Physics Exam
2009 University of Houston Math Contest

Name: _____

School: _____

Please read the questions carefully and give a clear indication of your answer on each question.

There is no penalty for guessing.

Judges will use written comments and/or calculations to settle ties.
Good luck.

PHYSICS CONTEST EXAMINATION - 2009

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

Circle your answers.

1. Vector **A** has components A_x, and A_y. Vector **B** has magnitude B and makes an angle of θ measured clockwise with respect to the negative y axis as shown.
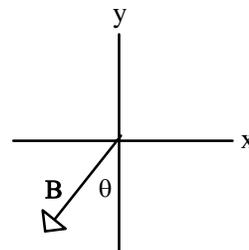
The y-component of the vector **A** + **B** is given by

(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 tennis ball is thrown from ground level with a speed of v_o at an angle of θ_o with respect to the horizontal. Neglecting air resistance, the time at which the x-component of the ball's velocity is equal to its y-component of velocity is given by

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

3. Three blocks, all having mass m, are arranged as shown. The only friction in the system is between the two blocks on the table. The minimum coefficient of friction for the top block not to slide off the bottom block is given by
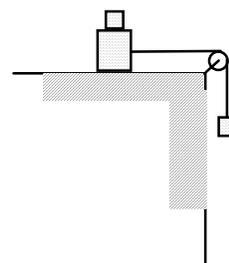
(A) 1/2   (B) 1/3   (C) 1/4   (D) 1/5
(E) none of the previous answers

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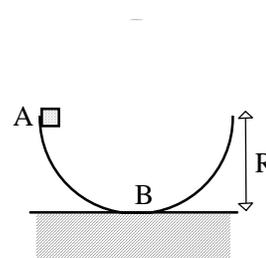
(A) mg   (B) 2mg   (C) 3mg   (D) 4mg
(E) none of the previous answers

5. 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
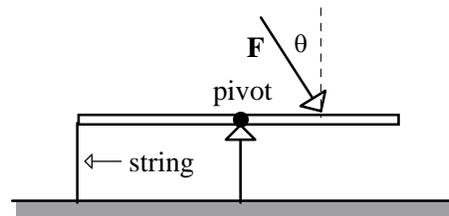
(A) (F/2) sin θ　　　　(B) (mg/4) sin θ　　　　(C) (F/2) cos θ　　　　(D) (mg/4) cos θ
(E) none of the previous answers

6. An object of mass m slides along a frictionless table with speed v_0. It collides with a stationary object of mass M. After the collision, mass m has a speed $v_0/2$ in the same direction as its initial velocity. If M=2m, the kinetic energy of mass M after the collision is given by

(A) $mv_0^2/16$　　　　(B) $mv_0^2/8$　　　　(C) $mv_0^2/4$　　　　(D) $mv_0^2/2$
(E) none of the previous answers

7. A mass m is attached to a spring having a natural length L and spring constant k. The spring is stretched to a length of 1.5 L and released at time t = 0. Assume the mass slides on a surface without friction. The speed of the mass when the spring again has length L is given by

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

8. One mole of an ideal gas undergoes the thermodynamic cycle shown. Use $P_D = P_C = P_0$ and $P_A = P_B = 3P_0$, $V_C = V_B = 4.0 V_0$ and $V_A = V_D = V_0$. If the temperature at A is T_0, the temperature at C is given by
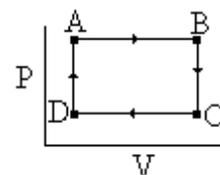
(A) $(3/4)T_0$　　　　(B) $(4/3)T_0$　　　　(C) $(T_0/3)$　　　　(D) $(3T_0)$
(E) none of the previous answers

9. Standing waves on a string are shown. The speed of the waves is v_0. The string has a length L. The amplitude is greatly exaggerated for clarity. The frequency of the wave for the case shown is given by
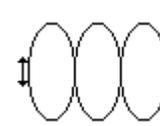
(A) v_0/L　　　　(B) $3v_0/4L$　　　　(C) $v_0/2L$　　　　(D) $3v_0/2L$
(E) none of the previous answers

10. A block having mass m is pulled along a floor as shown. The tension in the string is T, and the coefficient of kinetic friction between the block and the floor is μ_k. The block moves a distance L with constant velocity **v**. The work done by the force of friction is given by
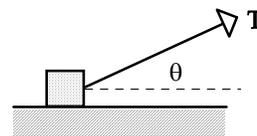
(A) $\mu_k mgL$ (B) zero   (C) $-TL \cos \theta$ (D) mgL sin θ
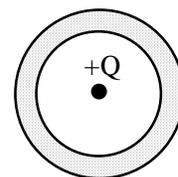(E) none of the previous answers

11. A skater spins with angular velocity ω_o and moment of inertia I_o. Initially, he has kinetic energy K_o and angular momentum L_o. He stretches his arms in to increase his moment of inertia to $1.5I_o$. His new angular momentum is given by

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

12. Water flows along a pipe of diameter d_o with a speed v_o when it encounters a part of the pipe with a diameter $(2/3)d_o$. The speed of the water in the narrow portion of the pipe is given by

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

13. 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) $9E_o$ (D) zero
(E) none of the previous answers

14. Two point charges, +2Q and –Q, are a distance 2L from one another as shown. The electric potential midway between the two charges is V_o. If point B is a distance L from charge –Q, the electric potential at point B is given by
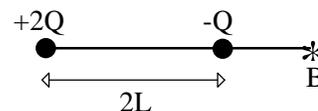
(A) $-V_o/2$ (B) $V_o/2$ (C) $V_o/3$ (D) $-V_o/3$
(E) none of the previous answers

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15. A magnetic field is along the +x direction as shown. A charge q having mass m enters the magnetic field region with a velocity **v** that makes an angle θ with respect to **B**. The radius of the helical path made by the charge is given by

(A) (qB/mv sin θ)   (B) (mv cos θ)/qB
(C) (mv sin θ)/qB   (D) (qB/mv cos θ)
(E) none of the previous answers
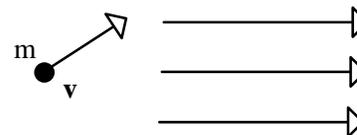
16. Linearly polarized light whose intensity is I_o passes through a polarizer whose transmission axis makes an angle θ with respect to the electric field of the light. If the intensity of the wave after passing through the linear polarizer is fI_o, where f is between zero and 1, the angle θ is

(A) arccos (f)   (B) arccos (1/f)   (C) arccos (f)$^{1/2}$ (D) arccos (1/f)$^{1/2}$
(E) none of the previous answers

17. An object having height h_o is placed a distance (3/2)f from a convex lens with focal length f. The image height and orientation are given by

(A) h_o, inverted   (B) $2h_o$, inverted   (C) $3h_o$, inverted   (D) (1/2)h_o, inverted
(E) none of the previous answers

18. 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

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

(A) 10R   (B) 3R/2   (C)2R
(D) 3R   (E) none of the previous answers

4
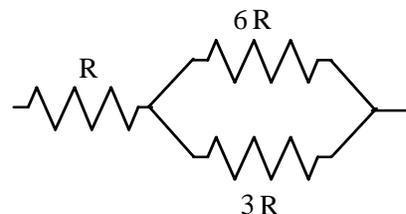
20. Light having a vacuum wavelength λ strikes a plate coated with a thin film of thickness t. The index of refraction of the film n_f is less than that of the plate n_p. The reflected light will be minimum when the relationship between λ, n_f, n_p, and t is given by

(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

21. 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 reduced to $w_o/2$, the width b and intensity I of the central diffraction peak are most likely to be given by

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

22. An electron with mass m and charge q is accelerated through a potential difference V. Let h be Planck's constant. Its de Broglie wavelength is given by

(A) $h/(qmV)^{1/2}$ (B) $h/(2qmV)^{1/2}$ (C) $(qmV)^{1/2}/h$ (D) $(2qmV)^{1/2}/h$
(E) none of the previous answers

23. If a fossil bone contains 0.25 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 is given by

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

24. Using the standard notation of n, l, m_l, and m_s as the four quantum numbers, which of the following set of quantum numbers is not possible? Each set is ordered as above.

(A) 4, 3, +2, +1/2   (B) 5, 4, -4, -1/2   (C) 3, 1, 0, -1/2   (D) 6, 2, -1, +1/2
(E) 2, 3, -2, +1/2

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

(A) α (B) p   (C) β^+ (D) β^- (E) n