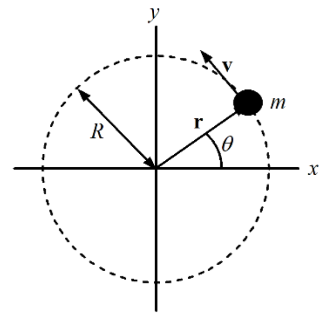
Name___________________________________ School________________________________

PHYSICS CONTEST EXAMINATION – 2020

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 $G = 6.67\ \times 10^{-11} \mathrm{N} \cdot \mathrm{m}^2/\mathrm{kg}^2$ be the universal gravitational constant. To simplify calculations, you may use $g = 10$ m/s^2.



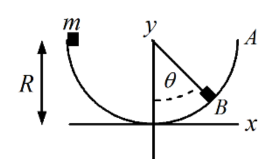
Questions 1 and 2 pertain to a mass m moves in a circle of radius R at constant speed v as shown. The coefficient of static friction between mass m and the surface is μ_s. Vector **r** is the position vector, and vector **v** is the velocity vector.

1. The relationship between R, m, μ_s, and g is given by

(A) $v = \mu_s g$ (B) $v = \mu_s g m$ (C) $v = \sqrt{\mu_s g R}$ (D) $v = \sqrt{\mu_s g m}$
(E) none of the previous answers

2. The acceleration $\boldsymbol{a}$ of mass m is given by

(A) $-\frac{v^2}{R}\ (\cos\theta\,\hat{\mathbf{x}} + \sin\theta\,\mathbf{y})$ (B) $\frac{v^2}{R}\ (\cos\theta\,\hat{\mathbf{x}} + \sin\theta\,\mathbf{y})$
(C) $-\frac{v^2}{R}\ (\sin\theta\,\hat{\mathbf{x}} + \cos\theta\,\mathbf{y})$ (D) $\frac{v^2}{R}\ (-\cos\theta\,\hat{\mathbf{x}} + \sin\theta\,\mathbf{y})$
(E) none of the previous answers



Questions 3 and 4 pertain to a mass m that is released from rest and slides inside a friction-free hemispherical bowl having radius R as shown.

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

(A) $3mg\cos\theta$ (B) $3mg\sin\theta$ (C) $3mg$ (D) mg
(E) none of the previous answers

4. The acceleration $\boldsymbol{a}$ of mass m at point A is given by

(A) zero (B) $-g\hat{\mathbf{x}}$ (C) $-g\hat{\mathbf{y}}$
(D) $g(-\hat{\mathbf{x}} + \hat{\mathbf{y}})$ (E) none of the previous answers

Name________________________________ School______________________________

Questions 5 and 6 pertain to an object having mass *m* that is projected straight up from near the surface of the earth with a speed v_o.

5. The times at which mass *m* has reached 9/10 of its maximum height are given by

(A) $\pm\frac{9v_o}{10g}$ (B) $\pm\frac{81v_o}{100g}$ (C) $\frac{v_o}{g}\left(1\pm\frac{\sqrt{10}}{10}\right)$

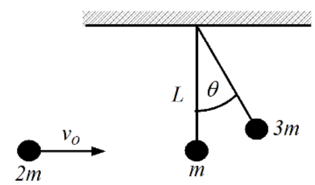
(D) $\frac{v_o}{g}\left(1\pm\frac{10}{\sqrt{10}}\right)$ (E) none of the previous answers

6. The height at which mass *m* has a kinetic energy of 9/10 its maximum kinetic energy is given by

(A) $\frac{v_o^2}{5g}$ (B) $\frac{9v_o^2}{10g}$ (C) $\frac{v_o^2}{10g}$ (D) $\frac{v_o^2}{20g}$

(E) none of the previous answers

Questions 7 - 9 pertain to a simple pendulum with mass *m* attached to a massless string as shown. Mass *m* is struck by an object having mass 2*m* and speed v_o. The two masses stick together after colliding and rise to a height indicated by the angle θ.



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

(A) $-\frac{1}{6}\,mv_o^2$ (B) $-\frac{1}{2}mv_o^2$ (C) $-\frac{2}{3}mv_o^2$ (D) $-\frac{1}{3}mv_o^2$

(E) none of the previous answers

8. The angle θ is given by

(A) $\cos\theta = 1-\frac{2v_o^2}{9Lg}$ (B) $\cos\theta = 1-\frac{9v_o^2}{2Lg}$ (C) $\sin\theta = 1-\frac{2v_o^2}{9Lg}$

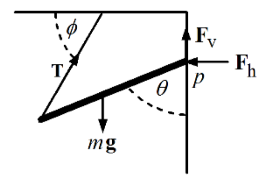
(D) $\sin\theta = 1-\frac{9v_o^2}{2Lg}$ (E) none of the previous answers

9. The time required to travel from the bottom to the maximum height is given by

(A) $2\pi\sqrt{\frac{L}{g}}$ (B) $\pi\sqrt{\frac{L}{g}}$ (C) $\frac{\pi}{2}\sqrt{\frac{L}{g}}$ (D) $\frac{\pi}{4}\sqrt{\frac{L}{g}}$

(E) none of the previous answers

Name___________________________________ School________________________________



Questions 10 and 12 pertain to the figure to the right. A bar having mass m and length L is held in static equilibrium using a pin p as shown and a massless string at the top. The horizontal and vertical components of the force the pin exerts on the bar are labeled $\mathbf{F}_h$ and $\mathbf{F}_v$, respectively, and the tension in the string is labeled $\mathbf{T}$. The center of mass of the bar is at $(3L/8)$ as measured along the bar from the end tied to the string. Consider ϕ and θ as positive angles.

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

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

11. The equation that represents the algebraic sum of the forces in the horizontal direction is given by

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

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

(A) $-TL\sin(\phi+\theta) + \frac{3mgL}{8}\sin\theta = 0$ (B) $TL\cos(\phi+\theta) - \frac{3mgL}{8}\cos\theta = 0$

(C) $-TL\sin(\phi+\theta) - \frac{5mgL}{8}\sin\theta = 0$ (D) $TL\cos(\phi+\theta) + \frac{5mgL}{8}\sin\theta = 0$
(E) none of the previous answers

Questions 13 and 14 pertain to a person having mass m who runs at speed v_o and jumps onto a friction-free merry-go-round initially at rest having a moment of inertia I_m given by $I_m = mkR^2$ and a radius R. Here, k is a numerical value that defines the moment of inertia.

13. The final angular velocity of the merry-go-round and the person is given by

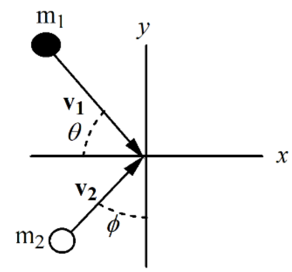
(A) $\frac{v_o}{R}$ (B) $\frac{v_o}{kR}$ (C) $\frac{v_o}{(k+1)R}$ (D) $\frac{v_o(k+1)}{R}$
(E) none of the previous answers

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

(A) $-\left(\frac{k}{k+1}\right)^2$ (B) $-\frac{k}{k+1}$ (C) $-\frac{k+1}{k}$ (D) $-\left(\frac{k+1}{k}\right)^2$
(E) none of the previous answers

Name_________________________________ School______________________________

Questions 15 - 17 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 $v_1 = 2v_2$. Please use $\sin\theta = \frac{3}{5}$ and $\cos\phi = \frac{4}{5}$.



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

(A) $\frac{19}{15}v_2$ (B) $\frac{19}{15}v_1$ (C) $\frac{15}{19}v_2$ (D) $\frac{15}{19}v_1$
(E) none of the previous answers

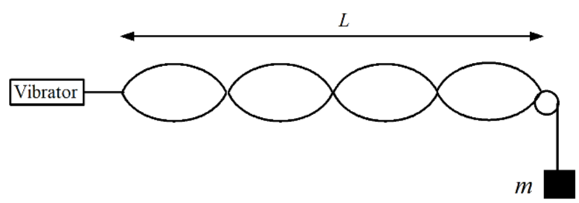
16. The y-component of the velocity of the combination after the collision is given by

(A) $-\frac{15}{8}v_1$ (B) $\frac{8}{15}v_1$ (C) $-\frac{15}{8}v_2$ (D) $-\frac{8}{15}v_2$
(E) none of the previous answers

17. The angle, measured counter-clockwise with respect to the positive x-axis, that the combination makes after the collision is given by

(A) $\tan^{-1}\left(\frac{-8}{19}\right)$ (B) $\tan^{-1}\left(\frac{-8}{19}\right) + 2\pi$ (C) $\tan^{-1}\left(\frac{-8}{19}\right) + \pi$ (D) $\tan^{-1}\left(\frac{-19}{8}\right) + 2\pi$

Questions 18 - 20 pertain to a string that is stretched between a vibrator and a pulley from which mass m hangs. The tension in the string is provided by the hanging mass m, the length of the string is L, the speed of a wave on the string is v, and the wavelength is λ. The linear mass density of the string is d_ℓ. The vibrator oscillates at a frequency f.



18. The correct relationship between the appropriate variables selected from m, L, f, v, g, and d_ℓ is given by

(A) $v = \sqrt{\frac{d_\ell}{mg}}$ (B) $f = \frac{2}{L}\sqrt{\frac{mg}{d_\ell}}$ (C) $f = \frac{L}{2}\sqrt{\frac{mg}{d_\ell}}$
(D) $f = \frac{2}{L}\sqrt{\frac{d_\ell}{mg}}$ (E) none of the previous answers

19. Changing only d_ℓ to 5/7 of its initial value without changing any other variables causes the speed of the wave to be given by

(A) $(5/7)\,v$ (B) $(7/5)\,v$ (C) $\sqrt{(7/5)}\,v$ (D) $\sqrt{(5/7)}\,v$
(E) none of the previous answers

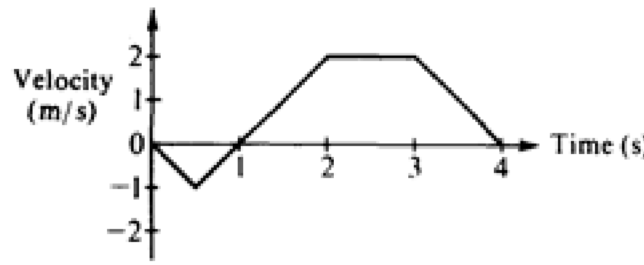
Name____________________________________ School________________________________

20. Suppose mass *m* starts to oscillate as a simple pendulum. The amplitude of the standing waves will

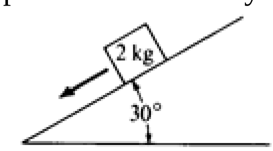
(A) increase (B) stay the same (C) decrease
(D) be undetermined without knowing the amplitude of the simple pendulum
(E) be none of the previous answers

21. The graph shows the velocity versus time for an object moving in a straight line. At what time after t = 0 does the object again pass through its initial position?

(A) Between 0 and 1 s
(B) 1 s
(C) Between 1 and 2 s
(D) 2 s
(E) Between 2 and 3 s



22. A 2 kg block slides down a 30° incline as shown with an acceleration of 2 m/s^2. The magnitude of the friction force along the plane is most nearly



(A) 2.5 N
(B) 4 N
(C) 16 N
(D) 10 N
(E) 6 N

23. A child pulls a box of weight W with a rope across a horizontal, frictionless floor. Initially, the rope has tension T < W and makes an angle Θ_0 above the horizontal. If the child now pulls with the same tension T in the rope, but at a new angle $\Theta > \Theta_0$, which of the following correctly describes the change in motion of the box? Note that Θ is still less than 90˚ with the horizontal.

(A) The motion of the box will not change because the Tension T in the rope has not changed and the angle is irrelevant.
(B) The box will experience a greater acceleration because the box pushes on the ground less, causing the normal force on the box to be less.
(C) The box will experience a smaller acceleration because a smaller component of the tension contributes to the net force in the x direction.
(D) The change in motion of the box cannot be determined until values for T, Θ, and Θ_0 are known.
(E) None of the previous answers

Name____________________________________ School________________________________

24. A projectile is launched horizontally from a height h with speed v_0 and travels a horizontal distance x before it hits the ground. If the height of launch is increased to 3h while all other factors remain unchanged, to what horizontal distance will the projectile travel now?

(A) 1.7x
(B) 2.4x
(C) 3.0x
(D) 9.0x
(E) None of the previous answers

25. An athlete kicks a ball at angle Θ above the horizontal with speed v_0. The ball travels over a flat field without air resistance. Which of the following equations represents the horizontal distance the ball will travel across the flat field in terms of given variables and fundamental constants?

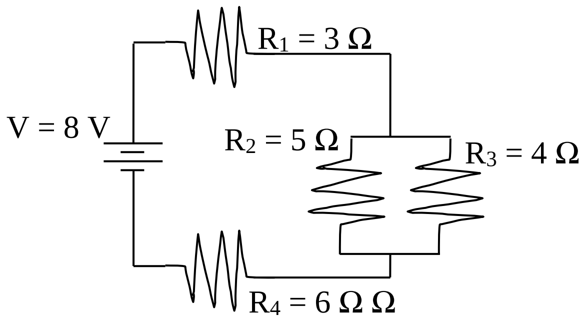
(A) $(2v_0^2\sin\Theta)/g$
(B) $(v_0^2\sin\Theta\cos\Theta)/(2g)$
(C) $(2v_0^2\cos\Theta)/g$
(D) $(2v_0^2\sin\Theta\cos\Theta)/g$
(E) None of the previous answers

26. Two identical conducting spheres 1 and 2 carry equal amounts of charge. They are separated by a distance that is large compared with their diameters. They repel each other with an electrical force F. A third identical sphere 3 with an insulated handle is initially uncharged. It is touched first to sphere 1, then to sphere 2, and then removed. The force between spheres 1 and 2 is now

(A) F/2
(B) F/4
(C) 3F/8
(D) F/16
(E) None of the previous answers

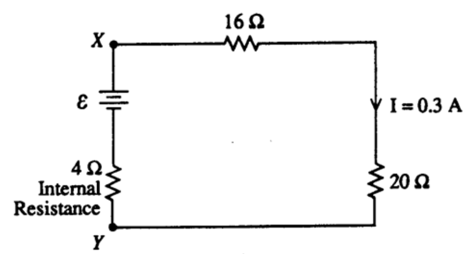
Name________________________________ School______________________________

27. The circuit shown contains four ohmic resistors connected to an ideal battery. Which of the following best describes the changes in current through resistors 1, 2, and 4 if resistor 3 is removed from the socket (and the connection left open).



	Resistor 1	Resistor 2	Resistor 4
(A)	I Increases	I Increases	I Increases
(B)	I Decreases	I Increases	I Decreases
(C)	I Increases	I Decreases	I Increases
(D)	I Decreases	I Decreases	I Decreases
(E)	More information is needed		

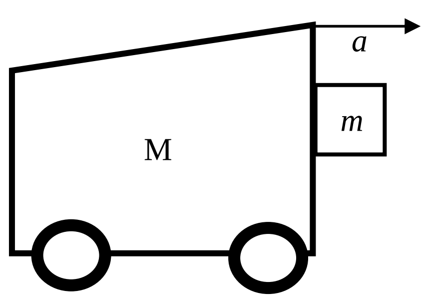
28. What is the magnitude of the potential difference across the X and Y of the battery?



(A) 1.2 V
(B) 6.0 V
(C) 10.8 V
(D) 12.0 V
(E) 13.2 V

29. The figure shows a cart of mass M accelerating to the right with a block of mass *m* held to the front surface only by friction. The coefficient of friction between the surfaces is *u*. What is the minimum acceleration *a* of the car such that the block will not fall?

(A) μg
(B) $\frac{g}{\mu}$
(C) $\frac{gm}{\mu(M+m)}$
(D) $\frac{gM}{\mu(M+m)}$
(E) $\frac{\mu gM}{M+m}$

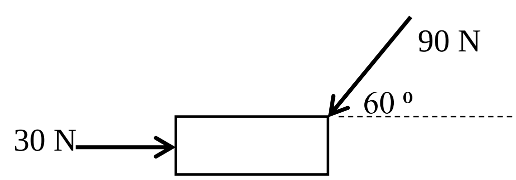


Name____________________________________ School_________________________________

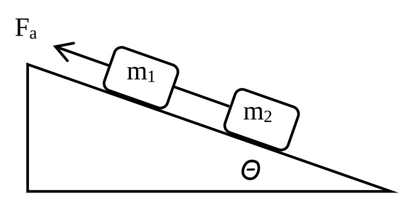
30. An object initially at rest is subjected to a constant net force. Measurements are taken of its velocity *v* at different distances d from the staring position. A graph of which of the following should exhibit a straight-line relationship?
(A) d^2 versus v^{-2}
(B) d^2 versus v
(C) d versus v
(D) d^2 versus v^{-1}
(E) d versus v^2

31. An isolated pair of charged particles X and Y, with masses m_x and m_y, repel one another and $m_y = 2\ m_x$. The electrostatic force is the only force between them. If particle X accelerates at 4.4 m/s^2, what is the acceleration of particle Y?
(A) 0.55 m/s^2
(B) 1.1 m/s^2
(C) 2.2 m/s^2
(D) 4.4 m/s^2
(E) 8.8 m/s^2

32. A block of mass 10 kg slides on a horizontal frictionless surface. A force of 30 N acts on the block in a horizontal direction and the force of 90 N acts on the block at an angle of 60 degrees as shown. What is the magnitude of the resulting acceleration?
(A) 1.5 m/s^2
(B) 3.0 m/s^2
(C) 4.8 m/s^2
(D) 6.0 m/s^2
(E) None of the previous answers



33. Two masses are connected by light strings and accelerated up an inclined plane as shown below. The surface of the plane has negligible friction. If $m_1 = 3$ kg, $m_2 = 6$ kg, $\Theta = 30°$, and $F_a = 100$ N, what is the tension in the string between the boxes?
(A) 37 N
(B) 67 N
(C) 88 N
(D) 100 N
(E) None of the previous answers



Name____________________________________ School________________________________

34. A 10 kg pail is attached to a rope and accelerated downward at 2 m/s^2. What is the approximate tension in the rope?
   (A) 60 N
   (B) 80 N
   (C) 100 N
   (D) 120 N
   (E) None of the previous answers

35. A moon is orbiting a planet of mass 9.0×10^{24} kg at a distance of 6.0×10^{8} m. Determine the tangential speed of the moon about the planet if the orbit is circular.
   (A) 1.3×10^{-3} m/s
   (B) 4.1×10^{-2} m/s
   (C) 1.0×10^{3} m/s
   (D) 4.1×10^{3} m/s
   (E) 1.0×10^{6} m/s