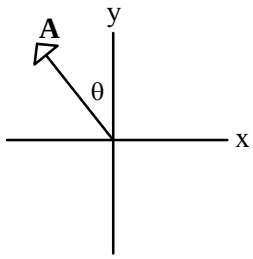
Name: _____

PHYSICS CONTEST EXAMINATION - 2011

Unless otherwise specified, please use g as the acceleration due to gravity at the surface of the earth.

Questions 1 and 2 pertain to two vectors, **B** having components B_x, and B_y, and **A** having magnitude A and making an angle of θ measured counter-clockwise with respect to the positive y-axis as shown. Let B be the magnitude of **B**. Note that $A \neq 0$, $B \neq 0$, and $A \neq B$.



1. The x-component of the vector **A – B** is given by

(A) $-B_x - A \sin\theta$ (B) $-B_x + A \cos\theta$ (C) $-A \cos\theta - B_x$ (D) $A \sin\theta - B_x$
(E) none of the previous answers

2. Which of the following values could not possibly represent the magnitude of **A** + **B**?

(A) A + B (B) A - B (C) B – A (D) zero
(E) none of the previous answers

Questions 3 and 4 pertain to a basketball that is thrown downward with an initial speed v_o at an angle θ_o below the horizontal. It strikes the floor a horizontal distance L from where it was thrown. Note a_x = acceleration along x, a_y = acceleration along y, v_x = velocity along x, v_y = velocity along y, and v = speed at any time.

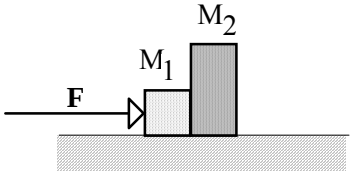
3. The magnitude of the ball's y component of velocity is given by

(A) $v_o \sin\theta_o + [v_o \cos\theta_o/(gL)]$ (B) $-v_o \sin\theta_o + [v_o \cos\theta_o/(gL)]$
(C) $v_o \sin\theta_o + [gL/(v_o \cos\theta_o)]$ (D) $-v_o \sin\theta_o - [gL/(v_o \cos\theta_o)]$
(E) none of the previous answers

4. The quantities that remain constant during the basketball's motion are given by

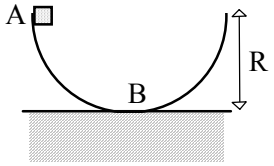
(A) a_x and v_y (B) v_x and a_y (C) v_y and a_y (D) v and a_y
(E) none of the previous answers

5. A constant force having magnitude F pushes on two masses as shown. Frictional forces are negligible. If $M_2 = 2M_1$, the magnitude of the normal force of contact between the two masses is given by



(A) (3/2)F (B) (2/3)F (C) 2F
(D) F/2 (E) none of the previous answers

6. A mass m is released from rest and slides on a hemispherical bowl as shown. When reaching point B, mass m has lost one-half of its original energy. The magnitude of the normal force of contact at point B is given by



(A) mg (B) 3mg (C) 3mg/2
(D) mg/2 (E) none of the previous answers

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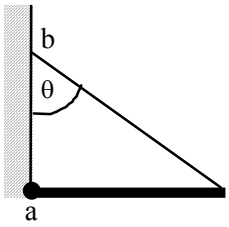
7. A nonuniform bar is held to a wall at point a and tied to the wall with a string at point b. The bar has length L and mass m. If sin θ = 0.8 and the tension in the string is (2/3)mg, the magnitude of the vertical component of force the wall exerts on the bar is given by

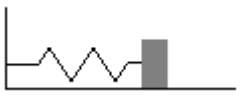


(A) (2/3)mg (B) (4/5)mg (C) (3/5)mg (D) (2/5)mg
(E) none of the previous answers

8. An object of mass m slides along a frictionless air track with speed v_o. It collides with an object of mass M having a velocity v_o in the opposite direction of mass m. After the collision, mass M has a speed $v_o/3$ in the same direction as its initial velocity. If M=2m, the kinetic energy of mass m after the collision is given by

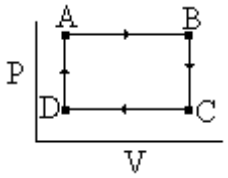
(A) $mv_o^2/18$ (B) $mv_o^2/6$ (C) $mv_o^2/4$ (D) $3mv_o^2/2$
(E) none of the previous answers

9. A mass m is attached to a spring having a natural length L and spring constant k. When the spring is in its relaxed position, the mass on the spring is struck with a hammer to give it a speed of v_o. The amplitude of oscillations is given by



(A) $(m/2k)^{(1/2)}v_o$ (B) $(m/k)^{(1/2)}v_o$ (C) $(k/2m)^{(1/2)}v_o$
(D) $(k/m)^{(1/2)}v_o$ (E) none of the previous answers

10. One mole of an ideal gas undergoes the thermodynamic cycle shown. Use $P_D = P_C = P_o$ and $P_A = P_B = 3P_o$, $V_C = V_B = 4.0\ V_o$ and $V_A = V_D = V_o$. The ratio of the absolute temperature at point A to that at point C is given by

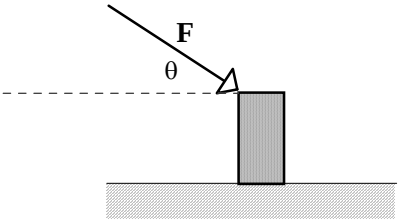


(A) 3/1 (B) 4/1 (C) 4/3
(D) 3/4 (E) none of the previous answers

11. The wave function for a particular wave is y(z,t) = 5.0 cos (7z – 28t), where all quantities are measured in the SI unit system. The speed of this wave is given by

(A) 4 m/s along y (B) 0.25 m/s along y (C) 4 m/s along z (D) 0.25 m/s along z
(E) none of the previous answers

12. A block having mass m is acted on by a force **F** as shown. The coefficient of static friction between the block and the floor is μ_s. The maximum angle that F can make with the floor and still move the block is given by



(A) $\tan^{-1}\mu_s$ (B) $\cos^{-1}\mu_s$ (C) $\sin^{-1}\mu_s$
(D) $\cot^{-1}\mu_s$ (E) none of the previous answers

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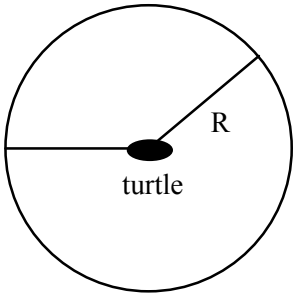
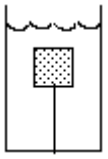
13. A turtle having mass M walks outward along the radius of a spinning disk as shown. The turtle is initially located at the center of the disk. The mass of the disk is M and its radius is R. Its moment of inertia is $(1/2)MR^2$. The initial angular velocity of the spinning disk is ω_i, and the direction of the rotation is counter-clockwise. The angular velocity of the disk-turtle system when the turtle reaches the edge of the disk is given by



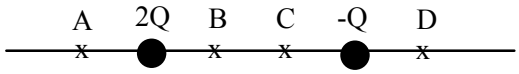
(A) $2\omega_i$ (B) $3\omega_i$ (C) $(1/3)\omega_i$ (D) $(1/2)\omega_i$
(E) none of the previous answers

14. A piece of wood is held under water by a string as shown. The mass of the wood is m and its density is (1/5) that of water. The tension in the string is



(A) 5mg (B) (1/5)mg (C) (1/2)mg (D) 2mg
(E) none of the previous answers

Questions 15 and 16 pertain to the set of charges shown.



15. The most likely place for the electric field to be zero is at point

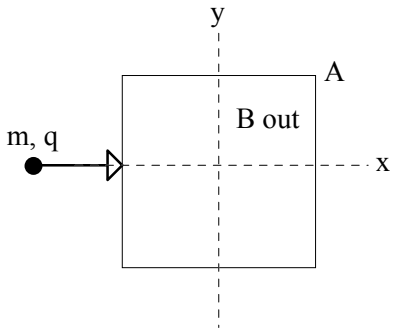
(A) A (B) B (C) C (D) D
(E) none of the previous answers

16. The most likely place for the electric potential to be maximum is at point

(A) A (B) B (C) C (D) D
(E) none of the previous answers

17. A magnetic field is along the +z direction (out of the page) as shown. The field exists over a square region of space 2L on a side. A charge q having mass m enters the magnetic field region with a velocity **v** along the x-axis. For reference, point A is (L, L). The speed v and charge q required for the charge to exit the field at point (0, L) are given by

(A) $v = (|q|BL/m)^{(1/2)}$ with $q<0$ (B) $v = (|q|BL/m)^{(1/2)}$ with $q>0$
(C) $v = |q|BL/m$ with $q<0$ (D) $v = |q|BL/m$ with $q>0$
(E) none of the previous answers



18. Unpolarized light transmits through two ideal linear polarizers, one with its axis of transmission at an angle θ with respect to the other one. If the intensity of the light incident on the first polarizer is I_o, the intensity of the light emerging from the second polarizer is given by

(A) $I_o \cos^2\theta$ (B) $(I_o/2) \cos^2\theta$ (C) $(I_o/3) \cos^2\theta$ (D) $(I_o/4) \cos^2\theta$
(E) none of the previous answers

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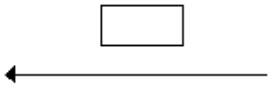
19. A real image having height h_i is formed a distance (4/3)f from a convex lens with focal length f. The object distance and size are given, respectively, by

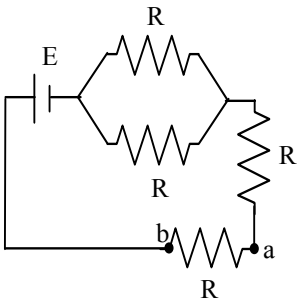
(A) 4f, $(3h_i)$ (B) 3f, $(2/5)h_i$ (C) f, $(3/2)h_i$ (D) 4f, $(1/3)h_i$
(E) none of the previous answers

20. A long straight wire is in the same plane as a rectangular conducting loop as shown. The straight wire carries an increasing current in the direction shown. The direction of the induced current I and induced magnetic field **B** are given, respectively, by



(A) I counter-clockwise, B out of page (B) I clockwise, B into page
(C) I counter-clockwise, B into page (D) I clockwise, B out of page
(E) none of the previous answers

Questions 21 and 22 pertain to the circuit shown to the right.



21. The current through the battery E is given by

(A) E/(2R) (B) E/(4R) (C) 4E/R (D) 4E/(5R)
(E) none of the previous answers

22.The power dissipated in the resistor between points a and b is given by

(A) $4E^2/(5R)$ (B) $4E^2/(25R)$ (C) 4E/(5R) (D) 4E/(25R)
(E) none of the previous answers

23. Light having a vacuum wavelength λ strikes a plate coated with a thin film of thickness t. Assume normal incidence. The index of refraction of the film n_f is greater than that of the plate n_p. The reflected light will be minimum when the relationship between λ, n_f, n_p, and t is given by

(A) $4t = \lambda/n_f$ (B) $2t = \lambda/n_p$ (C) $t = 2\lambda/n_p$ (D)$2t = \lambda/n_f$
(E) none of the previous answers

24. A slit of width w_o is illuminated by a laser beam whose width is much greater than w_o. The width and intensity of the central diffraction peak are b_o and I_o, respectively. If the slit width is decreased to $2w_o/3$, the width b and intensity I of the central diffraction peak (assuming far-field diffraction) are most likely to be given by

(A) $I < I_o$, $b < b_o$ (B) $I < I_o$, $b > b_o$ (C) $I > I_o$, $b < b_o$ (D) $I > I_o$, $b > b_o$
(E) none of the previous answers

25. An electron with mass m and charge q is accelerated from zero velocity by a constant electric field E through a distance d. Let h be Planck's constant. Its de Broglie wavelength after leaving the field is given by

(A) h/(qmEd) (B) h/(2qmEd) (C) (qmEd)/h (D) (2qmEd)/h
(E) none of the previous answers

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26. If a fossil bone contains $(1/16)^{th}$ as much carbon-14 as the bone of a living animal, the approximate age of the fossil is, in terms of the half-life $T_{1/2}$ of carbon-14, given by

(A) $T_{1/2}$ (B) $2T_{1/2}$ (C) $3T_{1/2}$ (D) $4T_{1/2}$
(E) none of the previous answers

27. Using the standard notation of n, l, m_l, and m_s as the four quantum numbers, the set of quantum numbers that is not possible is given by

(A) 4, 3, +2, +1/2 (B) 5, 4, -4, -1/2 (C) 2, 3, -2, -1/2 (D) 6, 2, -1, +1/2
(E) none of the previous answers

28. In the nuclear reaction, ${}^{236}_{92}U \rightarrow {}^{232}_{90}Th + X$, X is most likely to be given by

(A) α (B) p (C) β^+ (D) β^-
(E) none of the previous answers