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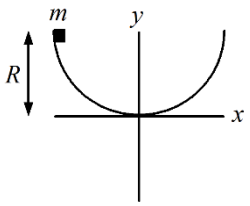
University of Houston Mathematics Contest: Physics Exam 2017

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. Let G be the universal gravitational constant.

Questions 1 and 2 pertain to a mass m that slides on a hemispherical bowl as shown. Mass m is given a downward speed $v_0 = (gR)^{1/2}$ at the top of the bowl.



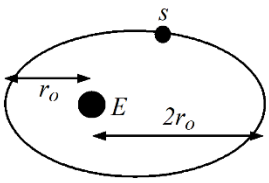
1. If no friction is present, the normal force of contact the bowl exerts on mass m at the bottom of the bowl is given by

   (A) $4mg\hat{\mathbf{y}}$ (B) $-4mg\hat{\mathbf{y}}$ (C) $3mg\hat{\mathbf{y}}$ (D) $-3mg\hat{\mathbf{y}}$
   (E) none of the previous answers

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

   (A) $-(3/2)mgR$ (B) $-mgR$ (C) $-(1/2)mgR$
   (D) cannot be determined without knowing the coefficient of kinetic friction
   (E) none of the previous answers

Questions 3 - 5 pertain to a satellite s in an elliptical orbit around the earth E as shown. The distance of closest approach is r_o and the distance of farthest approach is $2r_o$.



3. The ratio of the satellite's kinetic energy 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

4. The total energy of interaction between the earth and the satellite is given by

   (A) less than zero (B) zero (C) greater than zero
   (D) cannot be determined without specifying the distance between s and E
   (E) none of the previous answers

5. Quantities that are conserved as the satellite moves around the earth are given by

   (A) Linear momentum only (B) Angular momentum only
   (C) Total energy only (D) Linear momentum and total energy
   (E) Total energy and angular momentum

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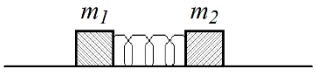
Questions 6 and 7 pertain to two masses, m_1 and m_2, held at the end of a spring that is compressed a distance d from its natural length. Masses m_1 and m_2 are released and acquire velocities of $\mathbf{v}_1$ and $\mathbf{v}_2$, respectively. The spring constant of the spring is k.



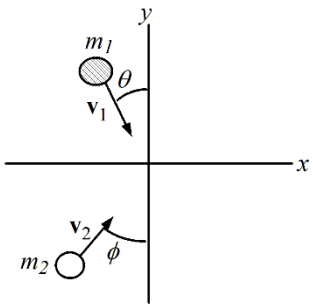
6. The total kinetic energy of m_1 and m_2 is given by

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

7. The relationship between the velocities of m_1 and m_2 is given by

   (A) $\mathbf{v}_1 = -(m_2/m_1)\,\mathbf{v}_2$ (B) $\mathbf{v}_1 = (m_2/m_1)\,\mathbf{v}_2$ (C) $\mathbf{v}_2 = -(m_2/m_1)\,\mathbf{v}_1$ (D) $\mathbf{v}_2 = (m_2/m_1)\,\mathbf{v}_1$
   (E) none of the previous answers

Questions 8 and 9 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 x axis.



8. 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

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

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

10. The most likely range of possible angles for β is given by

    (A) $-90^o \le \beta \le 90^o$ (B) $0^o \le \beta \le 180^o$ (C) $90^o \le \beta \le 270^o$
    (D) $180^o \le \beta \le 360^o$ (E) none of the previous answers

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Questions 11 and 12 pertain to a skater who spins with angular velocity ω_0, moment of inertia I_0, kinetic energy K_0, and angular momentum L_0. Initially, his arms are outstretched as far as possible. He pulls his arms in to change his moment of inertia to $(2/3)I_o$.

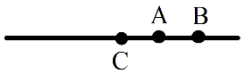
11. As a result of changing his moment of inertia, his angular momentum becomes

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

12. As a result of changing his moment of inertia, his kinetic energy becomes

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

Questions 13 and 14 pertain to a rod having length $2L$ that spins with constant angular acceleration α_o about its center C as shown. A and B indicate points that are located at $(1/3)L$ and $(2/3)L$, respectively..



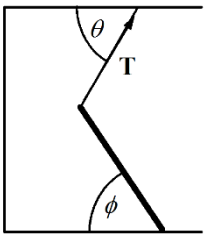
13. The ratio of the angular velocity of point A to that of point B at any time is given by

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

14. The ratio of the linear velocity of point B to that of point A at any time is given by

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

15. The figure shows a rod that is held in place by friction on the floor and by a string tied to a support above it. The tension in the string is designated by **T**, and the rod has length L. The torque on the rod produced by the tension in the string about the contact point on the floor is given by



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

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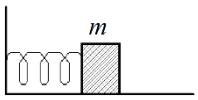
Questions 16 and 17 pertain to a mass m that is attached to a spring with spring constant k as shown. The surface on which mass m rests has no friction. The mass is pulled to the right to stretch the spring an amount A from its equilibrium length of L and released from rest.



16. The total energy of the mass-spring system is given by

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

17. The time required for the mass to travel from $L + A$ to $L - A$ is given by

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

Questions 18 and 19 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 $d\ell$. One of the supports is a vibrator that can vibrate with frequency f.

18. If the vibrator is set to a frequency to create standing waves with two nodes between the supports, the wavelength of the wave is given by

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

19. Increasing the tension in the string to $2T$ would cause the speed of the wave on the string to become

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

20. When sound waves pass through an opening, you can usually hear the sound even if you are not in the line of sight of the sound source. The reason for this is that

(A) sound waves are refracted by the opening
(B) sound waves interfere with the opening
(C) sound waves are reflected by the opening
(D) sound waves are diffracted by the opening
(E) none of the previous answers

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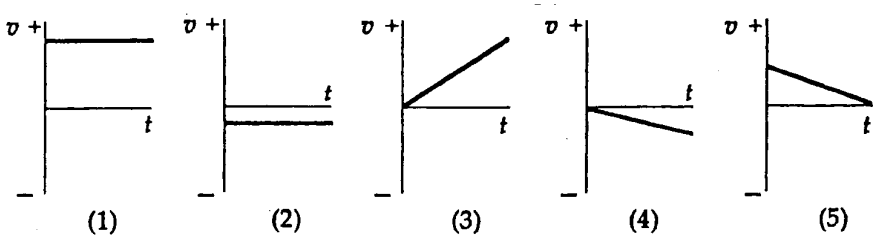
21. In which graph of ***v*** vs. *t* does the particle end up farthest from its starting point?

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



22. A car and a truck, starting from rest, have the same acceleration, but the truck accelerates for one/half the length of time. Compared with the car, the truck will travel

(A) twice as far.
(B) one-third as far.
(C) one-fourth as far.
(D) four times as far.
(E) one-half as far.

23. You drive for 2 hours at 100 km/h and then stop for 1 hour. You then drive 3 hours at 80 km/h. Your average speed for the entire trip is

(A) 73 km/h
(B) 83 km/h
(C) 88 km/h
(D) 90 km/h
(E) 97 km/h

24. A bullet is fired with a velocity v at an angle Θ above the horizontal. Which of the following best describes the velocity of the bullet at its highest point?

(A) vcosΘ
(B) vsinΘ
(C) v
(D) ½ v
(E) 0

25. A cannon fires a ball at an angle above the horizontal and strikes the front portion of a pirate ship. The cannon then fires a second shot at the same speed but aimed at a higher angle than before, and this second shot strikes the pirate ship in the same location as the first. Which of the following is true regarding the time the cannon ball is in the air?

(A) The first ball will be in the air longer than the second ball.
(B) The second ball will be in the air longer than the first ball.
(C) Both the first and the second ball will be in the air for the same amount of time.
(D) To determine which ball was in the air longer would require more information.

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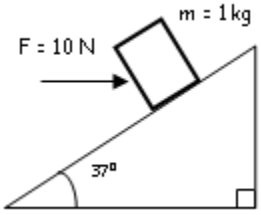
26. A rock is dropped off a cliff and falls the first half of the distance to the ground in 2.0 seconds. How long will it take to fall the second half? (Ignore air resistance.)

(A) 2.0 s
(B) 1.0 s
(C) 1.4 s
(D) 0.8 s
(E) 2.4 s

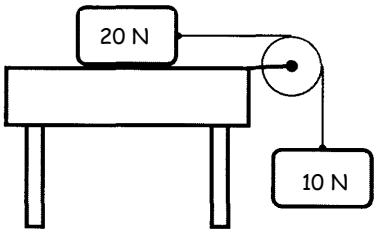
27. A force of 10 N acts horizontally on a mass of 1 kg being pushed up a frictionless incline that makes a 37^0 angle with the horizontal. The magnitude of the acceleration of the mass up the incline is equal to

(A) 1 m/s^2
(B) 2 m/s^2
(C) 3 m/s^2
(D) 4 m/s^2
(E) 5 m/s^2



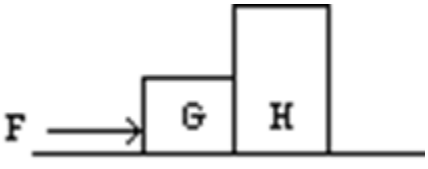
28. In the figure shown, a 20-N object is attached by a light string over a frictionless pulley to a 10-N object hanging below. The 20-N object rests on a rough surface, with a coefficient of friction of 0.20. If the system is released, what will be the tension in the string?

(A) 8 N
(B) 12 N
(C) 10 N
(D) 5 N
(E) 7 N



29. Two cardboard boxes full of books are in contact with each other on a frictionless table. Box H has twice the mass of box G. If you push on box G with a horizontal force F, then box H will experience a net force of

(A) 2/3 F
(B) F
(C) 3/2 F
(D) 2F
(E) F/3



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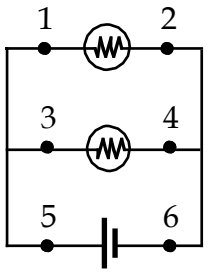
30. If three resistors with unequal resistance are connected in parallel in a DC circuit, which of the following is true of the total resistance?

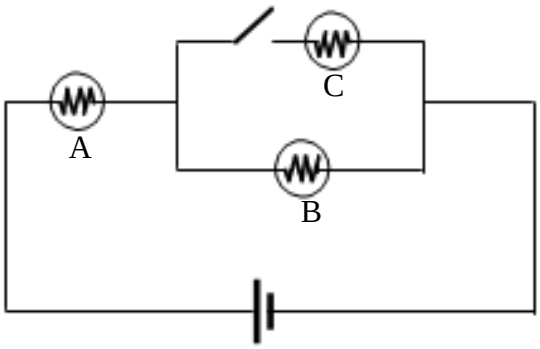
(A) It is higher than the value of the highest resistance.
(B) It is equal to the middle resistance.
(C) It is equal to the average of the three resistances.
(D) It is lower than the value of the lowest resistance.
(E) It cannot be determined without knowing the emf applied across the combination.

31. Rank the currents at points 1, 2, 3, 4, 5, and 6 from highest to lowest. Assume that all bulbs have equal resistances. Assume ideal wires.



(A) 5, 3, 1, 2, 4, 6
(B) 5, 3, 1, 4, 2, 6
(C) 5 =6, 3 = 4, 1 =2
(D) 5 = 6, 1 = 2 = 3 = 4
(E) 1 = 2 = 3 = 4 = 5 = 6

32. What happens to the brightness of bulbs A and B when the switch is closed? Assume that all bulbs have equal resistances. Assume ideal wires.



(A) A stays the same, B dims
(B) A gets brighter, B dims
(C) A and B increase
(D) A and B decrease
(E) A and B remain the same

33. If a metal wire carries a current of 80 mA, how long does it take for 3.00×10^{20} electrons to pass a given cross-sectional area of the wire?

(A) 0.60 s
(B) 600 s
(C) 1500 s
(D) 230 s
(E) None of the above

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34. Two isolated charges, + q and - $2q$, are 2 centimeters apart. If F *is* the magnitude of the force acting on charge - $2q$, what are the magnitude and direction of the force acting on charge + q?

	Magnitude	Direction
(A)	$1/2\ F$	Toward charge $-2q$
(B)	$1/2\ F$	Away from charge $-2q$
(C)	F	Toward charge $-2q$
(D)	F	Away from charge $-2q$
(E)	$2F$	Toward charge $-2q$

35. A wire of length L and radius r has a resistance R. What is the resistance of a second wire made from the same material that has a length $L/2$ and a radius $r/2$?

(A) $4R$
(B) $2R$
(C) R
(D) $R/2$
(E) $R/4$