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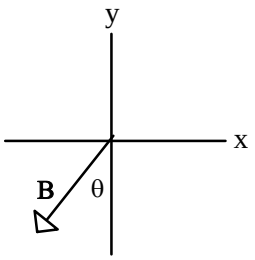
PHYSICS CONTEST EXAMINATION - 2013

Unless otherwise specified, please use g as the acceleration due to gravity at the surface of the earth. Please note that $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$ are unit vectors along the x-axis, y-axis, and z-axis, respectively.

Questions 1 and 2 pertain to two vectors **A** and **B** with $\mathbf{A} = A_x\hat{\mathbf{i}} + A_y\hat{\mathbf{j}}$, whereas **B** is shown in the diagram.



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

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

2. A vector that is antiparallel to **A** + **B** could have an x-component given by

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

Questions 3 and 4 pertain to a rock that is thrown from ground level with a speed of v_o m/s at an angle of θ with respect to the horizontal.

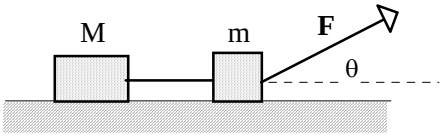
3. The distance the rock has traveled in the horizontal direction when it is at its highest point is given by

(A) $v_o^2 \cos\theta \sin\theta/g$ (B) $2 v_o^2 \sin\theta \cos\theta /g$ (C) $(v_o \sin\theta)^2/g$
(D) $(v_o \cos\theta)^2/g$ (E) none of the previous answers

4. The y-component of the rock's velocity when it has been in the air for ¼ of the total time it is in the air is given by

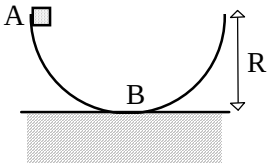
(A) $(v_o \sin\theta)/4$ (B) $(v_o \cos\theta)/4$ (C) $(v_o \sin\theta)/2$
(D) $(v_o \cos\theta)/2$ (E) none of the previous answers

5. Two masses, M and m, are pulled along a frictionless surface by a force **F** as shown. If M = 2m, the tension in the string connecting the two masses is given by



(A) $(2F \cos\theta)/3$ (B) $(3F \sin\theta)/2$ (C) $2F \cos\theta$
(D) $2F \sin\theta$ (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-fourth of its original energy. The magnitude of the normal force of contact at point B is given by



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

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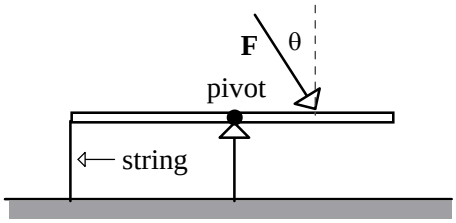
7. An object of mass M rests on a frictionless surface. It explodes into two pieces, one of mass M/4 and the other with a mass of 3M/4. After 3 seconds, the ratio of the distance mass M/4 travels to the distance mass 3M/4 travels is given by

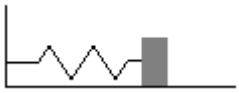
(A) 1/3 (B) 1/4 (C) 3/1 (D) 4/1
(E) none of the previous answers

8. A uniform thin rod can rotate about a pivot fixed at its center as shown. The left end of the rod is tied to a string attached to the floor. A force F is applied at an angle of θ and keeps the rod in equilibrium while horizontal. F is applied L/4 from the right end. The mass of the rod is m and its overall length is L. The tension in the string is given by



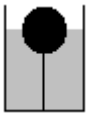
(A) (F/2) sin θ (B) (F/2) cos θ (C) (mg/2) cos θ (D) (mg/2) sin θ
(E) none of the previous answers

9. A mass m is attached to a spring having a natural length L and spring constant k. The spring is compressed to a length of L/2 and released at time t = 0. The speed of the mass when the spring has length 5L/4 is given by



(A) $(L/4)(3k/2m)^{1/2}$ (B) $(L/2)(3k/m)^{1/2}$ (C) $(L/4)(3k/m)^{1/2}$
(D) $(L/8)(3k/m)^{1/2}$ (E) none of the previous answers

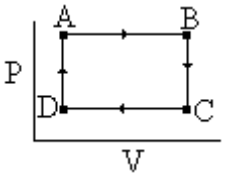
10. A hollow spherical shell has a mass m (including air inside) and radius R. It is held under water with half its volume submerged as shown. Note $V_{sphere} = (4/3)\,\pi\,R^3$ and let ρ_W be the density of water.



The tension T in the string is given by

(A) $mg - (4/3)g\pi R^3\rho_W$ (B) $mg + (2/3)g\pi R^3\rho_W$ (C) $mg - (2/3)g\pi R^3\rho_W$
(D) $-mg + (4/3)g\pi R^3\rho_W$ (E) none of the previous answers

11. 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 work done by the gas in going from point B to point D is given by



(A) $-3P_oV_o$ (B) $3P_oV_o$ (C) $-P_oV_o$ (D) P_oV_o
(E) none of the previous answers

12. Standing waves on a string are shown. The velocity of the wave is v_o.. The string has a length L. The amplitude is greatly exaggerated for clarity. The frequency of the wave is given by

(A) $(3v_o/2L)$ (B) $(2v_o/3L)$ (C) $(3v_o/2L)^{1/2}$ (D) $(2v_o/3L)^{1/2}$
(E) none of the previous answers

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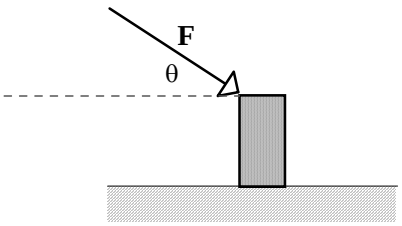
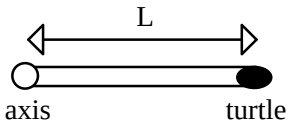
13. A block having mass m is acted on by a force **F** as shown. The coefficient of static friction between the block and the floor is μ_S. The maximum angle that F can make with the floor and still move the block is given by



(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

Questions 14 and 15 pertain to a turtle of mass m that walks from the edge of a bar having mass m and length L to a final position L/2 from the center as shown. The bar initially spins about an axis perpendicular to the page at angular velocity ω_o. The moment of inertia of the bar about its center of mass is $(1/12)mL^2$.



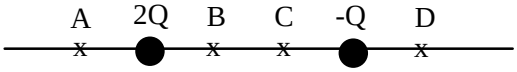
14. The angular velocity of the system when the turtle reaches its final position is given by

(A)$\omega_o/2$ (B) $2\omega_o$ (C) $(16/7)\omega_o$ (D) $(7/16)\omega_o$
(E) none of the previous answers

15. The final kinetic energy of the turtle is given by

(A) $32mL^2\omega_o^2/7$ (B) $32mL^2\omega_o^2/49$ (C) $7mL^2\omega_o^2/32$ (D) $49mL^2\omega_o^2/32$
(E) none of the previous answers

Questions 16 and 17 pertain to the set of charges shown.



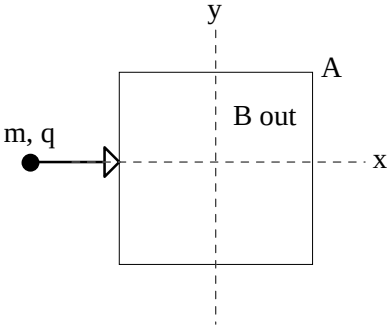
16. The most likely place for the magnitude of the electric field to be maximum is at point

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

17. The most likely place for the electric potential to be zero is at point

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

Questions 18 and 19 pertain to a charge q having mass m that enters a magnetic field region that exists in a square region of length 2L on a side as shown. The magnetic field points out of the page. The velocity **v** of the charge is along the x-axis. For reference, point A is (L, L).



18. The speed v and charge q required for the charge to exit the field at point (0, L) are given by

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

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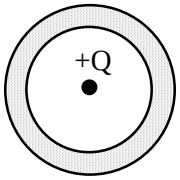
19. The work done by the magnetic field is given by

(A) zero (B) $-2\pi LqvB$ (C) $qvBL$ (D) $2\pi LqvB$
(E) none of the previous answers

Questions 20 and 21 pertain to a charge +Q that is placed inside a hollow, isolated conductor having a wall thickness t as shown. The radius of the inner wall of the conductor is R.



20. If the magnitude of the electric field at R/2 is E_o, the magnitude of the electric field at a distance (2/3)R is given by

(A) $(3/4)E_o$ (B) $(2/3)E_o$ (C) $(9/16)E_o$ (D) $(4/9)E_o$
(E) none of the previous answers

21. The surface charge density on the inner wall is given by

(A) –Q (B) +Q (C) $+Q/(4\pi R^2)$ (D) $-Q/(4\pi R^2)$
(E) none of the previous answers

22. 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) $(I_o/8) \cos^2\theta$ (D) $(I_o/4) \cos^2\theta$
(E) none of the previous answers

23. Quartz has an index of refraction n_q. If quartz is immersed in oil having an index of refraction n_o, where $n_o < n_q$, the critical angle for total internal reflection is given by

(A) n_o/n_q (B) n_q/n_o (C) $\arcsin (n_q/n_o)$ (D) $\arcsin (n_o/n_q)$
(E) none of the previous answers

24. An object having height h_o is placed a distance (5/2)f from a convex lens with focal length f. The height of the image is given by

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

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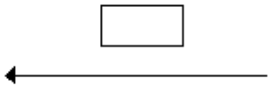
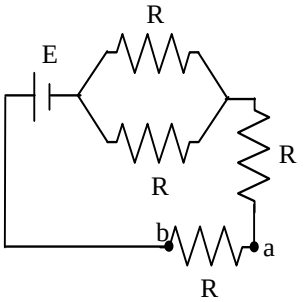
25. A long straight wire is in the same plane as a rectangular conducting loop as shown. The straight wire carries a decreasing current in the direction shown. The direction of the induced current I and induced magnetic field **B** are given, respectively, by



(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 26 and 27 pertain to the circuit shown to the right.



26. The effective resistance of the circuit is given by

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

27.The current through one of the parallel resistors is given by

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

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

29. 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