PHYSICS C

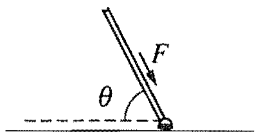
SECTION I, MECHANICS

Time— 28 minutes

35 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 force F is exerted by a broom handle on the head of the broom, which has a mass m. The handle is at an angle θ to the horizontal, as shown above. The work done by the force on the head of the broom as it moves a distance d across a horizontal floor is

   (A) $Fd \sin \theta$
   (B) $Fd \cos \theta$
   (C) $Fm \cos \theta$
   (D) $Fm \tan \theta$
   (E) $Fmd \sin \theta$

2. The velocity of a projectile at launch has a horizontal component v_h and a vertical component v_v. Air resistance is negligible. When the projectile is at the highest point of its trajectory, which of the following show the vertical and horizontal components of its velocity and the vertical component of its acceleration?

	Vertical Velocity	Horizontal Velocity	Vertical Acceleration
(A)	v_v	v_h	0
(B)	v_v	0	0
(C)	0	v_h	0
(D)	0	0	g
(E)	0	v_h	g

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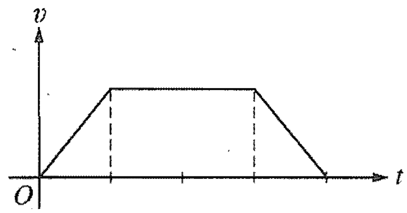
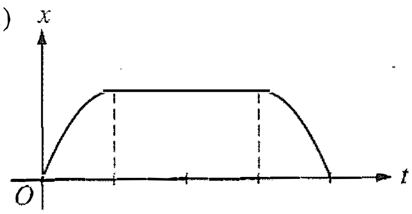


3. The graph above shows the velocity v as a function of time t for an object moving in a straight line. Which of the following graphs shows the corresponding displacement x as a function of time t for the same time interval?

(A)


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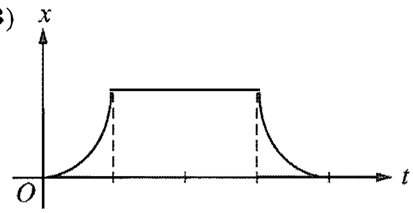

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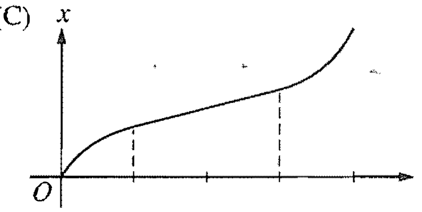

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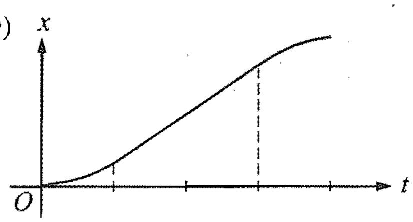
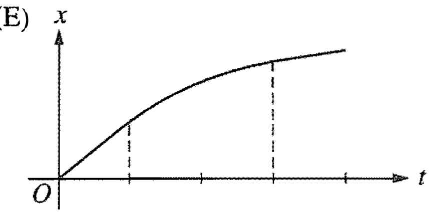


(E)


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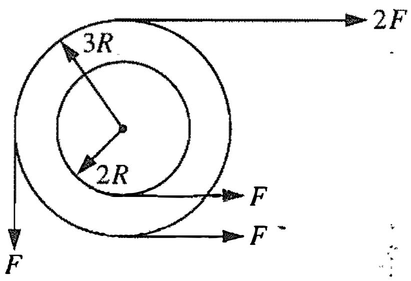
4. The position of a toy locomotive moving on a straight track along the x-axis is given by the equation $x = t^3 - 6t^2 + 9t$, where x is in meters and t is in seconds. The net force on the locomotive is equal to zero when t is equal to

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



5. A system of two wheels fixed to each other is free to rotate about a frictionless axis through the common center of the wheels and perpendicular to the page. Four forces are exerted tangentially to the rims of the wheels, as shown above. The magnitude of the net torque on the system about the axis is

(A) zero
(B) FR
(C) $2FR$
(D) $5FR$
(E) $14FR$

6. A wheel of mass M and radius R rolls on a level surface without slipping. If the angular velocity of the wheel is ω, what is its linear momentum?

(A) $M\omega R$

(B) $M\omega^2 R$

(C) $M\omega R^2$

(D) $\dfrac{M\omega^2 R^2}{2}$

(E) Zero

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Questions 7-8 refer to a ball that is tossed straight up from the surface of a small, spherical asteroid with no atmosphere. The ball rises to a height equal to the asteroid's radius and then falls straight down toward the surface of the asteroid.

7. What forces, if any, act on the ball while it is on the way up?
   (A) Only a decreasing gravitational force that acts downward
   (B) Only an increasing gravitational force that acts downward
   (C) Only a constant gravitational force that acts downward
   (D) Both a constant gravitational force that acts downward and a decreasing force that acts upward
   (E) No forces act on the ball.

8. The acceleration of the ball at the top of its path is
   (A) at its maximum value for the ball's flight
   (B) equal to the acceleration at the surface of the asteroid
   (C) equal to one-half the acceleration at the surface of the asteroid
   (D) equal to one-fourth the acceleration at the surface of the asteroid
   (E) zero

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9. The equation of motion of a simple harmonic oscillator is $\frac{d^2x}{dt^2} = -9x$, where x is displacement and t is time. The period of oscillation is
   (A) 6π
   (B) $\frac{9}{2\pi}$
   (C) $\frac{3}{2\pi}$
   (D) $\frac{2\pi}{3}$
   (E) $\frac{2\pi}{9}$

10. A pendulum with a period of 1 s on Earth, where the acceleration due to gravity is g, is taken to another planet, where its period is 2 s. The acceleration due to gravity on the other planet is most nearly
    (A) $g/4$
    (B) $g/2$
    (C) g
    (D) $2g$
    (E) $4g$

11. A satellite of mass M moves in a circular orbit of radius R with constant speed v. True statements about this satellite include which of the following?
    I. Its angular speed is v/R.
    II. Its tangential acceleration is zero.
    III. The magnitude of its centripetal acceleration is constant.

    (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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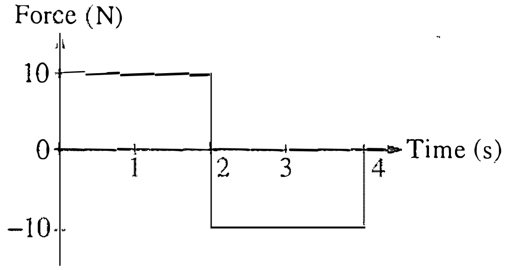
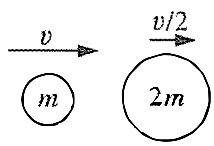


12. The graph above shows the force on an object of mass M as a function of time. For the time interval 0 to 4 s, the total change in the momentum of the object is

(A) 40 kg•m/s
(B) 20 kg•m/s
(C) 0 kg•m/s
(D) −20 kg•m/s
(E) indeterminable unless the mass M of the object is known



Top View

13. As shown in the top view above, a disc of mass m is moving horizontally to the right with speed v on a table with negligible friction when it collides with a second disc of mass $2m$. The second disc is moving horizontally to the right with speed $\frac{v}{2}$ at the moment of impact. The two discs stick together upon impact. The speed of the composite body immediately after the collision is

(A) $\frac{v}{3}$

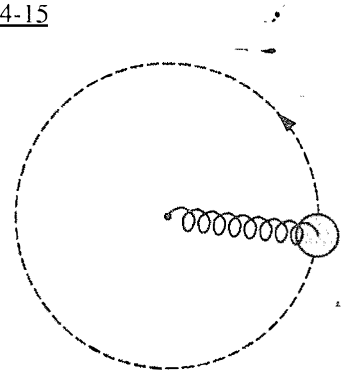
(B) $\frac{v}{2}$

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

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

(E) $2v$

<u>Questions 14-15</u>



Top View

A spring has a force constant of 100 N/m and an unstretched length of 0.07 m. One end is attached to a post that is free to rotate in the center of a smooth table, as shown in the top view above. The other end is attached to a 1 kg disc moving in uniform circular motion on the table, which stretches the spring by 0.03 m. Friction is negligible.

14. What is the centripetal force on the disc?

(A) 0.3 N
(B) 3 N
(C) 10 N
(D) 300 N
(E) 1,000 N

15. What is the work done on the disc by the spring during one full circle?

(A) 0 J
(B) 94 J
(C) 186 J
(D) 314 J
(E) 628 J

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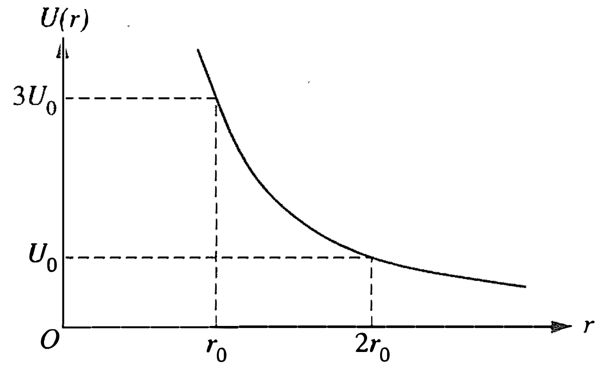
Questions 16-17 refer to the following graph, which represents a hypothetical potential energy curve for a particle of mass m.



16. If the particle is released from rest at position r_0, its speed at position $2r_0$ is most nearly

(A) $\sqrt{\frac{8U_0}{m}}$

(B) $\sqrt{\frac{6U_0}{m}}$

(C) $\sqrt{\frac{4U_0}{m}}$

(D) $\sqrt{\frac{2U_0}{m}}$

(E) $\sqrt{\frac{U_0}{m}}$

17. If the potential energy function is given by $U(r) = br^{-3/2} + c$, where b and c are constants, which of the following is an expression for the force on the particle?

(A) $\frac{3b}{2} r^{-5/2}$

(B) $\frac{3b}{2} r^{-1/2}$

(C) $\frac{3}{2} r^{-1/2}$

(D) $2br^{-1/2} + cr$

(E) $\frac{2b}{5} r^{-5/2} + cr$

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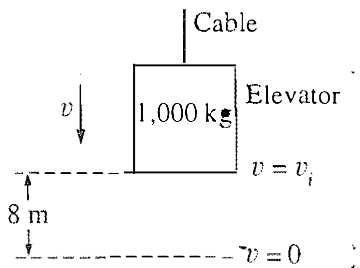
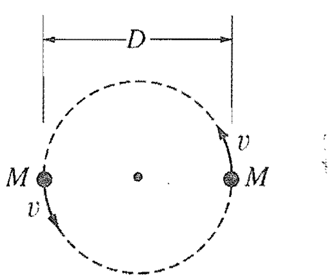
18. A frictionless pendulum of length 3 m swings with an amplitude of 10°. At its maximum displacement, the potential energy of the pendulum is 10 J. What is the kinetic energy of the pendulum when its potential energy is 5 J ?

(A) 3.3 J
(B) 5 J
(C) 6.7 J
(D) 10 J
(E) 15 J



19. A descending elevator of mass 1,000 kg is uniformly decelerated to rest over a distance of 8 m by a cable in which the tension is 11,000 N. The speed v_i of the elevator at the beginning of the 8 m descent is most nearly

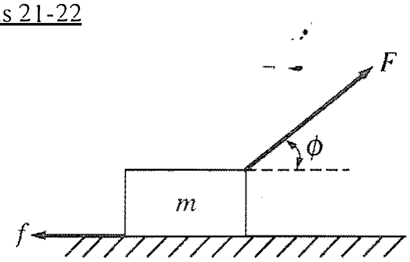
(A) 4 m/s
(B) 10 m/s
(C) 13 m/s
(D) 16 m/s
(E) 21 m/s



20. Two identical stars, a fixed distance D apart, revolve in a circle about their mutual center of mass, as shown above. Each star has mass M and speed v. G is the universal gravitational constant. Which of the following is a correct relationship among these quantities?

(A) $v^2 = GM/D$
(B) $v^2 = GM/2D$
(C) $v^2 = GM/D^2$
(D) $v^2 = MGD$
(E) $v^2 = 2GM^2/D$

Questions 21-22



A block of mass m is accelerated across a rough surface by a force of magnitude F that is exerted at an angle ϕ with the horizontal, as shown above. The frictional force on the block exerted by the surface has magnitude f.

21. What is the acceleration of the block?

(A) $\dfrac{F}{m}$

(B) $\dfrac{F\cos\phi}{m}$

(C) $\dfrac{F-f}{m}$

(D) $\dfrac{F\cos\phi - f}{m}$

(E) $\dfrac{F\sin\phi - mg}{m}$

22. What is the coefficient of friction between the block and the surface?

(A) $\dfrac{f}{mg}$

(B) $\dfrac{mg}{f}$

(C) $\dfrac{mg - F\cos\phi}{f}$

(D) $\dfrac{f}{mg - F\cos\phi}$

(E) $\dfrac{f}{mg - F\sin\phi}$

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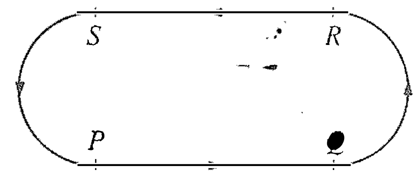
23. This question was not counted when the exam was scored.

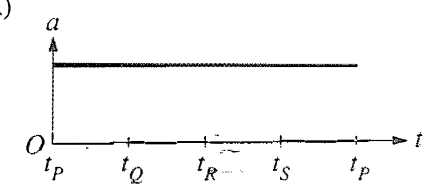
24. Two people are initially standing still on frictionless ice. They push on each other so that one person, of mass 120 kg, moves to the left at 2 m/s, while the other person, of mass 80 kg, moves to the right at 3 m/s. What is the velocity of their center of mass?

(A) Zero
(B) 0.5 m/s to the left
(C) 1 m/s to the right
(D) 2.4 m/s to the left
(E) 2.5 m/s to the right

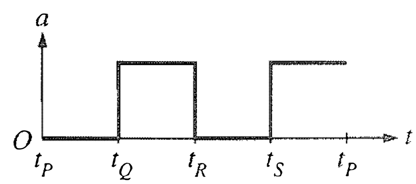


25. A figure of a dancer on a music box moves counterclockwise at constant speed around the path shown above. The path is such that the lengths of its segments, PQ, QR, RS, and SP, are equal. Arcs QR and SP are semicircles. Which of the following best represents the magnitude of the dancer's acceleration as a function of time t during one trip around the path, beginning at point P ?

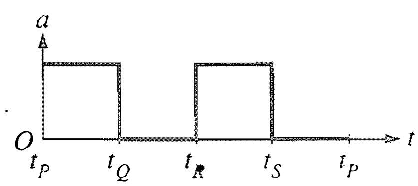
(A)



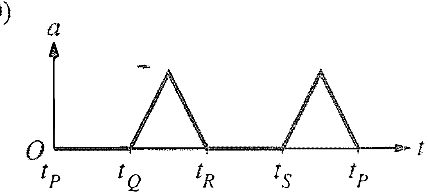
(B)



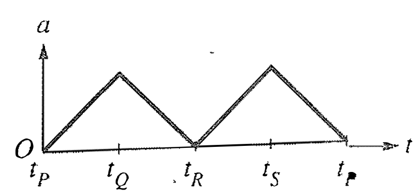
(C)



(D)



(E)



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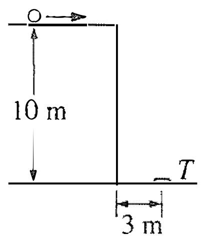


26. A target T lies flat on the ground 3 m from the side of a building that is 10 m tall, as shown above. A student rolls a ball off the horizontal roof of the building in the direction of the target. Air resistance is negligible. The horizontal speed with which the ball must leave the roof if it is to strike the target is most nearly

    (A) $\frac{3}{10}$ m/s

    (B) $\sqrt{2}$ m/s

    (C) $\frac{3}{\sqrt{2}}$ m/s

    (D) 3 m/s

    (E) $10\sqrt{\frac{5}{3}}$ m/s

27. To stretch a certain nonlinear spring by an amount x requires a force F given by $F = 40x - 6x^2$, where F is in newtons and x is in meters. What is the change in potential energy when the spring is stretched 2 meters from its equilibrium position?

    (A) 16 J
    (B) 28 J
    (C) 56 J
    (D) 64 J
    (E) 80 J

28. When a block slides a certain distance down an incline, the work done by gravity is 300 J. What is the work done by gravity if this block slides the same distance up the incline?

    (A) 300 J
    (B) Zero
    (C) –300 J
    (D) It cannot be determined without knowing the distance the block slides.
    (E) It cannot be determined without knowing the coefficient of friction.

29. A particle moves in the xy-plane with coordinates given by

    $$x = A\cos\omega t \text{ and } y = A\sin\omega t,$$

    where $A = 1.5$ meters and $\omega = 2.0$ radians per second. What is the magnitude of the particle's acceleration?

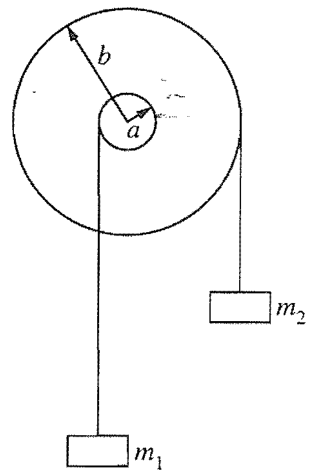
    (A) Zero

    (B) 1.3 m/s^2

    (C) 3.0 m/s^2

    (D) 4.5 m/s^2

    (E) 6.0 m/s^2



30. For the wheel-and-axle system shown above, which of the following expresses the condition required for the system to be in static equilibrium?

    (A) $m_1 = m_2$
    (B) $am_1 = bm_2$
    (C) $am_2 = bm_1$
    (D) $a^2m_1 = b^2m_2$
    (E) $b^2m_1 = a^2m_2$

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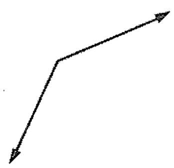
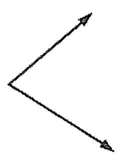
31. An object having an initial momentum that may be represented by the vector above strikes an object that is initially at rest. Which of the following sets of vectors may represent the momenta of the two objects after the collision?

(A)

(B)

(C) 

(D) 

(E) 

Questions 32-33

A wheel with rotational inertia I is mounted on a fixed, frictionless axle. The angular speed ω of the wheel is increased from zero to ω_f in a time interval T.

32. What is the average net torque on the wheel during this time interval?

(A) $\frac{\omega_f}{T}$

(B) $\frac{\omega_f}{T^2}$

(C) $\frac{I\omega_f^2}{T}$

(D) $\frac{I\omega_f}{T^2}$

(E) $\frac{I\omega_f}{T}$

33. What is the average power input to the wheel during this time interval?

(A) $\frac{I\omega_f}{2T}$

(B) $\frac{I\omega_f^2}{2T}$

(C) $\frac{I\omega_f^2}{2T^2}$

(D) $\frac{I^2\omega_f}{2T^2}$

(E) $\frac{I^2\omega_f^2}{2T^2}$

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34. An object is released from rest at time $t = 0$ and falls through the air, which exerts a resistive force such that the acceleration a of the object is given by $a = g - bv$, where v is the object's speed and b is a constant. If limiting cases for large and small values of t are considered, which of the following is a possible expression for the speed of the object as an explicit function of time?

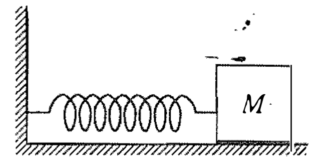
(A) $v = g\left(1 - e^{-bt}\right)/b$

(B) $v = \left(ge^{bt}\right)/b$

(C) $v = gt - bt^2$

(D) $v = (g + a)t/b$

(E) $v = v_0 + gt,\ v_0 \neq 0$



35. An ideal massless spring is fixed to the wall at one end, as shown above. A block of mass M attached to the other end of the spring oscillates with amplitude A on a frictionless, horizontal surface. The maximum speed of the block is v_m. The force constant of the spring is

(A) $\dfrac{Mg}{A}$

(B) $\dfrac{Mgv_m}{2A}$

(C) $\dfrac{Mv_m^2}{2A}$

(D) $\dfrac{Mv_m^2}{A^2}$

(E) $\dfrac{Mv_m^2}{2A^2}$

STOP

END OF SECTION I, MECHANICS

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION I, MECHANICS, ONLY.
DO NOT TURN TO ANY OTHER TEST MATERIALS.

PHYSICS C

SECTION I, ELECTRICITY AND MAGNETISM

Time—28 minutes

35 Questions

<u>Directions:</u> 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.

36. A resistor R and a capacitor C are connected in series to a battery of terminal voltage V_0. Which of the following equations relating the current I in the circuit and the charge Q on the capacitor describes this circuit?

(A) $V_0 + QC - I^2R = 0$

(B) $V_0 - \dfrac{Q}{C} - IR = 0$

(C) $V_0^2 - \dfrac{1}{2}\dfrac{Q^2}{C} - I^2R = 0$

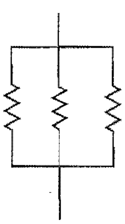
(D) $V_0 - C\dfrac{dQ}{dt} - I^2R = 0$

(E) $\dfrac{Q}{C} - IR = 0$

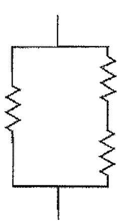
37. Which of the following combinations of 4 Ω resistors would dissipate 24 W when connected to a 12 V battery?

(A)

(B)

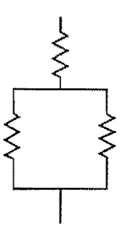


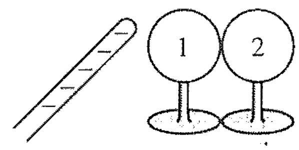
(C)



(D)

(E)





38. Two initially uncharged conductors, 1 and 2, are mounted on insulating stands and are in contact, as shown above. A negatively charged rod is brought near but does not touch them. With the rod held in place, conductor 2 is moved to the right by pushing its stand, so that the conductors are separated. Which of the following is now true of conductor 2 ?

(A) It is uncharged.
(B) It is positively charged.
(C) It is negatively charged.
(D) It is charged, but its sign cannot be predicted.
(E) It is at the same potential that it was before the charged rod was brought near.

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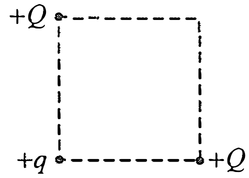
Questions 39-40



As shown above, two particles, each of charge $+Q$, are fixed at opposite corners of a square that lies in the plane of the page. A positive test charge $+q$ is placed at a third corner.

39. What is the direction of the force on the test charge due to the two other charges?

(A) 

(B)

(C) 

(D) 

(E) 

40. If F is the magnitude of the force on the test charge due to only one of the other charges, what is the magnitude of the net force acting on the test charge due to both of these charges?

(A) Zero
(B) $F/\sqrt{2}$
(C) F
(D) $\sqrt{2}\,F$
(E) $2\,F$

41. Gauss's law provides a convenient way to calculate the electric field outside and near each of the following isolated charged conductors EXCEPT a

(A) large plate
(B) sphere
(C) cube
(D) long, solid rod
(E) long, hollow cylinder

42. A wire of resistance R dissipates power P when a current I passes through it. The wire is replaced by another wire with resistance $3R$. The power dissipated by the new wire when the same current passes through it is

(A) $\frac{P}{9}$
(B) $\frac{P}{3}$
(C) P
(D) $3P$
(E) $6P$

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<u>Questions 43-44</u>

A narrow beam of protons produces a current of 1.6×10^{-3} A. There are 10^9 protons in each meter along the beam.

43. Of the following, which is the best estimate of the average speed of the protons in the beam?

(A) 10^{-15} m/s

(B) 10^{-12} m/s

(C) 10^{-7} m/s

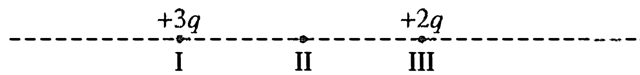
(D) 10^{7} m/s

(E) 10^{12} m/s

44. Which of the following describes the lines of magnetic field in the vicinity of the beam due to the beam's current?

(A) Concentric circles around the beam
(B) Parallel to the beam
(C) Radial and toward the beam
(D) Radial and away from the beam
(E) There is no magnetic field.

<u>Questions 45-46</u> refer to two charges located on the line shown in the figure below, in which the charge at point I is $+3q$ and the charge at point III is $+2q$. Point II is halfway between points I and III.



45. Other than at infinity, the electric field strength is zero at a point on the line in which of the following ranges?

(A) To the left of I
(B) Between I and II
(C) Between II and III
(D) To the right of III
(E) None; the field is zero only at infinity.

46. The electric potential is negative at some points on the line in which of the following ranges?

(A) To the left of I
(B) Between I and II
(C) Between II and III
(D) To the right of III
(E) None; this potential is never negative.

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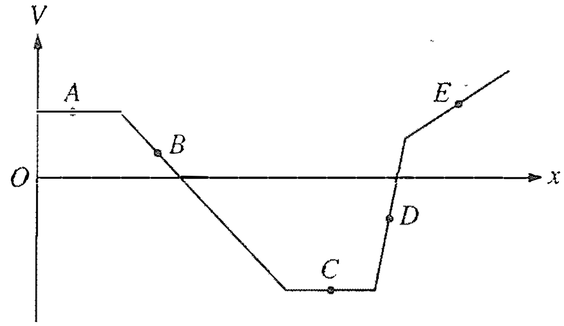
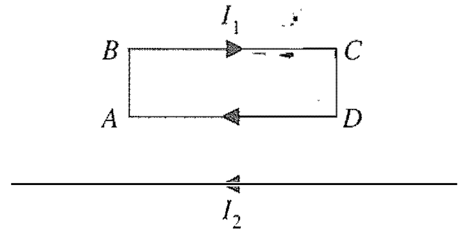


47. The graph above shows the electric potential V in a region of space as a function of position along the x-axis. At which point would a charged particle experience the force of greatest magnitude?

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

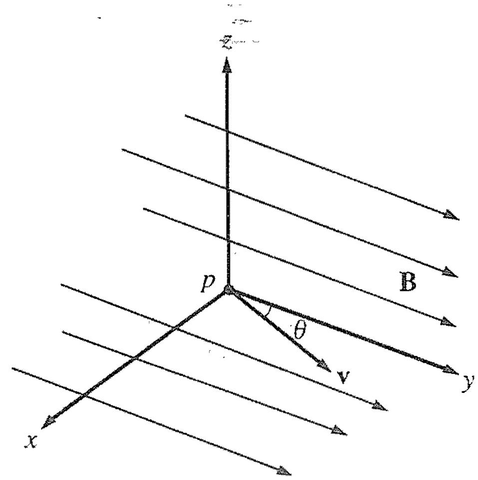
48. The work that must be done by an external agent to move a point charge of 2 mC from the origin to a point 3 m away is 5 J. What is the potential difference between the two points?

    (A) 4×10^{-4} V
    (B) 10^{-2} V
    (C) 2.5×10^{3} V
    (D) 2×10^{6} V
    (E) 6×10^{6} V



49. A rigid, rectangular wire loop $ABCD$ carrying current I_1 lies in the plane of the page above a very long wire carrying current I_2, as shown above. The net force on the loop is

    (A) toward the wire
    (B) away from the wire
    (C) toward the left
    (D) toward the right
    (E) zero



50. A uniform magnetic field **B** is parallel to the xy-plane and in the $+y$-direction, as shown above. A proton p initially moves with velocity **v** in the xy-plane at an angle θ to the magnetic field and the y-axis. The proton will subsequently follow what kind of path?

    (A) A straight-line path in the direction of **v**
    (B) A circular path in the xy-plane
    (C) A circular path in the yz-plane
    (D) A helical path with its axis parallel to the y-axis
    (E) A helical path with its axis parallel to the z-axis

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51. A parallel-plate capacitor has charge $+Q$ on one plate and charge $-Q$ on the other. The plates, each of area A, are a distance d apart and are separated by a vacuum. A single proton of charge $+e$, released from rest at the surface of the positively charged plate, will arrive at the other plate with kinetic energy proportional to

(A) $\frac{edQ}{A}$

(B) $\frac{Q^2}{eAd}$

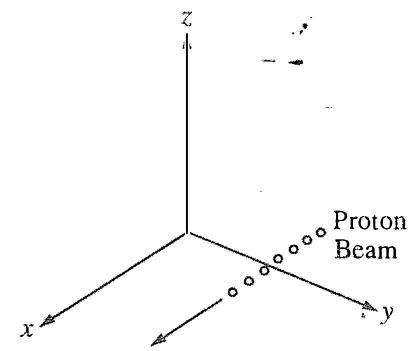
(C) $\frac{AeQ}{d}$

(D) $\frac{Q}{ed}$

(E) $\frac{eQ^2}{Ad}$

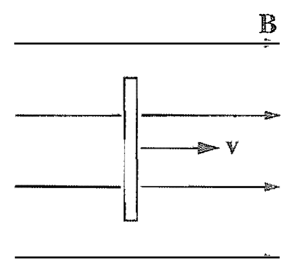
52. In which of the following cases does there exist a nonzero magnetic field that can be conveniently determined by using Ampere's law?

(A) Outside a point charge that is at rest
(B) Inside a stationary cylinder carrying a uniformly distributed charge
(C) Inside a very long current-carrying solenoid
(D) At the center of a current-carrying loop of wire
(E) Outside a square current-carrying loop of wire



53. A beam of protons moves parallel to the x-axis in the positive x-direction, as shown above, through a region of crossed electric and magnetic fields balanced for zero deflection of the beam. If the magnetic field is pointed in the positive y-direction, in what direction must the electric field be pointed?

(A) Positive y-direction
(B) Positive z-direction
(C) Negative x-direction
(D) Negative y-direction
(E) Negative z-direction



54. A vertical length of copper wire moves to the right with a steady velocity $\mathbf{v}$ in the direction of a constant horizontal magnetic field $\mathbf{B}$, as shown above. Which of the following describes the induced charges on the ends of the wire?

	Top End	Bottom End
(A)	Positive	Negative
(B)	Negative	Positive
(C)	Negative	Zero
(D)	Zero	Negative
(E)	Zero	Zero

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55. Suppose that an electron (charge $-e$) could orbit a proton (charge $+e$) in a circular orbit of constant radius R. Assuming that the proton is stationary and only electrostatic forces act on the particles, which of the following represents the kinetic energy of the two-particle system?

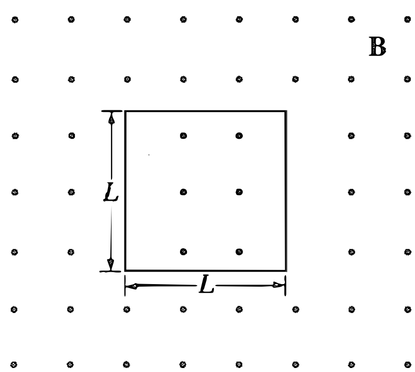
(A) $\frac{1}{4\pi\epsilon_0}\frac{e}{R}$

(B) $\frac{1}{8\pi\epsilon_0}\frac{e^2}{R}$

(C) $-\frac{1}{8\pi\epsilon_0}\frac{e^2}{R}$

(D) $\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2}$

(E) $-\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2}$



56. A square wire loop with side L and resistance R is held at rest in a uniform magnetic field of magnitude B directed out of the page, as shown above. The field decreases with time t according to the equation $B = a - bt$, where a and b are positive constants. The current I induced in the loop is

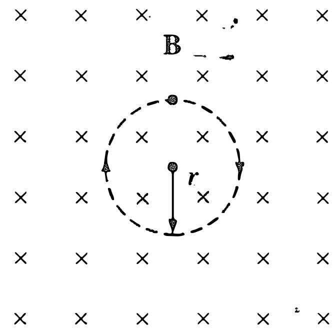
(A) zero

(B) aL^2/R, clockwise

(C) aL^2/R, counterclockwise

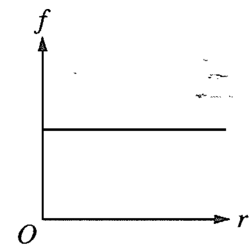
(D) bL^2/R, clockwise

(E) bL^2/R, counterclockwise

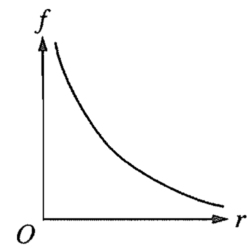


57. A negatively charged particle in a uniform magnetic field **B** moves in a circular path of radius r, as shown above. Which of the following graphs best depicts how the frequency of revolution f of the particle depends on the radius r ?

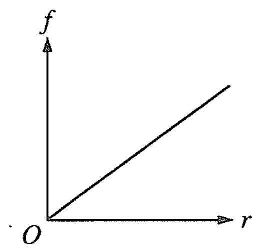
(A)



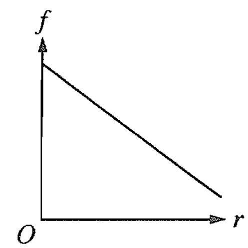
(B)



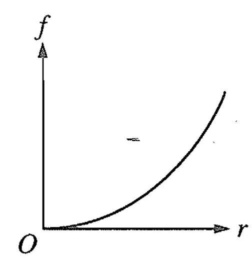
(C)



(D)



(E)



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58. If the only force acting on an electron is due to a uniform electric field, the electron moves with constant

    (A) acceleration in a direction opposite to that of the field
    (B) acceleration in the direction of the field
    (C) acceleration in a direction perpendicular to that of the field
    (D) speed in a direction opposite to that of the field
    (E) speed in the direction of the field

<u>Questions 59-60</u>

In a region of space, a spherically symmetric electric potential is given as a function of r, the distance from the origin, by the equation $V(r) = kr^2$, where k is a positive constant.

59. What is the magnitude of the electric field at a point a distance r_0 from the origin?

    (A) Zero

    (B) kr_0

    (C) $2kr_0$

    (D) kr_0^2

    (E) $\frac{2}{3}kr_0^3$

60. What is the direction of the electric field at a point a distance r_0 from the origin and the direction of the force on an electron placed at this point?

	Electric Field	Force on Electron
(A)	Toward origin	Toward origin
(B)	Toward origin	Away from origin
(C)	Away from origin	Toward origin
(D)	Away from origin	Away from origin
(E)	Undefined, since the field is zero	Undefined, since the force is zero

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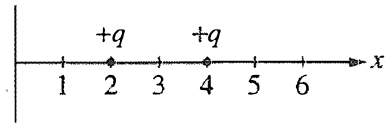
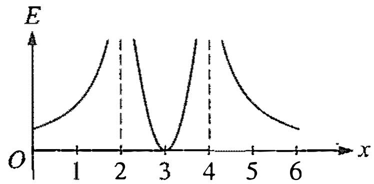
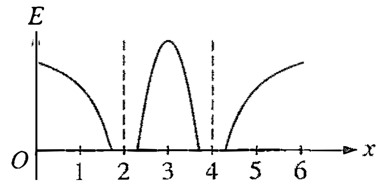
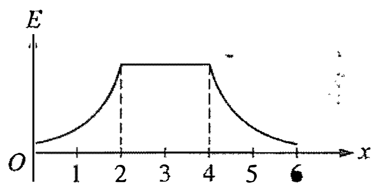
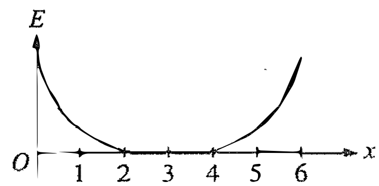


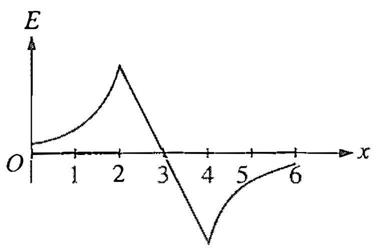
61. Two charged particles, each with a charge of $+q$, are located along the x-axis at $x = 2$ and $x = 4$, as shown above. Which of the following shows the graph of the magnitude of the electric field along the x-axis from the origin to $x = 6$?

(A)


(B)


(C)


(D)


(E)


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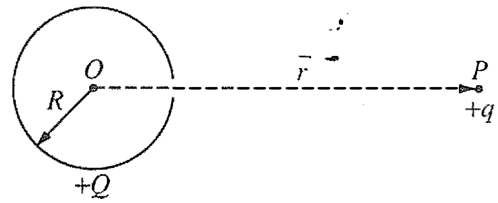
62. A positive electric charge is moved at a constant speed between two locations in an electric field, with no work done by or against the field at any time during the motion. This situation can occur only if the

(A) charge is moved in the direction of the field
(B) charge is moved opposite to the direction of the field
(C) charge is moved perpendicular to an equipotential line
(D) charge is moved along an equipotential line
(E) electric field is uniform



63. The nonconducting hollow sphere of radius R shown above carries a large charge $+Q$, which is uniformly distributed on its surface. There is a small hole in the sphere. A small charge $+q$ is initially located at point P, a distance r from the center of the sphere. If $k = 1/4\pi\epsilon_0$, what is the work that must be done by an external agent in moving the charge $+q$ from P through the hole to the center O of the sphere?

(A) Zero

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

(C) $\frac{kqQ}{R}$

(D) $\frac{kq(Q-q)}{r}$

(E) $kqQ\left(\frac{1}{R} - \frac{1}{r}\right)$

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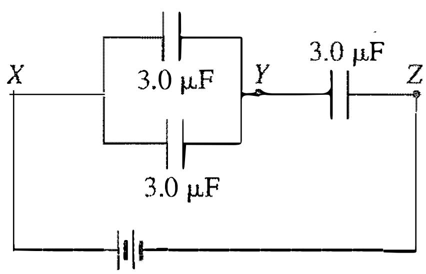
Questions 64-65



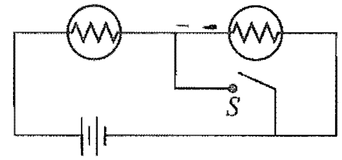
Three identical capacitors, each of capacitance 3.0 μF, are connected in a circuit with a 12 V battery as shown above.

64. The equivalent capacitance between points X and Z is

(A) 1.0 μF
(B) 2.0 μF
(C) 4.5 μF
(D) 6.0 μF
(E) 9.0 μF

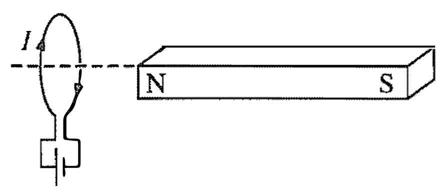
65. The potential difference between points Y and Z is

(A) zero
(B) 3 V
(C) 4 V
(D) 8 V
(E) 9 V



66. The circuit in the figure above contains two identical lightbulbs in series with a battery. At first both bulbs glow with equal brightness. When switch S is closed, which of the following occurs to the bulbs?

	Bulb 1	Bulb 2
(A)	Goes out	Gets brighter
(B)	Gets brighter	Goes out
(C)	Gets brighter	Gets slightly dimmer
(D)	Gets slightly dimmer	Gets brighter
(E)	Nothing	Goes out



67. A bar magnet and a wire loop carrying current I are arranged as shown above. In which direction, if any, is the force on the current loop due to the magnet?

(A) Toward the magnet
(B) Away from the magnet
(C) Toward the top of the page
(D) Toward the bottom of the page
(E) There is no force on the current loop.

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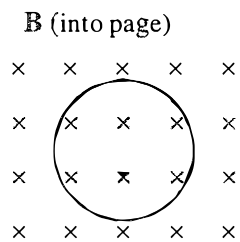


68. A wire loop of area A is placed in a time-varying but spatially uniform magnetic field that is perpendicular to the plane of the loop, as shown above. The induced emf in the loop is given by $\mathcal{E} = bAt^{1/2}$, where b is a constant. The time-varying magnetic field could be given by

(A) $\frac{1}{2}bAt^{-1/2}$

(B) $\frac{1}{2}bt^{-1/2}$

(C) $\frac{1}{2}bt^{1/2}$

(D) $\frac{2}{3}bAt^{3/2}$

(E) $\frac{2}{3}bt^{3/2}$

Questions 69-70

A capacitor is constructed of two identical conducting plates parallel to each other and separated by a distance d. The capacitor is charged to a potential difference of V_0 by a battery, which is then disconnected.

69. If any edge effects are negligible, what is the magnitude of the electric field between the plates?

(A) $V_0 d$

(B) V_0/d

(C) d/V_0

(D) V_0/d^2

(E) V_0^2/d

70. A sheet of insulating plastic material is inserted between the plates without otherwise disturbing the system. What effect does this have on the capacitance?

(A) It causes the capacitance to increase.
(B) It causes the capacitance to decrease.
(C) None; the capacitance does not change.
(D) Nothing can be said about the effect without knowing the dielectric constant of the plastic.
(E) Nothing can be said about the effect without knowing the thickness of the sheet.

STOP

END OF SECTION I, ELECTRICITY AND MAGNETISM

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.

Chapter V Answers to the 1998 AP Physics C Examination

- Section I: Multiple Choice
  - Blank Answer Sheet
- Section II: Free Response

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who answered each question correctly.

Answer Key and Percent Answering Correctly

Mechanics			Electricity & Magnetism		
Item No.	Correct Answer	Percent Correct	Item No.	Correct Answer	Percent Correct
1	B	82%	36	B	74%
2	E	82%	37	E	65%
3	D	78%	38	C	77%
4	B	67%	39	E	93%
5	C	69%	40	D	79%
6	A	56%	41	C	56%
7	A	56%	42	D	75%
8	D	45%	43	D	29%
9	D	18%	44	A	75%
10	A	53%	45	C	80%
11	E	45%	46	E	61%
12	C	68%	47	D	34%
13	C	81%	48	C	45%
14	B	61%	49	A	49%
15	A	42%	50	D	33%
16	C	54%	51	A	28%
17	A	50%	52	C	45%
18	B	82%	53	E	50%
19	A	35%	54	E	63%
20	B	18%	55	B	26%
21	D	89%	56	E	50%
22	E	42%	57	A	19%
*23	—	—	58	A	53%
24	A	67%	59	C	50%
25	B	56%	60	B	24%
26	C	63%	61	A	74%
27	D	46%	62	D	64%
28	C	59%	63	E	39%
29	E	29%	64	B	71%
30	B	71%	65	D	27%
31	E	48%	66	B	46%
32	E	65%	67	A	24%
33	B	36%	68	E	30%
34	A	37%	69	B	62%
35	D	58%	70	A	61%

*This question was not counted when the exam was scored.

Mechanics Multiple Choice Solutions
AP® Physics C 1998 Released Exam from the College Board

1) You ***are not*** allowed to use a calculator on the Multiple Choice section!
2) I use the term Free Body Diagram, however, sometimes people use the term Force Diagram instead.
3) UAM means Uniformly Accelerated Motion, in other words, when the acceleration is constant.
4) Remember that you can use g = 10 m/s^2 on the multiple choice. (Probably because you can't use your calculator)
5) When they give a force applied of just F (with no subscript), I always add a subscript, F_a, to identify it a little bit better.
6) They usually use, *f*, for the friction force. To be more clear, I use F_f.

1) The equation for work is, $W = Fdcos\theta$, where F is the force doing the work, d is the displacement of the object and θ is the angle between the Force and the Displacement. In this case the angle given in the problem is the angle between the force applied and the displacement. So the answer is $W = Fdcos\theta$ (B).

2) At the highest point in it's trajectory a projectile has a velocity in the y-direction of zero. (On the way up, the y-velocity is positive and on the way down, the y-velocity is negative, therefore it is zero at the top.)

There is no acceleration in the x-direction in projectile motion; therefore the velocity in the x-direction will remain constant at v_h.

The acceleration due to gravity is g. The acceleration in the y-direction for any object in projectile motion equals –g. Therefore, the answer should be –g, however, that isn't one of the choices. So g is the best answer. Therefore the "correct" answer is (E) [I wish the word "magnitude" had been used in the question.]

3) Start by remembering that the slope of a velocity versus time graph is acceleration. Let's split the motion in to three parts:

1. Part 1 is where the object has a constant, positive acceleration.
2. Part 2 is where the object has a constant acceleration of zero and therefore a constant velocity.
3. Part 3 is where the object has a constant negative acceleration.

Also remember that the slope of a position versus time graph is velocity. Walking through the graph from left to right. The initial velocity is zero, therefore the initial slope of the position versus time graph needs to be zero or horizontal: (A), (C) & (E) don't fit this criterion. For part 2 (B) has a constant position, not a constant velocity, therefore it can't be (B). The only answer it could be is (D). We could stop here, however, let's just point out that Part 2 for (D) shows a constant slope on the position versus time graph which means there is a constant velocity, which is correct. Also (D) shows a positive acceleration for Part 1 and a negative acceleration for Part 2.

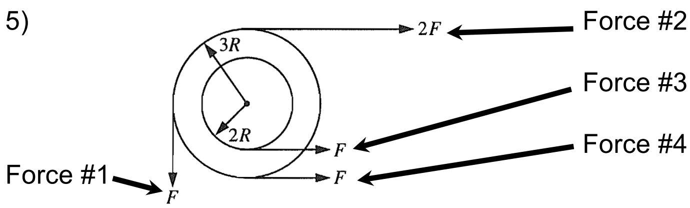
4) $x = t^3 - 6t^2 + 9t$ (note: this assumes t_i = 0) & F_{net} = 0, t = ?

Newton's 2nd law states: $\sum \vec{F} = m\vec{a}$, so $\sum \vec{F} = m\vec{a} = 0 \Rightarrow \vec{a} = 0$ & acceleration is the 2nd derivative of position as a function of time. (Because this is all in the x-direction, we can drop the vector notation.)

$$0 = \frac{d^2x}{dt^2} = \frac{d^2}{dt^2}\left(t^3 - 6t^2 + 9t\right) = \frac{d}{dt}\left(3t^2 - 2\cdot 6t + 9\right) = \frac{d}{dt}\left(3t^2 - 12t + 9\right) = 6t - 12 \Rightarrow 6t = 12 \Rightarrow t = 2\,\text{sec}$$

Correct answer is (B)

5)



Limber up and use the Right Hand Rule to find the direction of the torque. For F_1 for example: start at the Axis of Rotation (AOR) or in the middle of the wheel. Using your right hand, point your fingers along the lever arm or directly to the left and curl your fingers in the direction of F_1. Your thumb points out of the page, which is defined as positive. For F_2: start at the AOR and point your fingers along the lever arm, which is straight up the page and then your fingers in the direction of F_2. Your thumb points into the page, which is defined as negative. For F_3 & F_4: start at the AOR and point your fingers along the lever arm, which is straight down the page and curl your fingers in the direction of F_3 & F_4. Your thumb points out of the page, which is defined as positive.

$$\sum \tau = \tau_1 - \tau_2 + \tau_3 + \tau_4 = r_1F_1\sin\theta_1 - r_2F_2\sin\theta_2 + r_3F_3\sin\theta_3 + r_4F_4\sin\theta_4$$

All the angles between the lever arms, r, and the Forces, F, are 90° and sin(90°) = 1

$$\Rightarrow \sum \tau = r_1F_1 - r_2F_2 + r_3F_3 + r_4F_4 = (3R)F - (3R)2F + (2R)F + (3R)F = (RF)(3-6+2+3) = 2RF$$

The answer is (C)

6) The equation for the velocity of the center of mass of an object rolling without slipping is $v_{cm} = R\omega$.
The equation for the magnitude of momentum is $p = mv$. So: $p = mv = mR\omega$. The answer is (A)

7) There are no other field forces mentioned and nothing is touching the ball, so there are no contact forces. Therefore, the only force that acts on the ball is the gravitational field force. Newton's Universal Law of Gravitation (or the Big "G" Equation) is: $F_g = \frac{Gm_1m_2}{r^2}$ (Magnitude only)

The two masses would be the masses of the ball and the asteroid. r is the distance between the center of masses of the asteroid and the ball. As the ball moves up, r, increases and therefore 1/r decreases, therefore F_g decreases. The answer is (A)

8) $\sum F_y = ma_y \Rightarrow F_g = \frac{Gm_1m_2}{r^2} = ma_y \Rightarrow \frac{Gm_{ball}m_{asteroid}}{r^2} = m_{ball}a_y \Rightarrow a_y = \frac{Gm_{ball}}{r^2}$

$a_{asteroid\,surface} = \frac{Gm_{ball}}{R^2_{asteroid}}$ & $a_{top} = \frac{Gm_{ball}}{(2R_{asteroid})^2} = \frac{Gm_{ball}}{4R^2_{asteroid}} = \frac{1}{4}\left(\frac{Gm_{ball}}{R^2_{asteroid}}\right) = \frac{1}{4}a_{asteroid\,surface}$ The answer is (D)

9) $\frac{d^2x}{dt^2} = -9x$ & the equation that defines simple harmonic motion is $\frac{d^2x}{dt^2} = -\omega^2 x$, therefore:

$\omega^2 = 9 \Rightarrow \omega = 3\frac{rad}{s}$ & $\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi\ rad}{T} \Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi}{3}\sec$ The answer is (D)

Note: The dimensions work out like this: $T \Rightarrow \frac{rad}{rad/s} \Rightarrow \frac{rad}{rad}\cdot\frac{s}{1} = \sec$

Also: I know the equation $T = \frac{2\pi}{\omega}$ is on the equation sheet, however, I prefer to memorize as little as possible and it is easy to remember that something rotates 2π radians during one period.

10) $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow \frac{T}{2\pi} = \sqrt{\frac{L}{g}} \Rightarrow \frac{T^2}{4\pi^2} = \frac{L}{g} \Rightarrow g = \frac{4\pi^2 L}{T^2}$ & $g_{Earth} = \frac{4\pi^2 L}{1^2} = 4\pi^2 L$

$g_{Planet} = \frac{4\pi^2 L}{2^2} = \frac{4\pi^2 L}{4} = \frac{g_{Earth}}{4}$ The answer is (A)

11) Satellite with mass, M. Circular orbit radius, R. and constant tangential speed, v.

I. $v_t = r\omega \Rightarrow \omega = \frac{v}{R}$ (I is true)

II. $a_t = r\alpha$ & $\alpha = \frac{\Delta\omega}{\Delta t}$ and if the tangential velocity is not changing and the radius is not changing, then the angular velocity is changing and therefore the angular acceleration, α, is zero. Therefore the tangential acceleration is zero. (II is true)

III. $a_c = \frac{v_t^2}{r}$ is the equation for centripetal acceleration. The tangential velocity and the radius are not changing therefore the *magnitude* of the centripetal acceleration is not changing. (III is true)

The answer is (E). Notice that this question would be a lot more fun if the word "magnitude" had been left out of statement III. In other words: "The centripetal acceleration is constant". Because then the correct answer would be that I and II are true because III would be false because the direction of the centripetal acceleration is always "center seeking" or inward and therefore the centripetal acceleration is always changing. However, the magnitude of the centripetal acceleration is constant.

12) This is a classic *Area "Under" the Curve* question. Impulse, $J = \int F\,dt = \Delta p$. And the integral is the Area "Under" the Curve. I put "area" in quotes because technically it is the area between the curve and the horizontal axis where area above the axis is positive and area below the axis is negative. Therefore the total *area "under" the curve* in this graph is zero. The answer is (C).

13) This is an inelastic collision where all forces are internal and therefore momentum is conserved.
Let's identify m as m_1 and 2m as m_2.

$$\sum \vec{p}_i = \sum \vec{p}_f \Rightarrow \vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{tf} \Rightarrow m_1 v_{1i} + m_2 v_{2i} = m_t v_{tf} = \left(m_1 + m_2\right) v_{tf}$$

$$\Rightarrow (m)(v) + (2m)\left(\frac{v}{2}\right) = (m + 2m) v_{tf} \Rightarrow mv + mv = 3mv_{tf} \Rightarrow 2v = 3v_{tf} \Rightarrow v_{tf} = \frac{2v}{3}$$ The answer is (C)

14) k = 100 N/m, L_i = 0.07 m, m_{disc} = 1 kg, Uniform Circular Motion, i.e. α = 0,
L_f = 0.1 m (spring is stretched 0.03 m, so x = 0.03 m)
no friction. There are 3 forces in the free body diagram: Force Normal is up, Force of Gravity is down and the Spring Force is inward.

$$\sum F_{in} = F_{spring} = ma_c \Rightarrow F_{spring} = kx = (100)(0.03) = 3N$$ Answer is (B)

Please note that the equation for F_{spring} is: F_{spring} = -kx and that negative shows that the force of the spring is opposite the direction of displacement. And, when an object is moving in a circle, the "in" direction is always positive. Therefore when we sum the forces in the "in" direction, the Force of the Spring is positive because it is in the "in" direction and we use the magnitude of the equation for the Force of the Spring.

15) Remember that the angle in the work equation is the angle between the force doing the work and the object's displacement. $W = Fd\cos\theta = F_{spring} d\cos(90) = 0$ Answer is (A).

16) There is no mention of non-conservative / friction forces; therefore we are to assume that we can use Conservation of Energy.

$$ME_i = ME_f \Rightarrow U_i = U_f + KE_f \Rightarrow 3U_o = U_o + \frac{1}{2}mv_f^2 \Rightarrow \frac{1}{2}mv_f^2 = 2U_o \Rightarrow v_f = \sqrt{\frac{4U_o}{m}}$$ Answer is (C)

17) $U(r) = br^{-\frac{3}{2}} + c$ again, it doesn't mention it, however, we are to assume that this is a conservative force and therefore we need to use the equation for a conservative force that seems comes up on every AP® Physics C test and is not on the provided equation sheet: (in this problem our position variable is *r* not *x*)

$$F(x) = -\frac{dU}{dx} \Rightarrow F(r) = -\frac{dU}{dr} = -\frac{d}{dr}\left(br^{-\frac{3}{2}} + c\right) = -\left(-\frac{3}{2}\right)\left(br^{\left(-\frac{3}{2}-1\right)}\right) = \frac{3}{2}br^{-\frac{5}{2}}$$ Answer is (A)

18) L = 3 m, A = 10°, U_{max} = 10 J, KE = ? (when U = 5 J): Again Conservation of Energy:

$$ME_i = ME_f \Rightarrow U_i = U_f + KE_f \Rightarrow 10 = 5 + KE_f \Rightarrow KE_f = 5J$$ Answer is (B)

19) m_e = 1000 kg, a = constant, v_f = 0, Δy = -8 m, T = 11000 N, v_i = ?

In our Free Body Diagram the Tension force is up and the force of gravity is down. Use Newton's 2nd law to find the constant acceleration and then UAM to find the velocity initial.

$$\sum F_y = T - F_g = T - mg = ma_y \Rightarrow a_y = \frac{T}{m} - g = \frac{11000}{1000} - 10 = 11 - 10 = 1$$

& $v_f^2 = v_i^2 + 2a_y\Delta_y \Rightarrow 0^2 = v_i^2 + 2(1)(-8) \Rightarrow v_i = \sqrt{16} = 4\frac{m}{s}$ Answer is (A)

20) D is Diameter of the orbital circle. Mass is M and speed is v. Hmm. I like this one. Where to start doesn't leap out at you. Let's start by summing the forces in the in direction on one of the two stars and see what happens. The only force in the Free Body Diagram is the Newton's Universal Force of Gravity.

$$\sum F_{in} = F_g = ma_c \Rightarrow \frac{Gm_sm_s}{r^2} = m_s\frac{v_t^2}{r} \Rightarrow \frac{GM}{D^2} = \frac{v^2}{D/2} \Rightarrow \frac{GM}{D} = 2v^2 \Rightarrow v^2 = \frac{GM}{2D}$$ Answer is (B)

Remember that "r" in Newton's Universal Law of Gravitation equation is defined as the distance between the center of masses of the two objects, *not* the radius.

21) Mass of block is m, Force applied is F_a, angle between F_a and horizontal is ϕ, Friction force has a magnitude F_f, a = ?

The free body diagram will have a Force Normal, F_N, up, the Force of Gravity, F_g, down, the Friction Force, F_f to the left and the Force Applied, F_a, to the right and up at an angle of ϕ with the horizontal. Now, you might leap into this one by starting to sum the forces in the y-direction, because, heck, that is where we usually start, however, not this time. We usually start in the y-direction so we can determine the Force Normal because the Force of Friction depends on F_n, however, we already know F_f, so we just jump right to the x-direction.

$$\sum F_x = F_{ax} - F_f = ma_x \Rightarrow a_x = \frac{F_{ax} - F_f}{m} = \frac{F\cos\phi - f}{m}$$ Answer is (D)

22) Now that we are trying to find the coefficient of friction, μ, we do need to sum the forces in the y-direction.

$$\sum F_y = F_N + F_{ay} - F_g = ma_y = m(0) = 0 \Rightarrow F_N = F_g - F_{ay} = mg - F\sin\phi$$

& $F_f = \mu F_N \Rightarrow \mu = \dfrac{F_f}{F_N} = \dfrac{f}{mg - F\sin\phi}$ Answer is (E)

23) "This question was not counted when the exam was scored." Yes. Mistakes happen.

24) According to Newton's 3rd law the force that Person 1 exerts on Person 2 is equal in magnitude and opposite in direction to the force exerted by Person 2 on Person 1.

$$\vec{F}_{12} = -\vec{F}_{21}$$

Therefore when both people push on one another they create a mechanical "explosion" where the forces are all internal and cancel one another out. Therefore, using Newton's 2nd Law, we can see that, because the net force on the system is zero, then the acceleration of the system is also zero.

$$\sum \vec{F} = 0 = m\vec{a} \Rightarrow \vec{a} = 0$$

Therefore, because the initial velocity of the system is zero, it will remain zero because the acceleration is zero. Answer is (A)

If you would prefer to use some of the numbers in the problem, you can use the equation for center of mass for a system of particles…

$x_{cm} = \dfrac{x_1 m_1 + x_2 m_2}{m_1 + m_2}$ & $v_{cm} = \dfrac{dx_{cm}}{dt} = \dfrac{d}{dt}\left(\dfrac{x_1 m_1 + x_2 m_2}{m_1 + m_2}\right) = \dfrac{v_1 m_1 + v_2 m_2}{m_1 + m_2} = \left(\dfrac{(-2)(120) + (3)(80)}{120 + 80}\right) = 0$

25) The dancer moves at a constant speed the entire time. Therefore, when the dancer moves in a straight line, he will also be moving at a constant velocity and have zero acceleration. $a_{PQ} = a_{RS} = 0$. As the dancer moves on the semicircles, he may be moving with a constant speed, however, his direction will be changing and he will have a centripetal acceleration inward. Because his speed will be constant, his centripetal acceleration will also be constant. $\left(a_c = \dfrac{v_t^2}{r}\right)$. The answer is (B)

26) Projectile Motion. Y-direction Knowns: $v_{iy} = 0$, $a_y = -10\ m/s^2$, $\Delta y = -10\ m$, $\Delta t = ?$

$$\Delta y = v_{iy}\Delta t + \frac{1}{2}a_y \Delta t^2 \Rightarrow -10 = (0)\Delta t + \frac{1}{2}(-10)\Delta t^2 \Rightarrow -10 = -5\Delta t^2 \Rightarrow \Delta t^2 = \frac{-10}{-5} \Rightarrow \Delta t = \sqrt{2}$$

Time is a scalar and independent of direction so now we can look at the X-direction:

$v_x = \dfrac{\Delta x}{\Delta t} = \dfrac{3}{\sqrt{2}}\dfrac{m}{s}$ The answer is (C)

27) We are to assume that this is a conservative force and therefore:

$$F(x) = -\frac{dU}{dx} \Rightarrow dU = -F(x)dx \Rightarrow \int_{U_i}^{U_f} dU = -\int_{x_i}^{x_f}\left(40x - 6x^2\right)dx \Rightarrow U_f - U_i = -\left(\frac{40x^2}{2} - \frac{6x^3}{3}\right)\Bigg]_0^2$$

$$\Rightarrow \Delta U = -\left((20)(2)^2 - (2)(2)^3\right) - \left(-\left((20)(0)^2 - (2)(0)^3\right)\right) = -(80 - 16) - (0) = -64\,J$$

The force in this equation is the $F_{applied}$ which is equal and oppsite to the F_{spring}. Therefore the answer should be the energy stored in the spring which equal and opposite to the energy put into the spring by the Force Applied and is +64 J. (D)

28) $W_{F_g} = F_g d\cos\phi$ The angle in this equation, ϕ, is the angle between the Force of Gravity and the displacement of the object or F_g and d. If we define the angle of the incline to be θ then, on the way down the incline, ϕ = 90 - θ. However on the way up the incline, ϕ = 90 + θ. Therefore if the work done by F_g on the way down the incline is +300 J, then, because $\cos(90-\theta) = -\cos(90+\theta)$, the work done by F_g on the way up the incline must be -300 J. Answer is (C)
[Note: F_g and d are the same going up and down the incline] [Also Note: The angle in the work equation is usually θ and I used ϕ this time. This is because I started by defining the angle of the incline as θ. It might have been good for me to change it, however, I knew you could handle it.]

29) The x and y equations here describe the motion of an object moving in a circle, where A represents the radius and ω represents the angular velocity. Therefore the acceleration of the object is a centripetal acceleration where: $a_c = r\omega^2 = (1.5)(2)^2 = 6\frac{m}{s^2}$ Answer is (E)

If you didn't recognize A as the radius and ω as the angular velocity, you could also solve the problem this way:

$$a_x = \frac{d^2x}{dt^2} = \frac{d^2}{dt^2}\left(A\cos(\omega t)\right) = \frac{d}{dt}\left(-A\omega\sin(\omega t)\right) = -A\omega^2\cos(\omega t) = -(1.5)(2)^2\cos(2t) = -6\cos(2t)$$

$$a_y = \frac{d^2y}{dt^2} = \frac{d^2}{dt^2}\left(A\sin(\omega t)\right) = \frac{d}{dt}\left(A\omega\cos(\omega t)\right) = -A\omega^2\sin(\omega t) = -(1.5)(2)^2\sin(2t) = -6\sin(2t)$$

$$a^2 = a_x{}^2 + a_y{}^2 \Rightarrow a = \sqrt{a_x{}^2 + a_y{}^2} = \sqrt{\left(-6\cos(2t)\right)^2 + \left(-6\sin(2t)\right)^2} = \sqrt{36\left(\cos^2(2t)+\sin^2(2t)\right)} = \sqrt{36(1)} = 6\frac{m}{s^2}$$

Note: This uses the trig identity: $\cos^2\theta + \sin^2\theta = 1$ And an easy way to remember this is that it is just Pythagorean's theorem where the hypotenuse has a length of 1.

30) For this object to be in static equilibrium the net torque about the very center needs to equal zero.

$$\sum\tau_{center} = +\tau_{W_1} - \tau_{W_2} = 0 \Rightarrow \tau_{W_1} = \tau_{W_2} \Rightarrow r_1W_1\sin\theta_1 = r_2W_w\sin\theta_2 \Rightarrow (a)(m_1g)\sin 90 = (b)(m_2g)\sin 90$$

$\Rightarrow am_1 = bm_2$ Answer is (B) [use the Right Hand Rule to find directions of torques.]

31) During this collision the momentum is conserved, therefore, because the initial momentum of the 2nd object is zero, the total momentum of the system initial is only the initial momentum of the moving object and is represented by the arrow given in the problem.

(A) The two vectors appear to cancel.
(B) The two vectors will be twice as long as the original one.
(C) The resultant vector will be in the correct direction, however, will not have enough magnitude.
(D) The resultant vector will be down and to the right.
The only answer that comes close to two vectors that add up to the original vector is (E).

32) Knowns: I, ω_i = 0, ω_f, Δt = T, $\sum\tau$ = ?

$$\sum\tau = I\alpha = I\frac{\Delta\omega}{\Delta t} = I\left(\frac{\omega_f - \omega_i}{T}\right) = I\left(\frac{\omega_f - 0}{T}\right) = \frac{I\omega_f}{T}$$

Answer is (E)

33) Linear form of the average Power equation with a constant force is $\overline{P} = F\cdot\overline{v}$ & the rotational form for a constant torque is $\overline{P} = \tau\overline{\omega}$. Therefore: $\overline{P} = \tau\overline{\omega} = \left(\frac{I\omega_f}{T}\right)\left(\frac{\omega_f + \omega_i}{2}\right) = \left(\frac{I\omega_f}{T}\right)\left(\frac{\omega_f + 0}{2}\right) = \frac{I\omega_f{}^2}{2T}$ Answer is (B)

34) "If limiting cases for large and small values of *t* are considered"… When know when *t* is very large that the object will have reached a terminal velocity, v_t, and the acceleration of the object will be zero:

$$t(\infty) \Rightarrow a = 0 = g - bv_t \Rightarrow bv_t = g \Rightarrow v_t = \frac{g}{b}$$

So let's look at each answer with t approaching infinity and see which one matches our solution:

(A) $v = \frac{g\left(1-e^{-bt}\right)}{b} = \frac{g\left(1-e^{-(b)(\infty)}\right)}{b} = \frac{g(1-0)}{b} = \frac{g}{b}$ Answer is (A)

(B) $v = \frac{\left(ge^{bt}\right)}{b} = \frac{\left(ge^{(b)(\infty)}\right)}{b} = \left(\frac{g(0)}{b}\right) = 0 \neq \frac{g}{b}$

(C) $v = gt - bt^2 = g(\infty) - b(\infty)^2 = ¿huh? \neq \frac{g}{b}$

(D) $v = \frac{(g+a)t}{b} = \frac{(g+a)(\infty)}{b} = \infty \neq \frac{g}{b}$

(E) $v = v_o + gt = v_o + g(\infty) \neq \frac{g}{b}$

35) Where did they find this ideal, massless spring? I want one too!

No friction. Ideal. No force applied. Conservation of Mechanical Energy!!

$$ME_i = ME_f \Rightarrow KE_{\max} = PE_{\max} \Rightarrow \frac{1}{2}m{v_{\max}}^2 = \frac{1}{2}k{x_{\max}}^2 \Rightarrow m{v_m}^2 = kA^2 \Rightarrow k = \frac{m{v_m}^2}{A^2}$$

Answer is (D)