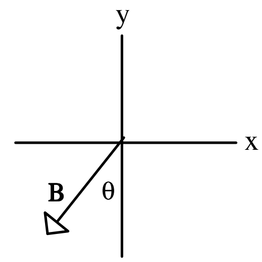
Name________________________________ School________________________________

PHYSICS CONTEST EXAMINATION – 2015

January 31, 2015

Please use g as the acceleration due to gravity at the surface of the earth unless otherwise noted. 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.



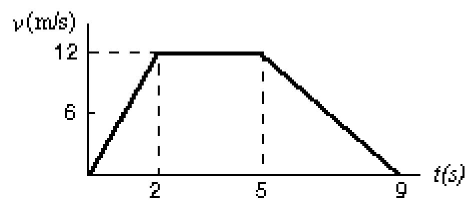
Questions 1 and 2 pertain to two vectors **A** and **B**. Vector **A** has magnitude A and is given by $\mathbf{A} = A_x\hat{\mathbf{i}} + A_y\hat{\mathbf{j}}$. Vector **B** has magnitude B and makes an angle of θ measured as shown. Note that $A \neq 0$, $B \neq 0$, and $A \neq B$.

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. If vector **A** were perpendicular to vector **B**, vector **A** could be represented by

(A) $A\cos\theta\,\hat{\mathbf{i}} - A\sin\theta\,\hat{\mathbf{j}}$ (B) $A\cos\theta\,\hat{\mathbf{i}} + A\sin\theta\,\hat{\mathbf{j}}$ (C) $-A\cos\theta\,\hat{\mathbf{i}} - A\sin\theta\,\hat{\mathbf{j}}$
(D) any vector with **A** = **-B** (E) none of the previous answers



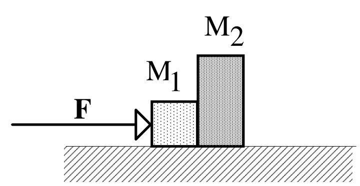
Questions 3 and 4 pertain to the graph of the speed of a particle along the positive x axis versus time t shown to the right. Note that v is measured in meters and t is measured in seconds.

3. The particle's acceleration at t = 1.5 s is given by

(A) 6.0 m/s^2 $\hat{\mathbf{i}}$ (B) 2.0 m/s^2 $\hat{\mathbf{i}}$ (C) -2.0 m/s^2 $\hat{\mathbf{i}}$ (D) -6.0 m/s^2 $\hat{\mathbf{i}}$
(E) none of the previous answers

4. The displacement of the particle from 0 s to 5 s is given by

(A) 60 m $\hat{\mathbf{i}}$ (B) 24 m $\hat{\mathbf{i}}$ (C) 48 m $\hat{\mathbf{i}}$ (D) 36 m $\hat{\mathbf{i}}$
(E) none of the previous answers



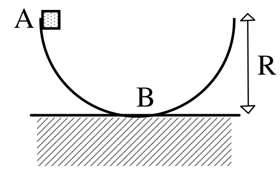
5. A constant force having magnitude F pushes on two masses as shown. Frictional forces are negligible. If $M_2 = 2M_1$, the magnitude of the normal force of contact between the two masses is given by

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

6. A golf ball leaves a tee at ground level with a speed v_o at an angle θ_o with respect to level ground. The target (hole) is a horizontal distance d from the tee. Assume that θ_o cannot change. The value of v_o for the golf ball to travel the distance d to the hole is given by

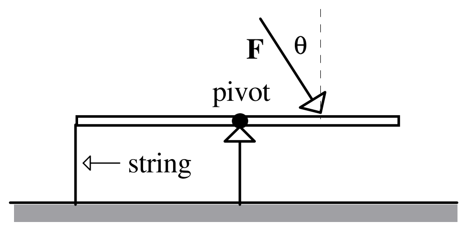
(A) $\{gd/[\sin(\theta_o)\cos(\theta_o)]\}^{(1/2)}$ (B) $\{gd/[2\cos(\theta_o)\sin(\theta_o)]\}^{(1/2)}$ (C) $gd/[\sin(\theta_o)\cos(\theta_o)]$
(D) $gd/[2\sin(\theta_o)\cos(\theta_o)]$ (E) none of the previous answers

7. A mass m slides on a frictionless hemispherical bowl as shown. The block is given a downward speed $v_o=(gR)^{1/2}$ at point A. The magnitude of the normal force of contact between the mass and the bowl at the bottom (point B) is given by



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

8. A uniform, thin rod having length L 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 having magnitude 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 magnitude of the upward force the pivot exerts on the rod is given by

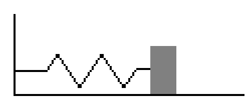


(A) $F\sin\theta - mg$ (B) $mg + F\sin\theta$ (C) $mg + F\cos\theta$ (D) $mg - F\cos\theta$
(E) none of the previous answers

9. An object of mass m slides along a frictionless table with speed v. It collides with a stationary object of mass M. After the collision, mass m has a speed $v/2$ in the same direction as its initial velocity. If $M=m/2$, the kinetic energy of mass M after the collision is given by

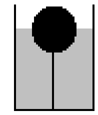
(A) $mv^2/16$ (B) $mv^2/8$ (C) $mv^2/4$ (D) $mv^2/2$
(E) none of the previous answers

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

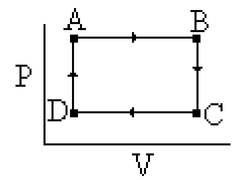
11. A hollow spherical shell has a mass *m* (including air inside) and radius *R*. It is held under water with half its volume submerged as shown. Note $V_{sphere} = (4/3)\ \pi\ R^3$ and let ρ_w be the density of water.



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) $-mg + (2/3)\ g\pi R^3 \rho_w$ (E) none of the previous answers

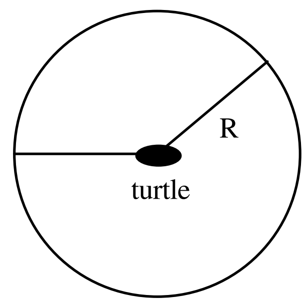
12. 0.5 mole of an ideal gas undergoes the thermodynamic cycle shown. Use $P_D = P_C = P_o$ and $P_A = P_B = 3P_o$, $V_C = V_B = 4.0\ V_o$ and $V_A = V_D = V_o$.



The work done in one cycle is given by

(A) $3\ P_oV_o$ (B) $4.5\ P_oV_o$ (C) $6\ P_oV_o$ (D) $9P_oV_o$
(E) none of the previous answers

Questions 13 and 14 pertain to a turtle having mass *M* that walks outward along the radius of a spinning disk as shown. The turtle is initially located at the center of the disk and is treated as a point mass. 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_1, and the direction of the rotation is counter-clockwise.



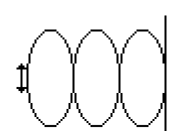
13. The angular velocity of the disk-turtle system when the turtle reaches the edge of the disk is given by

(A) $2\omega_1$ (B) $3\omega_1$ (C) $(1/3)\ \omega_1$ (D) $(1/2)\ \omega_1$
(E) none of the previous answers

14. The change in the kinetic energy of the system is given by

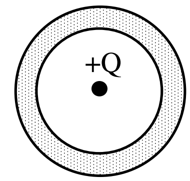
(A) $(1/6)MR^2\omega_1^2$ (B) $-(1/6)\ MR^2\omega_1^2$ (C) $(1/4)MR^2\omega_1^2$ (D) $-(1/4)MR^2\omega_1^2$
(E) none of the previous answers

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



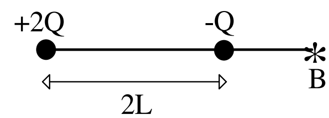
(A) $(1/3)\ fL$ (B) $(2/3)\ fL$ (C) $3\ fL$ (D) $(3/2)\ fL$
(E) none of the previous answers

16. A charge $+Q$ 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. If the magnitude of the electric field at $R/2$ is E_o, the magnitude of the electric at a distance $(3/2)R$ [with $(3/2)R > (R+t)$] is given by



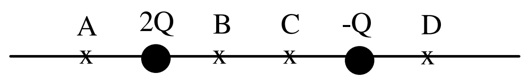
(A) (1/3) E_o (B) (1/9) E_o (C) 9 E_o (D) zero
(E) none of the previous answers

17. Two point charges, $+2Q$ and $-Q$, are a distance $2L$ from one another as shown. The electric potential at point B at distance L from charge $-Q$ is given by V_o. The electric potential midway between the two charges is given by



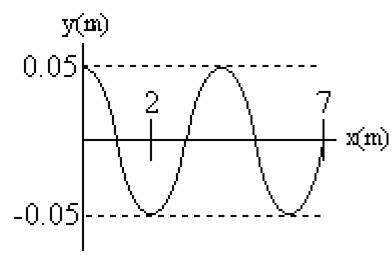
(A) $-2\ V_o$ (B) $2\ V_o$ (C) $3\ V_o$ (D) $-3\ V_o$
(E) none of the previous answers

18. For the charges shown, 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

Questions 19 and 20 refer to a wave whose wave function is shown. The wave speed is 24 m/s along the -x-axis.



19. The frequency of the wave is given by

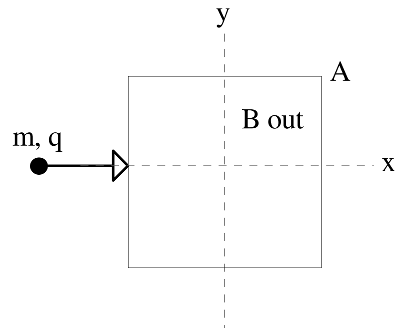
(A) 6.0 Hz (B) 24 Hz (C) 2.0 Hz (D) 0.05 Hz

(E) none of the previous answers

20. The general form of the wave function that could represent this wave is given by

(A) $A \cos (kx - \omega t)$ (B) $A \sin (kx - \omega t)$ (C) $A \cos (kx + \omega t)$ (D) $A \sin (kx + \omega t)$
(E) none of the previous answers

Questions 21 and 22 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).



21. 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

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

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

23. 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

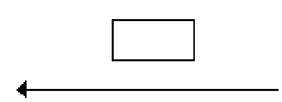
24. Light that has a wavelength λ in a vacuum travels in a material whose index of refraction is n. Let c be the speed of light in a vacuum. Its wavelength in the material is given by

(A) $n\lambda$ (B) λ/n (C) $(n-1)\lambda$ (D) $\lambda/(n-1)$
(E) none of the previous answers

25. 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

26. 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

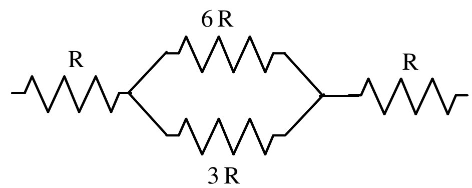


(A) I counter-clockwise, **B** out of page (B) I clockwise, **B** into page
(C) I counter-clockwise, **B** into page (D) I clockwise, **B** out of page
(E) none of the previous statements

27. Diamond has an index of refraction n_d. If a diamond is immersed in oil having an index of refraction n_o, where $n_o < n_d$, the critical angle for total internal reflection is given by

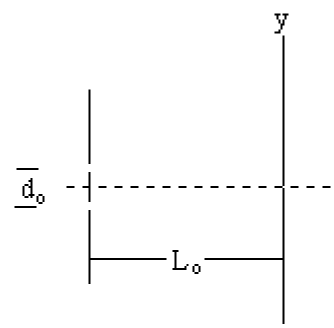
(A) n_o/n_d (B) n_d/n_o (C) arcsin (n_d/n_o) (D) arcsin (n_o/n_d)
(E) none of the previous answers

28. The equivalent resistance of the resistor combination shown is given by



(A) $11R$ (B) $4R$ (C) $2R$ (D) $3R$
(E) none of the previous answers

Questions 29 and 30 pertain to a Young's double-slit experiment in which the slit spacing is d_o, the light wavelength is λ_o, and the distance from the slits to the observation screen is L_o. The spacing of the bright fringes on the screen is Δy_o. You may assume that tan θ = sin θ.



29. If the wavelength is changed to $2\lambda_o$ (with all other variables unchanged), the spacing between the bright interference fringes is given by

(A) becomes $\Delta y_o/4$ (B) becomes $\Delta y_o/2$ (C) becomes 2 Δy_o
(D) becomes 4 Δy_o (E) none of the previous answers

30. If the slit spacing is changed to $d_o/2$ (with all other variables unchanged), the spacing between the dark interference fringes is given by

(A) becomes $\Delta y_o/4$ (B) becomes $\Delta y_o/2$ (C) becomes 2 Δy_o (D) becomes 4 Δy_o
(E) none of the previous answers