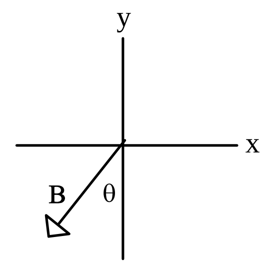
PHYSICS CONTEST EXAMINATION – 2012

NAME:____

SCHOOL: ____

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.



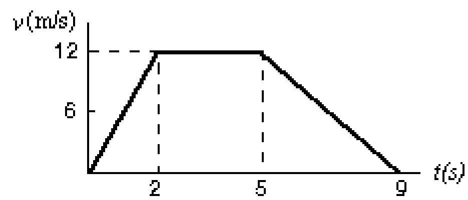
1. The y-component of **A – B** is given by

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

2. For **A** to be perpendicular to **B**, the ratio of A_y to A_x should be

(A) $-\tan\theta$ (B) $-\sin\theta$ (C) $-\cos\theta$ (D) $-\cot\theta$
(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 (D) 6.0 m/s^2
(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

Questions 5 and 6 pertain to an arrow that is fired from a height of H meters above level ground with a speed v_o m/s and angle of elevation θ_o.

5. The time required for the arrow to reach its highest point is given by

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

6. The x-component of the arrow's velocity when it strikes the ground is given by

(A) $v_o \sin \theta_o$ (B) $2\, v_o \sin \theta_o$ (C) $2v_o \cos \theta_o$ (D) $v_o \cos \theta_o$
(E) none of the previous answers

Questions 7 and 8 pertain to a block of mass *m* that rests on the floor of an elevator.

7. The force that the block exerts on the elevator floor when the elevator moves upward with a constant velocity $\mathbf{v} = 4\, \hat{\mathbf{j}}$ m/s is

(A) $-\, mg\, \hat{\mathbf{j}}$ (B) $5\, mg\, \hat{\mathbf{j}}$ (C) $-5\, mg\, \hat{\mathbf{j}}$ (D) $mg\, \hat{\mathbf{j}}$
(E) none of the previous answers

8. If the elevator floor exerts a force of $2\, mg\, \hat{\mathbf{j}}$ on the block, the acceleration of the elevator is

(A) $-g\, \hat{\mathbf{j}}$ (B) $2\, g\, \hat{\mathbf{j}}$ (C) $g\, \hat{\mathbf{j}}$ (D) $-2\, g\, \hat{\mathbf{j}}$
(E) none of the previous answers

Questions 9 and 10 pertain to a ball of mass *m* and velocity $\mathbf{v} = -v_{ox}\, \hat{\mathbf{i}} + v_{oy}\, \hat{\mathbf{j}}$ that collides with a fixed wall. After the collision, the ball's velocity is $\mathbf{v} = v_{ox}\, \hat{\mathbf{i}} + 2v_{oy}\, \hat{\mathbf{j}}$.

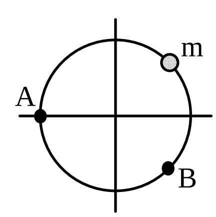
9. If the ball is in contact with the wall for a time Δt, the *y*-component of the force the wall exerts on the ball is

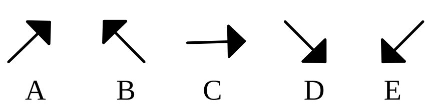
(A) $(-mv_{oy})/\Delta t$ (B) $(-2\, mv_{oy})/\Delta t$ (C) $(2\, mv_{oy})/\Delta t$ (D) $(mv_{oy})/\Delta t$
(E) none of the previous answers

10. The change in the ball's kinetic energy is

(A) $-mv_{oy}^2$ (B) $(3/2)mv_{oy}^2$ (C) $-(3/2)mv_{oy}^2$ (D) mv_{oy}^2
(E) none of the previous answers

Questions 11 and 12 pertain to a stone that is traveling in a horizontal circle as shown. The stone is not moving at a constant speed, but it has a tangential acceleration that increases its speed as it moves in the clockwise direction. Questions 11 and 12 refer only to acceleration in the horizontal plane. Select answers from the following vectors.





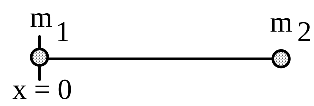
11. The vector that could represent the particle's acceleration at point A is

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

12. If the string holding the stone were cut when the stone is at point B, the direction that the stone would travel could be represented by vector

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

Questions 13 and 14 refer to two masses m_1 = 2.0 kg and m_2 = 3.0 kg that are initially held apart a distance of 1000 m by a massless rod. The rod is removed and the masses approach one another because of gravitational attraction.



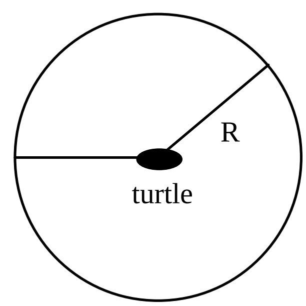
13. The center of mass is located at

(A) 0 m (B) 200 m (C) 400 m (D) 600 m
(E) none of the previous answers

14. If the velocity of m_1 is observed to be 0.06 **i** m/s, the velocity of m_2 is

(A) 0.06 $\hat{\mathbf{i}}$ m/s (B) –0.04 $\hat{\mathbf{i}}$ m/s (C) 0.04 $\hat{\mathbf{i}}$ m/s (D) –0.06 $\hat{\mathbf{i}}$ m/s
(E) none of the previous answers

Questions 15 and 16 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. 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.



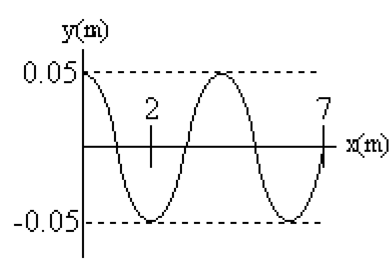
15. The angular velocity of the disk-turtle system when the turtle reaches the edge of the disk is given by

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

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

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

Questions 17 and 18 refer to a periodic wave on a string where the wave speed is 24 m/s along the -x-axis. The diagram shows the displacements of the particles as a function of position at t = 0, *i. e.*, the waveform.



17. The frequency of the wave is

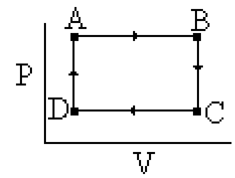
(A) 6.0 Hz (B) 24 Hz (C) 2.0 Hz (D) 0.05 Hz

(E) none of the previous answers

18. The general form of the wave function that could represent this wave is

(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 19 and 20 pertain to 0.5 mole of an ideal gas undergoing 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 $V_A = V_D = V_o$.



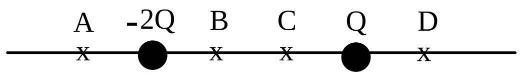
19. The work done in one cycle is given by

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

20. The ratio of the temperature at A to the temperature at C is given by

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

Questions 21 and 22 pertain to two point charges, $-2Q$ and Q that lie along the x-axis and are a distance $2L$ from one another as shown. Points A, B, C, and D label 4 different points of interest.



21. The point where the electric potential could be zero is given by

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

22. The point where the electric field could be zero is given by

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

Questions 23 and 24 pertain to a charge Q uniformly distributed over a spherical volume of radius R. Let r designate the distance from the center of the sphere to an arbitrary point.

23. When $r < R$, the electric field has a dependence on r given by

(A) r (B) r^2 (C) $(1/r)$ (D) $(1/r^2)$
(E) none of the previous answers

24. When $r > R$, the electric field has a dependence on r given by

(A) r (B) r^2 (C) $(1/r)$ (D) $(1/r^2)$
(E) none of the previous answers

Questions 25 and 26 refer to a charge Q having velocity **v** that enters a region where the magnetic field is $\mathbf{B} = B_o\hat{\mathbf{k}}$.

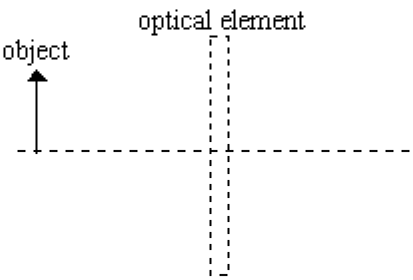
25. For the charge to move in a straight line, its initial velocity **v** should be given by

(A) $\mathbf{v} = v_z\hat{\mathbf{k}}$ (B) $\mathbf{v} = v_x\hat{\mathbf{i}}$ (C) $\mathbf{v} = v_y\hat{\mathbf{j}}$ (D) $\mathbf{v} = v_x\hat{\mathbf{i}} + v_y\hat{\mathbf{j}}$
(E) none of the previous answers

26. For the charge to move in a helical path, its initial velocity **v** could be given by

(A) $\mathbf{v} = v_z\hat{\mathbf{k}}$ (B) $\mathbf{v} = v_x\hat{\mathbf{i}}$ (C) $\mathbf{v} = v_y\hat{\mathbf{j}}$ (D) $\mathbf{v} = v_x\hat{\mathbf{i}} + v_z\hat{\mathbf{k}}$
(E) none of the previous answers

Questions 27 and 28 pertain to an object placed to the left of an optical element as shown.



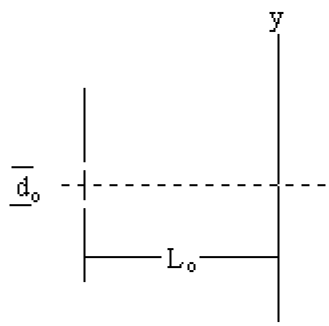
27. The element that could produce a virtual upright image of magnification one to the right of the element is

(A) plane mirror (B) concave mirror
(C) convex mirror (D) converging lens
(E) diverging lens

28. The element that could produce a real enlarged image to the right of the element is

(A) plane mirror (B) concave mirror (C) convex mirror (D) converging lens
(E) diverging lens

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 $\tan\theta = \sin\theta$.



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

(A) becomes $\Delta y_o/4$ (B) becomes $\Delta y_o/2$ (C) becomes $2\,\Delta y_o$
(D) becomes $4\,\Delta y_o$ (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

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

Questions 31 and 32 pertain to a slit of width w_o illuminated by a laser beam having wavelength λ_o whose beam width is much greater than w_o. The width and intensity of the central diffraction peak are b_o and I_o, respectively.

31. If the slit width is increased to $3w_o/2$ (with all other variables unchanged), 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

32. If the wavelength is decreased to $4\,\lambda_o/5$ (with all other variables unchanged), 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