Name_____ School_____

PHYSICS CONTEST EXAMINATION – 2016

Please use g as the acceleration due to gravity at the surface of the earth unless otherwise noted. G is the universal gravitational constant. 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 a car having mass M traveling around a flat, level track in a circle of radius R at constant speed v. The coefficient of static friction between the car and the track is μ_s, and the coefficient of kinetic friction is μ_k.

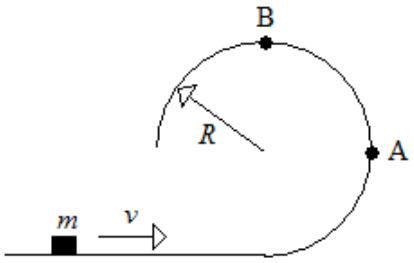
1. Which of the following statements concerning the car is true?

   (A) The car has a constant acceleration.
   (B) The car has a constant velocity.
   (C) The magnitude of the car's displacement after one revolution is $2\pi R$.
   (D) The car's acceleration vector is always tangent to the circle.
   (E) None of the previous answers is true.

2. The maximum speed v the car can have without slipping is given by

   (A) $\mu_s mg$ (B) $(\mu_s gR)^{1/2}$ (C) $(\mu_s gR)$ (D) $1/(\mu_s gR)^{1/2}$
   (E) none of the previous answers

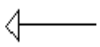
Questions 3 and 4 pertain to mass m that moves around the circular track having radius R shown.



3. The minimum speed v for mass m to reach point B without losing contact with the track is given by

   (A) $(gR)^{1/2}$ (B) $(2gR)^{1/2}$ (C) $(4gR)^{1/2}$
   (D) $(5gR)^{1/2}$ (E) none of the previous answers

4. The vector that best represents mass m's acceleration at point A is given by

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

(E) none of the previous answers

5. A satellite having mass m moves in a circular orbit of radius r around the earth (mass M). The speed of the satellite is given by

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

Questions 6 and 7 pertain to a person standing on a boat in water. Assume that no friction exists between the boat and the water. The mass of the person is two times the mass of the boat, and the boat has a length L.

6. If the person walks from one end of the boat to the other, which of the following statements is true?

   (A) The location of the center of mass of the boat does not change.
   (B) The location of the center of mass of the boat plus the person does not change.
   (C) The velocity of the center of mass of the boat plus the person is constant.
   (D) Both statements (A) and (C) are true.
   (E) Both statements (B) and (C) are true.

7. If the person jumps off the boat with velocity $v_o\hat{\mathbf{i}}$, the velocity of the boat is given by

   (A) $2v_o\hat{\mathbf{i}}$ (B) $(1/2)v_o\hat{\mathbf{i}}$ (C) $-2v_o\hat{\mathbf{i}}$ (D) $-(1/2)v_o\hat{\mathbf{i}}$
   (E) none of the previous answers

Questions 8 and 9 pertain to an object having mass m and speed v_o. It explodes into two pieces, each one having mass $m/2$. One of the pieces is at rest after the explosion.

8. The speed of the moving mass after the explosion is given by

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

9. The energy released as a result of the explosion is given by

   (A) zero (B) $2mv_o^2$ (C) $(1/2)mv_o^2$ (D) $(1/4)mv_o^2$
   (E) none of the previous answers

10. An object having mass m is dropped from a height h and undergoes an elastic collision with the floor. If it is in contact with the floor for Δt seconds, the magnitude of the force exerted on the object by the floor is given by

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

Questions 11 and 12 pertain to a long, thin rod having length $2L$ that rotates with a constant angular acceleration α about an axis that is perpendicular to the rod and passes through its center.

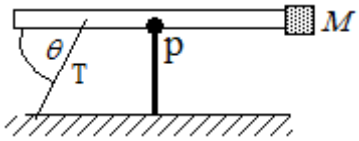
11. The ratio of the angular speed (at any time) of a point on the end of the rod to that of a point a distance L/2 from the center of the rod is given by

    (A) 2:1 (B) 4:1 (C) 1:2 (D) 1:4
    (E) none of the previous answers

12. The ratio of the centripetal acceleration of a point on the end of the rod to that of a point a distance $L/2$ from the end of the rod is given by

    (A) 2:1 (B) 4:1 (C) 1:2 (D) 1:4
    (E) none of the previous answers

13. The figure shows a uniform, thin rod having length $2L$ and negligible mass pivoted at its center p. Attached to the end of the rod is a piece of clay having mass M. The rod is kept in equilibrium by a string attached to the middle of the other end of the rod and making an angle θ as shown. The tension in the string is given by



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

Questions 14 and 15 pertain to a solid sphere of radius R and mass M that rotates about a diameter with angular speed ω_o. Under the action of internal forces, the sphere collapses to a final radius of $R/2$.

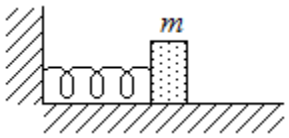
14. The final angular speed of the sphere is given by

    (A) $2\ \omega_o$ (B) $4\ \omega_o$ (C) $\omega_o/2$ (D) $\omega_o/4$
    (E) none of the previous answers

15. The ratio of the final kinetic energy of the sphere to its initial kinetic energy is given by

    (A) 2:1 (B) 1:2 (C) 4:1 (D) 1:4
    (E) none of the previous answers

Questions 16 and 17 pertain to a mass m resting on a table without friction. It is attached to a spring with spring constant k and length L as shown. Initially, the spring is neither stretched nor compressed.



16. If mass m is given an initial speed v that causes the spring to compress, the amplitude of the oscillations is given by

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

17. If the mass and spring were hung vertically, the total length of the spring would be

(A) $L - (mg/k)$ (B) $(mg/k) + L$ (C) $(k/mg) + L$ (D) $L - (k/mg)$
(E) none of the previous answers

Questions 18 and 19 pertain to a rope under tension T_o stretched between two posts. The speed of a wave pulse on the rope is v_o.

18. If the tension is increased to $9T_o$ (with all other quantities remaining constant), the speed of a wave pulse changes to

(A) $9\,v_o$ (B) $3\,v_o$ (C) $(1/3)\,v_o$ (D) $(1/9)\,v_o$
(E) none of the previous answers

19. If identical wave pulses are sent along the rope from opposite ends,

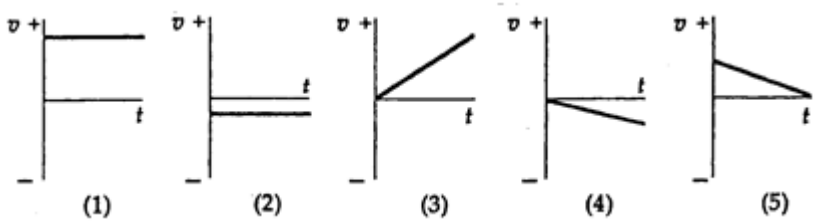
(A) the two pulses will reflect off each other.
(B) the two pulses will diffract off each other.
(C) the two pulses will pass through each other and produce beats.
(D) the two pulses will interfere to produce a standing wave.
(E) none of the previous answers is correct.

20. A sound source and a detector are at rest when the detector measures a frequency of f_o. For the detector to measure the highest frequency,

(A) the detector and the sound source should remain at rest.
(B) the detector and the sound source should recede from one another.
(C) the detector and the sound source should approach one another.
(D) the detector should remain at rest while the sound source approaches it.
(E) none of the previous answers is correct.

21. The displacement of an object during any time interval is always _____ the distance it travels during that same time interval.
    (A) greater than or equal to
    (B) less than or equal to
    (C) equal to
    (D) greater than
    (E) much greater than

22. Which of the *v* vs. *t* graphs best depicts the motion of a particle with positive velocity and negative acceleration?
    (A) 1
    (B) 2
    (C) 3
    (D) 4
    (E) 5



23. A projectile is launched at an angle of 60^0 with a velocity of 200 m/s. If air resistance is negligible, what is the magnitude of the horizontal velocity of the projectile when it reaches maximum altitude?
    (A) 0 m/s
    (B) 100 m/s
    (C) 125 m/s
    (D) 200 m/s
    (E) 250 m/s

24. A soccer ball is kicked horizontally off of a vertical cliff with speed *v* and lands at a distance *d* from the base of the cliff. How far from the base of the cliff would the soccer ball have landed if it was kicked horizontally with a speed of 4*v*?
    (A) d
    (B) $\sqrt{2d}$
    (C) $2d$
    (D) $4d$
    (E) The height of the cliff must be given

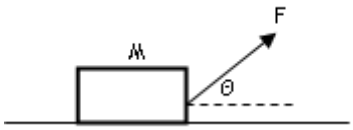
25. A cannon launches a cannon ball straight upward with an initial speed of v_0. If a second cannon launches a ball upward with a speed of $2v_0$ instead, how much higher will it travel than the first shot?
    (A) One quarter as high
    (B) Half as high
    (C) The same height
    (D) Twice as high
    (E) Four times as high

26. A box, tied to a loose string, is sliding across a smooth, frozen lake at a constant 10 m/s to the right. Suppose that the string is now pulled tight and causes the box to experience a constant 2 m/s^2 acceleration to the left. Which of the following best describes the box's motions after 6 seconds?

(A) The box is moving left and speeding up.
(B) The box is moving left and slowing down.
(C) The box is moving right and speeding up.
(D) The box is moving right and slowing down.
(E) The box is moving right at a constant speed.

27. In the diagram shown below, a force **F** is applied to a mass M at an angle Θ to the horizontal. The mass is moving along a flat, smooth, horizontal surface. What is the magnitude of the normal force?

(A) $Mg + F \sin \Theta$
(B) $Mg/(F \sin \Theta)$
(C) $(F \sin \Theta)/Mg$
(D) $Mg - F \sin \Theta$
(E) Mg



28. Assuming a frictionless, massless pulley, determine the acceleration of the blocks once they are released from rest if $M > m$.

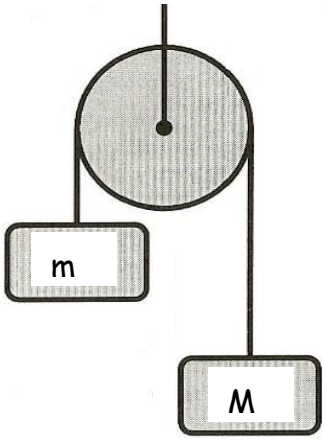
(A) $\dfrac{m}{(M + m)}\,\mathbf{g}$

(B) $\dfrac{(M - m)}{(M + m)}\,\mathbf{g}$

(C) $\dfrac{M}{m}\,\mathbf{g}$

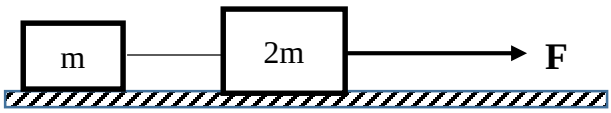
(D) $\dfrac{M}{(M + m)}\,\mathbf{g}$

(E) $\dfrac{(M + m)}{(M - m)}\,\mathbf{g}$



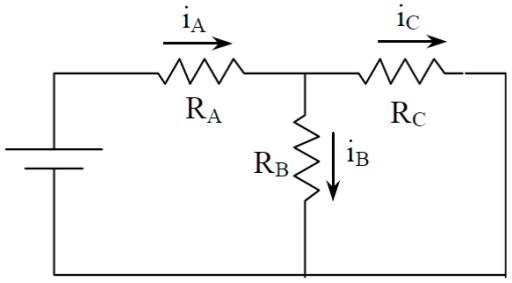
29. When the frictionless system shown is accelerated by an applied force of magnitude F, the tension in the string between the blocks is

(A) $2F$
(B) F
(C) $\frac{2}{3}\,F$
(D) $\frac{1}{2}\,F$
(E) $\frac{1}{3}\,F$



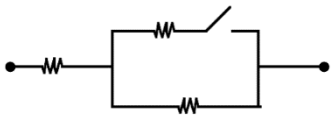
30. A mass *M* rests on top of a frictionless inclined plane. Which of the following statements is correct about the normal force acting on the mass as the angle of elevation increases?
    (A) The normal force decreases.
    (B) The normal force increases.
    (C) The normal force increases, then decreases.
    (D) The normal force decreases, then increases.
    (E) The normal force remains constant.

31. Refer to the figure in which R_A is identical to R_B and their resistance if half of R_C, $R_A = R_B = \frac{1}{2} R_C$. What is the relationship between i_B and i_C?
    (A) $i_B = \frac{1}{3} i_C$
    (B) $i_B = \frac{1}{2} i_C$
    (C) $i_B = i_C$
    (D) $i_B = 2 i_C$
    (E) $i_B = 3 i_C$

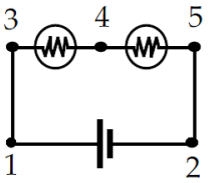


32. By using a maximum of two resistors, R1 and R2, a student is able to obtain equivalent resistances of 3 Ω, 4 Ω, 12 Ω, and 16 Ω. The values of R1 and R2 in ohms are:
    (A) 3, 4
    (B) 2, 12
    (C) 3, 16
    (D) 4, 12
    (E) 4, 16

33. Assuming identical resistors, how does the resistance between the endpoints change when the switch is closed?
    (A) Increases by R
    (B) Increases by R/2
    (C) Stays the same
    (D) Decreases by R/2
    (E) Decreases by R



34. Assuming identical resistors, rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown from highest to lowest.
    (A) 1 and 2; 3 and 4; 4 and 5
    (B) 1 and 2; 4 and 5; 3 and 5
    (C) 3 and 4; 4 and 5; 1 and 2
    (D) 3 and 4 = 4 and 5; 1 and 2
    (E) 1 and 2; 3 and 4 = 4 and 5



35. Two small charged objects repel each other with a force F when separated by a distance r. If the charge one of the objects is reduced to one-fourth of its original value and the distance between them is increased to $2r$, the force becomes:

(A) $F/16$
(B) $F/8$
(C) $F/4$
(D) $F/2$
(E) F