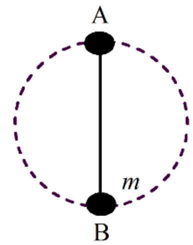
Name___________________________________ School________________________________

PHYSICS CONTEST EXAMINATION – 2018

January 27, 2018

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 vertical circle of radius R at a constant speed v as shown. Mass m is attached to a string that develops a tension T as the mass revolves.



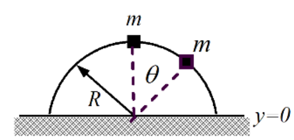
1. The quantity that remains constant during one revolution is given by

   (A) velocity (B) acceleration (C) energy
   (D) magnitude of the acceleration (E) none of the previous answers

2. The difference between the tension in the string when mass m is a point B to that when it is a point A, $T_B - T_A$, is given by

   (A) zero (B) $2mg$ (C) mg (D) $3mg$
   (E) none of the previous answers

Questions 3 and 4 pertain to a mass m that can slide along a semicircular wire as shown. Mass m is slightly displaced from rest so that it slides along the wire.



3. If no friction is present, the normal force of contact between mass m and the wire is zero at an θ given by

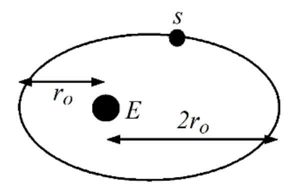
   (A) $\cos^{-1}(2/3)$ (B) $\cos^{-1}(1/3)$ (C) $\sin^{-1}(2/3)$ (D) $\sin^{-1}(1/3)$
   (E) none of the previous answers

4. Suppose that friction is present, and mass m stops at the bottom of the wire. The work done by friction in bringing mass m to rest is given by

   (A) $-(3/2)mgR$ (B) $-2mgR$ (C) $-mgR$
   (D) cannot be determined without knowing the coefficient of kinetic friction
   (E) none of the previous answers

Name___________________________________ School________________________________

Questions 5 and 6 pertain to a satellite s having mass m in an elliptical orbit around the earth E, mass $M = 2m$, as shown. The distance of closest approach is r_o and the distance of farthest approach is $2r_o$.



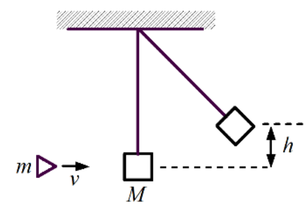
5. The ratio of the satellite's angular momentum at r_o to that at $2r_o$ is given by

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

6. Suppose the satellite were stopped at a distance $2r_o$ from the earth so that both were attracted to each other by the gravitational force. The distance from the earth that you need to place an object so that it experiences zero gravitational force from the earth and the satellite is given by

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

Questions 7 and 8 pertain to an object having mass m traveling with speed v that collides with another mass M that is suspended from a massless string as shown. Mass m remains embedded in mass M. After the collision, mass M rises to a height h above its initial point.



7. Immediately after the collision, the speed V of the combined mass is given by

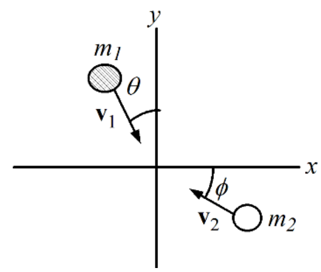
   (A) $\left(\frac{m}{m+M}\right)v$ (B) $\left(\frac{m}{M}\right)v$ (C) $\left(\frac{M}{m}\right)v$ (D) $\left(\frac{m+M}{M}\right)v$
   (E) none of the previous answers

8. The height h to which the combined mass rises is given by

   (A) $2g\left(\frac{mv}{m+M}\right)^2$ (B) $\frac{1}{2g}\left(\frac{mv}{m+M}\right)$ (C) $\frac{1}{2g}\left(\frac{mv}{m+M}\right)^2$ (D) $2g\left(\frac{mv}{m+M}\right)$
   (E) none of the previous answers

Name___________________________________ School________________________________

Questions 9 and 10 pertain to a completely inelastic collision between two masses m_1 and m_2 as shown. The masses collide at the origin and stick together as they move away from the origin with speed V at an angle β with respect to the positive y axis.



9. The kinetic energy of the combined masses after the collision is most likely

(A) equal to $(1/2)m_1v_1^2 + (1/2)m_2v_2^2$
(B) greater than $(1/2)m_1v_1^2 + (1/2)m_2v_2^2$
(C) less than $(1/2)m_1v_1^2 + (1/2)m_2v_2^2$
(D) undetermined without numbers
(E) none of the previous answers

10. The equation that represents conservation of linear momentum in the y-direction is given by

(A) $-m_1v_1 \cos\theta + m_2v_2 \cos\phi = (m_1 + m_2) V \cos\beta$
(B) $-m_1v_1 \cos\theta + m_2v_2 \sin\phi = (m_1 + m_2) V \sin\beta$
(C) $-m_1v_1 \sin\theta + m_2v_2 \sin\phi = (m_1 + m_2) V \sin\beta$
(D) $-m_1v_1 \cos\theta + m_2v_2 \sin\phi = (m_1 + m_2) V \cos\beta$
(E) none of the previous answers

Questions 11 and 12 pertain to a rotating platform (disk) that spins with angular velocity ω_0, moment of inertia $I_0=(1/2)MR^2$, kinetic energy K_0, and angular momentum L_0. A person having mass M walks from the center of the platform to its edge a distance R from the center.

11. When the person reaches the edge, the angular velocity of the system is given by

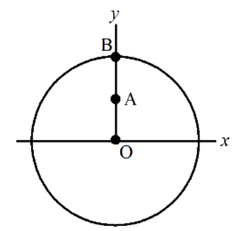
(A) $\omega_0/2$ (B) $2\omega_0$ (C) $\omega_0/3$ (D) $3\omega_0$
(E) none of the previous answers

12. As a result of the walk, the kinetic energy of the system changes to

(A) $(1/9)\,K_o$ (B) $(1/3)\,K_o$ (C) $(1/2)\,K_o$ (D) $(1/4)\,K_o$
(E) none of the previous answers

Name____________________________________ School_________________________________

Questions 13 and 14 pertain to a wheel of radius R that rotates about its center at constant angular acceleration α_o as shown. The rotation is clockwise about point O. Please use OA = (1/2)R, and assume that the wheel has zero initial angular velocity.



13. The time required for one revolution of the wheel is given by

(A) $\sqrt{\frac{4\pi}{\alpha_o}}$ (B) $\sqrt{\frac{2\pi}{\alpha_o}}$ (C) $\sqrt{\frac{4\pi R}{\alpha_o}}$ (D) $\sqrt{\frac{2\pi R}{\alpha_o}}$
(E) none of the previous answers

14. The vector expressions for the linear velocity $\boldsymbol{v}_B$ of point B and the angular acceleration $\boldsymbol{\alpha}$ of the wheel are given by

(A) $\boldsymbol{\alpha} = \alpha_o\hat{\mathbf{z}},\ \boldsymbol{v}_B = -v_B\hat{\mathbf{x}}$ (B) $\boldsymbol{\alpha} = -\alpha_o\hat{\mathbf{z}},\ \boldsymbol{v}_B = -v_B\hat{\mathbf{x}}$
(C) $\boldsymbol{\alpha} = -\alpha_o\hat{\mathbf{z}},\ \boldsymbol{v}_B = -v_B\hat{\mathbf{x}}$ (D) $\boldsymbol{\alpha} = -\alpha_o\hat{\mathbf{z}},\ \boldsymbol{v}_B = v_B\hat{\mathbf{x}}$
(E) none of the previous answers

Questions 15 and 16 refer to a rod that is held in place by a pivot P and by a string tied to a support above it. Let the tension in the string be designated by **T** and the rod length by L.

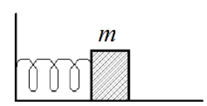
15. The magnitude of the torque on the rod produced by the tension in the string about the pivot P is given by

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

16. The horizontal component of the force F_h that the pivot exerts on the rod is given by

(A) $-T \cos\phi\ \hat{\mathbf{x}}$ (B) $-T \cos\theta\ \hat{\mathbf{x}}$ (C) $T \sin\theta\ \hat{\mathbf{x}}$ (D) $T \cos\phi\ \hat{\mathbf{x}}$
(E) none of the previous answers

Questions 17 and 18 pertain to a mass m that is attached to a spring having spring constant k as shown. As shown, the spring is neither compressed nor stretched. The surface on which mass m rests has no friction. The spring is compressed by an amount A from its equilibrium length of L, and mass m released from rest.



17. Mass m will arrive back to its equilibrium position in a time given by

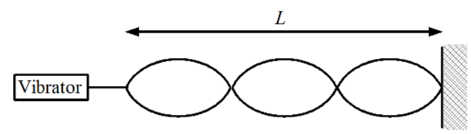
(A) $2\pi\sqrt{\frac{m}{k}}$ (B) $\pi\sqrt{\frac{m}{k}}$ (C) $\frac{\pi}{2}\sqrt{\frac{m}{k}}$ (D) $\pi\sqrt{\frac{k}{m}}$
(E) none of the previous answers

Name________________________________ School______________________________

18. The total kinetic energy of mass m when it arrives back to its equilibrium position is given by

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

Questions 19 and 20 pertain to a string that is stretched between two supports. The tension in the string is T, the length of the string is L, and the speed of a wave on the string is v_o. 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.



19. The wavelength of the wave is given by

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

20. Replacing the string by one whose linear mass density is (2/3) d_ℓ changes the speed of the wave to

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

21. A truck traveled 400 meters north in 80 seconds, and then it traveled 300 meters east in 70 seconds. The magnitude of the average velocity of the truck was most nearly

(A) 9.3 m/s
(B) 6.6 m/s
(C) 4.6 m/s
(D) 3.3 m/s
(E) 1.2 m/s

22. A speeder passes a parked police car at a constant speed of v. At that instant the police car starts from rest with a uniform acceleration a. Find the time, t, it takes before the speeder is overtaken by the police car.

(A) t = v – ½ a
(B) t = ½ a –v
(C) t = v/a
(D) t = 2v/a
(E) t = v^2/2a

Name________________________________ School________________________________

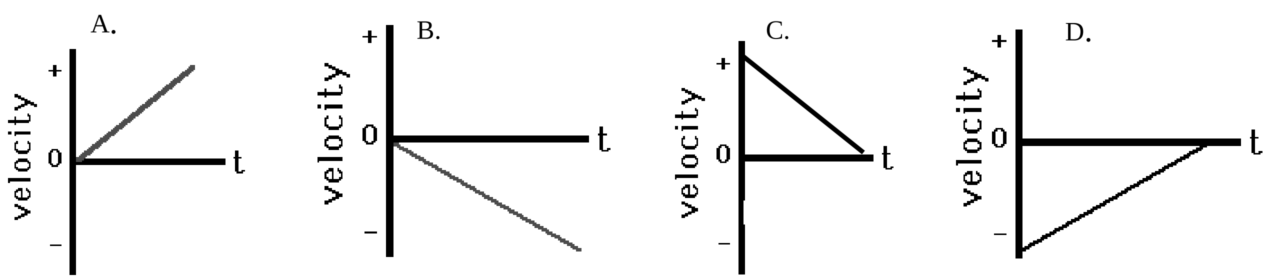
23. A player on a horizontal field kicks a soccer ball at an angle above the horizontal. The ball is in the air for a total of 2.4 seconds. Ignore the effects of air resistance. Consider vertically upward the positive direction. Which of the following best describes the vertical velocity and vertical acceleration of the ball at its highest point above the ground?

(A) Vertical Velocity of Positive, Vertical Acceleration is Negative
(B) Vertical Velocity is Positive, Vertical Acceleration is Zero
(C) Vertical Velocity is Zero, Vertical Acceleration is Negative
(D) Vertical Velocity is Zero, Vertical Acceleration is Zero
(E) Vertical Velocity is Negative, Vertical Acceleration is Zero

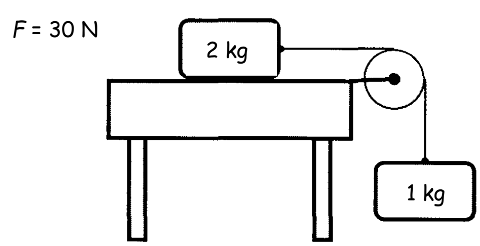
24. An object is released from rest on a planet that has no atmosphere. The object falls freely for 3.0 meters in the first second. What is the magnitude of the acceleration due to gravity on the planet?

(A) 6.0 m/s^2
(B) 3.0 m/s^2
(C) 1.5 m/s^2
(D) 12.0 m/s^2
(E) 10.0 m/s^2

25. Which of the following graphs shows an object that is speeding up in the negative direction?



26. Two masses are connected by light string. The horizontal mass of 2 kg is being pulled to the left with a force of 30 N along a frictionless surface. What is the magnitude of the acceleration of both masses?



(A) 3.5 m/s^2
(B) 6.7 m/s^2
(C) 8.3 m/s^2
(D) 9.0 m/s^2
(E) 1.3 m/s^2

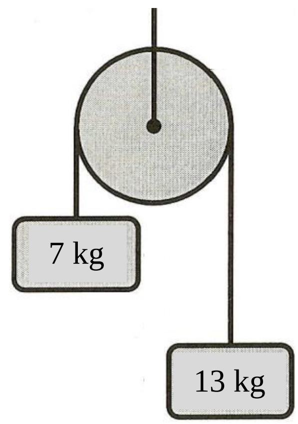
Name____________________________________ School__________________________________

27. A vertical rope is attached to an object that has a mass of 40.0 kg and is at rest. Determine the tension in the rope when the object has an upward speed of 3.50 m/s in 0.700 s.

(A) 600 N
(B) 380 N
(C) 200 N
(D) 980 N
(E) 390 N

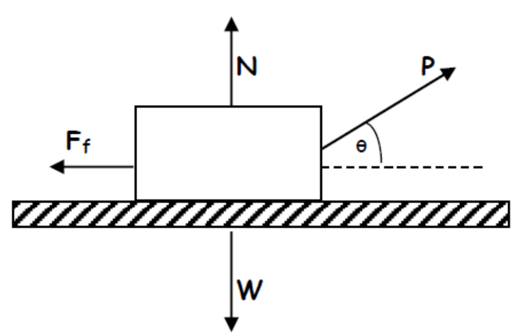
28. The Atwood pulley shown below is massless and frictionless and attached to the ceiling. A massless inextensible string is attached to an 7-kg mass and a 13-kg mass. Find the tension in the string.

(A) 91 N
(B) 21 N
(C) 130 N
(D) 49 N
(E) 39 N



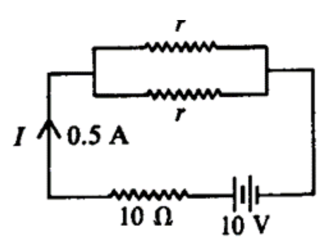
29. A boy pulls a wooden box along a rough horizontal floor at constant speed by means of a force **P** as shown. Which of the following must be true (**F_f** is the magnitude of the force of friction, **N** is the magnitude of the normal force, and **W** is the magnitude of the weight):

(A) $P = F_f$ and $N = W$
(B) $P = F_f$ and $N > W$
(C) $P > F_f$ and $N = W$
(D) $P > F_f$ and $N < W$
(E) None of these



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

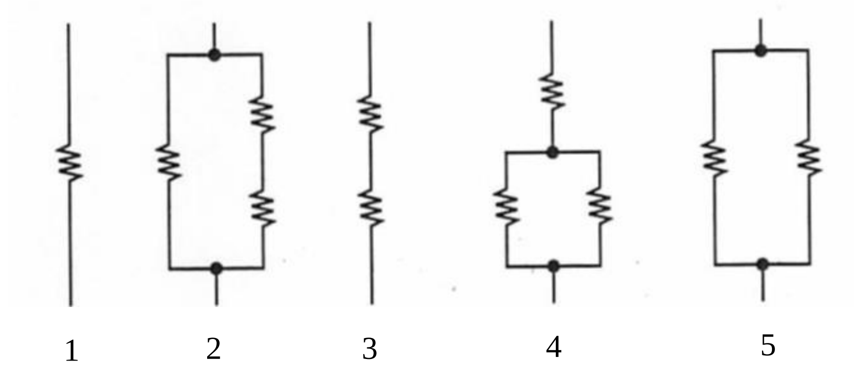
(A) 0 Ω
(B) 1 Ω
(C) 5 Ω
(D) 10 Ω
(E) 20 Ω

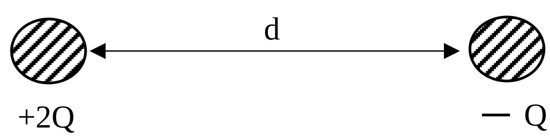


Name__________________________________ School_________________________________

31. Rank the following networks in order of highest to lowest resistance. Assume all the linear resistors are identical.

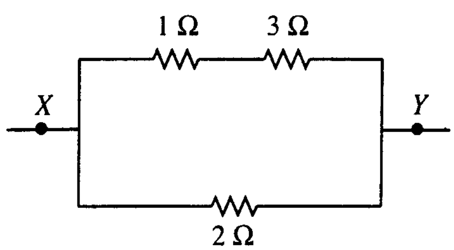
(A) 3,4,1,2,5
(B) 3,4,2,1,5
(C) 1,4,2,3,5
(D) 5,2,1,3,4
(E) 2,4,5,3,1





32. Two identical conducting spheres are charged to +2Q and –Q respectively, are separated by a distance d (much greater than the radii of the spheres) as shown above. The magnitude of the force of attraction on the left sphere is F_1. After the two spheres are made to touch and then are re-separated by the distance d, the magnitude of the force on the left sphere is F_2. Which of the following relationships is correct?

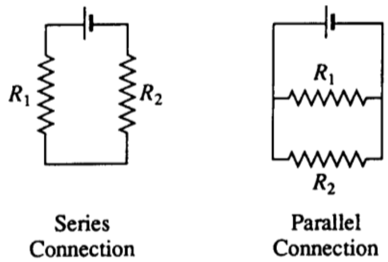
(A) $2F_1 = F_2$
(B) $F_1 = F_2$
(C) $F_1 = 2F_2$
(D) $F_1 = 4F_2$
(E) $F_1 = 8F_2$



33. When there is a steady current in the circuit, the amount of charge passing a point per unit of time is

(A) the same everywhere in the circuit
(B) greater at point X than at point Y
(C) greater in the 2 Ω resistor than in the 3 Ω resistor
(D) greater in the 1 Ω resistor than in the 2 Ω resistor
(E) greater in the 1 Ω resistor than in the 3 Ω resistor

Name___________________________________ School________________________________



34. In the diagrams above, resistors R_1 and R_2 are shown in two different connections to the same source of emf ε that has no internal resistance. How does the power dissipated by the resistors in these two cases compare?

(A) It is greater for the parallel connection.
(B) It is greater for the series connection.
(C) It is the same for both connections.
(D) It is different for each connection, but one must know the values of R_1 and R_2 to know which is greater.
(E) It is different for each connection, but one must know the value of ε to know which is greater.

35. The five resistors shown below have the lengths and cross-sectional areas indicated and are made of material with the same resistivity. Which resistor has the least resistance?