(C) It is the same for both connections.
(D) It is different for each connection, but one must know the values of . R_1 and R_2 to know which is greater.
(E) It is different for each connection, but one must know the value of ε to know which is greater.

51. The product

2 amperes x 2 volts x 2 seconds

is equal to

(A) 8 coulombs
(B) 8 newtons
(C) 8 joules
(D) 8 calories
(E) 8 newton-amperes

52. A radar operates at a wavelength of 3 centimeters. The frequency of these waves is

(A) 10^{-10} Hz
(B) 10^{6} Hz
(C) 10^{8} Hz
(D) 3×10^{8} Hz
(E) 10^{10} Hz

53. In the photoelectric effect, the maximum speed of the electrons emitted by a metal surface when it is illuminated by light depends on which of the following?

I. Intensity of the light
II. Frequency of the light
III. Nature of the photoelectric surface

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

54. Atoms of isotopes of the same element contain the same number of

(A) protons but a different number of neutrons

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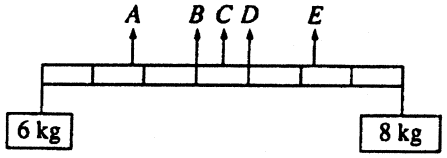
(B) electrons but a different number of protons
(C) neutrons but a different number of protons
(D) neutrons as electrons
(E) protons as neutrons

55. In each cycle of a Carnot engine, 100 joules of heat is absorbed from the high-temperature reservoir and 60 joules is exhausted to the low-temperature reservoir. What is the efficiency of the engine?

(A) 40%
(B) 60%
(C) 67%
(D) 150%
(E) 167%

56. In the Bohr model of the atom, the postulate stating that the orbital angular momentum of the electron is quantized can be interpreted in which of the following ways?

(A) An integral number of electron wavelengths must fit into the electron's circular orbit.
(B) Only one electron can exist in each possible electron state.
(C) An electron has a spin of 1/2.
(D) The atom is composed of a small, positively charged nucleus orbited by electrons.
(E) An incident photon is completely absorbed when it causes an electron to move to a higher energy state.



57. Two objects, of masses 6 and 8 kilograms, are hung from the ends of a stick that is 70 centimeters long and has marks every 10 centimeters, as shown above. If the mass of the stick is negligible, at which of the points indicated should a cord be attached if the stick is to remain horizontal when suspended from the cord?

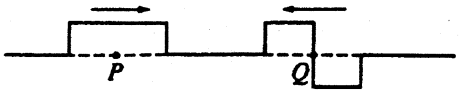
(A) A
(B) B
(C) C
(D) D
(E) E

58. In the Doppler effect for sound waves, factors that affect the frequency that the observer hears include which of the following?

I. The speed of the source
II. The speed of the observer
III. The loudness of the sound

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

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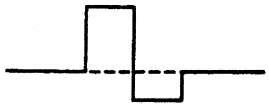


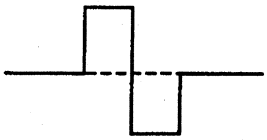
59. The figure above shows two wave pulses that are approaching each other. Which of the following best shows the shape of the resultant pulse when the centers of the pulses, points P and Q. coincide?

(A) 

(B) 

(C) 

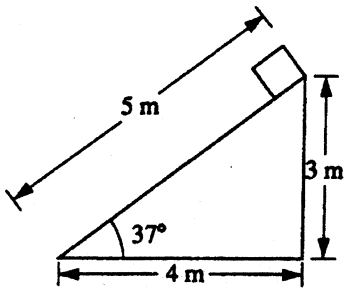
(D) 

(E) 

60. Observations that indicate that visible light has a wavelength much shorter than a centimeter include which of the following?

I. The colored pattern seen in a soap bubble
II. The colored pattern seen when light passes through a diffraction grating
III. The bending of light when it passes from one medium to another medium

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



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A plane 5 meters in length is inclined at an angle of 37°, as shown above. A block of weight 20 newtons is placed at the top of the plane and allowed to slide down.

61. The mass of the block is most nearly

(A) 1.0 kg
(B) 1.2 kg
(C) 1.6 kg
(D) 2.0 kg
(E) 2.5 kg

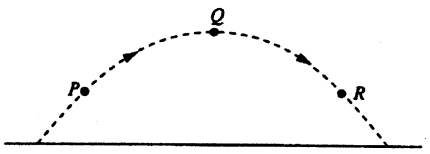
62. The magnitude of the normal force exerted on the block by the plane is most nearly

(A) l0 N
(B) 12N
(C) l6 N
(D) 20 N
(E) 33 N

63. The work done on the block by the gravitational force during the 5-meter slide down the plane is most nearly

(A) 20 J
(B) 60 J
(C) 80
(D) 100
(E) l30 J

Questions 64-66



A ball is thrown and follows the parabolic path shown above. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground.

64. How do the speeds of the ball at the three points compare?

(A) $v_P < v_Q < v_R$
(B) $v_R < v_Q < v_P$
(C) $v_Q < v_R < v_P$
(D) $v_Q < v_P = v_R$
(E) $v_P = v_R < v_Q$

65. Which of the following diagrams best shows the direction of the acceleration of the ball at point P ?

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(A) 

(B) 

(C)

(D) 

(E)

66. Which of the following best indicates the direction of the net force, if any, on the ball at point Q ?

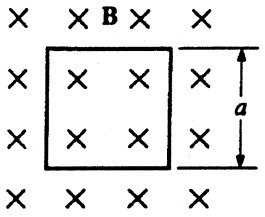
(A)

(B)

(C)

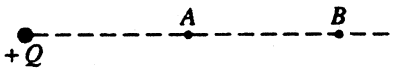
(D) 

(E) There is no net force on the ball at point Q.



67. A square loop of wire of resistance R and side a is oriented with its plane perpendicular to a magnetic field B. as shown above. What must be the rate of change of the magnetic field in order to produce a current I in the loop?

(A) IR/a^2
(B) la^2/R
(C) la /R
(D) Ra/l
(E) IRa



68. The diagram above shows an isolated, positive charge Q. Point B is twice as far away from Q as point A. The ratio of the electric field strength at point A to the electric field strength at point B is

(A) 8 to 1
(B) 4 to 1

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(C) 2 to 1
(D) 1 to 1
(E) 1 to 2

69. If the object distance for a converging thin lens is more than twice the focal length of the lens, the image is

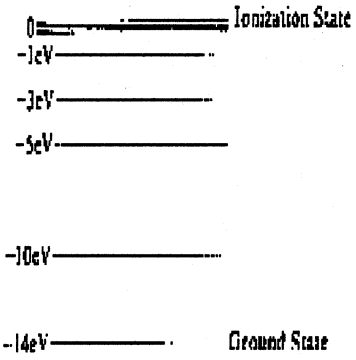
(A) virtual and erect
(B) larger than the object
(C) located inside the focal point
(D) located at a distance between f and 2f from the lens
(E) located at a distance more than by from the lens



70. Two conducting spheres of different radii, as shown above, each have charge - Q. Which of the following occurs when the two spheres are connected with a conducting wire?

(A) No charge flows.
(B) Negative charge flows from the larger sphere to the smaller sphere until the electric field at the surface of each sphere is the same.
(C) Negative charge flows from the larger sphere to the smaller sphere until the electric potential of each sphere is the same.
(D) Negative charge flows from the smaller sphere to the larger sphere until the electric field at the surface of each sphere is the same.
(E) Negative charge flows from the smaller sphere to the larger sphere until the electric potential of each sphere is the same.

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70. The energy level diagram above is for a hypothetical atom. A gas of these atoms initially in the ground state is irradiated with photons having a continuous range of energies between 7 and 10 electron volts, One would expect photons of which of the following energies to he emitted from the gas?
(A) 1, 2, and 3 eV only
(B) 4, 5, and 9 eV only
(C) 1, 3, 5, and 10 eV only
(D) 1, 5, 3, and 10 eV only
(E) Since the original photons have a range of energies, one would expect a range of emitted photons with no particular energies

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1998 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 $g = 10\ m/s^2$ in all problems.

1. A solid metal ball and a hollow plastic ball of the same external radius are released from rest in a large vacuum chamber. When each has fallen I m, they both have the same

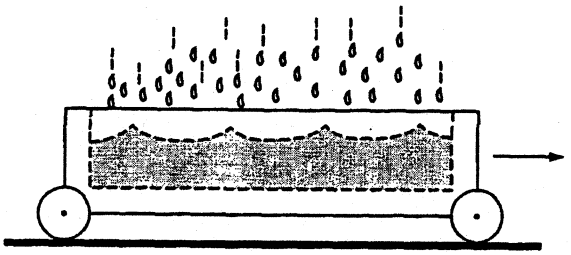
(A) inertia
(B) speed
(C) momentum
(D) kinetic energy
(E) change in potential energy

2. A student weighing 700 N climbs at constant speed to the top of an 8 in vertical rope in 10 s. The average power expended by the student to overcome gravity is most nearly

(A) 1.1 W
(B) 87.5 W
(C) 560 W
(D) 875 W
(E) 5,600 W

3. A railroad car of mass m is moving at speed υ when it collides with a second railroad car of mass M which is at rest. The two cars lock together instantaneously and move along the track. What is the speed of the cars immediately after the collision?

(A) $\frac{\upsilon}{2}$
(B) $\frac{m\upsilon}{M}$
(C) $\frac{M\upsilon}{m}$
(D) $\frac{(m+M)\upsilon}{m}$
(E) $\frac{mv}{m+M}$



4. An open cart on a level surface is rolling without frictional loss through a vertical downpour of rain, as shown above. As the cart rolls, an appreciable amount of rainwater accumulates in the cart. The speed of the cart will

(A) increase because of conservation of momentum
(B) increase because of conservation of mechanical energy
(C) decrease because of conservation of momentum
(D) decrease because of conservation of mechanical energy
(E) remain the same because the raindrops are falling perpendicular to the direction of the cart's motion

5. Units of power include which of the following?

I. Watt
II. Joule per second
III. Kilowatt-hour

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

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6. A 2 kg object moves in a circle of radius 4 m at a constant speed of 3 m/s. A net force of 4.5 N acts on the object. What is the angular momentum of the object with respect to an axis perpendicular to the circle and through its center?

(A) $9\frac{N \cdot m}{kg}$

(B) $12\frac{m^2}{s}$

(C) $13.5\frac{kg \cdot m^2}{s^2}$

(D) $18\frac{N \cdot m}{kg}$

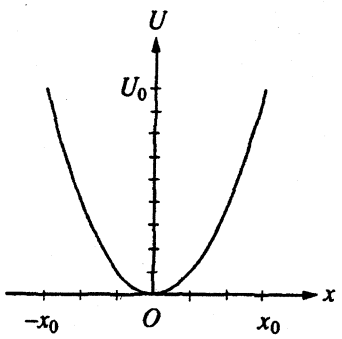
(E) $24\frac{kg \cdot m^2}{s}$

7. Three forces act on an object. If the object is in translational equilibrium, which of the following must be true?

I. The vector sum of the three forces must equal zero.
II. The magnitudes of the three forces must be equal
III. All three forces must be parallel

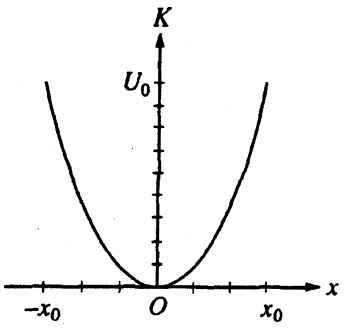
(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

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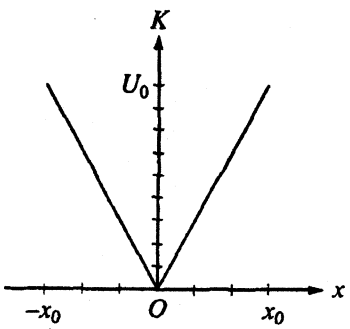


8. The graph above represents the potential energy U as a function of displacement x for an object on the end of a spring oscillating in simple harmonic motion with amplitude x_0. Which of the following graphs represents the kinetic energy **K** of the object as a function of displacement x?

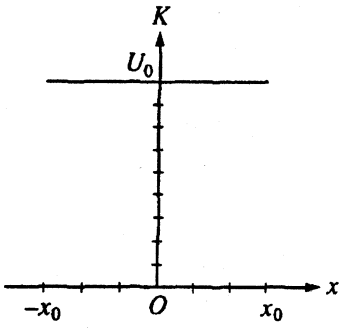
(A)



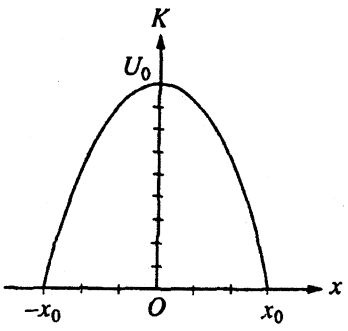
(B)



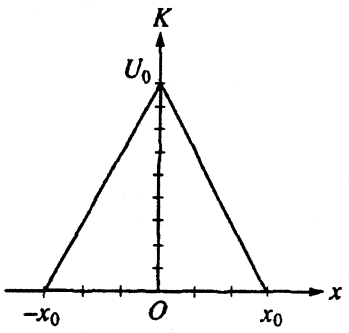
(C)



(D)



(E)



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9. A child pushes horizontally on a box of mass m which moves with constant speed υ across a horizontal floor. The coefficient of friction between the box and the floor is μ. At what rate does the child do work on the box?

(A) $\mu mg\upsilon$
(B) $mg\upsilon$
(C) $\upsilon/\mu mg$
(D) $\mu mg/\upsilon$
(E) $\mu m\upsilon^2$

10. Quantum transitions that result in the characteristic sharp lines of the X-ray spectrum always involve

(A) the inner electron shells
(B) electron energy levels that have the same principal quantum number
(C) emission of beta particles from the nucleus
(D) neutrons within the nucleus
(E) protons within the nucleus

11. Which of the following experiments provided evidence that electrons exhibit wave properties?

I. Millikan oil-drop experiment
II. Davisson-Germer electron-diffraction experiment
III. J. J. Thomson's measurement of the charge-to-mass ratio of electrons

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

12. Quantities that are conserved in all nuclear reactions include which of the following?

I. Electric charge
II. Number of nuclei
III. Number of protons

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

13. Which of the following is true about the net force on an uncharged conducting sphere in a uniform electric field?

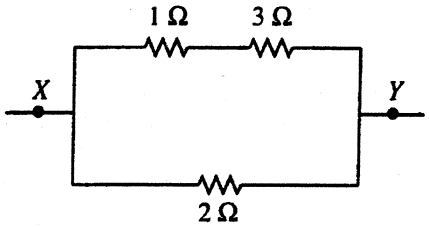
(A) It is zero.
(B) It is in the direction of the field.
(C) It is in the direction opposite to the field.
(D) It produces a torque on the sphere about the direction of the field.
(E) It causes the sphere to oscillate about an equilibrium position.

14. Two parallel conducting plates are connected to a constant voltage source. The magnitude of the electric field between the plates is 2,000 N/C. If the voltage is doubled and the distance between the plates is reduced to 1/5 the original distance, the magnitude of the new electric field is

(A) 800 N/C
(B) 1,600 N/C
(C) 2,400 N/C
(D) 5,000 N/C
(E) 20,000 N/C

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Questions 15-16 refer to the following diagram that shows part of a closed electrical circuit.



15. The electrical resistance of the part of the circuit shown between point X and point Y is

(A) $1\frac{1}{3}\Omega$

(B) 2Ω

(C) $2\frac{3}{4}\Omega$

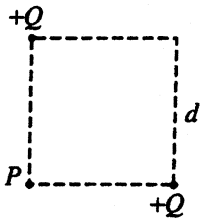
(D) 4Ω

(E) 6Ω

16. When there is a steady current in the circuit, the amount of charge passing a point per unit of time is

(A) the same everywhere in the circuit
(B) greater at point X than at point Y
(C) greater in the 1Ω resistor than in the 2Ω resistor
(D) greater in the 1Ω resistor than in the 3Ω resistor
(E) greater in the 2Ω resistor than in the 3Ω resistor

Questions 17-18



The figure above shows two particles, each with a charge of +Q, that are located at the opposite corners of a square of side *d*.

17. What is the direction of the net electric field at point P ?

(A) ↖

(B) ↗

(C) ↙

(D) ↘

(E) ↓

18. What is the potential energy of a particle of charge $+q$ that is held at point P ?

(A) Zero

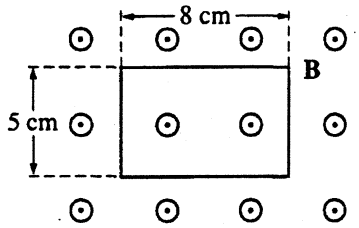
(B) $\frac{\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{qQ}{d}$

(D) $\frac{2}{4\pi\epsilon_0}\frac{qQ}{d}$

(E) $\frac{2\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

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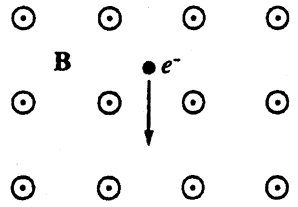


19. A rectangular wire loop is at rest in a uniform magnetic field **B** of magnitude 2 T that is directed out of the page. The loop measures 5 cm by 8 cm, and the plane of the loop is perpendicular to the field, as shown above. The total magnetic flux through the loop is

(A) zero
(B) 2×10^{-3} T•m^2
(C) 8×10^{-3} T•m^2
(D) 2×10^{-1} T•m^2
(E) 8×10^{-1} T•m^2

20. A certain coffeepot draws 4.0 A of current when it is operated on 120 V household lines. If electrical energy costs 10 cents per kilowatt-hour, how much does it cost to operate the coffeepot for 2 hours?

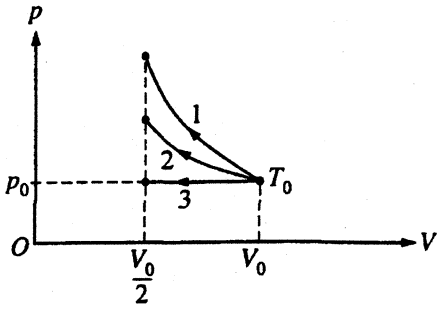
(A) 2.4 cents
(B) 4.8 cents
(C) 8.0 cents
(D) 9.6 cents
(E) 16 cents



22. An electron is in a uniform magnetic field **B** that is directed out of the plane of the page, as shown above. When the electron is moving in the plane of the page in the direction indicated by the arrow, the force on the electron is directed

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

Questions 22-23



A certain quantity of an ideal gas initially at temperature T_0, pressure p_0, and volume V_0 is compressed to one-half its initial volume. As shown above, the process may be adiabatic (process 1), isothermal (process 2), or isobaric (process 3).

21. Which of the following is true of the mechanical work done on the gas?

(A) It is greatest for process 1.
(B) It is greatest for process 3.
(C) It is the same for processes I and 2 and less for process 3.
(D) It is the same for processes 2 and 3 and less for process 1.
(E) It is the same for all three processes.

23. Which of the following is true of the final temperature of this gas?

(A) It is greatest for process 1.
(B) It is greatest for process 2.
(C) It is greatest for process 3.
(D) It is the same for processes 1 and 2.
(E) It is the same for processes 1 and 3.

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24. In a certain process, 400 J of heat is added to a system and the system simultaneously does 100 J of work. The change in internal energy of the system is

(A) 500 J
(B) 400 J
(C) 300 J
(D) -100 J
(E) -300 J

25. An ice cube of mass m and specific heat c_i is initially at temperature T_1, where $T_1 < 273$ K. If L *is* the latent heat of fusion of water, and the specific heat of water is c_w how much energy is required to convert the ice cube to water at temperature T_2, where $273 \text{ K} < T_2 < 373 \text{ K}$?

(A) $m[c_i(273 - T_1) + L + c_w(373 - T_2)]$

(B) $m[c_i(273 - T_1) + L + c_w(T_2 - 273)]$

(C) $c_i(273 - T_1) + c_w(T_2 - 273)$

(D) $mL + c_w(T_2 - T_1)$

(E) $mL + \left(\frac{c_w + c_i}{2}\right)(T_2 - T_1)$

26. A concave mirror with a radius of curvature of 1.0 m is used to collect light from a distant star. The distance between the mirror and the image of the star is most nearly

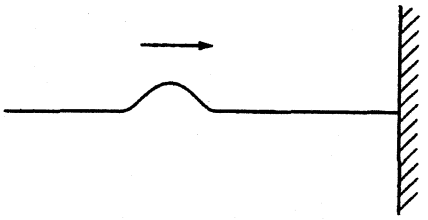
(A) 0.25m
(B) 0.50 m
(C) 0.75 m
(D) 1.0 m
(E) 2.0 m

27. When light passes from air into water, the frequency of the light remains the same. What happens to the speed and the wavelength of light as it crosses the boundary in going from air into water?

	Speed	Wavelength
(A)	Increases	Remains the same
(B)	Remains the same	Decreases
(C)	Remains the same	Remains the same
(D)	Decreases	Increases
(E)	Decreases	Decreases

28. A physics student places an object 6.0 cm from a converging tens of focal length 9.0 cm. What is the magnitude of the magnification of the image produced?

(A) 0.6
(B) 1.5
(C) 2.0
(D) 3.0
(E) 3.6

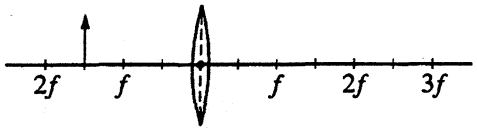


29. One end of a horizontal string is fixed to a wall. A transverse wave pulse is generated at the other end, moves toward the wall as shown above, and is reflected at the wall. Properties of the reflected pulse include which of the following?

I. It has a greater speed than that of the incident pulse.
II. It has a greater amplitude than that of the incident pulse.
III. It is on the opposite side of the string from the incident pulse.

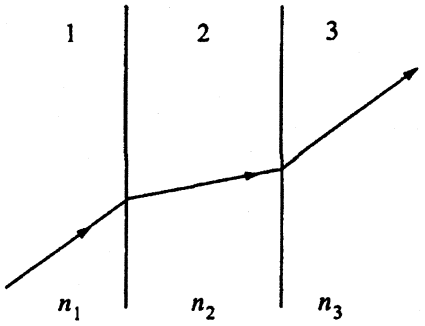
(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

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30. An object is placed at a distance of $1.5f$ from a converging lens of focal length f, as shown above. What type of image is formed and what is its size relative to the object?

Type	Size
(A) Virtual	Larger
(B) Virtual	Same size
(C) Virtual	Smaller
(D) Real	Larger
(E) Real	Smaller



31. A light ray passes through substances 1, 2, and 3, as shown above. The indices of refraction for these three substances are n_1, n_2, and n_3, respectively. Ray segments in 1 and in 3 are parallel. From the directions of the ray, one can conclude that

(A) n_3 must be the same as n_1
(B) n_2 must be less than n_1
(C) n_2 must be less than n_3
(D) n_1 must be equal to 1.00
(E) all three indices must be the same

32. At noon a radioactive sample decays at a rate of 4,000 counts per minute. At 12:30 P.m. the decay rate has decreased to 2,000 counts per minute. The predicted decay rate at 1:30 P m. is

(A) 0 counts per minute
(B) 500 counts per minute
(C) 667 counts per minute
(D) 1,000 counts per minute
(E) 1,333 counts per minute

33. A negative beta particle and a gamma ray are emitted during the radioactive decay of a nucleus of $^{214}_{82}\mathrm{Pb}$. Which of the following is the resulting nucleus?

(A) $^{214}_{80}\mathrm{Hg}$
(B) $^{214}_{81}\mathrm{Tl}$
(C) $^{213}_{83}\mathrm{Bi}$
(D) $^{214}_{83}\mathrm{Bi}$
(E) $^{218}_{84}\mathrm{Po}$

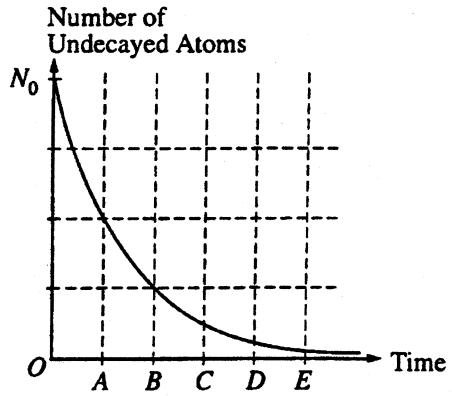
34. If the momentum of an electron doubles, its de Broglie wavelength is multiplied by a factor of

(A) $\frac{1}{4}$
(B) $\frac{1}{2}$
(C) 1
(D) 2
(E) 4

35. Quantum concepts are critical in explaining all of the following EXCEPT

(A) Rutherford's scattering experiments
(B) Bohr's theory of the hydrogen atom
(C) Compton scattering
(D) the blackbody spectrum
(E) the photoelectric effect

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36. The graph above shows the decay of a sample of carbon 14 that initially contained N_0 atoms. Which of the lettered points on the time axis could represent the half-life of carbon 14 ?

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

37. If photons of light of frequency f have momentum p, photons of light of frequency $2f$ will have a momentum of

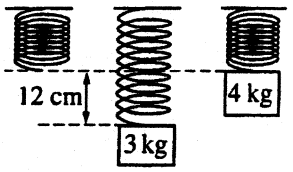
(A) $2p$

(B) $\sqrt{2}p$

(C) p

(D) $\frac{p}{\sqrt{2}}$

(E) $\frac{1}{2}p$



38. A block of mass 3.0 kg is hung from a spring, causing it to stretch 12 cm at equilibrium, as shown above. The 3.0 kg block is then replaced by a 4.0 kg block, and the new block is released from the position shown above, at which the spring is unstretched. How far will the 4.0 kg block fall before its direction is reversed?

(A) 9 cm
(B) 18 cm
(C) 24 cm
(D) 32 cm
(E) 48 cm

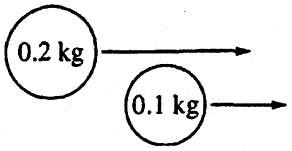
39. An object has a weight W when it is on the surface of a planet of radius R. What will be the gravitational force on the object after it has been moved to a distance of $4R$ from the center of the planet?

(A) $16W$
(B) $4W$
(C) W
(D) $\frac{1}{4}W$
(E) $\frac{1}{16}W$

40. What is the kinetic energy of a satellite of mass m that orbits the Earth, of mass M, in a circular orbit of radius R ?

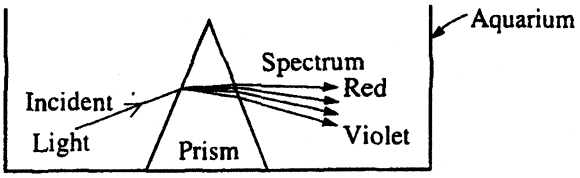
(A) Zero
(B) $\frac{1}{2}\frac{GMm}{R}$
(C) $\frac{1}{4}\frac{GMm}{R}$
(D) $\frac{1}{2}\frac{GMm}{R^2}$
(E) $\frac{GMm}{R^2}$

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41. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown above. The 0.2 kg object overtakes and collides with the 0. 1 kg object. Immediately after the collision, the y-component of the velocity of the 0.2 kg object is 1 m/s upward. What is the y-component of the velocity of the 0.1 kg object immediately after the collision?

(A) 2 m/s downward
(B) 0.5 m/s downward
(C) 0 m/s
(D) 0.5 m/s upward
(E) 2 m/s upward

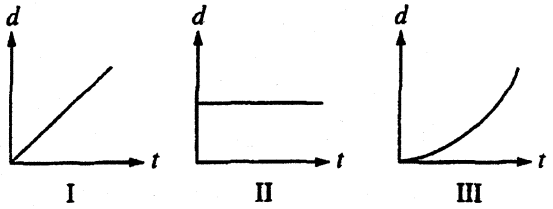


42. A beam of white Bight is incident on a triangular glass prism with an index of refraction of about 1.5 for visible light, producing a spectrum. Initially, the prism is in a glass aquarium filled with air, as shown above. If the aquarium is filled with water with an index of refraction of 1.3, which of the following is true?

(A) No spectrum is produced.
(B) A spectrum is produced, but the deviation of the beam is opposite to that in air.
(C) The positions of red and violet are reversed in the spectrum.
(D) The spectrum produced has greater separation between red and violet than that produced in air.
(E) The spectrum produced has less separation between red and violet than that produced in air.

Questions 43-44

Three objects can only move along a straight, level path. The graphs below show the position d of each of the objects plotted as a function of time t.



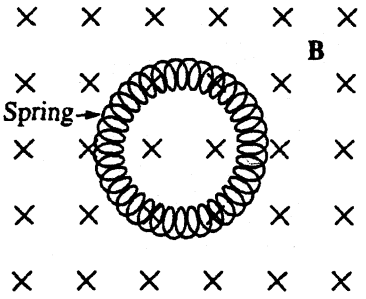
43. The magnitude of the momentum of the object is increasing in which of the cases?

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

44. The sum of the forces on the object is zero in which of the cases?

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

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45. A metal spring has its ends attached so that it forms a circle. It is placed in a uniform magnetic field, as shown above. Which of the following will NOT cause a current to be induced in the spring?

(A) Changing the magnitude of the magnetic field
(B) Increasing the diameter of the circle by stretching the spring
(C) Rotating the spring about a diameter
(D) Moving the spring parallel to the magnetic field
Moving the spring in and out of the magnetic field

A magnetic field of 0.1 T forces a proton beam of 1.5 mA to move in a circle of radius 0.1 m. The plane of the circle is perpendicular to the magnetic field.

46. Of the following, which is the best estimate of the work done by the magnetic field on the protons during one complete orbit of the circle?

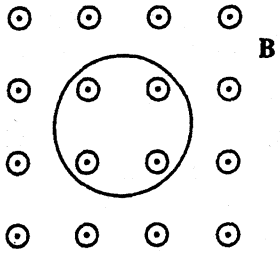
(A) 0 J
(B) 10^{-22} J
(C) 10^{-5} J
(D) 10^{2} J
(E) 10^{20} J

47. Of the following, which is the best estimate of the speed of a proton in the beam as it moves in the circle?

(A) 10^{-2} m/s
(B) 10^{3} m/s
(C) 10^{6} m/s
(D) 10^{8} m/s
(E) 10^{15} m/s

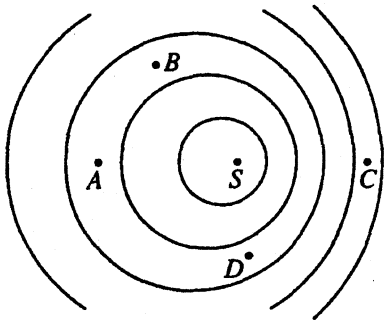
Questions 46-47

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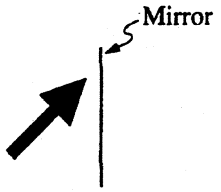
48. A single circular loop of wire in the plane of the page is perpendicular to a uniform magnetic field B directed out of the page, as shown above. If the magnitude of the magnetic field is decreasing, then the induced current in the wire is

(A) directed upward out of the paper
(B) directed downward into the paper
(C) clockwise around the loop
(D) counterclockwise around the loop
(E) zero (no current is induced)



49. A small vibrating object on the surface of a ripple tank is the source of waves of frequency 20 Hz and speed 60 cm/s. If the source S is moving to the right, as shown above, with speed 20 cm/s, at which of the labeled points will the frequency measured by a stationary observer be greatest?

(A) A
(B) B
(C) C
(D) D
(E) It will be the same at all four points.

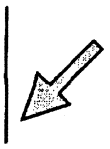


50. An object, slanted at an angle of 45°, is placed in front of a vertical plane mirror, as shown above. Which of the following shows the apparent position and orientation of the object's image?

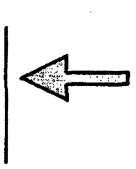
(A)



(B)



(C)



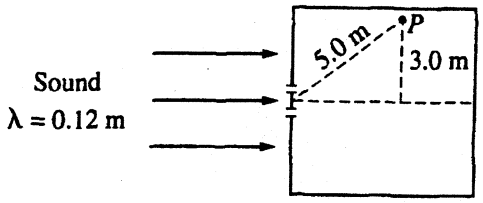
(D)



(E)

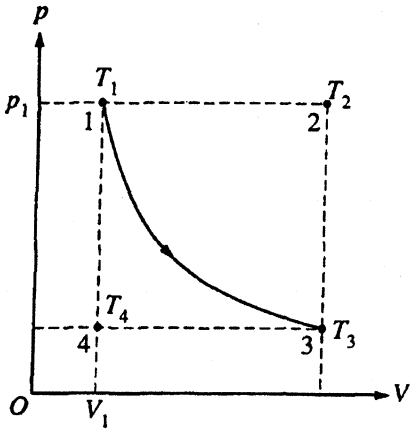


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51. Plane sound waves of wavelength 0.12 m are incident on two narrow slits in a box with nonreflecting walls, as shown above. At a distance of 5.0 m from the center of the slits, a first-order maximum occurs at point P, which is 3.0 m from the central maximum. The distance between the slits is most nearly

(A) 0.07 m
(B) 0.09 m
(C) 0.16 m
(D) 0.20 m
(E) 0.24 m



52. An ideal gas is initially in a state that corresponds to point 1 on the graph above, where it has pressure p_1, volume V_1, and temperature T_1. The gas undergoes an isothermal process represented by the curve shown, which takes it to a final state 3 at temperature T_3. If T_2 and T_4 are the temperatures the gas would have at points 2 and 4, respectively, which of the following relationships is true?

(A) $T_1 < T_3$
(B) $T_1 < T_2$
(C) $T_1 < T_4$
(D) $T_1 = T_2$
(E) $T_1 = T_4$

53. The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?

	Pressure	Density
(A)	Remains the same	Remains the same
(B)	Remains the same	Doubles
(C)	Doubles	Remains the same
(D)	Doubles	Is multiplied by a factor of 4
(E)	Is multiplied by a factor of 4	Doubles

54. The disk-shaped head of a pin is 1.0 mm in diameter. Which of the following is the best estimate of the number of atoms in the layer of atoms on the top surface of the pinhead?

(A) 10^4
(B) 10^{14}
(C) 10^{24}
(D) 10^{34}
(E) 10^{50}

55. In an experiment, light of a particular wavelength is incident on a metal surface, and electrons are emitted from the surface as a result, To produce more electrons per unit time but with less kinetic energy per electron, the experimenter should do which of the following?

(A) Increase the intensity and decrease the wavelength of the light.
(B) Increase the intensity and the wavelength of the light.
(C) Decrease the intensity and the wavelength of the light.
(D) Decrease the intensity and increase the wavelength of the light.
(E) None of the above would produce the desired result.

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56. An object moves up and down the y -axis with an acceleration given as a function of time t by the expression $a = A\sin\omega t$, where A and ω are constants. What is the period of this motion?

(A) ω

(B) $2\pi\omega$

(C) $\omega^2 A$

(D) $\dfrac{2\pi}{\omega}$

(E) $\dfrac{\omega}{2\pi}$

57. A ball of mass 0.4 kg is initially at rest on the ground. It is kicked and leaves the kicker's foot with a speed of 5.0 m/s in a direction 60° above the horizontal. The magnitude of the impulse imparted by the ball to the foot is most nearly

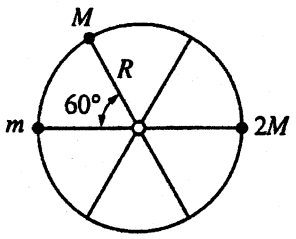
(A) $1\ \text{N}\cdot\text{s}$

(B) $\sqrt{3}\ \text{N}\cdot\text{s}$

(C) $2\ \text{N}\cdot\text{s}$

(D) $\dfrac{2}{\sqrt{3}}\ \text{N}\cdot\text{s}$

(E) $4\ \text{N}\cdot\text{s}$



58. A wheel of radius R and negligible mass is mounted on a horizontal frictionless axle so that the wheel is in a vertical plane. Three small objects having masses m, M, and $2M$, respectively, are mounted on the rim of the wheel, as shown above. If the system is in static equilibrium, what is the value of m in terms of M?

(A) $\dfrac{M}{2}$

(B) M

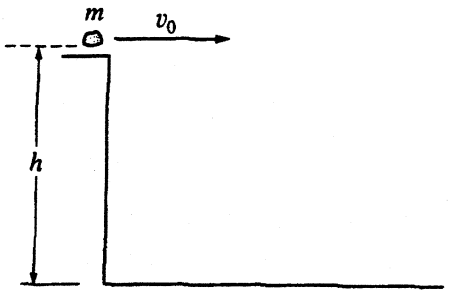
(C) $\dfrac{3M}{2}$

(D) $2M$

(E) $\dfrac{5m}{2}$

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Questions 59-60



A rock of mass *m* is thrown horizontally off a building from a height *h*, as shown above. The speed of the rock as it leaves the thrower's hand at the edge of the building is υ_0.

59. How much time does it take the rock to travel from the edge of the building to the ground?

(A) $\sqrt{h\upsilon_0}$

(B) h/υ_0

(C) $h\upsilon_0/g$

(D) $2h/g$

(E) $\sqrt{2h/g}$

60. What is the kinetic energy of the rock just before it hits the ground?

(A) mgh

(B) $\frac{1}{2}m\upsilon_0^2$

(C) $\frac{1}{2}m\upsilon_0^2 - mgh$

(D) $\frac{1}{2}m\upsilon_0^2 + mgh$

(E) $mgh - \frac{1}{2}m\upsilon_0^2$

61. Which of the following statements is NOT a correct assumption of the classical model of an ideal gas?

(A) The molecules are in random motion.
(B) The volume of the molecules is negligible compared with the volume occupied by the gas.
(C) The molecules obey Newton's laws of motion.
(D) The collisions between molecules are inelastic.
(E) The only appreciable forces on the molecules are those that occur during collisions.

62. A sample of an ideal gas is in a tank of constant volume. The sample absorbs heat energy so that its temperature changes from 300 K to 600 K. If υ_1 is the average speed of the gas molecules before the absorption of heat and υ_2 is their average speed after the absorption of heat, what is the ratio υ_2/υ_1?

(A) $\frac{1}{2}$

(B) 1

(C) $\sqrt{2}$

(D) 2

(E) 4

63. Two people of unequal mass are initially standing still on ice with negligible friction. They then simultaneously push each other horizontally. Afterward, which of the following is true?

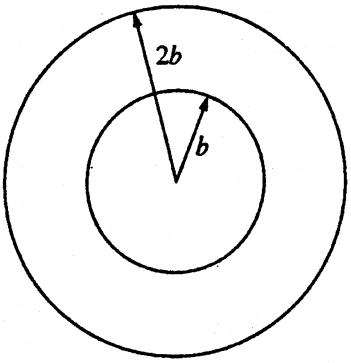
(A) The kinetic energies of the two people are equal.
(B) The speeds of the two people are equal.
(C) The momenta of the two people are of equal magnitude.
(D) The center of mass of the two-person system moves in the direction of the less massive person.
(E) The less massive person has a smaller initial acceleration than the more massive person.

64. Two parallel conducting plates, separated by a distance *d*, are connected to a battery of emf ε. Which of the following is correct if the plate separation is doubled while the battery remains connected?

(A) The electric charge on the plates is doubled.
(B) The electric charge on the plates is halved.
(C) The potential difference between the plates is doubled.
(D) The potential difference between the plates is halved.
(E) The capacitance is unchanged.

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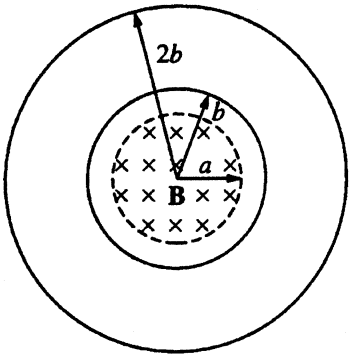
Questions 65-66



Two concentric circular loops of radii b and $2b$, made of the same type of wire, lie in the plane of the page, as shown above.

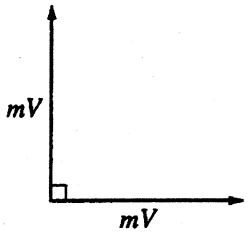
65. The total resistance of the wire loop of radius b is R. What is the resistance of the wire loop of radius $2b$?

(A) $R/4$
(B) $R/2$
(C) R
(D) $2R$
(E) $4R$



66. A uniform magnetic field **B** that is perpendicular to the plane of the page now passes through the loops, as shown above. The field is confined to a region of radius a, where a < b, and is changing at a constant rate. The induced emf in the wire loop of radius b is $\mathcal{E}$. What is the induced emf in the wire loop of radius 2b ?

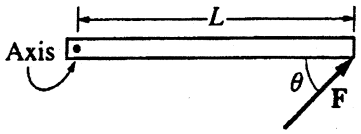
(A) Zero
(B) $\mathcal{E}/2$
(C) $\mathcal{E}$
(D) $2\mathcal{E}$
(E) $4\mathcal{E}$



67. A stationary object explodes, breaking into three pieces of masses m, m, and $3m$. The two pieces of mass m move off at right angles to each other with the same magnitude of momentum mV, as shown in the diagram above. What are the magnitude and direction of the velocity of the piece having mass $3m$?

	Magnitude	Direction
(A)	$\frac{V}{\sqrt{3}}$	↗
(B)	$\frac{V}{\sqrt{3}}$	↙
(C)	$\frac{\sqrt{2}\,V}{3}$	↗
(D)	$\frac{\sqrt{2}\,V}{3}$	↙
(E)	$\sqrt{2}\,V$	↙

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View from Above

68. A rod on a horizontal tabletop is pivoted at one end and is free to rotate without friction about a vertical axis, as shown above. A force **F** is applied at the other end, at an angle θ to the rod. If **F** were to be applied perpendicular to the rod, at what distance from the axis should it be applied in order to produce the same torque?

(A) $L\sin\theta$
(B) $L\cos\theta$
(C) L
(D) $L\tan\theta$
(E) $\sqrt{2}L$

69. Which of the following imposes a limit on the number of electrons in an energy state of an atom?

(A) The Heisenberg uncertainty principle
(B) The Pauli exclusion principle
(C) The Bohr model of the hydrogen atom
(D) The theory of relativity
(E) The law of conservation of energy

70. A 4 μF capacitor is charged to a potential difference of 100 V. The electrical energy stored in the capacitor is

(A) 2×10^{-10} J
(B) 2×10^{-8} J
(C) 2×10^{-6} J
(D) 2×10^{-4} J
(E) 2×10^{-2} J

S T 0 P

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY
CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU
ARE TOLD TO DO SO.

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1993
AP Physics B Examination
with Key



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$x = 0.075m$ $F = kx$ $k = \frac{F}{x} = \frac{5N}{0.075} = 66$

1. In which of the following situations would an object be accelerated?

   I. It moves in a straight line at constant speed.
   II. It moves with uniform circular motion.
   III. It travels as a projectile in a gravitational field with negligible air resistance.

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

2. A ball falls straight down through the air under the influence of gravity. There is a retarding force F on the ball with magnitude given by $F = bv$, where v is the speed of the ball and b is a positive constant. The magnitude of the acceleration a of the ball at any time is equal to which of the following?

   (A) $g - b$
   (B) $g - \frac{bv}{m}$
   (C) $g + \frac{bv}{m}$
   (D) $\frac{g}{b}$
   (E) $\frac{bv}{m}$



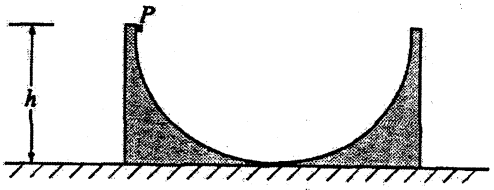
$mg - bv = ma$

$a = \frac{mg - bv}{m}$

$= g - \frac{bv}{m}$

3. An ideal spring obeys Hooke's law, $\mathbf{F} = -k\mathbf{x}$. A mass of 0.50 kilogram hung vertically from this spring stretches the spring 0.075 meter. The value of the force constant for the spring is most nearly

   (A) 0.33 N/m
   (B) 0.66 N/m
   (C) 6.6 N/m
   (D) 33 N/m
   (E) 66 N/m



4. The figure above shows a rough semicircular track whose ends are at a vertical height h. A block placed at point P at one end of the track is released from rest and slides past the bottom of the track. Which of the following is true of the height to which the block rises on the other side of the track?

   (A) It is equal to $h/2\pi$.
   (B) It is equal to $h/4$.
   (C) It is equal to $h/2$.
   (D) It is equal to h.
   (E) It is between zero and h; the exact height depends on how much energy is lost to friction.

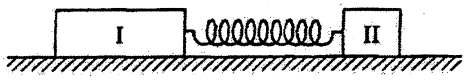
5. An object is released from rest on a planet that has no atmosphere. The object falls freely for 3.0 meters in the first second. What is the magnitude of the acceleration due to gravity on the planet?

(A) 1.5 m/s^2
(B) 3.0 m/s^2
(C) 6.0 m/s^2
(D) 10.0 m/s^2
(E) 12.0 m/s^2

6. If Spacecraft X has twice the mass of Spacecraft Y, then true statements about X and Y include which of the following?

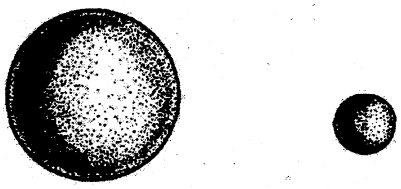
I. On Earth, X experiences twice the gravitational force that Y experiences.
II. On the Moon, X has twice the weight of Y.
III. When both are in the same circular orbit, X has twice the centripetal acceleration of Y.

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



7. Two pucks are attached by a stretched spring and are initially held at rest on a frictionless surface, as shown above. The pucks are then released simultaneously. If puck I has three times the mass of puck II, which of the following quantities is the same for both pucks as the spring pulls the two pucks toward each other?

(A) Speed
(B) Velocity
(C) Acceleration
(D) Kinetic energy
(E) Magnitude of momentum



8. The two spheres pictured above have equal densities and are subject only to their mutual gravitational attraction. Which of the following quantities must have the same magnitude for both spheres?

(A) Acceleration
(B) Velocity
(C) Kinetic energy
(D) Displacement from the center of mass
(E) Gravitational force

9. When an object oscillating in simple harmonic motion is at its maximum displacement from the equilibrium position, which of the following is true of the values of its speed and the magnitude of the restoring force?

	Speed	Restoring Force
(A)	Zero	Maximum
(B)	Zero	Zero
(C)	$\frac{1}{2}$ maximum	$\frac{1}{2}$ maximum
(D)	Maximum	$\frac{1}{2}$ maximum
(E)	Maximum	Zero

10. Which of the following is true when an object of mass m moving on a horizontal frictionless surface hits and sticks to an object of mass $M > m$, which is initially at rest on the surface?

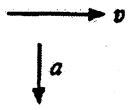
(A) The collision is elastic.
(B) All of the initial kinetic energy of the less-massive object is lost.
(C) The momentum of the objects that are stuck together has a smaller magnitude than the initial momentum of the less-massive object.
(D) The speed of the objects that are stuck together will be less than the initial speed of the less-massive object.
(E) The direction of motion of the objects that are stuck together depends on whether the hit is a head-on collision.

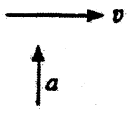
11. Two objects having the same mass travel toward each other on a flat surface, each with a speed of 1.0 meter per second relative to the surface. The objects collide head-on and are reported to rebound after the collision, each with a speed of 2.0 meters per second relative to the surface. Which of the following assessments of this report is most accurate?

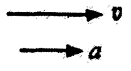
(A) Momentum was not conserved, therefore the report is false.
(B) If potential energy was released to the objects during the collision, the report could be true.
(C) If the objects had different masses, the report could be true.
(D) If the surface was inclined, the report could be true.
(E) If there was no friction between the objects and the surface, the report could be true.

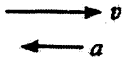


12. An automobile moves at constant speed down one hill and up another hill along the smoothly curved surface shown above. Which of the following diagrams best represents the directions of the velocity and the acceleration of the automobile at the instant that it is at the lowest position, as shown?

(A) 

(B) 

(C) 

(D) 

(E) 

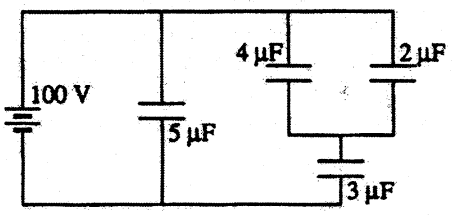
13. Which of the following will cause the electrical resistance of certain materials known as superconductors to suddenly decrease to essentially zero?

(A) Increasing the voltage applied to the material beyond a certain threshold voltage
(B) Increasing the pressure applied to the material beyond a certain threshold pressure
(C) Cooling the material below a certain threshold temperature
(D) Stretching the material to a wire of sufficiently small diameter
(E) Placing the material in a sufficiently large magnetic field

14. Kirchhoff's loop rule for circuit analysis is an expression of which of the following?

(A) Conservation of charge
(B) Conservation of energy
(C) Ampère's law
(D) Faraday's law
(E) Ohm's law

Questions 15-16 refer to the circuit shown below.



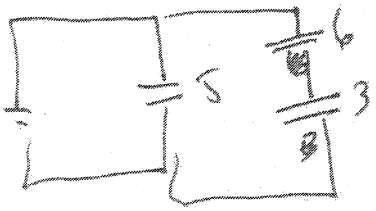
15. The equivalent capacitance for this network is most nearly

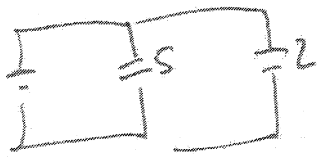
(A) 10/7 μF
(B) 3/2 μF
(C) 7/3 μF
(D) 7 μF
(E) 14 μF

16. The charge stored in the 5-microfarad capacitor is most nearly

(A) 360 μC
(B) 500 μC
(C) 710 μC
(D) 1,100 μC
(E) 1,800 μC

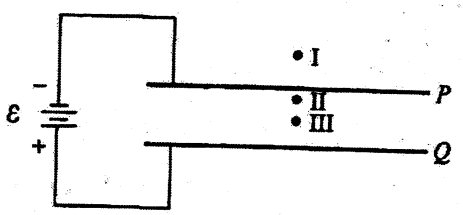
$Q = CV = 5\mu f(100V)$
$= 500\,\mu C$





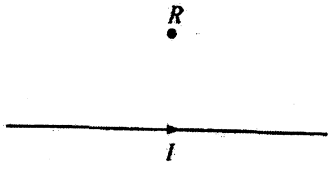
$\frac{1}{6} + \frac{2}{6} = \frac{3}{6}$
$C_{eq} = 2$





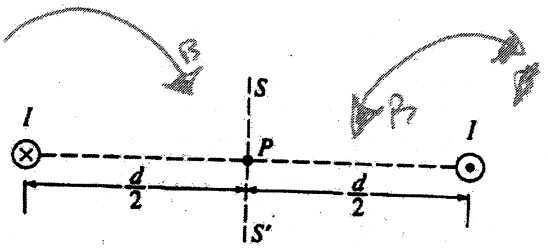
17. Two large parallel conducting plates P and Q are connected to a battery of emf $\mathcal{E}$, as shown above. A test charge is placed successively at points I, II, and III. If edge effects are negligible, the force on the charge when it is at point III is

(A) of equal magnitude and in the same direction as the force on the charge when it is at point I
(B) of equal magnitude and in the same direction as the force on the charge when it is at point II
(C) equal in magnitude to the force on the charge when it is at point I, but in the opposite direction
(D) much greater in magnitude than the force on the charge when it is at point II, but in the same direction
(E) much less in magnitude than the force on the charge when it is at point II, but in the same direction



18. The direction of the magnetic field at point R caused by the current I in the wire shown above is

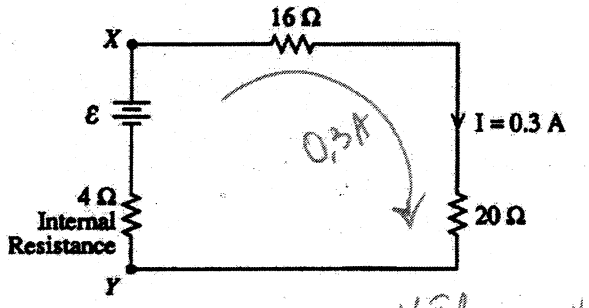
(A) to the left
(B) to the right
(C) toward the wire
(D) into the page
(E) out of the page



19. Two long, parallel wires are separated by a distance d, as shown above. One wire carries a steady current I into the plane of the page while the other wire carries a steady current I out of the page. At what points in the plane of the page and outside the wires, besides points at infinity, is the magnetic field due to the currents zero?

(A) Only at point P
(B) At all points on the line SS'
(C) At all points on the line connecting the two wires
(D) At all points on a circle of radius $2d$ centered on point P
(E) At no points

Questions 20-22 relate to the following circuit diagram, which shows a battery with an internal resistance of 4.0 ohms connected to a 16-ohm and a 20-ohm resistor in series. The current in the 20-ohm resistor is 0.3 amperes.



20. What is the emf of the battery?

(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

21. What is the potential difference across the terminals X and Y of the battery?

(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

22. What power is dissipated by the 4-ohm internal resistance of the battery?

(A) 0.36 W
(B) 1.2 W
(C) 3.2 W
(D) 3.6 W
(E) 4.8 W

23. If the gas in a container absorbs 275 joules of heat, has 125 joules of work done on it, and then does 50 joules of work, what is the increase in the internal energy of the gas?

(A) 100 J
(B) 200 J
(C) 350 J
(D) 400 J
(E) 450 J

Questions 24-25

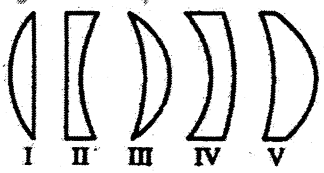
A piece of metal with a mass of 1.50 kilograms, specific heat of 200 J/kg · C°, and initial temperature of 100° C is dropped into an insulated jar that contains liquid with a mass of 3.00 kilograms, specific heat of 1,000 J/kg · C°, and initial temperature of 0° C. The piece of metal is removed after 5 seconds, at which time its temperature is 20° C. Neglect any effects of heat transfer to the air or to the insulated jar.

24. The temperature of the liquid after the metal is removed is

(A) 0° C
(B) 4° C
(C) 8° C
(D) 10° C
(E) 20° C

25. The average rate at which heat is transferred while the piece of metal is in the liquid is

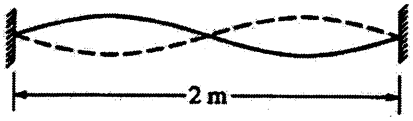
(A) 4,000 J/s
(B) 4,800 J/s
(C) 6,000 J/s
(D) 9,600 J/s
(E) 16,000 J/s



26. Which three of the glass lenses above, when placed in air, will cause parallel rays of light to converge?

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

Questions 27-28



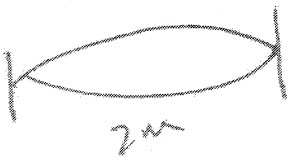
A standing wave of frequency 5 hertz is set up on a string 2 meters long with nodes at both ends and in the center, as shown above.

27. The speed at which waves propagate on the string is

(A) 0.4 m/s
(B) 2.5 m/s
(C) 5 m/s
(D) 10 m/s
(E) 20 m/s

28. The fundamental frequency of vibration of the string is

(A) 1 Hz
(B) 2.5 Hz
(C) 5 Hz
(D) 7.5 Hz
(E) 10 Hz



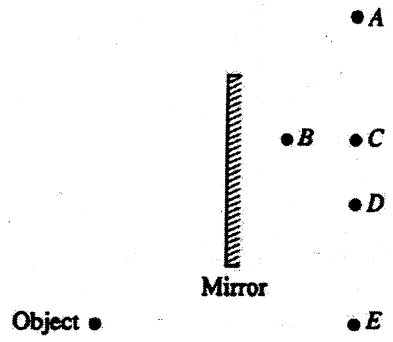
Radio waves
Infrared radiation
Visible light
Ultraviolet radiation
Gamma radiation

29. For the five types of electromagnetic radiation listed above, which of the following correctly describes the way in which wavelength, frequency, and photon energy change as one goes from the top of the list to the bottom?

	Wavelength	Frequency	Photon Energy
(A)	Decreases	Decreases	Increases
(B)	Decreases	Increases	Increases
(C)	Increases	Decreases	Decreases
(D)	Increases	Decreases	Increases
(E)	Increases	Increases	Increases

30. Sound in air can best be described as which of the following types of waves?

(A) Longitudinal
(B) Transverse
(C) Torsional
(D) Electromagnetic
(E) Polarized



31. An object is placed near a plane mirror, as shown above. Which of the labeled points is the position of the image?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

Questions 32-33 deal with nuclear fission for which the following reaction is a good example.

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{56}Ba + {}^{95}_{36}Kr$ + neutrons + released energy

32. The total number of free neutrons in the products of this reaction is

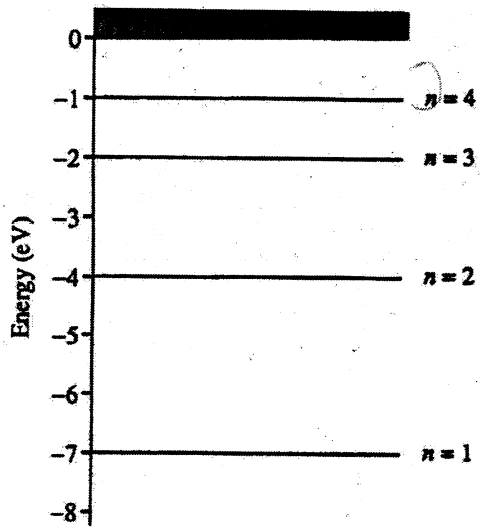
(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

33. Which of the following statements is always true for neutron-induced fission reactions involving $^{235}_{92}U$?

I. The end products always include Ba and Kr.
II. The rest mass of the end products is less than that of $^{235}_{92}U + {}^{1}_{0}n$.
III. The total number of nucleons (protons plus neutrons) in the end products is less than that in $^{235}_{92}U + {}^{1}_{0}n$.

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

Questions 34-35



A hypothetical atom has four energy states as shown above.

34. Which of the following photon energies could NOT be found in the emission spectra of this atom after it has been excited to the $n = 4$ state?

(A) 1 eV
(B) 2 eV
(C) 3 eV
(D) 4 eV
(E) 5 eV

35. Which of the following transitions will produce the photon with the longest wavelength?

(A) $n = 2$ to $n = 1$
(B) $n = 3$ to $n = 1$
(C) $n = 3$ to $n = 2$
(D) $n = 4$ to $n = 1$
(E) $n = 4$ to $n = 3$

36. Cobalt 60 is a radioactive source with a half-life of about 5 years. After how many years will the activity of a new sample of cobalt 60 be decreased to 1/8 its original value?

(A) 2.5 years
(B) 5 years
(C) 10 years
(D) 15 years
(E) It depends on the original amount of cobalt 60.

37. Of the following phenomena, which provides the best evidence that light can have particle properties?

(A) Interference of light in thin films
(B) Electromagnetic radiation
(C) Photoelectric effect
(D) Electron diffraction
(E) X-ray diffraction

38. Of the following phenomena, which provides the best evidence that particles can have wave properties?

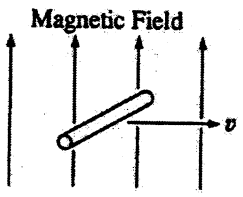
(A) The absorption of photons by electrons in an atom
(B) The α-decay of radioactive nuclei
(C) The interference pattern produced by neutrons incident on a crystal
(D) The production of x-rays by electrons striking a metal target
(E) The scattering of photons by electrons at rest

39. A muon, with a lifetime of 2×10^{-6} second in its frame of reference, is created in the upper atmosphere with a velocity of $0.998c$ toward the Earth. The lifetime of the muon, as measured by an observer on the Earth, is most nearly

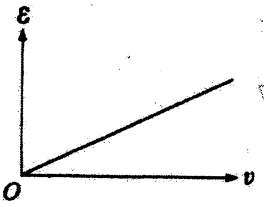
(A) 3×10^{-2} s
(B) 3×10^{-3} s
(C) 3×10^{-4} s
(D) 3×10^{-5} s
(E) 3×10^{-6} s

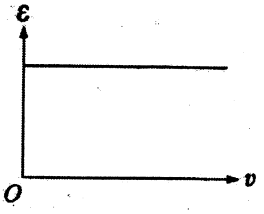
40. The operator of a space station observes a space vehicle approaching at a constant speed v. The operator sends a light signal at speed c toward the space vehicle. The speed of the light signal relative to the space vehicle is

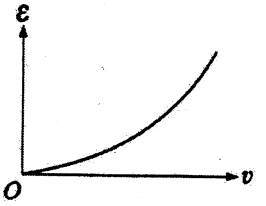
(A) $c + v$
(B) $c - v$
(C) c
(D) $v/\sqrt{1 - v^2/c^2}$
(E) $c\sqrt{1 - v^2/c^2}$

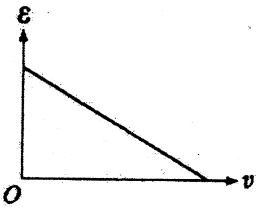


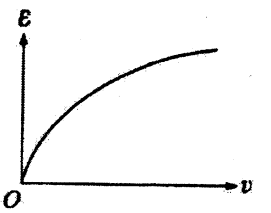
41. A wire of constant length is moving in a constant magnetic field, as shown above. The wire and the velocity vector are perpendicular to each other and are both perpendicular to the field. Which of the following graphs best represents the potential difference $\mathcal{E}$ between the ends of the wire as a function of the speed v of the wire?

(A)


(B)


(C)


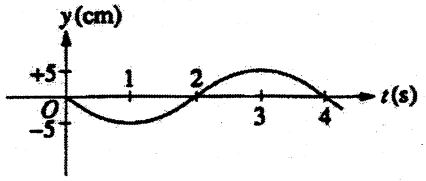
(D)


(E)


42. Forces between two objects which are inversely proportional to the square of the distance between the objects include which of the following?

I. Gravitational force between two celestial bodies
II. Electrostatic force between two electrons
III. Nuclear force between two neutrons

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

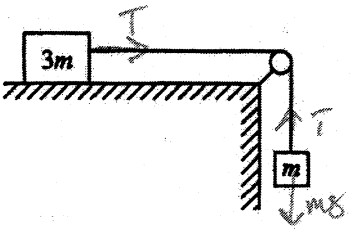


43. A particle oscillates up and down in simple harmonic motion. Its height y as a function of time t is shown in the diagram above. At what time t does the particle achieve its maximum positive acceleration?

(A) 1 s
(B) 2 s
(C) 3 s
(D) 4 s
(E) None of the above, because the acceleration is constant

44. A weight lifter lifts a mass m at constant speed to a height h in time t. What is the average power output of the weight lifter?

(A) mg
(B) mh
(C) mgh
(D) $mght$
(E) mgh/t



45. A block of mass $3m$ can move without friction on a horizontal table. This block is attached to another block of mass m by a cord that passes over a frictionless pulley, as shown above. If the masses of the cord and the pulley are negligible, what is the magnitude of the acceleration of the descending block?

(A) Zero
(B) $g/4$
(C) $g/3$
(D) $2g/3$
(E) g

46. A car initially travels north and then turns to the left along a circular curve. This causes a package on the seat of the car to slide toward the right side of the car. Which of the following is true of the net force on the package while it is sliding?

(A) The force is directed away from the center of the circle.
(B) The force is directed north.
(C) There is not enough force directed north to keep the package from sliding.
(D) There is not enough force tangential to the car's path to keep the package from sliding.
(E) There is not enough force directed toward the center of the circle to keep the package from sliding.

47. A block of mass m slides on a horizontal frictionless table with an initial speed v_0. It then compresses a spring of force constant k and is brought to rest. How much is the spring compressed from its natural length?

(A) $\frac{v_0^2}{2g}$

(B) $\frac{mg}{k} v_0$

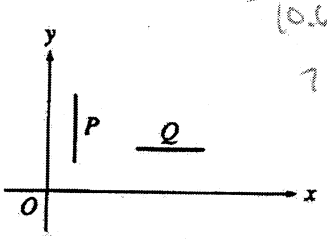
(C) $\frac{m}{k} v_0$

(D) $\sqrt{\frac{m}{k}} v_0$

(E) $\sqrt{\frac{k}{m}} v_0$

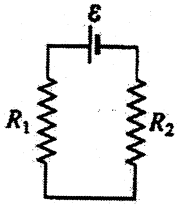
48. The planet Mars has mass 6.4×10^{23} kilograms and radius 3.4×10^6 meters. The acceleration of an object in free-fall near the surface of Mars is most nearly

(A) zero
(B) 1.0 m/s^2
(C) 1.9 m/s^2
(D) 3.7 m/s^2
(E) 9.8 m/s^2

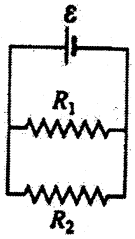


49. Rods P and Q are at rest in an inertial reference frame and oriented as shown above. Both rods have length L in this reference frame. A person moves at a relativistic speed in the y direction. Which of the following would be the lengths, as compared to L, observed for these rods by the person?

	P	Q
(A)	Less than L	Less than L
(B)	Less than L	L
(C)	Less than L	Greater than L
(D)	L	Less than L
(E)	L	L



Series Connection



Parallel Connection

50. In the diagrams above, resistors R_1 and R_2 are shown in two different connections to the same source of emf ε that has no internal resistance. How does the power dissipated by the resistors in these two cases compare?

(A) It is greater for the series connection.
(B) It is greater for the parallel connection.
(C) It is the same for both connections.
(D) It is different for each connection, but one must know the values of R_1 and R_2 to know which is greater.
(E) It is different for each connection, but one must know the value of ε to know which is greater.

51. The product

2 amperes × 2 volts × 2 seconds

is equal to

(A) 8 coulombs
(B) 8 newtons
(C) 8 joules
(D) 8 calories
(E) 8 newton-amperes

52. A radar operates at a wavelength of 3 centimeters. The frequency of these waves is

(A) 10^{-10} Hz
(B) 10^6 Hz
(C) 10^8 Hz
(D) 3×10^8 Hz
(E) 10^{10} Hz

53. In the photoelectric effect, the maximum speed of the electrons emitted by a metal surface when it is illuminated by light depends on which of the following?

I. Intensity of the light
II. Frequency of the light
III. Nature of the photoelectric surface

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

54. Atoms of isotopes of the same element contain the same number of

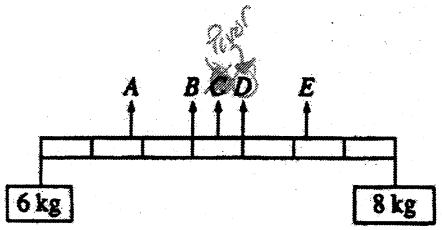
(A) protons but a different number of neutrons
(B) electrons but a different number of protons
(C) neutrons but a different number of protons
(D) neutrons as electrons
(E) protons as neutrons

55. In each cycle of a Carnot engine, 100 joules of heat is absorbed from the high-temperature reservoir and 60 joules is exhausted to the low-temperature reservoir. What is the efficiency of the engine?

(A) 40%
(B) 60%
(C) 67%
(D) 150%
(E) 167%

56. In the Bohr model of the atom, the postulate stating that the orbital angular momentum of the electron is quantized can be interpreted in which of the following ways?

(A) An integral number of electron wavelengths must fit into the electron's circular orbit.
(B) Only one electron can exist in each possible electron state.
(C) An electron has a spin of 1/2.
(D) The atom is composed of a small, positively charged nucleus orbited by electrons.
(E) An incident photon is completely absorbed when it causes an electron to move to a higher energy state.



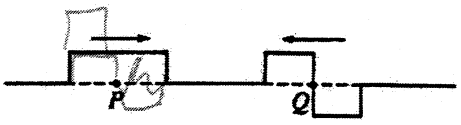
57. Two objects, of masses 6 and 8 kilograms, are hung from the ends of a stick that is 70 centimeters long and has marks every 10 centimeters, as shown above. If the mass of the stick is negligible, at which of the points indicated should a cord be attached if the stick is to remain horizontal when suspended from the cord?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

58. In the Doppler effect for sound waves, factors that affect the frequency that the observer hears include which of the following?

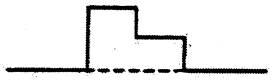
I. The speed of the source
II. The speed of the observer
III. The loudness of the sound

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

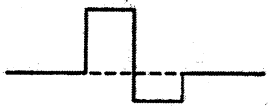


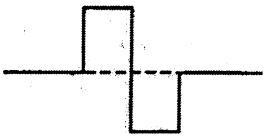
59. The figure above shows two wave pulses that are approaching each other. Which of the following best shows the shape of the resultant pulse when the centers of the pulses, points P and Q, coincide?

(A) 

(B) 

(C) 

(D) 

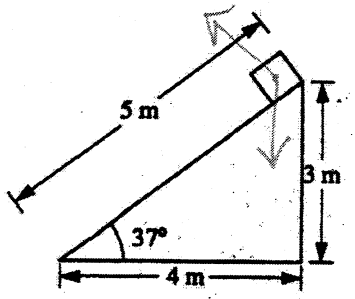
(E) 

60. Observations that indicate that visible light has a wavelength much shorter than a centimeter include which of the following?

I. The colored pattern seen in a soap bubble
II. The colored pattern seen when light passes through a diffraction grating
III. The bending of light when it passes from one medium to another medium

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

Questions 61-63



A plane 5 meters in length is inclined at an angle of 37°, as shown above. A block of weight 20 newtons is placed at the top of the plane and allowed to slide down.

61. The mass of the block is most nearly

(A) 1.0 kg
(B) 1.2 kg
(C) 1.6 kg
(D) 2.0 kg
(E) 2.5 kg

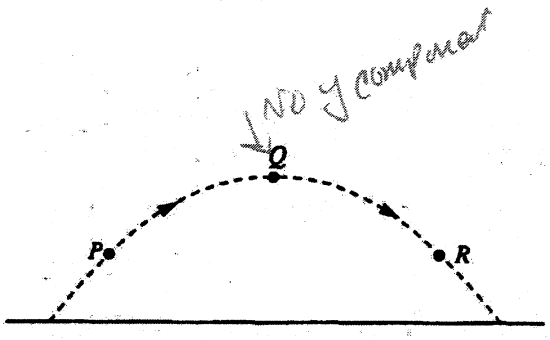
62. The magnitude of the normal force exerted on the block by the plane is most nearly

(A) 10 N
(B) 12 N
(C) 16 N
(D) 20 N
(E) 33 N

63. The work done on the block by the gravitational force during the 5-meter slide down the plane is most nearly

(A) 20 J
(B) 60 J
(C) 80 J
(D) 100 J
(E) 130 J

Questions 64-66



A ball is thrown and follows the parabolic path shown above. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground.

64. How do the speeds of the ball at the three points compare?

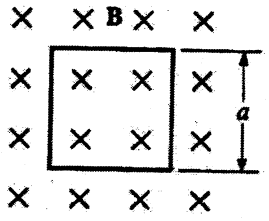
(A) $v_P < v_Q < v_R$
(B) $v_R < v_Q < v_P$
(C) $v_Q < v_R < v_P$
(D) $v_Q < v_P = v_R$
(E) $v_P = v_R < v_Q$

65. Which of the following diagrams best shows the direction of the acceleration of the ball at point P?

(A) ↙
(B) ↗
(C) →
(D) ↘
(E) ↓

66. Which of the following best indicates the direction of the net force, if any, on the ball at point Q?

(A) ↓
(B) ←
(C) →
(D) ↘
(E) There is no net force on the ball at point Q.



67. A square loop of wire of resistance R and side a is oriented with its plane perpendicular to a magnetic field **B**, as shown above. What must be the rate of change of the magnetic field in order to produce a current I in the loop?

(A) IR/a^2
(B) Ia^2/R
(C) Ia/R
(D) Ra/I
(E) IRa



68. The diagram above shows an isolated, positive charge Q. Point B is twice as far away from Q as point A. The ratio of the electric field strength at point A to the electric field strength at point B is

(A) 8 to 1
(B) 4 to 1
(C) 2 to 1
(D) 1 to 1
(E) 1 to 2

69. If the object distance for a converging thin lens is more than twice the focal length of the lens, the image is

(A) virtual and erect
(B) larger than the object
(C) located inside the focal point
(D) located at a distance between f and $2f$ from the lens
(E) located at a distance more than $2f$ from the lens



70. Two conducting spheres of different radii, as shown above, each have charge $-Q$. Which of the following occurs when the two spheres are connected with a conducting wire?

(A) No charge flows.
(B) Negative charge flows from the larger sphere to the smaller sphere until the electric field at the surface of each sphere is the same.
(C) Negative charge flows from the larger sphere to the smaller sphere until the electric potential of each sphere is the same.
(D) Negative charge flows from the smaller sphere to the larger sphere until the electric field at the surface of each sphere is the same.
(E) Negative charge flows from the smaller sphere to the larger sphere until the electric potential of each sphere is the same.

RELEASED EXAMS

1998 AP Physics B and Physics C

Contains:

- Multiple-Choice Questions and Answer Key
- Free-Response Questions, Scoring Guidelines, and Sample Student Responses and Commentary
- Statistical Information About Student Performance on the 1998 Exams

CollegeBoard AP

PHYSICS B

You must take the entire B Exam as follows:

First 90 minutes	Section I — Multiple Choice 70 Questions This booklet, pp. 3-19 No calculators allowed Percent of Total Grade — 50
2-minute interval	Survey Questions 7 Questions (101-107) This booklet, pp. 20-21
Second 90 minutes	Section II — Free Response 8 Questions Pink Booklet, pp. 4-20 Any battery-operated, hand-held calculator allowed Percent of Total Grade — 50

Each multiple-choice question has equal weight. Rulers or straightedges may be used in both sections. However, calculators may be used in Section II only, NOT in Section I. Calculators may not be shared. A table of information that may be helpful is found on page 2 of this book.

Section I of this examination contains 70 multiple-choice questions. Therefore, please be careful to fill in only the ovals that are preceded by numbers 1 through 70 on your answer sheet. Also, please be careful to fill in the ovals preceded by the numbers 101 through 107 when answering the survey questions.

General Instructions

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE INSTRUCTED TO DO SO.

INDICATE ALL YOUR ANSWERS TO QUESTIONS IN SECTION I ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination booklet, but you may use the booklet for notes or scratchwork. After you have decided which of the suggested answers is best, COMPLETELY fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.

Example:

Chicago is a

(A) state
(B) city
(C) country
(D) continent
(E) village

Sample Answer



Many candidates wonder whether or not to guess the answers to questions about which they are not certain. In this section of the examination, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. It is improbable, therefore, that mere guessing will improve your score significantly; it may even lower your score, and it does take time. If, however, you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices as wrong, your chance of getting the right answer is improved, and it may be to your advantage to answer such a question.

Use your time effectively, working as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all the multiple-choice questions.

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TABLE OF INFORMATION FOR 1998

CONSTANTS AND CONVERSION FACTORS

1 unified atomic mass unit,	$1u = 1.66 \times 10^{-27}$ kg $= 931\ \text{MeV}/c^2$
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ C
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31\ \text{J/(mol} \cdot \text{K)}$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ J/K
Speed of light,	$c = 3.00 \times 10^8$ m/s
Planck's constant,	$h = 6.63 \times 10^{-34}$ J · s $= 4.14 \times 10^{-15}$ eV · s
	$hc = 1.99 \times 10^{-25}$ J · m $= 1.24 \times 10^3$ eV · nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N} \cdot \text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T} \cdot \text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}\ (\text{T} \cdot \text{m})/\text{A}$
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg} \cdot \text{s}^2$
Acceleration due to gravity at the Earth's surface,	$g = 9.8\ \text{m/s}^2$
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^5\ \text{N/m}^2$ $= 1.0 \times 10^5$ Pa
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ J
1 angstrom,	$1\ \text{Å} = 1 \times 10^{-10}$ m

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
mole	mol
hertz	Hz
newton	N
pascal	Pa
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω
henry	H
farad	F
tesla	T
degree Celsius	°C
electron-volt	eV

PREFIXES

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	sin θ	cos θ	tan θ
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

IV. The work done by a thermodynamic system is defined as a positive quantity.

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 solid metal ball and a hollow plastic ball of the same external radius are released from rest in a large vacuum chamber. When each has fallen 1 m, they both have the same

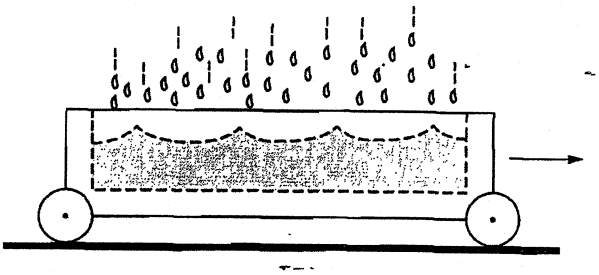
   (A) inertia
   (B) speed
   (C) momentum
   (D) kinetic energy
   (E) change in potential energy

2. A student weighing 700 N climbs at constant speed to the top of an 8 m vertical rope in 10 s. The average power expended by the student to overcome gravity is most nearly

   (A) 1.1 W
   (B) 87.5 W
   (C) 560 W
   (D) 875 W
   (E) 5,600 W

3. A railroad car of mass m is moving at speed v when it collides with a second railroad car of mass M which is at rest. The two cars lock together instantaneously and move along the track. What is the speed of the cars immediately after the collision?

   (A) $\frac{v}{2}$
   (B) $\frac{mv}{M}$
   (C) $\frac{Mv}{m}$
   (D) $\frac{(m + M)v}{m}$
   (E) $\frac{mv}{m + M}$



4. An open cart on a level surface is rolling without frictional loss through a vertical downpour of rain, as shown above. As the cart rolls, an appreciable amount of rainwater accumulates in the cart. The speed of the cart will

   (A) increase because of conservation of momentum
   (B) increase because of conservation of mechanical energy
   (C) decrease because of conservation of momentum
   (D) decrease because of conservation of mechanical energy
   (E) remain the same because the raindrops are falling perpendicular to the direction of the cart's motion

5. Units of power include which of the following?

   I. Watt
   II. Joule per second
   III. Kilowatt-hour

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

GO ON TO THE NEXT PAGE

6. A 2 kg object moves in a circle of radius 4 m at a constant speed of 3 m/s. A net force of 4.5 N acts on the object. What is the angular momentum of the object with respect to an axis perpendicular to the circle and through its center?

(A) $9\frac{\text{N}\cdot\text{m}}{\text{kg}}$

(B) $12\frac{\text{m}^2}{\text{s}}$

(C) $13.5\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$

(D) $18\frac{\text{N}\cdot\text{m}}{\text{kg}}$

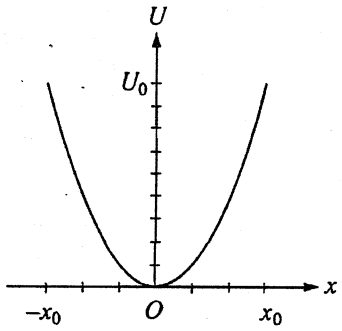
(E) $24\frac{\text{kg}\cdot\text{m}^2}{\text{s}}$

7. Three forces act on an object. If the object is in translational equilibrium, which of the following must be true?

I. The vector sum of the three forces must equal zero.
II. The magnitudes of the three forces must be equal.
III. All three forces must be parallel.

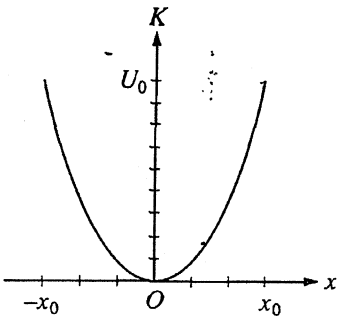
(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

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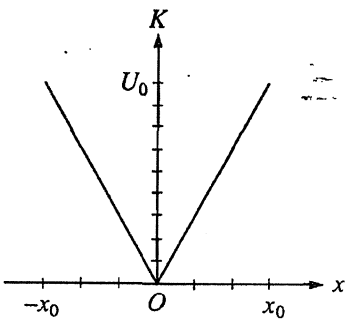


8. The graph above represents the potential energy U as a function of displacement x for an object on the end of a spring oscillating in simple harmonic motion with amplitude x_0. Which of the following graphs represents the kinetic energy K of the object as a function of displacement x ?

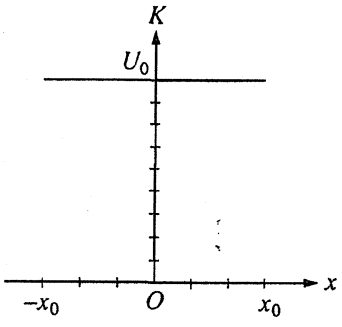
(A)



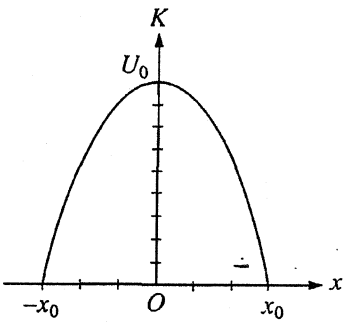
(B)



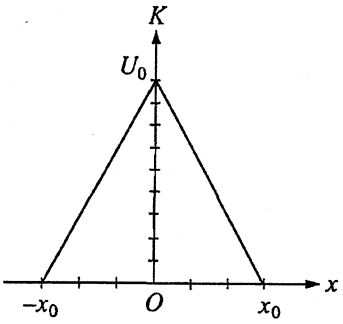
(C)



(D)



(E)



GO ON TO THE NEXT PAGE

9. A child pushes horizontally on a box of mass m which moves with constant speed v across a horizontal floor. The coefficient of friction between the box and the floor is μ. At what rate does the child do work on the box?

(A) μmgv
(B) mgv
(C) $v/\mu mg$
(D) $\mu mg/v$
(E) μmv^2

10. Quantum transitions that result in the characteristic sharp lines of the X-ray spectrum always involve

(A) the inner electron shells
(B) electron energy levels that have the same principal quantum number
(C) emission of beta particles from the nucleus
(D) neutrons within the nucleus
(E) protons within the nucleus

11. Which of the following experiments provided evidence that electrons exhibit wave properties?

I. Millikan oil-drop experiment
II. Davisson-Germer electron-diffraction experiment
III. J. J. Thomson's measurement of the charge-to-mass ratio of electrons

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

12. Quantities that are conserved in all nuclear reactions include which of the following?

I. Electric charge
II. Number of nuclei
III. Number of protons

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

13. Which of the following is true about the net force on an uncharged conducting sphere in a uniform electric field?

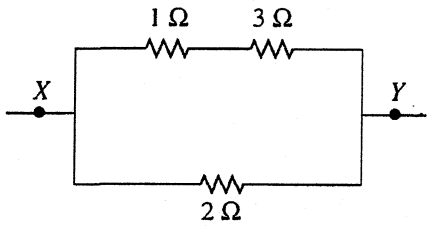
(A) It is zero.
(B) It is in the direction of the field.
(C) It is in the direction opposite to the field.
(D) It produces a torque on the sphere about the direction of the field.
(E) It causes the sphere to oscillate about an equilibrium position.

14. Two parallel conducting plates are connected to a constant voltage source. The magnitude of the electric field between the plates is 2,000 N/C. If the voltage is doubled and the distance between the plates is reduced to 1/5 the original distance, the magnitude of the new electric field is

(A) 800 N/C
(B) 1,600 N/C
(C) 2,400 N/C
(D) 5,000 N/C
(E) 20,000 N/C

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Questions 15-16 refer to the following diagram that shows part of a closed electrical circuit.



15. The electrical resistance of the part of the circuit shown between point X and point Y is

(A) $1\frac{1}{3}\ \Omega$

(B) $2\ \Omega$

(C) $2\frac{3}{4}\ \Omega$

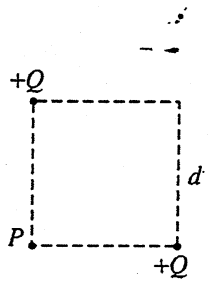
(D) $4\ \Omega$

(E) $6\ \Omega$

16. When there is a steady current in the circuit, the amount of charge passing a point per unit of time is

(A) the same everywhere in the circuit
(B) greater at point X than at point Y
(C) greater in the 1 Ω resistor than in the 2 Ω resistor
(D) greater in the 1 Ω resistor than in the 3 Ω resistor
(E) greater in the 2 Ω resistor than in the 3 Ω resistor

Questions 17-18



The figure above shows two particles, each with a charge of $+Q$, that are located at the opposite corners of a square of side d.

17. What is the direction of the net electric field at point P?

(A) ↖
(B) ↗
(C) ↙
(D) ↘
(E) ↓

18. What is the potential energy of a particle of charge $+q$ that is held at point P?

(A) Zero

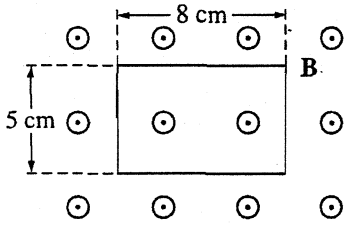
(B) $\frac{\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{qQ}{d}$

(D) $\frac{2}{4\pi\epsilon_0}\frac{qQ}{d}$

(E) $\frac{2\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

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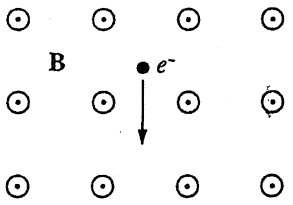


19. A rectangular wire loop is at rest in a uniform magnetic field **B** of magnitude 2 T that is directed out of the page. The loop measures 5 cm by 8 cm, and the plane of the loop is perpendicular to the field, as shown above. The total magnetic flux through the loop is

(A) zero
(B) 2×10^{-3} T·m^2
(C) 8×10^{-3} T·m^2
(D) 2×10^{-1} T·m^2
(E) 8×10^{-1} T·m^2

20. A certain coffeepot draws 4.0 A of current when it is operated on 120 V household lines. If electrical energy costs 10 cents per kilowatt-hour, how much does it cost to operate the coffeepot for 2 hours?

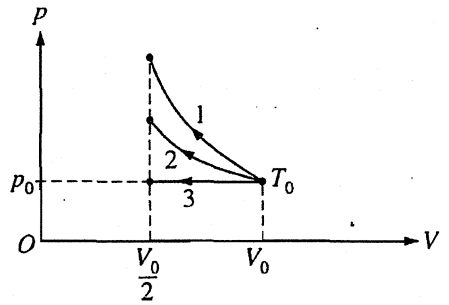
(A) 2.4 cents
(B) 4.8 cents
(C) 8.0 cents
(D) 9.6 cents
(E) 16 cents



21. An electron is in a uniform magnetic field **B** that is directed out of the plane of the page, as shown above. When the electron is moving in the plane of the page in the direction indicated by the arrow, the force on the electron is directed

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

Questions 22-23



A certain quantity of an ideal gas initially at temperature T_0, pressure p_0, and volume V_0 is compressed to one-half its initial volume. As shown above, the process may be adiabatic (process 1), isothermal (process 2), or isobaric (process 3).

22. Which of the following is true of the mechanical work done on the gas?

(A) It is greatest for process 1.
(B) It is greatest for process 3.
(C) It is the same for processes 1 and 2 and less for process 3.
(D) It is the same for processes 2 and 3 and less for process 1.
(E) It is the same for all three processes.

23. Which of the following is true of the final temperature of this gas?

(A) It is greatest for process 1.
(B) It is greatest for process 2.
(C) It is greatest for process 3.
(D) It is the same for processes 1 and 2.
(E) It is the same for processes 1 and 3.

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24. In a certain process, 400 J of heat is added to a system and the system simultaneously does 100 J of work. The change in internal energy of the system is

(A) 500 J
(B) 400 J
(C) 300 J
(D) −100 J
(E) −300 J

25. An ice cube of mass m and specific heat c_i is initially at temperature T_1, where $T_1 < 273$ K. If L is the latent heat of fusion of water, and the specific heat of water is c_w, how much energy is required to convert the ice cube to water at temperature T_2, where $273 \text{ K} < T_2 < 373$ K?

(A) $m[c_i(273 - T_1) + L + c_w(373 - T_2)]$

(B) $m[c_i(273 - T_1) + L + c_w(T_2 - 273)]$

(C) $c_i(273 - T_1) + c_w(T_2 - 273)$

(D) $mL + c_w(T_2 - T_1)$

(E) $mL + \left(\frac{c_w + c_i}{2}\right)(T_2 - T_1)$

26. A concave mirror with a radius of curvature of 1.0 m is used to collect light from a distant star. The distance between the mirror and the image of the star is most nearly

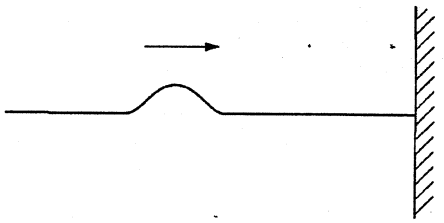
(A) 0.25 m
(B) 0.50 m
(C) 0.75 m
(D) 1.0 m
(E) 2.0 m

27. When light passes from air into water, the frequency of the light remains the same. What happens to the speed and the wavelength of light as it crosses the boundary in going from air into water?

	Speed	Wavelength
(A)	Increases	Remains the same
(B)	Remains the same	Decreases
(C)	Remains the same	Remains the same
(D)	Decreases	Increases
(E)	Decreases	Decreases

28. A physics student places an object 6.0 cm from a converging lens of focal length 9.0 cm. What is the magnitude of the magnification of the image produced?

(A) 0.6
(B) 1.5
(C) 2.0
(D) 3.0
(E) 3.6

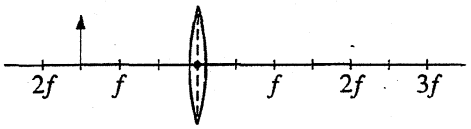


29. One end of a horizontal string is fixed to a wall. A transverse wave pulse is generated at the other end, moves toward the wall as shown above, and is reflected at the wall. Properties of the reflected pulse include which of the following?

I. It has a greater speed than that of the incident pulse.
II. It has a greater amplitude than that of the incident pulse.
III. It is on the opposite side of the string from the incident pulse.

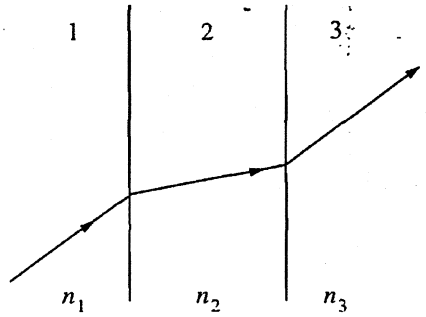
(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

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30. An object is placed at a distance of $1.5f$ from a converging lens of focal length f, as shown above. What type of image is formed and what is its size relative to the object?

	Type	Size
(A)	Virtual	Larger
(B)	Virtual	Same size
(C)	Virtual	Smaller
(D)	Real	Larger
(E)	Real	Smaller



31. A light ray passes through substances 1, 2, and 3, as shown above. The indices of refraction for these three substances are n_1, n_2, and n_3, respectively. Ray segments in 1 and in 3 are parallel. From the directions of the ray, one can conclude that

(A) n_3 must be the same as n_1
(B) n_2 must be less than n_1
(C) n_2 must be less than n_3
(D) n_1 must be equal to 1.00
(E) all three indices must be the same

32. At noon a radioactive sample decays at a rate of 4,000 counts per minute. At 12:30 P.M. the decay rate has decreased to 2,000 counts per minute. The predicted decay rate at 1:30 P.M. is

(A) 0 counts per minute
(B) 500 counts per minute
(C) 667 counts per minute
(D) 1,000 counts per minute
(E) 1,333 counts per minute

33. A negative beta particle and a gamma ray are emitted during the radioactive decay of a nucleus of $^{214}_{82}\text{Pb}$. Which of the following is the resulting nucleus?

(A) $^{210}_{80}\text{Hg}$
(B) $^{214}_{81}\text{Tl}$
(C) $^{213}_{83}\text{Bi}$
(D) $^{214}_{83}\text{Bi}$
(E) $^{218}_{84}\text{Po}$

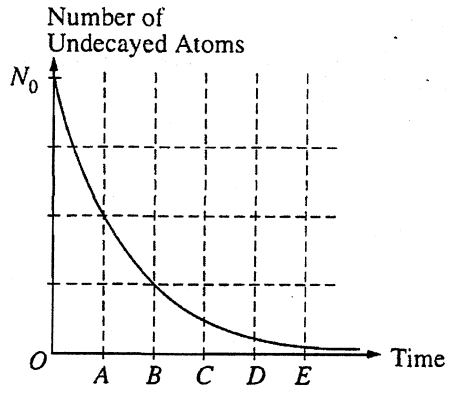
34. If the momentum of an electron doubles, its de Broglie wavelength is multiplied by a factor of

(A) $\frac{1}{4}$
(B) $\frac{1}{2}$
(C) 1
(D) 2
(E) 4

35. Quantum concepts are critical in explaining all of the following EXCEPT

(A) Rutherford's scattering experiments
(B) Bohr's theory of the hydrogen atom
(C) Compton scattering
(D) the blackbody spectrum
(E) the photoelectric effect

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36. The graph above shows the decay of a sample of carbon 14 that initially contained N_0 atoms. Which of the lettered points on the time axis could represent the half-life of carbon 14 ?

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

37. If photons of light of frequency f have momentum p, photons of light of frequency $2f$ will have a momentum of

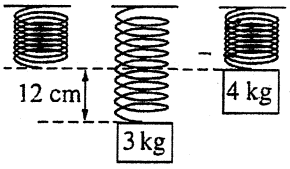
(A) $2p$

(B) $\sqrt{2}p$

(C) p

(D) $\frac{p}{\sqrt{2}}$

(E) $\frac{1}{2}p$



38. A block of mass 3.0 kg is hung from a spring, causing it to stretch 12 cm at equilibrium, as shown above. The 3.0 kg block is then replaced by a 4.0 kg block, and the new block is released from the position shown above, at which the spring is unstretched. How far will the 4.0 kg block fall before its direction is reversed?

(A) 9 cm
(B) 18 cm
(C) 24 cm
(D) 32 cm
(E) 48 cm

39. An object has a weight W when it is on the surface of a planet of radius R. What will be the gravitational force on the object after it has been moved to a distance of $4R$ from the center of the planet?

(A) $16W$

(B) $4W$

(C) W

(D) $\frac{1}{4}W$

(E) $\frac{1}{16}W$

40. What is the kinetic energy of a satellite of mass m that orbits the Earth, of mass M, in a circular orbit of radius R ?

(A) Zero

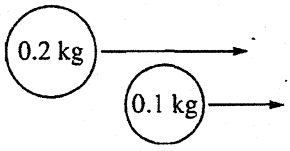
(B) $\frac{1}{2}\frac{GMm}{R}$

(C) $\frac{1}{4}\frac{GMm}{R}$

(D) $\frac{1}{2}\frac{GMm}{R^2}$

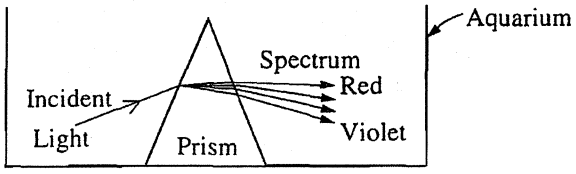
(E) $\frac{GMm}{R^2}$

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41. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown above. The 0.2 kg object overtakes and collides with the 0.1 kg object. Immediately after the collision, the y-component of the velocity of the 0.2 kg object is 1 m/s upward. What is the y-component of the velocity of the 0.1 kg object immediately after the collision?

(A) 2 m/s downward
(B) 0.5 m/s downward
(C) 0 m/s
(D) 0.5 m/s upward
(E) 2 m/s upward

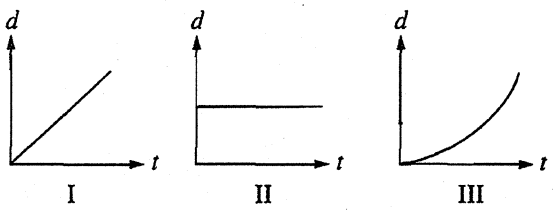


42. A beam of white light is incident on a triangular glass prism with an index of refraction of about 1.5 for visible light, producing a spectrum. Initially, the prism is in a glass aquarium filled with air, as shown above. If the aquarium is filled with water with an index of refraction of 1.3, which of the following is true?

(A) No spectrum is produced.
(B) A spectrum is produced, but the deviation of the beam is opposite to that in air.
(C) The positions of red and violet are reversed in the spectrum.
(D) The spectrum produced has greater separation between red and violet than that produced in air.
(E) The spectrum produced has less separation between red and violet than that produced in air.

Questions 43-44

Three objects can only move along a straight, level path. The graphs below show the position d of each of the objects plotted as a function of time t.



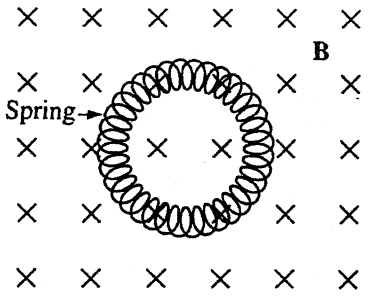
43. The magnitude of the momentum of the object is increasing in which of the cases?

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

44. The sum of the forces on the object is zero in which of the cases?

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

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45. A metal spring has its ends attached so that it forms a circle. It is placed in a uniform magnetic field, as shown above. Which of the following will NOT cause a current to be induced in the spring?

(A) Changing the magnitude of the magnetic field
(B) Increasing the diameter of the circle by stretching the spring
(C) Rotating the spring about a diameter
(D) Moving the spring parallel to the magnetic field
(E) Moving the spring in and out of the magnetic field

Questions 46-47

A magnetic field of 0.1 T forces a proton beam of 1.5 mA to move in a circle of radius 0.1 m. The plane of the circle is perpendicular to the magnetic field.

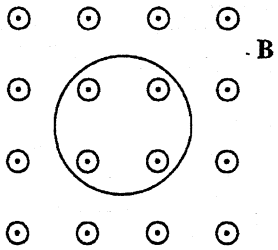
46. Of the following, which is the best estimate of the work done by the magnetic field on the protons during one complete orbit of the circle?

(A) 0 J
(B) 10^{-22} J
(C) 10^{-5} J
(D) 10^{2} J
(E) 10^{20} J

47. Of the following, which is the best estimate of the speed of a proton in the beam as it moves in the circle?

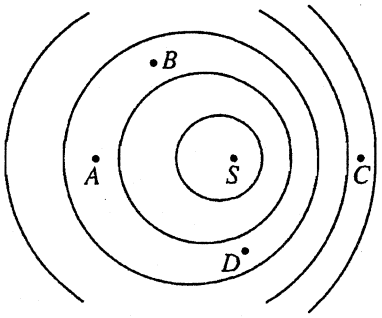
(A) 10^{-2} m/s
(B) 10^{3} m/s
(C) 10^{6} m/s
(D) 10^{8} m/s
(E) 10^{15} m/s

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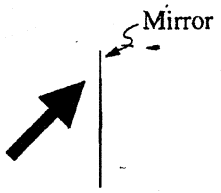
48. A single circular loop of wire in the plane of the page is perpendicular to a uniform magnetic field **B** directed out of the page, as shown above. If the magnitude of the magnetic field is decreasing, then the induced current in the wire is

(A) directed upward out of the paper
(B) directed downward into the paper
(C) clockwise around the loop
(D) counterclockwise around the loop
(E) zero (no current is induced)



49. A small vibrating object on the surface of a ripple tank is the source of waves of frequency 20 Hz and speed 60 cm/s. If the source S is moving to the right, as shown above, with speed 20 cm/s, at which of the labeled points will the frequency measured by a stationary observer be greatest?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) It will be the same at all four points.

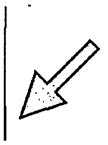


50. An object, slanted at an angle of 45°, is placed in front of a vertical plane mirror, as shown above. Which of the following shows the apparent position and orientation of the object's image?

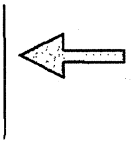
(A)



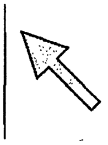
(B)



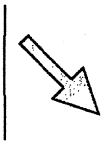
(C)



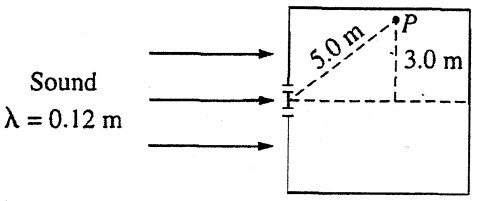
(D)



(E)

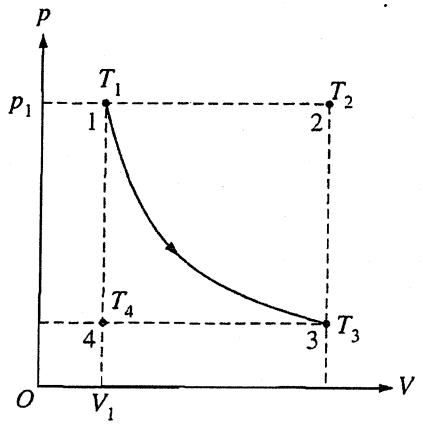


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51. Plane sound waves of wavelength 0.12 m are incident on two narrow slits in a box with nonreflecting walls, as shown above. At a distance of 5.0 m from the center of the slits, a first-order maximum occurs at point P, which is 3.0 m from the central maximum. The distance between the slits is most nearly

(A) 0.07 m
(B) 0.09 m
(C) 0.16 m
(D) 0.20 m
(E) 0.24 m



52. An ideal gas is initially in a state that corresponds to point 1 on the graph above, where it has pressure p_1, volume V_1, and temperature T_1. The gas undergoes an isothermal process represented by the curve shown, which takes it to a final state 3 at temperature T_3. If T_2 and T_4 are the temperatures the gas would have at points 2 and 4, respectively, which of the following relationships is true?

(A) $T_1 < T_3$
(B) $T_1 < T_2$
(C) $T_1 < T_4$
(D) $T_1 = T_2$
(E) $T_1 = T_4$

53. The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?

	Pressure	Density
(A)	Remains the same	Remains the same
(B)	Remains the same	Doubles
(C)	Doubles	Remains the same
(D)	Doubles	Is multiplied by a factor of 4
(E)	Is multiplied by a factor of 4	Doubles

54. The disk-shaped head of a pin is 1.0 mm in diameter. Which of the following is the best estimate of the number of atoms in the layer of atoms on the top surface of the pinhead?

(A) 10^4
(B) 10^{14}
(C) 10^{24}
(D) 10^{34}
(E) 10^{50}

55. In an experiment, light of a particular wavelength is incident on a metal surface, and electrons are emitted from the surface as a result. To produce more electrons per unit time but with less kinetic energy per electron, the experimenter should do which of the following?

(A) Increase the intensity and decrease the wavelength of the light.
(B) Increase the intensity and the wavelength of the light.
(C) Decrease the intensity and the wavelength of the light.
(D) Decrease the intensity and increase the wavelength of the light.
(E) None of the above would produce the desired result.

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56. An object moves up and down the y-axis with an acceleration given as a function of time t by the expression $a = A \sin \omega t$, where A and ω are constants. What is the period of this motion?

(A) ω

(B) $2\pi\omega$

(C) $\omega^2 A$

(D) $\frac{2\pi}{\omega}$

(E) $\frac{\omega}{2\pi}$

57. A ball of mass 0.4 kg is initially at rest on the ground. It is kicked and leaves the kicker's foot with a speed of 5.0 m/s in a direction 60° above the horizontal. The magnitude of the impulse imparted by the ball to the foot is most nearly

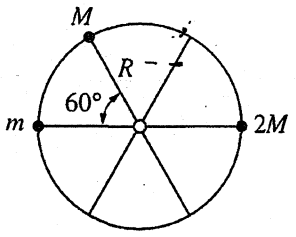
(A) 1 N·s

(B) $\sqrt{3}$ N·s

(C) 2 N·s

(D) $\frac{2}{\sqrt{3}}$ N·s

(E) 4 N·s



58. A wheel of radius R and negligible mass is mounted on a horizontal frictionless axle so that the wheel is in a vertical plane. Three small objects having masses m, M, and $2M$, respectively, are mounted on the rim of the wheel, as shown above. If the system is in static equilibrium, what is the value of m in terms of M ?

(A) $\frac{M}{2}$

(B) M

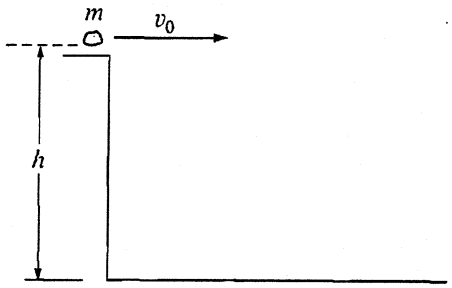
(C) $\frac{3M}{2}$

(D) $2M$

(E) $\frac{5M}{2}$

GO ON TO THE NEXT PAGE

Questions 59-60



A rock of mass m is thrown horizontally off a building from a height h, as shown above. The speed of the rock as it leaves the thrower's hand at the edge of the building is v_0.

59. How much time does it take the rock to travel from the edge of the building to the ground?

(A) $\sqrt{hv_0}$
(B) h/v_0
(C) hv_0/g
(D) $2h/g$
(E) $\sqrt{2h/g}$

60. What is the kinetic energy of the rock just before it hits the ground?

(A) mgh
(B) $\frac{1}{2}mv_0^2$
(C) $\frac{1}{2}mv_0^2 - mgh$
(D) $\frac{1}{2}mv_0^2 + mgh$
(E) $mgh - \frac{1}{2}mv_0^2$

61. Which of the following statements is NOT a correct assumption of the classical model of an ideal gas?

(A) The molecules are in random motion.
(B) The volume of the molecules is negligible compared with the volume occupied by the gas.
(C) The molecules obey Newton's laws of motion.
(D) The collisions between molecules are inelastic.
(E) The only appreciable forces on the molecules are those that occur during collisions.

62. A sample of an ideal gas is in a tank of constant volume. The sample absorbs heat energy so that its temperature changes from 300 K to 600 K. If v_1 is the average speed of the gas molecules before the absorption of heat and v_2 is their average speed after the absorption of heat, what is the ratio v_2/v_1 ?

(A) $\frac{1}{2}$
(B) 1
(C) $\sqrt{2}$
(D) 2
(E) 4

63. Two people of unequal mass are initially standing still on ice with negligible friction. They then simultaneously push each other horizontally. Afterward, which of the following is true?

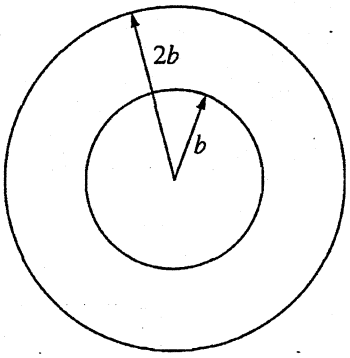
(A) The kinetic energies of the two people are equal.
(B) The speeds of the two people are equal.
(C) The momenta of the two people are of equal magnitude.
(D) The center of mass of the two-person system moves in the direction of the less massive person.
(E) The less massive person has a smaller initial acceleration than the more massive person.

64. Two parallel conducting plates, separated by a distance d, are connected to a battery of emf $\mathcal{E}$. Which of the following is correct if the plate separation is doubled while the battery remains connected?

(A) The electric charge on the plates is doubled.
(B) The electric charge on the plates is halved.
(C) The potential difference between the plates is doubled.
(D) The potential difference between the plates is halved.
(E) The capacitance is unchanged.

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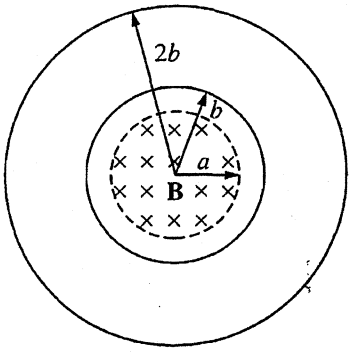
Questions 65-66



Two concentric circular loops of radii b and $2b$, made of the same type of wire, lie in the plane of the page, as shown above.

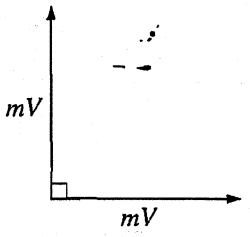
65. The total resistance of the wire loop of radius b is R. What is the resistance of the wire loop of radius $2b$?

(A) $R/4$
(B) $R/2$
(C) R
(D) $2R$
(E) $4R$



66. A uniform magnetic field **B** that is perpendicular to the plane of the page now passes through the loops, as shown above. The field is confined to a region of radius a, where $a < b$, and is changing at a constant rate. The induced emf in the wire loop of radius b is $\mathcal{E}$. What is the induced emf in the wire loop of radius $2b$?

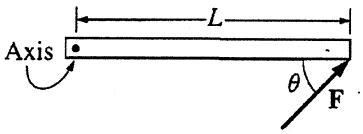
(A) Zero
(B) $\mathcal{E}/2$
(C) $\mathcal{E}$
(D) $2\mathcal{E}$
(E) $4\mathcal{E}$



67. A stationary object explodes, breaking into three pieces of masses m, m, and $3m$. The two pieces of mass m move off at right angles to each other with the same magnitude of momentum mV, as shown in the diagram above. What are the magnitude and direction of the velocity of the piece having mass $3m$?

	Magnitude	Direction
(A)	$\frac{V}{\sqrt{3}}$	↗
(B)	$\frac{V}{\sqrt{3}}$	↙
(C)	$\frac{\sqrt{2}\,V}{3}$	↗
(D)	$\frac{\sqrt{2}\,V}{3}$	↙
(E)	$\sqrt{2}\,V$	↙

GO ON TO THE NEXT PAGE



View from Above

68. A rod on a horizontal tabletop is pivoted at one end and is free to rotate without friction about a vertical axis, as shown above. A force **F** is applied at the other end, at an angle θ to the rod. If **F** were to be applied perpendicular to the rod, at what distance from the axis should it be applied in order to produce the same torque?

(A) $L \sin \theta$
(B) $L \cos \theta$
(C) L
(D) $L \tan \theta$
(E) $\sqrt{2}\, L$

69. Which of the following imposes a limit on the number of electrons in an energy state of an atom?

(A) The Heisenberg uncertainty principle
(B) The Pauli exclusion principle
(C) The Bohr model of the hydrogen atom
(D) The theory of relativity
(E) The law of conservation of energy

70. A 4 μF capacitor is charged to a potential difference of 100 V. The electrical energy stored in the capacitor is

(A) 2×10^{-10} J
(B) 2×10^{-8} J
(C) 2×10^{-6} J
(D) 2×10^{-4} J
(E) 2×10^{-2} J

STOP

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

AP® Physics B
2004 Multiple Choice Exam

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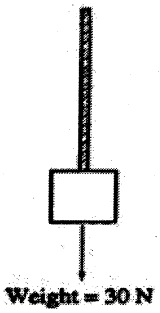
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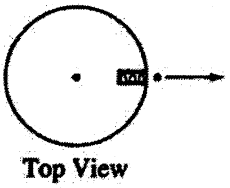
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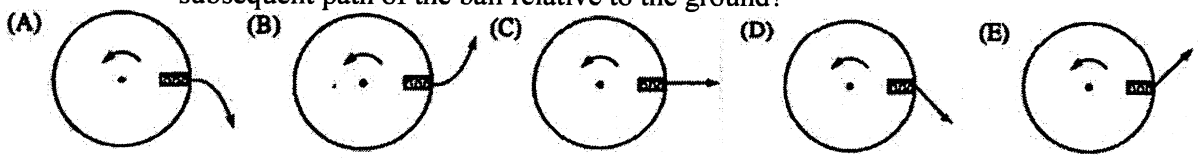
1. For which of the following motions of an object must the acceleration always be zero?
   I. Any motion in a straight line
   II. Simple harmonic motion
   III. Any motion in a circle
   a. I only b. II only c. III only d. Either I or III, but not II
   e. None of these motions guarantees zero acceleration.



2. A rope of negligible mass supports a block that weighs 30 N, as shown above. The breaking strength of the rope is 50 N. The largest acceleration that can be given to the block by pulling up on it with the rope without breaking the rope is most nearly
   a. 6 m/s^2 b. 6.7 m/s^2 c. 10 m/s^2 d. 15 m/s^2 e. 16.7 m/s^2

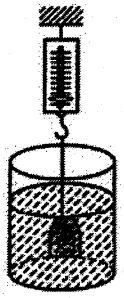


3. A compressed spring mounted on a disk can project a small ball. When the disk is not rotating, as shown in the top view above, the ball moves radially outward. The disk then rotates in a counterclockwise direction as seen from above, and the ball is projected outward at the instant the disk is in the position shown above. Which of the following best shows the subsequent path of the ball relative to the ground?



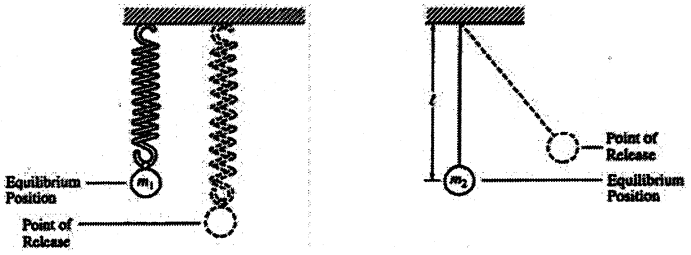
4. A ball is thrown straight up in the air. When the ball reaches its highest point, which of the following is true?
   a. It is in equilibrium. b. It has zero acceleration.
   c. It has maximum momentum. d. It has maximum kinetic energy.
   e. None of the above

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5. The figure above shows an object of mass 0.4 kg that is suspended from a scale and submerged in a liquid. If the reading on the scale is 3 N, then the buoyant force that the fluid exerts on the object is most nearly
   a. 1.3 N b. 1.0 N c. 0.75 N d. 0.33 N e. 0.25 N

Questions 6-7



A sphere of mass m_1, which is attached to a spring, is displaced downward from its equilibrium position as shown above left and released from rest. A sphere of mass m_2, which is suspended from a string of length l, is displaced to the right as shown above right and released from rest so that it swings as a simple pendulum with small amplitude. Assume that both spheres undergo simple harmonic motion

6. Which of the following is true for both spheres?
   a. The maximum kinetic energy is attained as the sphere passes through its equilibrium position.
   b. The maximum kinetic energy is attained as the sphere reaches its point of release.
   c. The minimum gravitational potential energy is attained as the sphere passes through its equilibrium position.
   d. The maximum gravitational potential energy is attained when the sphere reaches its point of release.
   e. The maximum total energy is attained only as the sphere passes through its equilibrium position.

7. If both spheres have the same period of oscillation, which of the following is an expression for the spring constant?
   a. $\frac{l}{m_1 g}$ b. $\frac{g}{m_2 l}$ c. $\frac{m_1 l}{g}$ d. $\frac{m_2 g}{l}$ e. $\frac{m_1 g}{l}$

8. A block attached to the lower end of a vertical spring oscillates up and down. If the spring obeys Hooke's law, the period of oscillation depends on which of the following?
   I. Mass of the block

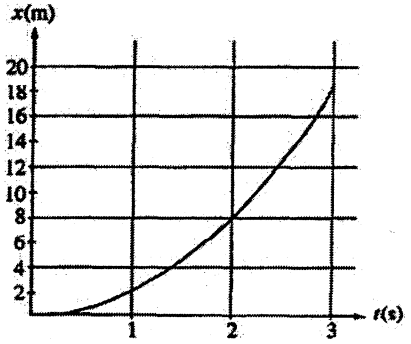
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II. Amplitude of the oscillation
III. Force constant of the spring

a. I only b. II only c. III only d. I and II e. I and III

9. An empty sled of mass M moves without friction across a frozen pond at speed v_o. Two objects are dropped vertically into the sled one at a time: first an object of mass m and then an object of mass $2m$. Afterward the sled moves with speed v_f. What would be the final speed of the sled if the objects were dropped into it in reverse order?
a. $v_f/3$ b. $v_f/2$ c. v_f d. $2v_f$ e. $3v_f$

10. A new planet is discovered that has twice the Earth's mass and twice the Earth's radius. On the surface of this new planet, a person who weighs 500 N on Earth would experience a gravitational force of
a. 125 N b. 250 N c. 500 N d. 1000 N e. 2000 N



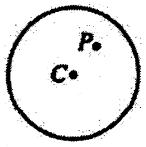
11. The graph above represents position x versus time t for an object being acted on by a constant force. The average speed during the interval between 1 s and 2 s is most nearly
a. 2 m/s b. 4 m/s c. 5 m/s d. 6 m/s e. 8 m/s

12. Two blocks of steel, the first of mass 1 kg and the second of mass 2 kg, are in thermal equilibrium with a third block of aluminum of mass 2 kg that has a temperature of 400 K. What are the respective temperatures of the first and second steel blocks?
a. 400 K and 200 K b. 200 K and 400 K c. 400 K and 400 K
d. 800 K and 400 K e. None of the above

13. An ideal gas may be taken from one state to another state with a different pressure, volume, and temperature along several different paths. Quantities that will always be the same for this process, regardless of which path is taken, include which of the following?
I. The change in internal energy of the gas
II. The heat exchanged between the gas and its surroundings
III. The work done by the gas
a. I only b. II only c. I and III only d. II and III only e. I, II, and III

14. Two parallel wires, each carrying a current I, repel each other with a force F. If both currents are doubled, the force of repulsion is
a. $2F$ b. $2\sqrt{2}\,F$ c. $4F$ d. $4\sqrt{2}\,F$ e. $8F$

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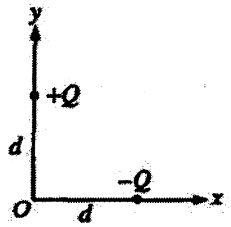
15. The hollow metal sphere shown above is positively charged. Point C is the center of the sphere and point P is any other point within the sphere. Which of the following is true of the electric field at these points?
a. It is zero at both points.
b. It is zero at C, but at P it is not zero and is directed inward.
c. It is zero at C, but at P it is not zero and is directed outward.
d. It is zero at P, but at C it is not zero.
e. It is not zero at either point.

16. The total capacitance of several capacitors in parallel is the sum of the individual capacitances for which of the following reasons?
a. The charge on each capacitor depends on its capacitance, but the potential difference across each is
the same.
b. The charge is the same on each capacitor, but the potential difference across each capacitor
depends on its capacitance.
c. Equivalent capacitance is always greater than the largest capacitance.
d. Capacitors in a circuit always combine like resistors in series.
e. The parallel combination increases the effective separation of the plates.

17. A wire of length L and radius r has a resistance R. What is the resistance of a second wire made from the same material that has a length $L/2$ and a radius $r/2$?
a. $4R$ b. $2R$ c. R d. $R/2$ e. $R/4$

18. The operating efficiency of a 0.5 A, 120 V electric motor that lifts a 9 kg mass against gravity at an average velocity of 0.5 m/s is most nearly
a. 7% b. 13% c. 25% d. 53% e. 75 %

Questions 19-20



Charges $-Q$ and $+Q$ are located on the x- and y-axes, respectively, each at a distance d from the origin O, as shown above.

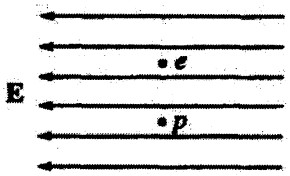
19. What is the direction of the electric field at the origin O ?

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a.  b.  c.  d.  e. 

20. What is the magnitude of the electric field at the origin O?

a. $\frac{kQ}{2d^2}$ b. $\frac{kQ}{\sqrt{2}d^2}$ c. $\frac{kQ}{d^2}$ d. $\frac{\sqrt{2}kQ}{d^2}$ e. $\frac{2kQ}{d^2}$



21. An electron e and a proton p are simultaneously released from rest in a uniform electric field **E**, as shown above. Assume that the particles are sufficiently far apart so that the only force acting on each particle after it is released is that due to the electric field. At a later time when the particles are still in the field, the electron and the proton will have the same

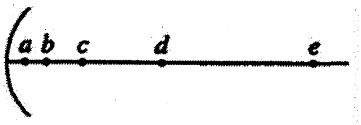
a. direction of motion
b. speed
c. displacement
d. magnitude of acceleration
e. magnitude of force acting on them

22. A square steel plate with sides of length 1.00 m has a hole in its center 0.100 m in diameter. If the entire plate is heated to such a temperature that its sides become 1.01 m long, the diameter of the hole will be

a. 0.090 m b. 0.099 m c. 0.100 m d. 0.101 m e. 0.110 m

23. Which of the following will occur if the average speed of the gas molecules in a closed rigid container is increased?

a. The density of the gas will decrease.
b. The density of the gas will increase.
c. The pressure of the gas will increase.
d. The pressure of the gas will decrease.
e. The temperature of the gas will decrease.



24. The spherical mirror shown above has a center of curvature at point c. Which point is nearest to the focal point?

a. a b. b c. c d. d e. e

25. The frequencies of the first two overtones (second and third harmonics) of a vibrating string are f and $3f/2$. What is the fundamental frequency of this string?

a. $f/3$ b. $f/2$ c. f d. $2f$ e. $3f$

26. An object is placed in front of a converging thin lens at a distance from the center of the lens equal to half the focal length. Compared to the object, the image is

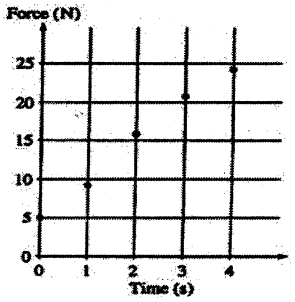
a. upright and larger
b. upright and smaller
c. inverted and larger
d. inverted and smaller
e. inverted and the same size

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27. A radio station broadcasts on a carrier frequency of 100 MHz. The wavelength of this radio wave is most nearly
    a. 3.0×10^{-3} m b. 1.0 m c. 3.0 m d. 3.3 m e. 3.0×10^{6} m

28. Which of the following is characteristic of both sound and light waves?
    a. They are longitudinal waves. b. They are transverse waves.
    c. They travel with the same velocity. d. They can be easily polarized.
    e. They give rise to interference effects.

Questions 29-30



A student obtains data on the magnitude of force applied to an object as a function of time and displays the data on the graph above.

29. The slope of the "best fit" straight line is most nearly
    a. 5 N/s b. 6 N/s c. 7 N/s d. 8 N/s e. 10 N/s

30. The increase in the momentum of the object between t = 0 s and t = 4 s is most nearly
    a. 40 N•s b. 50 N•s c. 60 N•s d. 80 N•s e. 100 N•s

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31. How does an air mattress protect a stunt person landing on the ground after a stunt?
a. It reduces the kinetic energy loss of the stunt person.
b. It reduces the momentum change of the stunt person.
c. It increases the momentum change of the stunt person.
d. It shortens the stopping time of the stunt person and increases the force applied during the landing. e. It lengthens the stopping time of the stunt person and reduces the force applied during the landing.

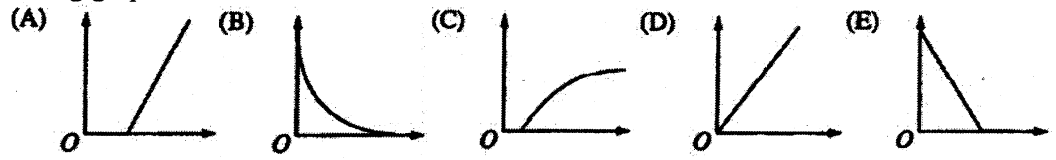
Questions 32-33

A horizontal, uniform board of weight 125 N and length 4 m is supported by vertical chains at each end. A person weighing 500 N is sitting on the board. The tension in the right chain is 250 N.

32. What is the tension in the left chain?
a. 250 N b. 375 N c. 500 N d. 625 N e. 875 N

33. How far from the left end of the board is the person sitting?
a. 0.4 m b. 1.5 m c. 2 m d. 2.5 m e. 3 m

Questions 34-35 relate to the photoelectric effect. For each question, choose an answer from the following graphs.

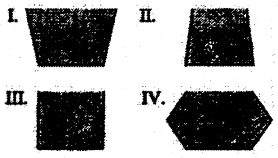


34. Which graph shows the maximum kinetic energy of the emitted electrons *versus* the frequency of the light?
a. A b. B c. C d. D e. E

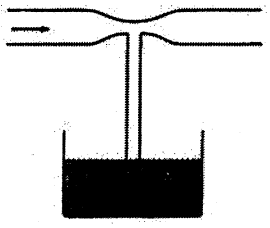
35. Which graph shows the total photoelectric current versus the intensity of the light for a fixed frequency above the cutoff frequency?
a. A b. B c. C d. D e. E

36. Which of the following statements about the number of protons Z and the number of neutrons N in stable nuclei is true?
a. All stable nuclei have $Z = N$.
b. Only heavy stable nuclei have $Z = N$.
c. Heavy stable nuclei tend to have $Z < N$.
d. All light stable nuclei have $Z < N$.
e. All light stable nuclei have $Z > N$.

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37. Each of the beakers shown above is filled to the same depth h with liquid of density p. The area A of the flat bottom is the same for each beaker. Which of the following ranks the beakers according to the net downward force exerted by the liquid on the flat bottom, from greatest to least force?
a. I, III, II, IV b. I, IV, III, II c. II, III, IV, I d. IV, III, I, II
e. None of the above; the force on each is the same.

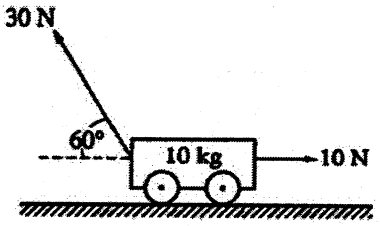


38. A T-shaped tube with a constriction is inserted in a vessel containing a liquid, as shown above. What happens if air is blown through the tube from the left, as shown by the arrow in the diagram?
a. The liquid level in the tube rises to a level above the surface of the liquid surrounding the tube.
b. The liquid level in the tube falls below the level of the surrounding liquid.
c. The liquid level in the tube remains where it is.
d. The air bubbles out at the bottom of the tube.
e. Any of the above depending on how hard the air flows.

39. A spring scale calibrated in kilograms is used to determine the density of a rock specimen. The reading on the spring scale is 0.45 kg when the specimen is suspended in air and 0.36 kg when the specimen is fully submerged in water. If the density of water is 1000 kg/m^3, the density of the rock specimen is
a. 2.0×10^2 kg/m^3 b. 8.0×10^2 kg/m^3 c. 1.25×10^3 kg/m^3 d. 4.0×10^3 kg/m^3
e. 5.0×10^3 kg/m^3

40. Two objects, *A* and *B*, initially at rest, are "exploded" apart by the release of a coiled spring that was compressed between them. As they move apart, the velocity of object *A* is 5 m/s and the velocity of object *B* is -2 m/s. The ratio of the mass of object *A* to the mass of object *B*, m_A/m_B, is
a. 4/25 b. 2/5 c. 1/1 d. 5/2 e. 25/4

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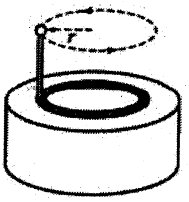
41. The cart of mass 10 kg shown above moves without frictional loss on a level table. A 10 N force pulls on the cart horizontally to the right. At the same time, a 30 N force at an angle of 60° above the horizontal pulls on the cart to the left. What is the magnitude of the horizontal acceleration of the cart? a. 0.5 m/s^2 b. 1.6 m/s^2 c. 2.0 m/s^2 d. 2.5 m/s^2 e. 2.6 m/s^2

42. A child has a toy tied to the end of a string and whirls the toy at constant speed in a horizontal circular path of radius R. The toy completes each revolution of its motion in a time period T. What is the magnitude of the acceleration of the toy?

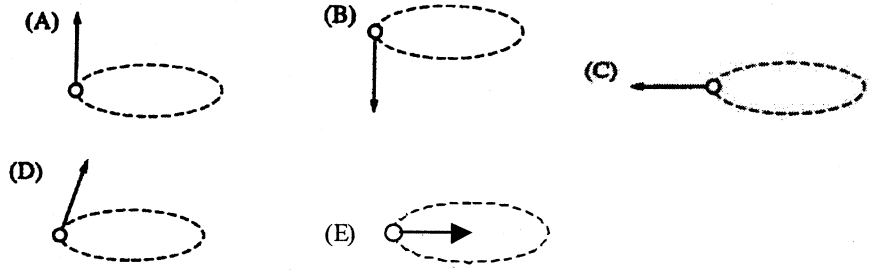
a. Zero b. $\frac{4\pi^2 R}{T^2}$ c. $\frac{\pi R}{T^2}$ d. g e. $2\pi g$

43. A simple pendulum and a mass hanging on a spring both have a period of 1 s when set into small oscillatory motion on Earth. They are taken to Planet X, which has the same diameter as Earth but twice the mass. Which of the following statements is true about the periods of the two objects on Planet X compared to their periods on Earth?

a. Both are shorter. b. Both are the same. c. Both are longer.
d. The period of the mass on the spring is shorter, that of the pendulum is the same.
e. The period of the pendulum is shorter; that of the mass on the spring is the same.

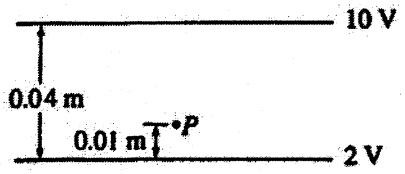


44. A steel ball supported by a stick rotates in a circle of radius r, as shown above. The direction of the net force acting on the ball when it is in the position shown is indicated by which of the following?



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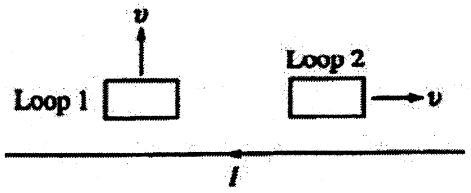
Questions 45-46



Two large, flat, parallel, conducting plates are 0.04 m apart, as shown above. The lower plate is at a potential of 2 V with respect to ground. The upper plate is at a potential of 10 V with respect to ground. Point P is located 0.01 m above the lower plate.

45. The electric potential at point P is
a. 10 V b. 8 V c. 6 V d. 4 V e. 2 V

46. The magnitude of the electric field at point P is
a. 800 V/m b. 600 V/m c. 400 V/m d. 200 V/m e. 100 V/m

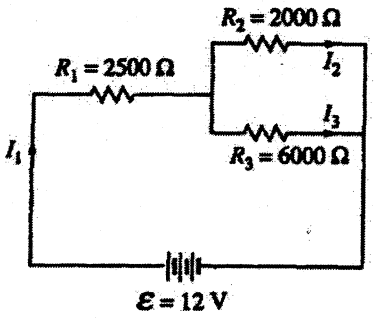


47. Two conducting wire loops move near a very long, straight conducting wire that carries a current I. When the loops are in the positions shown above, they are moving in the directions shown with the same constant speed v. Assume that the loops are far enough apart that they do not affect each other. Which of the following is true about the induced electric currents, if any, in the loops?

	Loop 1	Loop 2
a.	No current	No current
b.	No current	Counterclockwise direction
c.	Clockwise direction	No current
d.	Clockwise direction	Clockwise direction
e.	Counterclockwise direction	Clockwise direction

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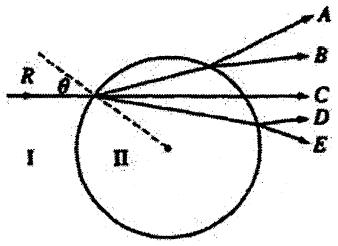
Questions 48-49 relate to the following circuit diagram.



48. What is the current I_1?
a. 0.8 mA b. 1.0 mA c. 2.0 mA d. 3.0 mA e. 6.0 mA

49. How do the currents I_1, I_2, and I_3 compare?
a. $I_1 > I_2 > I_3$ b. $I_1 > I_3 > I_2$ c. $I_2 > I_1 > I_3$ d. $I_3 > I_1 > I_2$ e. $I_3 > I_2 > I_1$

Questions 50-51



A light ray R in medium I strikes a sphere of medium II with angle of incidence θ, as shown above. The figure shows five possible subsequent paths for the light ray.

50. Which path is possible if medium I is air and medium II is glass?
a. A b. B c. C d. D e. E

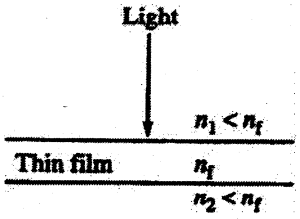
51. Which path is possible if medium I is glass and medium II is air?
a. A b. B c. C d. D e. E

52. Two fire trucks have sirens that emit waves of the same frequency. As the fire trucks approach a person, the person hears a higher frequency from truck X than from truck Y. Which of the following statements about truck X can be correctly inferred from this information?

I. It is traveling faster than truck Y.
II. It is closer to the person than truck Y.
III. It is speeding up. and truck Y is slowing down.

a. I only b. III only c. I and II only d. II and III only e. I, II, and III

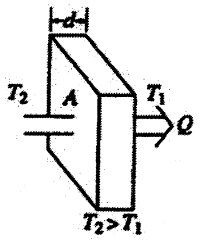
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53. A thin film with index of refraction n_f separates two materials, each of which has an index of refraction less than n_f. A monochromatic beam of light is incident normally on the film, as shown above. If the light has wavelength λ within the film, maximum constructive interference between the incident beam and the reflected beam occurs for which of the following film thicknesses?
a. 3λ b. 2λ c. λ d. $\lambda/2$ e. $\lambda/4$

54. An object is placed on the axis of a converging thin lens of focal length 2 cm, at a distance of 8 cm from the lens. The distance between the image and the lens is most nearly
a. 0.4 cm b. 0.8 cm c. 1.6 cm d. 2.0 cm e. 2.7 cm

55. A large lens is used to focus an image of an object onto a screen. If the left half of the lens is covered with a dark card, which of the following occurs?
a. The left half of the image disappears. b. The right half of the image disappears.
c. The image becomes blurred. d. The image becomes dimmer.
e. No image is formed.



56. In time t, an amount of heat Q flows through the solid door of area A and thickness d represented above. The temperatures on each side of the door are T_2 and T_1, respectively. Which of the following changes would be certain to decrease Q?
a. Increasing A only b. Decreasing d only
c. Increasing d and $T_2 - T_1$ only d. Decreasing A and $T_2 - T_1$ only
e. Increasing d, A, and $T_2 - T_1$

57. A gas with a fixed number of molecules does 32 J of work on its surroundings, and 16 J of heat are transferred from the gas to the surroundings. What happens to the internal energy of the gas?
a. It decreases by 48 J. b. It decreases by 16 J.
c. It remains the same. d. It increases by 16 J.
e. It increases by 48 J.

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58. When ^{10}B is bombarded by neutrons, a neutron can be absorbed and an alpha particle (^{4}He) emitted. If the ^{10}B target is stationary, the kinetic energy of the reaction products is equal to the
a. kinetic energy of the incident neutron
b. total energy of the incident neutron
c. energy equivalent of the mass decrease in the reaction
d. energy equivalent of the mass decrease in the reaction, minus the kinetic energy of the incident neutron e. energy equivalent of the mass decrease in the reaction, plus the kinetic energy of the incident neutron

59. The nuclide $^{214}_{82}Pb$ emits an electron and becomes nuclide X. Which of the following gives the mass number and atomic number of nuclide X?

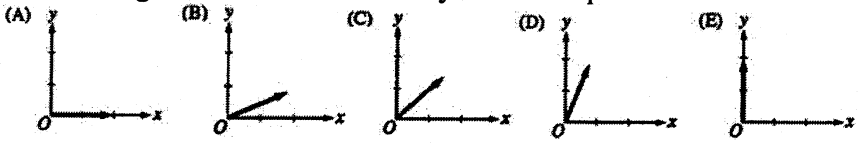
	Mass Number	Atomic Number
a.	210	80
b.	210	81
c.	213	83
d.	214	81
e.	214	83

60. A 50,000 W radio station transmits waves of wavelength 4 m. Which of the following is the best estimate of the number of photons it emits per second?
a. 10^{8} b. 10^{22} c. 10^{30} d. 10^{40} e. 10^{56}

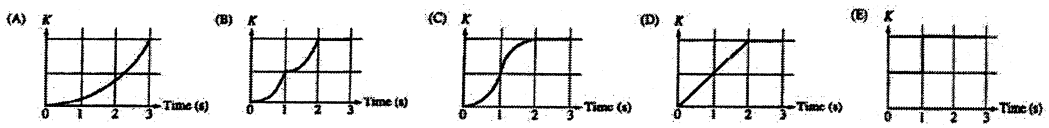
Questions 61-62

An object of mass m is initially at rest and free to move without friction in any direction in the xy-plane. A constant net force of magnitude F directed in the $+x$ direction acts on the object for 1 s. Immediately thereafter a constant net force of the same magnitude F directed in the $+y$ direction acts on the object for 1 s. After this, no forces act on the object.

61. Which of the following vectors could represent the velocity of the object at the end of 3 s, assuming the scales on the x and y axes are equal.



62. Which of the following graphs best represents the kinetic energy K of the object as a function of time?

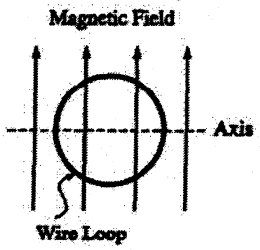


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63. The two blocks of masses M and $2M$ shown above initially travel at the same speed v but in opposite directions. They collide and stick together. How much mechanical energy is lost to other forms of energy during the collision?

a. Zero b. $\frac{1}{2}Mv^2$ c. $\frac{3}{4}Mv^2$ d. $\frac{4}{3}Mv^2$ e. $\frac{3}{2}Mv^2$

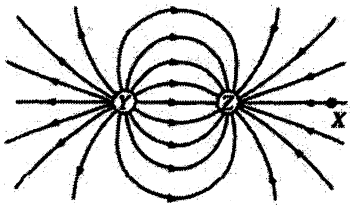


64. A wire loop is rotated in a uniform magnetic field about an axis perpendicular to the field. as shown above. How many times is the induced current in the loop reversed if the loop makes 3 complete revolutions from the position shown?

a. One b. Two c. Three d. Six e. Twelve

65. A particle of charge Q and mass m is accelerated from rest through a potential difference V, attaining a kinetic energy K. What is the kinetic energy of a particle of charge $2Q$ and mass $m/2$ that is accelerated from rest through the same potential difference?

a. 4 b. 2 c. K d. $2K$ e. $4K$



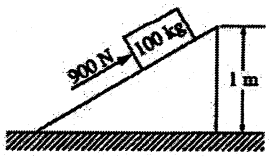
66. The diagram above shows electric field lines in an isolated region of space containing two small charged spheres, Y and Z. Which of the following statements is true?

a. The charge on Y is negative and the charge on Z is positive.
b. The strength of the electric field is the same everywhere.
c. The electric field is strongest midway between Y and Z.
d. A small negatively charged object placed at point X would tend to move toward the right.
e. Both charged spheres Y and Z carry charge of the same sign.

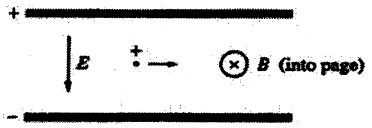
67. A satellite of mass m and speed v moves in a stable, circular orbit around a planet of mass M. What is the radius of the satellite's orbit?

a. $\frac{GM}{mv}$ b. $\frac{Gv}{mM}$ c. $\frac{GM}{v^2}$ d. $\frac{GmM}{v}$ e. $\frac{GmM}{v^2}$

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68. A constant force of 900 N pushes a 100 kg mass up the inclined plane shown above at a uniform speed of 4 m/s. The power developed by the 900 N force is most nearly
a. 400 W b. 800 W c. 900 W d. 1000 W e. 3600 W



69. As shown above, a positively charged particle moves to the right without deflection through a pair of charged plates. Between the plates are a uniform electric field E of magnitude 6.0 N/C and a uniform magnetic field B of magnitude 2.0 T, directed as shown in the figure. The speed of the particle is most nearly
a. 0.33 m/s b. 0.66 m/s c. 3.0 m/s d. 12 m/s e. 18 m/s

70. A hollow metal sphere 1.0 m in diameter carries a charge of 4.0 μC. The electric field at a distance of 2.0 m from the center of the sphere is most nearly
a. 9.0×10^3 N/C b. 1.8×10^4 N/C c. 2.4×10^4 N/C d. 3.6×10^4 N/C e. 1.4×10^5 N/C

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