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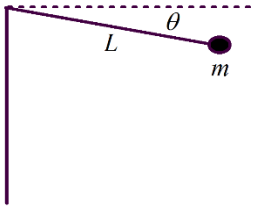
PHYSICS CONTEST EXAMINATION – 2019

Unless otherwise specified, please use g as the acceleration due to gravity at the surface of the earth. Vectors $\hat{\mathbf{x}}, \hat{\mathbf{y}}$, and $\hat{\mathbf{z}}$ are unit vectors along x, y, and z, respectively, in a normal Cartesian coordinate system. Let G be the universal gravitational constant. To simplify calculations, you may use $g = 10$ m/s^2.



Questions 1 and 2 pertain to a mass m that is revolved in a horizontal circle at a constant speed v as shown. The length of the string to which mass m is attached is L, and the angle the string makes with the horizontal is θ. For the position of mass m shown, **v** is into the page.

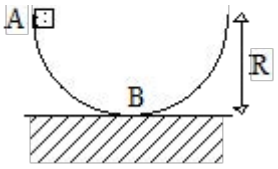
1. The magnitude of the centripetal acceleration is given by

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

2. The relationship between L, v, g, and θ is given by

   (A) $v = \frac{gL\cos\theta}{\sin\theta}$ (B) $v = \sqrt{\frac{gL}{\sin\theta}}\cos\theta$ (C) $v = \frac{gL\sin\theta}{\cos^2\theta}$ (D) $v = \sqrt{\frac{gL}{\cos\theta}}\sin\theta$
   (E) none of the previous answers

Questions 3 and 4 pertain to a mass m that is released from rest and slides inside a hemispherical bowl as shown. When reaching point B, mass m has lost one-third of its original energy.



3. The magnitude of the normal force of contact at point B is given by

   (A) $3mg$ (B) $(1/3)mg$ (C) $3mg/7$
   (D) $7mg/3$ (E) none of the previous answers

4. The magnitude of the average force due to friction in traveling from A to B is given by

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

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Questions 5 and 6 pertain to an object having mass m that is projected from the surface of the earth (mass M) with a speed v_o straight up. Let R be the radius of the earth.

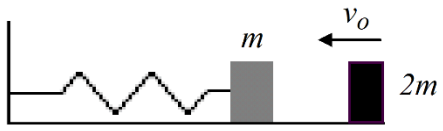
5. When the object is a distance $2R$ above the earth's surface, the ratio of the force at that point to the force on the surface of the earth is given by

   (A) 1:2 (B) 1:9 (C) 1:4 (D) 1:3
   (E) none of the previous answers

6. If the speed of the object is to be zero at a distance $2R$ above the earth's surface, its initial speed v_o must be given by

   (A) $\sqrt{\frac{5GM}{3R}}$ (B) $\sqrt{\frac{3GM}{5R}}$ (C) $\sqrt{\frac{4GM}{3R}}$ (D) $\sqrt{\frac{GM}{3R}}$
   (E) none of the previous answers

Questions 7 - 10 pertain to 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, it is struck by another mass $2m$ traveling with speed v_o as shown. The two masses stick together after colliding.



7. The speed of the two masses immediately after the collision is given by

   (A) $\left(\frac{2}{3}\right)v_o$ (B) $\left(\frac{3}{2}\right)v_o$ (C) $\left(\frac{1}{2}\right)v_o$ (D) $\left(\frac{1}{3}\right)v_o$
   (E) none of the previous answers

8. The fractional change in the kinetic energy resulting from the collision is given by

   (A) $\frac{1}{3}$ (B) $-\frac{1}{3}$ (C) $\frac{2}{3}$ (D) $-\frac{2}{3}$
   (E) none of the previous answers

9. The amplitude of the oscillations is given by

   (A) $2v_o\sqrt{\frac{m}{3k}}$ (B) $v_o\sqrt{\frac{m}{3k}}$ (C) $4v_o\sqrt{\frac{m}{k}}$ (D) $\frac{4v_o}{3}\sqrt{\frac{m}{k}}$
   (E) none of the previous answers

10. The frequency of oscillations is given by

    (A) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (B) $2\pi\sqrt{\frac{k}{m}}$ (C) $2\pi\sqrt{\frac{k}{3m}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{k}{3m}}$
    (E) none of the previous answers

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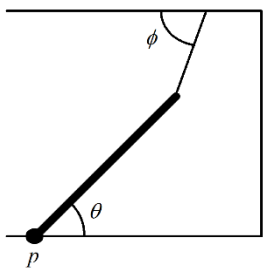
Questions 11 and 12 pertain to the figure to the right. A uniform bar having mass m and length L is held in static equilibrium using a pin p at the bottom and a massless string at the top. The horizontal and vertical components of the force the pin exerts on the bar should labeled F_h and F_v, respectively, and the tension in the string is labeled T.



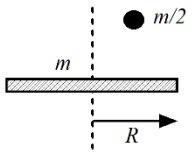
11. The equation that represent the algebraic sum of the torques exerted on the bar about point P is given by

(A) $TL\sin(\phi-\theta)-\frac{mgL}{2}\cos\theta=0$ (B) $TL\sin(\phi-\theta)+\frac{mgL}{2}\cos\theta=0$
(C) $TL\cos(\phi-\theta)-\frac{mgL}{2}\cos\theta=0$ (D) $TL\cos(\phi-\theta)+\frac{mgL}{2}\sin\theta=0$
(E) none of the previous answers

12. The equation that represents the algebraic sum of the forces in the vertical direction is given by

(A) $T+mg-F_v=0$ (B) $T\cos\phi-mg\sin\theta+F_v=0$
(C) $T\cos\phi+mg\sin\theta-F_v=0$ (D) $T\sin\phi-mg+F_v=0$
(E) none of the previous answers

Questions 13 and 14 pertain to the system shown to the right. A ball of putty having mass $m/2$ drops onto and sticks to a turntable that spins with an angular velocity ω_0. The mass of the turntable is m, and its moment of inertia is (1/2) mR^2, where R is the radius of the turntable. The putty ball lands a distance of (R/2) from the center of the turntable.



13. The final angular velocity of the putty and turntable is given by

(A) $\frac{2}{3}\omega_o$ (B) $\frac{5}{4}\omega_o$ (C) $\frac{3}{2}\omega_o$ (D) $\frac{4}{5}\omega_o$
(E) none of the previous answers

14. If the time required for the putty ball to reach the same angular velocity as the turntable is Δt, the magnitude of the torque that the putty ball exerts on the turntable is given by

(A) $\frac{mR^2\omega_o}{10\,\Delta t}$ (B) $\frac{mR^2\omega_o}{9\,\Delta t}$ (C) $\frac{mR^2\omega_o}{3\,\Delta t}$ (D) $\frac{mR^2\omega_o}{6\,\Delta t}$
(E) none of the previous answers

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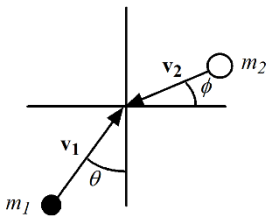
Questions 15 and 16 pertain to a two-dimensional collision shown in the figure to the right. The two masses stick together after the collision at the origin. Let $m_1 = 2m_2$ and $v_1 = v_2/2$.



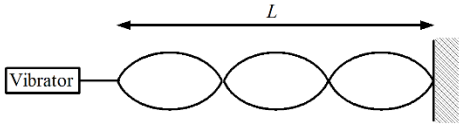
15. The x-component of the velocity of the combination after the collision is given by

(A) $\frac{v_2}{3}(\cos\theta - \sin\phi)$ (B) $\frac{v_2}{3}(\cos\phi + \sin\theta)$
(C) $\frac{v_2}{3}(\sin\theta - \cos\phi)$ (D) $\frac{v_2}{3}(\cos\theta + \sin\phi)$
(E) none of the previous answers

16. If $\phi = \theta = \frac{\pi}{4}$, the kinetic energy K of the combination and location of the combination (quadrant number) after the collision is most likely to be characterized by the following.

(A) $K = \frac{3}{4}m_2v_2^2$, quadrant 2 (B) $K = m_2v_2^2$, quadrant 2
(C) $K = \frac{3}{4}m_2v_2^2$, quadrant 3 (D) $K = \frac{1}{2}m_2v_2^2$, quadrant 2
(E) none of the previous answers

Questions 17 and 18 pertain to a string that is stretched between two supports. The tension in the string is T, the length of the string is L, the speed of a wave on the string is v_o., and the wavelength is λ. The linear mass density of the string is d_ℓ. One of the supports is a vibrator that can vibrate with frequency f causing a standing wave to be set up as shown.



17. The correct relationship between the appropriate variables selected from T, L, f, v_o, and d_ℓ is given by

(A) $v = \sqrt{\frac{d_\ell}{T}}$ (B) $f = \frac{3}{2L}\sqrt{\frac{T}{d_\ell}}$ (C) $T = d_\ell f^2\left(\frac{4L^2}{9}\right)$
(D) $f = \frac{3L}{2}\sqrt{\frac{T}{d_\ell}}$ (E) none of the previous answers

18. Changing only the tension to 4/9 of its initial value without changing any other variables causes the speed of the wave to be given by

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

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Questions 19 and 20 pertain to an explosion that causes an object at rest having mass *M* to break into two particles of mass *M*/3 and 2*M*/3. Assume that ½ of the total energy of the explosion transfers into the kinetic energy of the particles after the collision and that the larger mass travels along the positive x-axis. Assume that the speed of the larger particle is v_o.

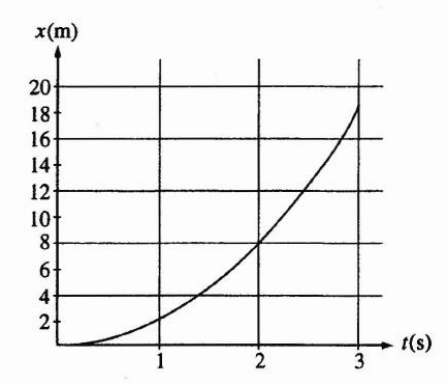
19. The ratio of the speed of the larger particle to that of the smaller particle is given by

(A) 1:3 (B) 3:1 (C) 2:1 (D) 1:2
(E) none of the previous answers

20. The total energy of the explosion is given by

(A) Mv_o^2 (B) $2Mv_o^2$ (C) $\frac{1}{2}Mv_o^2$ (D) $\frac{1}{3}Mv_o^2$
(E) none of the previous answers

21. The graph represents position x versus time t for an object being acted on by a constant force. The average speed during the interval between 1 s and 2 s is most nearly



(A) 2 m/s
(B) 4 m/s
(C) 5 m/s
(D) 6 m/s
(E) 8 m/s

22. Starting from rest, a ball rolls down a long incline with a constant acceleration. After 2 s, it has traveled 2 m. In the next second it will travel

(A) 1.25 m (B) 2.5 m (C) 3 m (D) 1 m
(E) 2 m

23. A certain plane's engines are capable of cruising at a speed of 600 km/h relative to the air. The plane makes the 1,200 km trip from Houston to El Paso multiple times per day. When traveling from Houston to El Paso, the plane encounters a strong 60 km/h headwind. When traveling from El Paso to Houston, the plane now encounters a 20 km/h tailwind. How long will the entire round trip (Houston to El Paso to Houston) take?

(A) 3.87 hours (B) 4.00 hours (C) 4.16 hours (D) 4.44 hours

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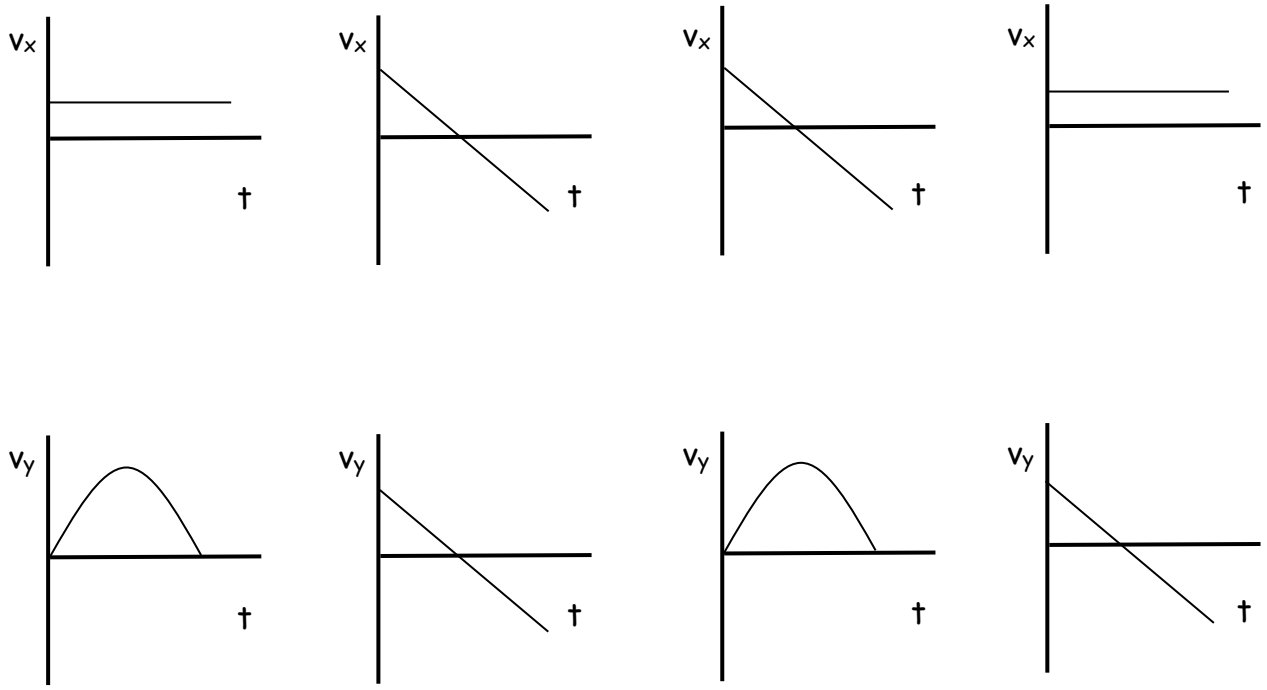
24. Three balls are projected from the edge of a cliff. I is fired horizontally, II is fired at an angle of 30° above the horizontal with the same speed as I, and III is released from rest. Which of the following is true?

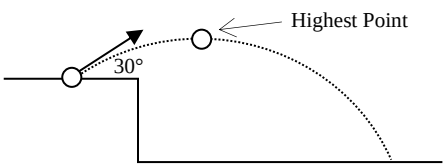
(A) I and II hit at the same time, and III hits later.
(B) I and II hit at the same time, and III hits earlier.
(C) I and III hit at the same time, and II hits earlier.
(D) I and III hit at the same time, and II hits later.
(E) All hit at the same time.

25. Which of the following pairs of graphs could represent the horizontal and vertical components of an object's velocity in projectile motion?

(A) (B) (C (D



26. A projectile is fired at 30° above the horizontal from a starting height of 20 m. At the highest point of the trajectory, the projectile is:



(A) has a horizontal velocity component equal to its initial value
(B) is instantaneously at rest
(C) has traveled half the distance to its impact point
(D) has 0 acceleration
(E) has more than one of the above properties

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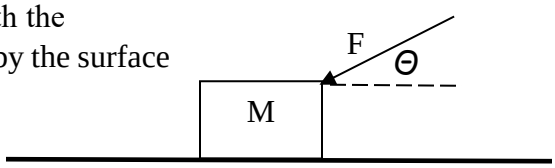
27. A block of mass M is pushed along a horizontal surface at a constant speed v by a force F which acts at an angle of θ with the horizontal as shown. The normal force exerted on the block by the surface has the following magnitude:

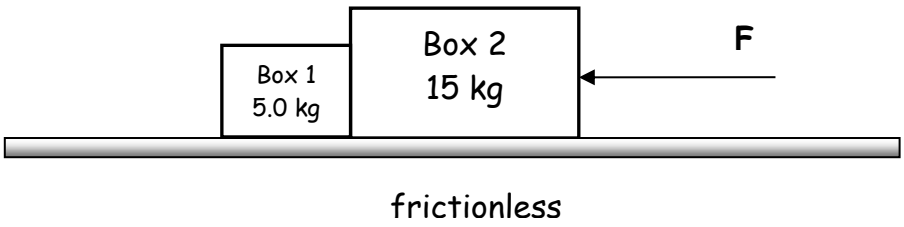


(A) Mg - FcosΘ (B) Mg + FcosΘ

(C) Mg + FsinΘ (D)Mg - FsinΘ

(E) Mg

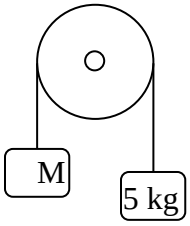
28. A force, F, pushes the two masses as shown on a smooth surface. Determine the magnitude of F if the force between the two boxes is 25 N.



(A) 150 N (B) 100 N (C) 75 N (D) 50 N
(D) 25 N

29. An Atwood pulley is setup as shown to the right. An unknown mass M is connected to a mass of 5 kg and the system is released from rest. If the unknown mass M is observed to accelerate downward a distance of 0.61 m meter in 0.5 s, what is the value of the unknown mass M?

(A) 5 kg
(B) 10 kg
(C) 15 kg
(D) 20 kg
(E) none of the above



30. A student stands on a bathroom scale inside an elevator. In which of the following scenarios will the scale reading be less than the student's weight?

(A) The elevator moves upward at a constant velocity.
(B) The elevator moves upward and is speeding up.
(C) The elevator moves upward but is slowing down.
(D) The elevator moves downward but is slowing down.
(E) More information is needed.

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31. A small metal sphere that carries an excess positive charge of +4 μC is touched to an identical metal sphere that carries an excess negative charge of -2 μC. What is the resulting charge on each sphere?

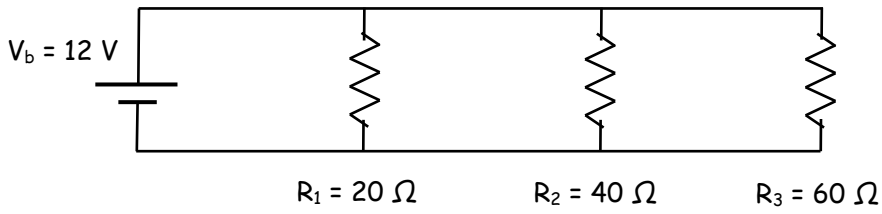
(A) + 0.5 μC
(B) +1 μC
(C) +2 μC
(D) +3 μC
(E) +4 μC

32. An electrician wires a sky scraper by using 150 meters of wire to reach the top floor and measures its resistance to be R_0. If she instead uses 450 meters of wire, which of the following correctly describes the resistance of this new wire?

(A) (1/9) R_0
(B) (1/2) R_0
(C) (1/3) R_0
(D) (2) R_0
(E) (3) R_0

33. Which of the following ranks the current through the battery, I_b, and the current through each resistor I_1, I_2, and I_3?

(A) $I_b = I_1 = I_2 = I_3$
(B) $I_b > I_1 > I_2 > I_3$
(C) $I_b > I_3 > I_2 > I_1$
(D) $I_b < I_1 < I_2 < I_3$
(E) None of the above



34. Two 40-W light bulbs rated for 120 V may be connected in series or parallel. Similarly, two 100-W light bulbs rated for 120 V may be connected in parallel or series. Which of the following statements is true? Assume that both bulbs are rated for a 120 V socket.
(A) Both will have the same brightness in series and parallel
(B) The 100 W bulb will be brighter in both series and parallel
(C) The 40 W bulb will be brighter in series and dimmer in parallel
(D) The 100 W bulb will be brighter in series and dimmer in parallel
(E) It depends on which bulb is closest to the negative terminal of the battery

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35. In the circuit shown, the value of r for which the current I is 0.5 ampere is

(A) 0Ω
(B) 1Ω
(C) 5Ω
(D) 10Ω
(E) 20Ω