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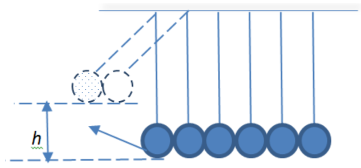
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. Which one of the following is not a unit of energy?

(a) J (b) N m (c) dyn cm (d) $kg\,m^3/s^2$ (e) W s

2. Consider a system of identical balanced balls shown in the figure. The balls can collide elastically with a negligible influence of air resistance on their motion. When two balls are pulled up and released from height h, which of the following statements about the collision is true?

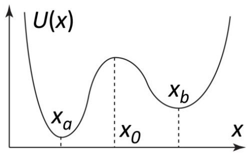


(a) One ball on the far right end rises up to $2h$ (b) Two balls on the far right end rise up to $h/2$ (c) Two balls on the far right end rise up to $2h$ (d) One ball on the far right end rises up to h (e) Two balls on the far right end rise up to h

3. You use your hand to stretch an ideal spring with a force constant k and a mass m to a final distance x_{max} from its equilibrium position and then slowly bring the spring back to equilibrium, applying a force $F = kx$ at each instant during the stretching. If the spring is stretched with a constant stretching rate v, what is the total work done by your hand?

(a) $(mv^2)/2$ (b) Zero (c) $-(kx_{max}^2)/2$ (d) None of them (e) $(kx_{max}^2)/2$

4. The potential energy function $U(x)$ of a particle moving along the x-axis has a local maximum at point x_0 located between local minima at x_a and x_b (see figure). At point x_0:



(a) The particle acceleration is in the negative x-direction (b) The particle speed is increasing (c) The particle acceleration is zero (d) The particle acceleration is in the positive x-direction (e) The particle speed is decreasing

5. A man starts to walk on a boat standing still in the water. Assume there is no friction between the boat and water. Mass of boat is twice the mass of the man. If the velocity of the man is $\vec{v}$ with respect to the boat, then what is the center of mass velocity of the boat-man system with respect to the stationary ground?

(a) $2\vec{v}$ (b) $-\vec{v}/2$ (c) $-2\vec{v}$ (d) $\vec{0}$ (e) $\vec{v}/2$

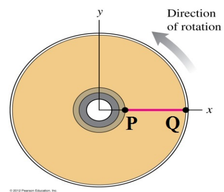
6. A sudden interaction changes the velocity of a particle of mass m from $-v\hat{j}$ to $v\hat{i}$. What is the net impulse that the particle experienced?

(a) $mv(\hat{i} - \hat{j})$ (b) $mv\hat{i}$ (c) $mv(\hat{i} \times \hat{j})$ (d) $mv(\hat{i} + \hat{j})$ (e) $\sqrt{2}mv\hat{i}$

7. Two objects of masses m and $2m$ moving in opposite directions collide head on, stick together, and stop immediately after the collision. The work done by the impulsive forces on the lighter object is W. What is the work done on the heavier one?

(a) $W/2$ (b) $4W$ (c) W (d) $W/4$ (e) $2W$

8. A DVD is rotating with an increasing speed. How do the centripetal acceleration a_{rad} and tangential acceleration a_{tan} compare at points P and Q?

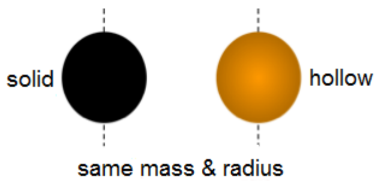


(a) Q has a greater a_{rad} and a greater a_{tan} than P. (b) P and Q have the same a_{rad}, but Q has a greater a_{tan} than P. (c) not enough information given to decide. (d) Q has a smaller a_{rad} and a greater a_{tan} than P. (e) P and Q have the same a_{rad} and a_{tan}.

9. An object at rest begins to rotate with a constant angular acceleration. If this object rotates through an angle θ in the time t, through what angle did it rotate in the time $t/2$?

(a) $(1/2)\theta$ (b) $(3/4)\theta$ (c) $(1/4)\theta$ (d) 4θ (e) 2θ

10. Two spheres have the same radius and equal masses. One is made of solid aluminum (density 2.7 g/cm^3), and the other is made from a hollow shell of gold (density 19.3 g/cm^3). Which one has the bigger moment of inertia about an axis through its center?



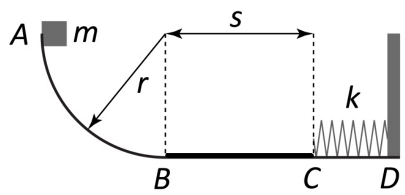
(a) solid aluminum = (1/2) hollow gold (b) solid aluminum (c) hollow gold (d) hollow gold = (1/2) solid aluminum (e) same

Questions 11-15

Consider the path ABCD shown in the figure. The section AB is one quadrant of a circle with radius $r = 5$ m and it is frictionless. The horizontal section BC has a length $s = 6$ m and a coefficient of kinetic friction $\mu_k = 0.3$. The section CD under the ideal spring with a force constant k is frictionless. A small block with mass $m = 2$ kg is released from rest at position A. After sliding along the path, if it compresses the spring by a distance $\Delta = 0.8$ m (take $g = 10$ m/s^2):

11. What is the speed of the block at point B?

(a) 10 m/s (b) 40 m/s (c) 15 m/s (d) 5 m/s (e) 20 m/s



12. What is the work done by the friction force while the block slides from B to C?

(a) -18 J (b) -36 J (c) 18 J (d) 36 J (e) -10 J

13. What is the speed of the block at point C?

(a) 4 m/s (b) 5 m/s (c) 2 m/s (d) 8 m/s (e) 10 m/s

14. What is the force constant k of the spring?

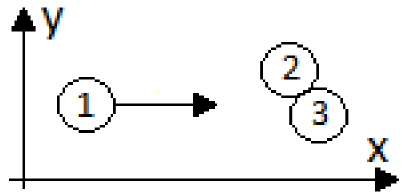
(a) 20 N/m (b) 400 N/m (c) 50 N/m (d) 100 N/m (e) 200 N/m

15. Consider now that the kinetic friction coefficient in the section CD under the spring is $\mu_k = 0.3$ and the spring still gets compressed by $\Delta = 0.8$ m. What is the force constant k of the spring?

(a) 50 N/m (b) 185 N/m (c) 250 N/m (d) 100 N/m (e) 370 N/m

Questions 16-20

The particle 1 moves parallel to the x axis and collides elastically with the other two particles which are initially at rest (see figure). Velocities of the particles 2 and 3 after the collision in (m/s) are $\vec{v}_2 = 5\hat{i} - 3\hat{j}$ and $\vec{v}_3 = 3\hat{i} + \hat{j}$ respectively. Collision occurs in the frictionless xy plane and $m_1 = m_2 = m_3 = 0.6$ kg.



16. What is the y component of velocity of the first particle after the collision?

(a) 1 m/s (b) -1 m/s (c) 2 m/s (d) 0 m/s (e) 3 m/s

17. What is the kinetic energy lost by the first particle?

(a) 13.2 J (b) 9.3 J (c) 28.5 J (d) 22.8 J (e) 17.7 J

18. What is the speed of the first particle before the collision?

(a) 7 m/s (b) 8 m/s (c) 9 m/s (d) 10 m/s (e) 6 m/s

19. What is the velocity of the center of mass in m/s?

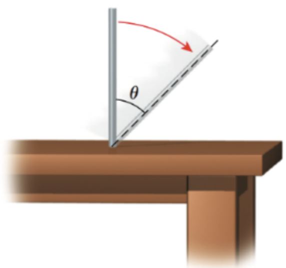
(a) $3\,\hat{i}$ (b) $10/3\,\hat{i}$ (c) $8/3\,\hat{i}$ (d) $2\,\hat{i}$ (e) $7/3\,\hat{i}$

20. If the initial speed is the same, but all three particles stick together after the collision, what is the kinetic energy lost? (In this case collision is not elastic.)

(a) 7.2 J (b) 16.2 J (c) 12.8 J (d) 20 J (e) 9.8 J

Questions 21-25

A uniform thin rod of mass M and length L is hinged at one end to a horizontal table and is released from vertical position with zero initial velocity. (Hinge is frictionless)



21. Which of the real forces are acting on the rod while it is falling?
i. centrifugal force
ii. gravitational force
iii. contact forces

(a) i, ii (b) only ii (c) ii, iii (d) only i (e) only iii

22. Which of the following integrals gives the moment of inertia of the rod around the hinge?

(a) $\frac{M}{L}\int_0^L x^2dx$ (b) $ML\int_0^L x^2dx$ (c) $\frac{M}{L}\int_{-L}^{L} x^2dx$ (d) $\frac{M}{L}\int_{-L/2}^{L/2} x^2dx$ (e) $ML\int_{-L/2}^{L/2} x^2dx$

23. What is the kinetic energy of the rod just before it hits the table?

(a) $MgL/2$ (b) 0 (c) MgL (d) $MgL/3$ (e) $MgL/12$

24. What is the angular speed of the tip (end of rod) at this instant?

(a) $\sqrt{3g/2L}$ (b) $\sqrt{5g/4L}$ (c) $\sqrt{3g/L}$ (d) 0 (e) $\sqrt{3gL}$

25. What is the linear speed of the tip at this instant?

(a) $\sqrt{5g/4L}$ (b) $\sqrt{5gL/4}$ (c) $\sqrt{3gL}$ (d) $\sqrt{3g/L}$ (e) 0

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1. A curling stone of mass 20 kg is given an initial velocity on the ice of 2 m/s. The coefficient of kinetic friction between the stone and the ice is 0.01. How far does the stone slide before it stops?

(a) 160 m (b) 20 m (c) 40 m (d) 200 m (e) 80 m

2. Which of the following is not a valid potential energy function for the spring force $F = -kx$?

(a) $(1/2)kx^2$ (b) $(1/2)kx^2 + 10J$ (c) $(1/2)kx^2 - 10J$ (d) None of the above is valid (e) $(-1/2)kx^2$

3. Which one is correct about the force $\vec{F} = Cy^2\hat{j}$ where C is a negative constant?

(a) This force never becomes zero (b) Unit of constant C is $N.m^2$ (c) F is a non-conservative force (d) F is a conservative force (e) Potential energy due to this force is equal to $-2Cy$

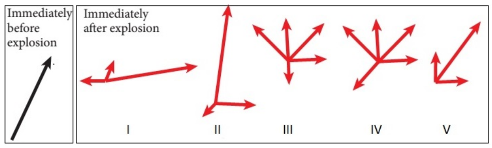
4. You use your hand to stretch a spring to a displacement x from its equilibrium position and then slowly bring it back to that position. Which is true for the whole process?

(a) None of the above statements is true. (b) The spring's ΔU is positive. (c) The spring's ΔU is negative. (d) The hand's ΔU is negative. (e) The hand's ΔU is positive.

5. Which of the following is a unit of energy?

(a) kilowatt-hour (b) newton-meter (c) joule (d) kgm^2/s^2 (e) all of the given

6. A fireworks projectile is traveling upward as shown on the right in the figure just before it explodes. Sets of possible momentum vectors for the shell fragments immediately after the explosion are shown. Which sets could actually occur?



(a) IV (b) V (c) III (d) I (e) II

7. Rank the following objects in terms of kinetic energy. Which case defines the highest energy?

(a) A 10-kg cannonball with a speed of 120 m/s (b) A 120-kg American football player with a speed of 10 m/s (c) A proton with a mass of 6.10^{-27} kg and a speed of 2.10^8 m/s (d) An asteroid with mass 10^6 kg and speed 500 m/s (e) A high-speed train with a mass of 180,000 kg and a speed of 300 km/h

8. Two objects with masses m_1 and m_2 are moving along the x-axis in the positive direction with speeds v_1 and v_2, respectively, where v_1 is less than v_2. The speed of the center of mass of this system of two bodies is

(a) less than v_1. (b) equal to v_1. (c) greater than v_1 and less than v_2. (d) equal to the average of v_1 and v_2. (e) greater than v_2.

9. Starting at t=0, a horizontal net force $\vec{F} = 0.4t\hat{i} - 0.6t^2\hat{j}$ is applied to a box that has an initial momentum $\vec{p} = -3\hat{i} + 4\hat{j}$. What is the momentum of the box at t=2.00 s?

(a) $2.4\hat{i} + 2.2\hat{j}$ (b) $2.2\hat{i} - 2.2\hat{j}$ (c) $-2.2\hat{i} + 2.4\hat{j}$ (d) $2.4\hat{i} - 2.2\hat{j}$ (e) $2.2\hat{i} + 2.4\hat{j}$

10. A ball attached to the end of a string is swung around in a circular path of radius r. If the radius is doubled and the linear speed is kept constant, the centripetal acceleration

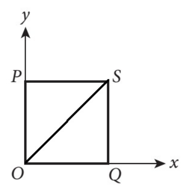
(a) increases by a factor of 2. (b) decreases by a factor of 4. (c) decreases by a factor of 2. (d) increases by a factor of 4. (e) remains the same.

11. A one-dimensional rod has a linear density that varies with position according to the relationship $\lambda(x) = cx$, where c is a constant and $x = 0$ is the left end of the rod. Where do you expect the center of mass to be located?

(a) To the left of the middle of the rod (b) At the right end of the rod (c) The middle of the rod (d) At the left end of the rod (e) To the right of the middle of the rod

Questions 12-14

A variable force acting on a 1.0 kg particle moving in the xy-plane is given by $F(x, y) = (x^2\hat{i} + y^2\hat{j})$ N, where x and y are in meters. Suppose that due to this force, the particle moves from the origin, O, to point S, with coordinates (3 m,3 m). The coordinates of points P and Q are (0 m,3 m) and (3 m,0 m), respectively.



12. What is the work performed by the force as the particle moves along the path O-P-S ?

(a) 36 J (b) 0.9 J (c) 27 J (d) 9 J (e) 18 J

13. What is the work performed by the force as the particle moves along the path O-S ?

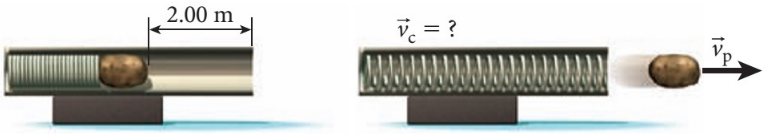
(a) 18 J (b) 9 J (c) 36 J (d) 0.9 J (e) 27 J

14. Now assume there is friction between the particle and the xy-plane, with μ=0,1. Determine the net work done by all forces on this particle when it takes OPS path. Take $g = 10.0 m/s^2$.

(a) 9 J (b) -6 J (c) 18 J (d) 12 J (e) 24 J

Questions 15-19

A potato cannon is used to launch a potato on a frozen lake, as shown in the figure. The mass of the cannon, m_c, is 10 kg, and the mass of the potato, m_p, is 1.0 kg. The cannon's spring (with spring constant $k = 1.10^2$ N/m) is compressed 2.0 m. Prior to launching the potato, the cannon is at rest. The potato leaves the cannon's muzzle moving horizontally to the right. Neglect the effects of the potato spinning. Assume there is no friction between the cannon and the lake's ice or between the cannon barrel and the potato.



15. What are the direction and magnitude of the cannon's velocity, v_c, after the potato leaves the muzzle?

(a) Cannon does not move (b) To the left with $\sqrt{20/11}$ m/s (c) To left with $\sqrt{40/11}$ m/s (d) To the left with $\sqrt{30/11}$ m/s (e) To the right with $\sqrt{20/11}$ m/s

16. What is the total mechanical energy of the potato/cannon system before firing of the potato?

(a) 0 J (b) 100 J (c) 300 J (d) 200 J (e) 400 J

17. What is the total mechanical energy of the potato/cannon system after firing of the potato?

(a) 300 J (b) 200 J (c) 400 J (d) 0 J (e) 100 J

For questions 18 and 19:
Now, the normal force acting on the potato is constant through the motion of the potato in the muzzle and it is 20 N and kinetic friction coefficient between the muzzle and the potato is 0.5;

18. What are the direction and magnitude of the cannon's velocity, v_c, after the potato leaves the muzzle?

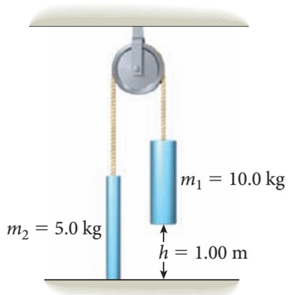
(a) To left with $\sqrt{38/11}$ m/s (b) To the right with $\sqrt{19/11}$ m/s (c) To the left with $\sqrt{19/11}$ m/s (d) To the left with $\sqrt{28/11}$ m/s (e) Cannon does not move

19. What is the total mechanical energy of the potato/cannon system after the potato leaves the muzzle?

(a) 190 J (b) 0 J (c) 200 J (d) 90 J (e) 290 J

Questions 20-21

Two masses are connected by a light string that goes over a light, frictionless pulley, as shown in the figure. The 10.0-kg mass is released and falls through a vertical distance of 1.00 m before hitting the ground. Take $g = 10.0 m/s^2$.



20. How fast the 5.00-kg mass is moving just before the 10.0-kg mass hits the ground?

(a) $\sqrt{20/3}$ m/s (b) $\sqrt{2/3}$ m/s (c) 2/3 m/s (d) 4/3 m/s (e) $\sqrt{4/3}$ m/s

21. What is the maximum height attained by the 5.00-kg mass.

(a) 2/3 m (b) 3/2 m (c) 1 m (d) 4/3 m (e) 5/2 m

Questions 22-25

In a department store toy display, a small disk (disk 1) of radius 0.100 m is driven by a motor and turns a larger disk (disk 2) of radius 0.500 m. Disk 2, in turn, drives disk 3, whose radius is 1.00 m. The three disks are in contact, and there is no slipping. Disk 3 is observed to sweep through one complete revolution every 30.0 s. Take $\pi = 3$.

22. What is the angular speed of disk 3?

(a) 0.4 rad/s (b) 2 rad/s (c) 0.1 rad/s (d) 0.2 rad/s (e) 10 rad/s

23. What is the ratio of (disk1/disk2/disk3) the tangential velocities of the rims of the three disks?

(a) 1/2/10 (b) 10/2/1 (c) 5/2/1 (d) 1/2/5 (e) 1/1/1

24. What is the angular speed of disks 1 and 2?

(a) 0.2 and 0.4 rad/s (b) 0.4 and 0.2 rad/s (c) 2.0 and 0.2 rad/s (d) 0.4 and 2.0 rad/s (e) 2.0 and 0.4 rad/s

25. If the motor malfunctions, resulting in an angular acceleration of 0.100 rad/s^2 for disk 1, what are disks 2 and 3's angular accelerations?

(a) 20 and 20 $mrad/s^2$ (b) 100 and 200 $mrad/s^2$ (c) 10 and 20 $mrad/s^2$ (d) 10 and 10 $mrad/s^2$ (e) 20 and 10 $mrad/s^2$

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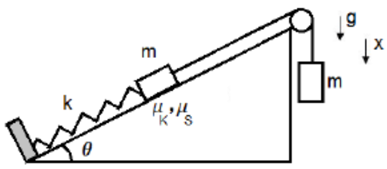
Questions 1-4

Two blocks of equal mass m are connected to each other by a string. One block is attached to an outstretched (at its natural length) spring on a surface with friction while the other is hanging from a frictionless pulley of negligible mass as shown in the figure. The system is released and the masses come to rest after moving a distance L. Acceleration due to gravity g=10 m/s^2, m=5 kg, spring constant k=10 N/m, the coefficients of static and kinetic friction between the inclined plane and the block on it are $\mu_S = 0.3$ and $\mu_K = 0.1$ respectively, $\sin\theta = 0.6$, $\cos\theta = 0.8$.



1. How much work does the net force do until the blocks stop?
(a) 152 J (b) 160 J (c) 64 J (d) 220 J (e) 0 J

2. By how much are the blocks displaced?
(a) 4.4 m (b) 2.8 m (c) 3.2 m (d) 1.6 m (e) 4 m

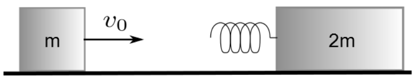
3. What is the displacement of the blocks when their speed is maximum?
(a) 2 m (b) 1.6 m (c) 3.2 m (d) 5.6 m (e) 2.2 m

4. What is the instantaneous power delivered to the system by gravity when the speed of the blocks is 1.4 m/s?
(a) 56 W (b) 14 W (c) 28 W (d) 42 W (e) 70 W

5. Suppose you throw a 0.5 kg ball with an initial speed of 10.0 m/s at an angle of 30° above the horizontal from a building 40.0 m high. What will be the speed of the ball when it hits the ground? Take $g = 10\,\text{m/s}^2$.
(a) 40 m/s (b) 30 m/s (c) 50 m/s (d) 20 m/s (e) 15 m/s

Questions 6-9

There are two blocks of mass m and $2m$ on a frictionless air rail. The former is moving with velocity v_0 toward the other. The latter is at rest and attached to a spring with force constant K. The moving block comes into contact with the spring and compresses it and eventually forces the second one to move. See figure.



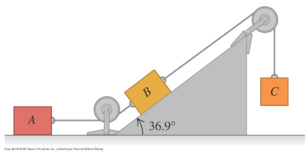
6. What is the minimum kinetic energy of the system?
(a) mv_0^2 (b) $mv_0^2/6$ (c) $mv_0^2/2$ (d) 0 (e) $2mv_0^2$

7. What is the maximum compression x_{max} of the spring?
(a) $\sqrt{\frac{m}{3K}}v_0$ (b) 0 (c) $\sqrt{\frac{4m}{3K}}v_0$ (d) $\sqrt{\frac{2m}{K}}v_0$ (e) $\sqrt{\frac{2m}{3K}}v_0$

8. What is the final kinetic energy of the system?
(a) $3mv_0^2/2$ (b) mv_0^2 (c) $mv_0^2/2$ (d) 0 (e) v_0^2

9. What is the final velocity of the block of mass m?
(a) $-v_0$ (b) 0 (c) v_0 (d) $-v_0/3$ (e) $-mv_0/3$

10. Three blocks are connected as shown. The ropes and pulleys are of negligible mass. When released, block C moves downward, block B moves up the ramp, and block A moves to the right. After each block has moved a distance d, the force of gravity has done
(a) zero work on A, negative work on B, and positive work on C. (b) zero work on A, positive work on B, and negative work on C. (c) none of these. (d) positive work on A, B, and C. (e) negative work on A, B and C.



Questions 11-13

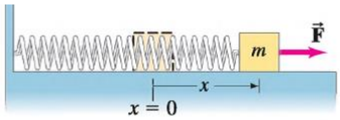
The position vector of an object with 2kg mass is given as $\vec{r} = t\hat{i} + t^3\hat{j}$

11. Find the force acting on the object?
(a) $24\hat{j}$N (b) cannot find. (c) $6\hat{j}$N (d) $12t\hat{j}$N (e) $12\hat{j}$N

12. Find the work done by the force in first 2 seconds.
(a) 144 J. (b) cannot find. (c) 100 J (d) 76.8 J (e) 77 J

13. Find the power at t = 1s.
(a) 0 (b) 72 Watt (c) 144 Watt (d) 9 Watt (e) 36 Watt

14. A mass m is attached to a spring which is held stretched a distance x by a force F, and then released. The spring compresses, pulling the mass. Assuming there is no friction, determine the speed of the mass m when the spring returns to half its original extensions.



(a) $\sqrt{\frac{3Fx}{4m}}$ (b) $\sqrt{\frac{Fx}{m}}$ (c) $\sqrt{\frac{Fx}{4m}}$ (d) $\sqrt{\frac{Fx}{2m}}$ (e) $\sqrt{\frac{2Fx}{m}}$

15. A bicyclist coasts down a slope with an angle α, for which $\sin(\alpha) = 0.1$, at a steady speed of 5 m/s. Assuming a total mass of 70 kg (bicycle plus rider), what must the cyclist's power output be to pedal up the same slope at the same speed? Take $g = 10\,\text{m/s}^2$.

(a) 3500 W (b) 700 W (c) 1200 W (d) 350 W (e) 1400 W

16. Is it possible to have a force which gives zero impulse over a nonzero time interval even though the force is not zero at least a part of that time interval? How?

(a) No, constant force. (b) Yes, non-constant force. (c) Not possible. (d) No, non-constant force. (e) Yes, constant force.

Questions 17-19

Suppose that two bodies, A (m_A = 1.0 kg) and B (m_B=2.0 kg), collide. The velocities before the collision are $\vec{v_A} = 1.5\hat{\imath} + 3\hat{\jmath}$ m/s and $\vec{v_B} = -0.5\hat{\imath} + 0.5\hat{\jmath}$ m/s. After the collision the velocity of block A is $\vec{v_A'} = -0.5\hat{\imath} + 2\hat{\jmath}$ m/s .

17. What is the x component of the velocity of B after collision in m/s?

(a) 2 (b) 3 (c) 0.5 (d) 1.5 (e) 1

18. What is the velocity of the center of mass of the system before collision in m/s?

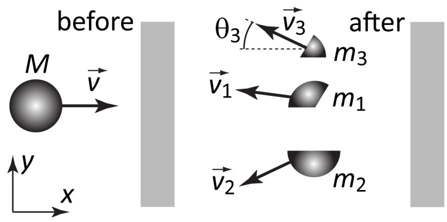
(a) $-\frac{1}{3}\hat{\imath} + \frac{1}{6}\hat{\jmath}$ (b) $\frac{1}{2}\hat{\imath} + \hat{\jmath}$ (c) $\frac{1}{6}\hat{\imath} + \frac{4}{3}\hat{\jmath}$ (d) $\frac{5}{6}\hat{\imath} + \frac{5}{6}\hat{\jmath}$ (e) $\frac{1}{6}\hat{\imath} + \frac{7}{6}\hat{\jmath}$

19. What is the position vector of the center of mass of the system before collision at $t = 2.0$ s in meter? Initial positions of the masses are given as $\vec{r_A}(t{=}0) = 0$ and $\vec{r_B}(t{=}0) = 0.5\hat{\imath} + 1\hat{\jmath}$ for m_A and m_B, respectively.

(a) $-\frac{1}{6}\hat{\imath} + \frac{4}{3}\hat{\jmath}$ (b) $\frac{1}{3}\hat{\imath} + \frac{7}{3}\hat{\jmath}$ (c) $6\hat{\imath} + 3\hat{\jmath}$ (d) $\frac{2}{3}\hat{\imath} + \frac{10}{3}\hat{\jmath}$ (e) $-\frac{1}{3}\hat{\imath} + \frac{8}{3}\hat{\jmath}$

Questions 20-21

A clay ball with mass $M = 6\sqrt{2}$ kg is thrown directly against a perpendicular wall at a velocity of $\vec{v} = (6/\sqrt{2})\hat{\imath}$ m/s along the positive x-axis and shatters into three pieces, which all fly backward, as shown in the figure. The wall exerts a normal force of 1930 N on the ball for 0.1 s. One piece of mass $m_1 = 2\sqrt{2}$ kg travels backward with velocity $\vec{v}_1 = \left[(-40/\sqrt{2})\hat{\imath} + (10/\sqrt{2})\hat{\jmath}\right]$ m/s. A second piece of mass $m_2 = 3\sqrt{2}$ kg travels backward at velocity $\vec{v}_2 = \left[(-25/\sqrt{2})\hat{\imath} - (6/\sqrt{2})\hat{\jmath}\right]$ m/s.



20. What is the speed v_3 of the third piece with mass m_3 after the collision?

(a) 2 m/s (b) $2\sqrt{2}$ m/s (c) $\sqrt{2}$ m/s (d) $4\sqrt{2}$ m/s (e) 1 m/s

21. What is the angle θ_3 between the direction of motion of the third piece with mass m_3 and the horizontal after the collision? Take positive angles for directions above the horizontal and negative angles for directions below the horizontal.

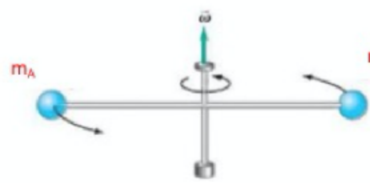
(a) 30° (b) 45° (c) −30° (d) −45° (e) −60°

22. The angular velocity of a wheel is rotating on a horizontal axle point west. In what direction is the linear velocity of point on the top of the wheel? If the angular acceleration point east, describe the tangential linear acceleration of this point at the top of the wheel. Is the angular speed increasing or decreasing?

(a) East, West, Decreasing (b) South, North, Decreasing (c) West, North, Increasing (d) West, East, Increasing (e) North, South, Decreasing

Questions 23-25

Two masses are attached to opposite ends of a thin L-long horizontal rod. The system is rotating at angular speed ω about a vertical axle at the center of the rod. If we increase the angular speed two times larger than the current system:



23. What will be the fraction of kinetic energy between two systems?

(a) 1 (b) 1/4 (c) 1/2 (d) 2 (e) 4

If we shift the vertical axle to the middle between m_A and the center of the rod:

24. What will be the mass ratio (m_A/m_B)to get an equal net force between two masses?

(a) 1/3 (b) 3/2 (c) 1 (d) 3 (e) 2/3

Now assuming that axle passes through the center-of-mass (CM) of the system:

25. Determine the kinetic energy with m_A=4.0 kg and m_B=3.0 kg, the length of the rod 14 cm and angular speed $\omega = 2$ rad/s.

(a) 0.48 J (b) 0.96 J (c) 1.92 J (d) 0.16 J (e) 0.32

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ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

Questions 1-5

A scale is adjusted so that when a large, shallow pan is placed on it, it reads zero Newton. There is a water faucet 1.6 m above the pan. When the faucet is turned on, water leaves the faucet with a speed of 2 m/s and falls into the pan at a rate R = 0.14 kg/s. Take g = 10 m/s^2.

1. What is the magnitude of the velocity of water as it strikes the pan in m/s?

(a) 3 (b) $4\sqrt{2}$ (c) 5 (d) 4 (e) 6

2. Just after water strikes the pan what is the momentum change per unit time in kgm/s^2?

(a) 0.14 (b) 0.56 (c) 0.84 (d) 0.42 (e) 0.28

3. What is the scale reading at t = 0 s (Water just strikes to the pan initially)

(a) 0.84 N (b) 1 N (c) 10 N (d) 1.4 N (e) 0.64 N

4. What is the mass of water in the pan at t = 4 s in kg?

(a) 0.56 kg (b) 1.5 kg (c) 2 kg (d) 1 kg (e) 3 kg

5. What is the scale reading at t = 4 s? (Assume that the increase in water level is negligible)

(a) 10.2 N (b) 15.6 N (c) 6.44 N (d) 21 N (e) 16 N

Questions 6-8

Two objects, A (m_A = 1.0 kg) and B (m_B = 2.0 kg), collide. The velocities before the collision are $\vec{v_A} = 2\hat{\imath}$ m/s and $\vec{v_B} = 4\hat{\jmath}$ m/s. The velocity of object A after the collision is given by $\vec{v_A}' = -0.4\hat{\imath} + 2\hat{\jmath}$ m/s.

6. What is the speed of object B just after the collision (v_B')?

(a) $\sqrt{8.76}$ m/s (b) $\sqrt{10.44}$ m/s (c) $\sqrt{8.44}$ m/s (d) $\sqrt{9.36}$ m/s (e) $\sqrt{9.64}$ m/s

7. What is $\tan\theta$, where θ is the angle between the velocity of B (v_B') and the x-axis?

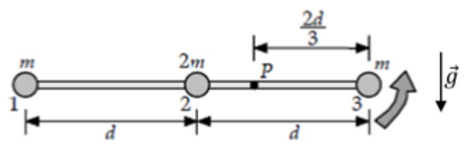
(a) 1.5 (b) 5 (c) 2 (d) 2.5 (e) 3

8. What is the energy lost due to the collision?

(a) 7.16 J (b) 7.48 J (c) 5.48 J (d) 6.56 J (e) 6.38 J

Questions 9-15

A rigid, massless rod has three masses attached to it. The rod is free to rotate in a vertical plane about a frictionless axle perpendicular to the rod through the point P, and it is released from rest in the horizontal position at t=0s.



9. Find the moment of inertia of the system about the point P.

(a) $7md^2$ (b) $4md^2$ (c) $\frac{7md^2}{3}$ (d) $\frac{22md^2}{9}$ (e) $\frac{4md^2}{9}$

10. Find the magnitude of the torque about point P at t=0s.

(a) 0 (b) mgd (c) $\frac{3}{4}mgd$ (d) $\frac{7mgd}{9}$ (e) $\frac{4}{3}mgd$

11. Find the angular acceleration of the system at t=0s.

(a) $\frac{6g}{11d}$ counter clockwise (b) $\frac{3g}{7d}$ counter clockwise (c) $\frac{3g}{7d}$ clockwise (d) $\frac{6d}{11g}$ counter clockwise (e) $\frac{6g}{11d}$ clockwise

12. Find the linear acceleration of the mass labelled as “3” at t=0s.

(a) $\frac{4g}{11}$ down (b) 0 (c) $\frac{2g}{7}$ up (d) $\frac{2g}{7}$ down (e) $\frac{4g}{11}$ up

13. Find the maximum kinetic energy of the system.

(a) $\frac{4}{5}mgd$ (b) $\frac{4}{3}mgd$ (c) $\frac{5}{4}mgd$ (d) $\frac{3}{4}mgd$ (e) mgd

14. Find the maximum angular speed attained by the rod.

(a) $\sqrt{\frac{7g}{6d}}$ (b) $\sqrt{\frac{4g}{3d}}$ (c) $\sqrt{\frac{12g}{11d}}$ (d) $\sqrt{\frac{6g}{7d}}$ (e) $\sqrt{\frac{11g}{12d}}$

15. Find the maximum value of the magnitude of the angular momentum of the system about point P.

(a) $md^{\frac{3}{2}}\sqrt{(\frac{14g}{3})}$ (b) $\frac{44}{9}md^{\frac{3}{2}}\sqrt{\frac{3g}{11}}$ (c) $md^{\frac{3}{2}}\sqrt{(\frac{5g}{14})}$ (d) $22md^{\frac{3}{2}}\sqrt{(\frac{14g}{3})}$ (e) $\frac{44}{9}md^{\frac{3}{2}}\sqrt{\frac{5g}{21}}$

Questions 16-20

The turbine and associated rotating parts of a jet engine have a total moment of inertia of 10 kgm^2. The turbine is accelerated uniformly from rest to an angular speed of 100 rad/s in a time of 25 s. Find

16. the angular acceleration,

(a) 1/4 rad/s^2 (b) 4 rad/s^2 (c) 1/2 rad/s^2 (d) 2 rad/s^2 (e) 5 rad/s^2

17. the net torque required,

(a) 20 Nm (b) 5 Nm (c) 50 Nm (d) 40 Nm (e) 2 Nm

18. the angle turned through in 25 s,

(a) 1750 rad (b) 1000 rad (c) 500 rad (d) 750 rad (e) 1250 rad

19. the work done by the net torque,

(a) 100000 J (b) 12500 J (c) 50000 J (d) 0 (e) 25000 J

20. the kinetic energy of the turbine at the end of the 25 s.

(a) 25000 J (b) 0 (c) 100000 J (d) 50000 J (e) 12500 J

Questions 21-25

The potential energy between two identical point like objects of the same mass, m, is given by the relation, $U(r) = m.A[(\frac{r_0}{r})^{12} - 2(\frac{r_0}{r})^6]$. Here r is the distance between the objects, r_0 is the equilibrium distance where the net force on the objects is zero, and A is a constant.

21. What is the unit of A?

(a) N.kg/m^9 (b) N.kg/m^6 (c) N.m/kg (d) N.kg/m^{12} (e) N/m.kg

22. What is the minimum value of the potential energy?

(a) $-6mA$ (b) $-mA$ (c) $3mA$ (d) $-2mA$ (e) $-3mA$

23. What is the magnitude of the force applied by one of the objects on the other at the distance that the *potential energy becomes minimum*?

(a) $F = 3mA$ (b) $F = mA[r_0^{11} - 2r_0^5]$ (c) $F = mA[r_0^{12} - 2r_0^6]$ (d) $F = 0$ (e) $F = 2mA$

24. What is the magnitude of the force applied on each object as a function of the distance r?

(a) $F = 12m.A[+\frac{r_0^{12}}{r^{13}} - \frac{r_0^6}{r^7}]$ (b) $F = m.A[-\frac{r_0^{13}}{r^{11}} - \frac{r_0^7}{r^5}]$ (c) $F = m.A[-\frac{r_0^{13}}{r^{11}} + \frac{r_0^7}{r^5}]$ (d) $F = 12m.A[-\frac{r_0^{12}}{r^{13}} - \frac{r_0^6}{r^7}]$ (e) $F = m.A[+\frac{r_0^{12}}{r^{13}} - \frac{r_0^6}{r^9}]$

25. Consider that one of the objects is fixed. What is the minimum work that must be done to bring the other object from a distance r_0 to $2r_0$.

(a) $W = mA(1 - 2^{-12} - 2^{-7})$ (b) $W = 12mA(1 + 2^{-11} - 2^{-6})$ (c) $W = 12mA(-1 - 2^{-11} + 2^{-6})$ (d) $W = mA(1 + 2^{-12} - 2^{-5})$ (e) $W = mA(-1 - 2^{-12} + 2^{-7})$

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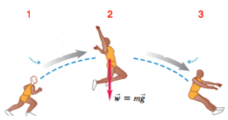
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

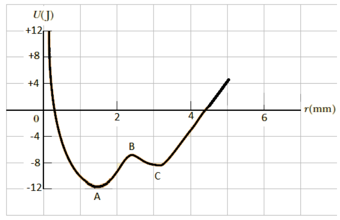
1. According to the figure in the right, which of the following is true for mechanical energy of the athlete when he jumps from point 1 to 2? What will be the total energy at point 3?



(a) Gravitational potential energy stays the same and nothing is changed for total energy
(b) Kinetic energy decreases, gravitational potential energy increases, the total energy is conserved
(c) Kinetic energy stays the same, gravitational potential energy increases, the total energy is conserved
(d) Kinetic energy decreases, gravitational potential energy increases, the total energy is not conconserved
(e) Kinetic energy increases, gravitational potential energy decreases, the total energy is conserved

2. An object moves along a line where the potential energy depends on its position r, as seen in the figure. Which point/points is/are equilibrium position for this object?

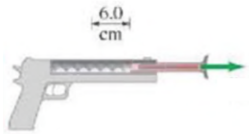
(a) A, B and C (b) A and C (c) none of them (d) only A (e) only B



3. You drop a ball from a height of 2.0 m, and it bounces back to a height of 1.5 m. What fraction of its initial energy is lost during the bounce?

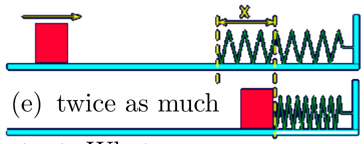
(a) 50% (b) 15% (c) 75% (d) 25% (e) 5%

4. A dart of mass 0.100 kg is pressed against the spring of a toy dart gun as shown in the figure. The spring (with spring constant k = 250 N /m and ignorable mass) is compressed 6.0 cm and released. If the dart detaches from the spring when the spring reaches its natural length, what speed does the dart acquire?



(a) 12.0 m/s (b) 3.0 m/s (c) 9.0 m/s (d) 6.0 m/s (e) 1.0 m/s

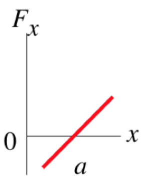
5. A box sliding on a frictionless flat surface runs into a fixed spring, which compresses a distance x to stop the box. If the initial speed of the box were doubled, how much would the spring compress in this case?



(a) half as much (b) the same amount (c) four times as much (d) $\sqrt{2}$ times as much (e) twice as much

6. Suppose the potential energy of an object is given by $U(x) = -ax/(b^2+x^2)$, where a and b are constants.What is the conservative force F as a function of x?

(a) $a(b^2-x^2)/(b^2+x^2)^3$ (b) $-a(b^2-x^2)/(b^2+x^2)^2$ (c) $-a(b^2+x^2)/(b^2+x^2)^2$ (d) $a(b^2-x^2)/(b^2+x^2)^2$ (e) $a(b^2+x^2)/(b^2+x^2)^2$



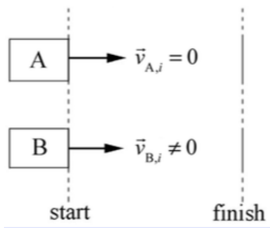
7. The graph shows a conservative force F_x as a function of x in the vicinity of $x = a$. As the graph shows, $F_x = 0$ at $x = a$. Which statement about the associated potential energy function U at $x = a$ is correct?

(a) U is a minimum at $x = a$ (b) Any of the above could be correct (c) U is neither a minimum or a maximum at $x = a$ (d) $U = 0$ at $x = a$ (e) U is a maximum at $x = a$

8. A body with mass m_A collides completely inelastically with a body with mass m_B that is initially at rest. What is the ratio of final to initial kinetic energy?

(a) m_A/m_B (b) m_B/m_A (c) $(m_A+m_B)/m_A$ (d) $m_A/(m_A+m_B)$ (e) $m_B/(m_A+m_B)$

9. Identical constant forces push two identical objects A and B continuously from a starting line to a finish line. If A is initially at rest and B is initially moving to the right, which of the following is true for the event? (Neglect friction)

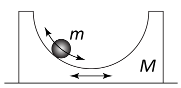


(a) Object A has a larger change in momentum (b) Object B experiences larger impulse than object A (c) Both objects have the same change in momentum (d) Not enough information is given to decide (e) Object B has a larger change in momentum

10. Some cars are designed with active deformation zones in the front that get severely damaged during head-on collisions. The purpose of this design is to

(a) make the repair as expensive as possible (b) reduce the impulse experienced by the driver during the collision (c) increase the impulse experienced by the driver during the collision (d) reduce the force acting on the driver by reducing the collision time (e) reduce the force acting on the driver by increasing the collision time

11. A particle of mass m slides without friction along the surface of a circular bowl of mass M (see figure). The circular bowl itself is free to slide along the horizontal surface without friction. What quantities of the joint system "particle + bowl" are conserved during their motion?

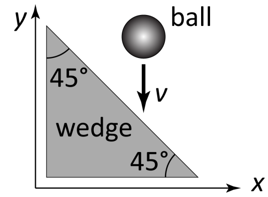


(a) both horizantal and vertical components of total momentum (b) neither horizantal nor vertical components of total momentum (c) horizantal component of total momentum (d) vertical component of total momentum (e) not enough information to decide

12. You are standing on a wooden board that in turn is resting on a frozen lake. Assume there is no friction between the board and the ice. The board has a weight five times smaller than your weight. If you begin walking along the board at 2 m/s relative to the ice, with what speed, relative to the ice, does the board move?

(a) the board does not move (b) 0.4 m/s (c) 5 m/s (d) 2 m/s (e) 10 m/s

Questions 13-14



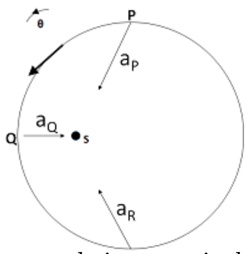
A ball of mass m falls straight down onto a 45° wedge and collides with it completely elastically. At the instant when the ball hits the wedge, it is moving with a downward speed v (see the figure). In the following, assume the wedge is solidly attached to the ground and does not move during the collision.

13. What is the direction of the velocity of the ball just after the collision?

(a) horizontal to the right (b) vertical up (c) it depends on v (d) it depends on m (e) perpendicular to the surface of the wedge

14. What is the magnitude of the momentum change of the ball in the collision?

(a) $2mv$ (b) not enough information to decide (c) $\sqrt{2}mv$ (d) mv (e) $mv/2$

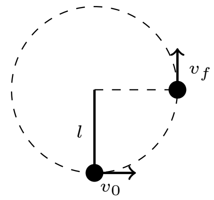


15. An object moves counter-clockwise along the circular path as shown in the figure. As it moves along the path, its acceleration vector continuously points toward the point S. The object

(a) Slows down at P and speeds up at Q (b) No object can have such a motion (c) Speeds up at P and slows down at R (d) Speeds up at P, Q and R (e) Speeds up at Q

Questions 16-17

A ball of negligible radius and mass m hangs from a string of length l. It is hit in such a way that it then travels in a vertical circle (i.e., the tension in the string is always greater than zero). The initial speed of the ball after being struck is v_0. You may ignore air resistance. Let g denote the gravitational constant.

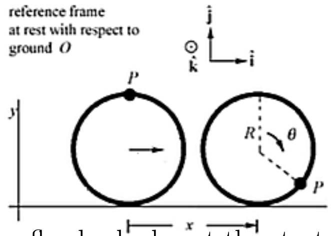


16. What is the tension in the string when the string is horizontal and the ball is moving with the speed v_f?

(a) $\frac{4mv_f^2}{l}$ (b) $\frac{mv_f^2}{l}$ (c) $\frac{mv_f^2}{2l}$ (d) $\frac{2mv_f^2}{l}$ (e) $\frac{mv_f^2}{4l}$

17. What is the speed of the ball v_f when the string is horizontal?

(a) $\sqrt{\frac{1}{2}v_0^2 - 4gl}$ (b) $\sqrt{2v_0^2 - 2gl}$ (c) $\sqrt{v_0^2 - gl}$ (d) $\sqrt{v_0^2 - 2gl}$ (e) $\sqrt{2v_0^2 - 3gl}$



18. If a wheel of radius R rolls without slipping through an angle θ, what is the relationship between the distance the wheel rolls, x, and the angle θ?

(a) $x < R\theta$ (b) $x = R\theta$ (c) $R = x\theta$ (d) $x > R\theta$ (e) $R > x\theta$

Questions 19-20

A flywheel with a radius of 0.300 m starts from rest and accelerates with a constant angular acceleration of 0.600 rad/s^2 .

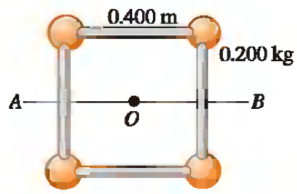
19. Compute the magnitude of the tangential acceleration and the radial acceleration of a point on the flywheel edge at the start. (π=3)

(a) (0180;0.600) m/s^2 (b) (0.600;0.180) m/s^2 (c) (0.180; 0) m/s^2 (d) (0.30;0) m/s^2 (e) (0;0) m/s^2

20. Compute approximate resultant linear acceleration of a point on the flywheel edge after it has turned through 60^o.

(a) 0.3 m/s^2 (b) 0.6 m/s^2 (c) 0 m/s^2 (d) 0.8 m/s^2 (e) 0.4 m/s^2

Questions 21-23



Four small spheres each of which you can regard as a point of mass 0.200 kg. are arranged in a square 0.400 m on a side and connected by extremely light rods shown in the figure. What is the moment of inertia of the system

21. about an axis through the center of the square, perpendicular to its plane (an axis through point 0 in the figure);

(a) 0.016 kg m^2 (b) 0.032 kg m^2 (c) 0.64 kg m^2 (d) 0 kg m^2 (e) 0.064 kg m^2

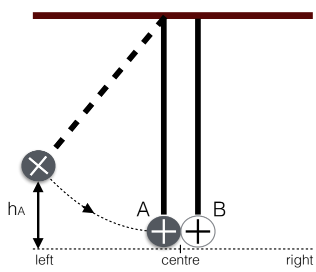
22. about an axis bisecting two opposite sides of the square (an axis along the line AB in the figure)

(a) 0.032 kg m^2 (b) 0 kg m^2 (c) 0.32 kg m^2 (d) 0.064 kg m^2 (e) 0.16 kg m^2

23. about an axis that passes through the centers of the upper left and lower right spheres and through point O.

(a) 0.032 kg m^2 (b) 0.16 kg m^2 (c) 0 kg m^2 (d) 0.064 kg m^2 (e) 0.01 kg m^2

Questions 24-25



In the Figure, a **solid sphere** (A) and a **thin-walled hollow sphere** (B) are **fixed** at the ends of two separate massless rigid rods that can rotate freely about their other ends. The length of the rods are the same and both spheres have the same mass and radius, and are initially stationary. Sphere A is displaced to the outlined position and released from the height h_A and then the spheres collide elastically and sphere B reaches the maximum height h_B.

24. Which of the following statements is correct?

(a) $h_A \leq h_B$ (b) $h_A > h_B$ (c) $h_A \geq h_B$ (d) $h_A = h_B$ (e) $h_A < h_B$

25. Where would these two spheres collide if we release them from the same height at the same time with zero initial velocities?

(a) At the center (b) The question cannot be answered with available information (c) On the right of the center (d) It depends on the initial height of the spheres (e) On the left of the center

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Student Number		Signature		

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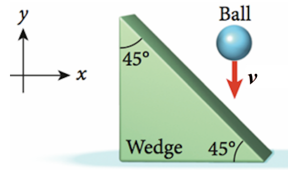
Questions 1-2

A ball falls straight down onto a wedge that is sitting on frictionless ice. The ball has a mass of 2 kg, and the wedge has a mass of 4 kg. The ball is moving a speed of $v = 4$ m/s when it strikes the wedge, which is initially at rest (see the figure). Assuming that the collision is instantaneous and perfectly elastic.



1. What is the velocity of the wedge after the collision in m/s?

(a) $-2\sqrt{6}/3$ (b) $-3\sqrt{6}/2$ (c) $-2\sqrt{6}/5$ (d) $-4\sqrt{6}/5$ (e) $-2\sqrt{6}$

2. What is the velocity of the ball after the collision in m/s?

(a) $4\sqrt{6}/3$ (b) $7\sqrt{6}/3$ (c) $2\sqrt{6}/3$ (d) $\sqrt{6}$ (e) $5\sqrt{6}/3$

Questions 3-5

In a tape recorder, the magnetic tape moves at a constant linear speed of 6.4 cm/s. To maintain this constant linear speed, the angular speed of the driving spool (the take-up spool) has to change accordingly.

3. What is the angular speed in rad/s of the take-up spool when it is empty (the figure on the left), with radius r_1=0.80 cm?

(a) 0.8 (b) 4 (c) 8 (d) 5.12 (e) 3.2

4. What is the angular speed in rad/s when the spool is full (the figure on the right), with radius $r_2 = 2.20$ cm?

(a) 2.9 (b) 6.4 (c) 1.5 (d) 3.8 (e) 3.3

5. If the total length of the tape is 128 m, what is the average angular acceleration of the take-up spool in rad/s^2 while the tape is being played?

(a) -0.150 (b) -0.255 (c) -0.200 (d) -0.285 (e) -0.325

6. A system initially at rest explodes into three pieces. Piece A mass of 2 kg, B has a mass of 3 kg and C has a mass of 1 kg. After the explosion A's velocity is (3 m/s)$\hat{\imath}$ and B's velocity is (-2 m/s)$\hat{\jmath}$. What is the speed of piece C (m/s) after the explosion?

(a) 0 (b) $5\sqrt{2}$ (c) $3\sqrt{2}$ (d) $4\sqrt{2}$ (e) $6\sqrt{2}$

7. Assume that your particle rotates about axis z. If the direction of rotation is counter-clock wise direction what is the direction of angular velocity?

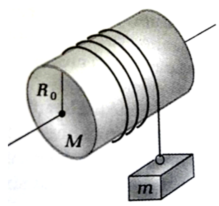
(a) $-\hat{k}$ (b) $+\hat{\jmath}$ (c) $+\hat{\imath}$ (d) $+\hat{k}$ (e) $-\hat{\imath}$

8. A 0.1 kg mass travels along a horizontal air track at a speed of 1 m/s. It makes an elastic collision with another mass that is initially at rest on the track. During the collision, which of the following is always true?

(a) All of them is wrong.
(b) The total momentum and kinetic energy are the same as before the collision.
(c) The momentum is shared equally between two masses after the impact.
(d) The kinetic energy is conserved but the momentum after the impact is less than before.
(e) The total momentum is the same as before the impact but the total kinetic energy is less.

Questions 9-10

A block of mass m is tied to a string of negligible mass that is wrapped around a uniform cylinder of mass M and radius R_0. The cylinder is free to rotate with negligible friction about a fixed axis through its center. After the block has dropped a vertical distance h from rest; (Moment of inertia of cylinder about center of mass is $I = (1/2)MR_0^2$)



9. What is the linear speed of the block?

(a) $\sqrt{2gh}$ (b) $\sqrt{\frac{gh}{1+(\frac{M}{m})}}$ (c) $\sqrt{\frac{2gh}{2+(\frac{M}{2m})}}$ (d) $\sqrt{\frac{2gh}{1+(\frac{M}{2m})}}$ (e) 0

10. What is the angular speed of the cylinder about its axis of rotation?

(a) $\sqrt{\frac{2gh}{1+(\frac{M}{2m})}}$ (b) $\frac{1}{R_0}\sqrt{\frac{2gh}{\frac{M}{2m}}}$ (c) $\frac{1}{R_0}\sqrt{\frac{2gh}{1+(\frac{M}{2m})}}$ (d) $\frac{1}{R_0}\sqrt{2gh}$ (e) 0

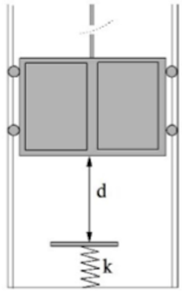
11. A stone is tied to a string and rotate in a horizontal plane at constant angular velocity. During the motion,

(a) Both linear and angular momentum change. (b) Linear and angular momentum are constant. (c) All is wrong. (d) Linear momentum is constant but angular momentum changes. (e) Angular momentum is conserved but linear momentum changes.

12. What is the unit of impulse?

(a) kgm/s^3 (b) Nm/s (c) kgm/s (d) N/s (e) kgm^2/s^2

13. The cable of the 4000 N elevator snaps when the elevator is rest at the first floor, where the bottom is a distance d=12 m above from the spring with a constant of k=10^3 N/m as shown in the figure. A safety device clamps the elevator against guide rails so that a constant frictional force of 1000 N opposes the motion of the elevator. Find the maximum distance x in m that the spring is compressed. ($\sqrt{324} = 18$, g = 10 m/s^2)



(a) 6 (b) 9 (c) 11 (d) 12 (e) 8

14. The angular momentum of a system remains constant

(a) all the time since it is a conserved quantity. (b) when no torque acts on the system. (c) when no net external force acts on the system. (d) when the linear momentum and the energy are constant. (e) when the total kinetic energy is constant.

Questions 14-15

A 4 kg box starts up a 30 degree inclined with 120.8 J of kinetic energy. (g=10 m/s^2, sin(30)=1/2, cos(30)=$\sqrt{3}/2$ and $\sqrt{3} = 1.7$)

15. How far will it slide up the plane if the coefficient of friction is 0.3?

(a) 5 (b) 3 (c) 4 (d) 1 (e) 2

16. What will be the final energy of the box in J?

(a) 80 (b) 20 (c) 100 (d) 60 (e) 40

17. Which of the following is true?

(a) In an isolated system, total energy of the system always remains constant.
(b) The internal energy of a system is equal to the elastic potential energy of the system.
(c) If a frictional force does work on a system, the total mechanical energy is equal to its potential energy change.
(d) Kinetic energy change is always equal to the work done by the system.
(e) The total energy of a system is always the sum of its kinetic and its potential energies.

Questions 17-18

Two 2 kg balls are attached to the ends of a thin rod of negligible mass and 6 cm long. The rod is free to rotate in a vertical plane without friction through its center. While the rod is horizontal a 1 kg wax drops onto one of the balls with a speed of 3 m/s and sticks to it.

18. What is the angular speed of the system just after the wax hits in rad/s?

(a) 5 (b) 20 (c) 25 (d) 10 (e) 15

19. What is the ratio of the kinetic energy of the entire system after the collision to that of before?

(a) 0.4 (b) 0.6 (c) 0.3 (d) 0.2 (e) 0.8

Questions 19-20

A uniform thin rod is pivoted at its center and it is free to rotate in a horizontal circle without friction. Two object each with a mass 2 kg sit on opposite ends of the rod with length 6 m and mass 2 kg. (Moment of inertia of rod about center of mass is $I = (1/12)Ml^2$)

20. What is the angular momentum of the system if it is rotating with angular speed ω_0 in a clockwise direction?

(a) $42\omega_0$ (b) $6\omega_0$ (c) $36\omega_0$ (d) $56\omega_0$ (e) $12\omega_0$

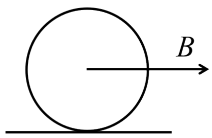
21. While the system is rotating, objects move towards the center of the rod until they are half as far from the center as before. What is the resulting angular speed in terms of ω_0?

(a) 7/12 (b) 24 (c) 14 (d) 1 (e) 14/5

22. A 1.25 kg ball begins rolling from rest with constant angular acceleration down a hill. If it takes 3 s for it to make the first complete revolution, how long will it take to make the next complete revolution?

(a) 2.10 (b) 1.53 (c) 1.80 (d) 1.65 (e) 1.24

23. A lawn roller in the form of a uniform solid cylinder is being pulled horizontally by a horizontal force B applied to an axle through the center of the roller, as shown in the figure. The roller has radius 0.65 meters and mass 50 kg and rolls without slipping. What magnitude of the force B is required to give the center of mass of the roller an acceleration of 3 m/s^2? ($I = (1/2)MR^2$)



(a) 180 (b) 275 (c) 225 (d) 450 (e) 300

24. The only force acting on an object moving along the x-axis is the conservative force given by F(x) = (2.00 N/m)x + (1.00 N/m^3)x^3. What is the change in potential energy when the object moves from x = 1.00 m to x = 2.00 m?

(a) -7.65 (b) 8 (c) -6.75 (d) -8 (e) 6.65

25. A dumbbell-shaped object is composed by two equal masses, m, connected by a rod of negligible mass and length r. If I_1 is the moment of inertia of this object with respect to an axis passing through the center of the rod and perpendicular to it and I_2 is the moment of inertia with respect to an axis passing through one of the masses, then what is the value of I_2 in term of I_1?

(a) $I_2 = (2/3)I_1$ (b) $I_2 = 4I_1$ (c) $I_2 = I_1$ (d) $I_2 = 0.5I_1$ (e) $I_2 = 2I_1$

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Questions 1-2

The potential energy function of a particle of mass 2 kg in a force field is described by $U = 3x^2 - x^3$ (for $x \leq 3$ m) and $U = 0$ (for $x \geq 3$ m) where U is in Joules and x is in meters.

1. For what values of x, the force F_x is zero?

(a) 2 (b) 0 and 1 (c) 0 and 2 (d) -2 and 2 (e) 0

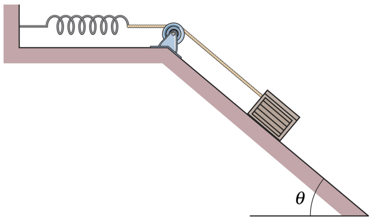
2. If the total energy of the particle is 12 J, what is its speed at $x = 2$ m?

(a) $\sqrt{2}$ m/s (b) 2 m/s (c) 0.5 m/s (d) 0.25 m/s (e) $2\sqrt{2}$ m/s

Questions 3-5

A 2.0 kg breadbox on a frictionless incline of angle 40^o is connected by a cord that runs over a pulley, to a spring of spring constant $k = 120$ N/m. The box is released from rest when the spring is unstrechted. Assume that the pulley is massless and frictionless.

Take $g = 10$ m/s^2, $sin40^o = 0.63$.



3. What is the speed of the box when it has moved 10 cm down the incline?

(a) $\sqrt{1.40}$ m/s (b) $\sqrt{0.66}$ m/s (c) $\sqrt{2.0}$ m/s (d) $\sqrt{1.86}$ m/s (e) $\sqrt{1.36}$ m/s

4. How far down the incline from its point of release does the box slide before momentarily stopping?

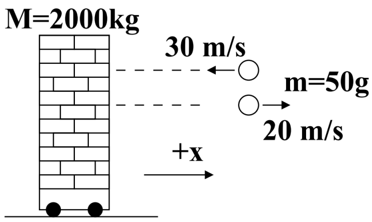
(a) 0.21 m (b) 0.56 cm (c) 0.15 cm (d) 0.42 cm (e) 0.33 cm

5. What is the magnitude of the box's acceleration at the instant it momentarily stops?

(a) 15.0 m/s^2 (b) 6.3 m/s^2 (c) 2.6 m/s^2 (d) 8.3 m/s^2 (e) 19.0 m/s^2

Questions 6-8

A tennis ball with $m = 50$ g mass approaches to a wall horizontally with 30 m/s speed as shown in the figure. After the collision, it reflects back horizontally with 20 m/s speed. The wall is massive ($M = 2000$ kg) but it is free to move on its wheels without any friction. If the collision is elastic and it takes 10 ms time.



6. What is the change in the magnitude and direction of the momentum of the ball?

(a) 5.0 k·gm/s in -x (b) 2.5 kg·m/s in +x (c) 5.0 kg·m/s in +x (d) 2.5 kg·m/s in -x (e) none

7. What is the magnitude and direction of the force acting on the ball during the collision?

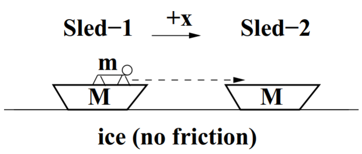
(a) 250 N, +x direction (b) 25 N, +x direction (c) 250 N, -x direction (d) 25 N, -x direction (e) 2500 N, +x direction

8. What is the magnitude and direction of the velocity of the wall just after the impact?

(a) $(5/4).10^{-3}$ m/s, -x direction (b) $\sqrt{1/80}$ m/s, -x direction (c) $\sqrt{1/20}$ m/s, -x direction (d) $(5/4).10^{-1}$ m/s, -x direction (e) $(5/4).10^{-2}$ m/s, -x direction

Questions 9-10

A cat with $m = 4$ kg mass sits on the sled-1 which is at rest. The cat momentarily jumps in horizontal direction from the sled-1 ($M = 20$ kg) to sled-2 ($M = 20$ kg) which is also at rest. There is no friction between the sleds and the ice. The speed of the cat is 3 m/s relative to the sled.



9. What is the velocity of the sled-1 for an observer on the ground after the jump?

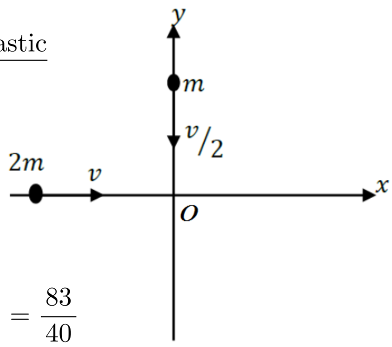
(a) $(-3$ m/s$)\hat{\imath}$ (b) $(-0.5$ m/s$)\hat{\imath}$ (c) $(0.6$ m/s$)\hat{\imath}$ (d) $(-0.6$ m/s$)\hat{\imath}$ (e) $(0$ m/s$)\hat{\imath}$

10. What is velocity of the sled-2 after the cat lands on it?

(a) $(0.5$ m/s$)\hat{\imath}$ (b) $(5/12$ m/s$)\hat{\imath}$ (c) $(0.4$ m/s$)\hat{\imath}$ (d) $(-5/12$ m/s$)\hat{\imath}$ (e) $(0.6$ m/s$)\hat{\imath}$

Questions 11-12

A collision occurs between a particle of mass $2m$ traveling with a velocity $\vec{v}_{1i} = (v)\hat{\imath}$ and a particle of mass m traveling with a velocity $\vec{v}_{2i} = -(v/2)\hat{\jmath}$. They make a completely inelastic collison at the origin and the composite system travels with a velocity $\vec{v}_f$.



11. Determine the final speed v_f in terms of v.

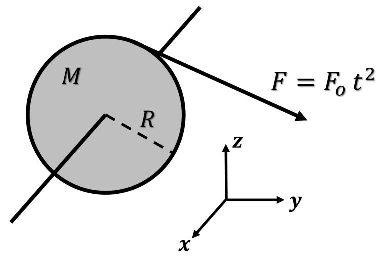
(a) $\frac{17}{\sqrt{6}}v$ (b) $\frac{\sqrt{2}}{5}v$ (c) $\sqrt{\frac{17}{6}}v$ (d) $\sqrt{\frac{2}{5}}v$ (e) $\frac{\sqrt{17}}{6}v$

12. What is the ratio of the energy loss to the initial energy?

(a) $\frac{|\Delta K|}{K_i} = \frac{27}{10}$ (b) $\frac{|\Delta K|}{K_i} = \frac{25}{74}$ (c) $\frac{|\Delta K|}{K_i} = \frac{10}{27}$ (d) $\frac{|\Delta K|}{K_i} = \frac{40}{83}$ (e) $\frac{|\Delta K|}{K_i} = \frac{83}{40}$

Questions 13-16

A string is wound around the rim of a uniform disk that is pivoted to rotate without friction about a fixed axis through its center. The mass of the disk is $m = 3$ kg and its radius is $R = 20$ cm. The string is initially at rest and is pulled with a time dependent force $F = F_0\,t^2$ where F_0 is given as 10 N/s^2.



13. What is the moment of inertia of this disk in kg·m^2?

(a) 0.48 (b) 0.12 (c) 0.03 (d) 0.06 (e) 0.24

14. What is the magnitude and direction of torque on the disk at $t = 2$ s ?

(a) 8 N·m, +x (b) 16 N·m, -z (c) 16 N·m, +y (d) 8 N·m, -x (e) 16 N·m, +z

15. What is the magnitude and direction of angular acceleration of the disk at $t = 2$ s?

(a) 800/3 rad/s^2, -z (b) 400/3 rad/s^2, +x (c) 800/3 rad/s^2, +y (d) 400/3 rad/s^2, -x
(e) 800/3 rad/s^2, +z

16. What is the magnitude and direction of the angular velocity of the disk at $t = 2$ s?

(a) 400 rad/s, -x (b) 800/9 rad/s, -x (c) 800 rad/s, +z (d) 800 rad/s, -z (e) 800 rad/s, +y

Questions 17-18

A 5-kg particle starts form the origin at time zero. Its position vector as a function of time is given by $\vec{r} = (2t^3)\hat{\imath} + (\mathrm{t}^2)\hat{\jmath}$ where $\vec{r}$ is in meter t is in seconds.

17. What are the net torque about the origin exerted on the particle and the angular momentum of the particle as a function of time?

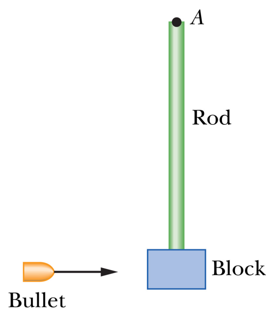
(a) $\vec{\tau} = -24t^3\hat{k}$ N·m , $\vec{L} = -24t^4\hat{k}$ J·s (b) $\vec{\tau} = 40t^3\hat{k}$ N·m , $\vec{L} = -110t^4\hat{k}$ J·s (c) $\vec{\tau} = 140t^3\hat{k}$ N·m , $\vec{L} = 200t^4\hat{k}$ J·s
(d) $\vec{\tau} = -140t^3\hat{k}$ N·m , $\vec{L} = 110t^4\hat{k}$ J·s (e) $\vec{\tau} = -40t^3\hat{k}$ N·m , $\vec{L} = -10t^4\hat{k}$ J·s

18. What is the power injected into the system of the particle as a function of time?

(a) $(360t^3 + 20t)$ W (b) $(36t^3 + 2t)$ W (c) $(36t^3 + 10t)$ W (d) $(36t^3 + 240t)$ W (e) $(81t^3 + 120t)$ W

Questions 19-20

A 1.0 g bullet is fired into a 499 g block attached to the end of a nonuniform rod of length 0.6 m. The block-rod-bullet system then rotates in the plane of the figure, about a fixed axis A. The moment of inertia of the rod alone about the axis A is 0.060 kg·m^2. Treat the block as a point particle.



19. What is the moment of inertia of the block-rod-bullet system about the axis A?

(a) 0.15 kg·m^2 (b) 0.24 kg·m^2 (c) 0.30 kg·m^2 (d) 0.42 kg·m^2 (e) 0.56 kg·m^2

20. If the angular speed of the system about A just after the impact is 4.5 rad/s, what is the bullet's speed just before the impact?

(a) 1125 m/s (b) 760 m/s (c) 2250 m/s (d) 1800 m/s (e) 3100 m/s

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1. Two objects move with the same speed v in opposite directions along a line. They meet and have a completely inelastic collision. After the collision, the composite object moves along the same line with a speed of $v/2$. What is the ratio of the masses m_1/m_2 of the two objects?

(a) 1 (b) 3/2 (c) 3 (d) 1/2 (e) 2

2. In a completely inelastic collision between object-1 of mass m_1 that is initially moving and object-2 of mass m_2 that is initially at rest, a measure of the energy dissipated is the ratio of the kinetic energy of the system after the collision to that before the collision. What is this ratio?

(a) $m_1/(m_1 - m_2)$ (b) $m_2/(m_1 + m_2)$ (c) m_2/m_1 (d) $m_1/(m_1 + m_2)$ (e) m_1/m_2

Questions 3-5

A thin stick of length $L = 2$ m is denser at one end than the other. Its mass density is $\lambda = \frac{1}{2} - \frac{x}{5}$, where x in meters and λ in kg/m. Here x measures the distance from the heavier end of the stick. The stick is initially at rest and it starts rotation with constant angular acceleration $\alpha = 2$ rad/s^2.

3. What is the rotational inertia (moment of inertia) of the stick about an axis perpendicular to the stick through the heavy end?

(a) $\frac{8}{15}$ kg·m^2 (b) $\frac{7}{15}$ kg·m^2 (c) $\frac{9}{14}$ kg·m^2 (d) $\frac{8}{13}$ kg·m^2 (e) $\frac{11}{15}$ kg·m^2

4. What is the rotational kinetic energy of the stick at $t = 2$ s about an axis perpendicular to the stick through the heavy end?

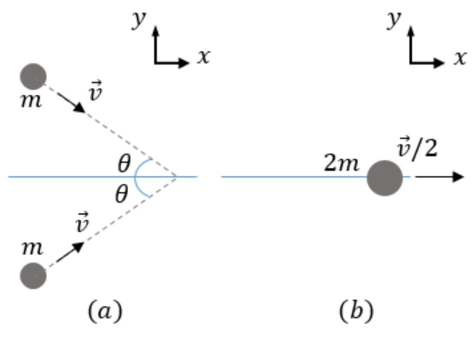
(a) $\frac{64}{15}$ J (b) $\frac{61}{13}$ J (c) $\frac{53}{15}$ J (d) $\frac{47}{15}$ J (e) $\frac{64}{19}$ J

5. What is the magnitude of the torque acting on the stick at $t = 2$ s about an axis perpendicular to the stick through the heavy end?

(a) $\frac{16}{15}\ N \cdot m$ (b) $\frac{19}{15}\ N \cdot m$ (c) $\frac{14}{15}\ N \cdot m$ (d) $\frac{17}{15}\ N \cdot m$ (e) $\frac{13}{15}\ N \cdot m$

Questions 6-7

Two objects with the same mass m and the same speed v have an inelastic collision (see the figure). After the collision the two-object system moves with speed $v/2$



6. What is the tangent of the angle θ between the final line of motion and either of the initial velocities, shown in the figure?

(a) $\sqrt{3}$ (b) $\sqrt{5/3}$ (c) $\sqrt{2}$ (d) $\sqrt{5}$ (e) $\sqrt{3/2}$

7. What is the initial velocity of the center of mass of the system?

(a) $\frac{3v}{2}\hat{\imath}$ (b) $\frac{v}{2}\hat{\imath}$ (c) $\frac{v}{3}\hat{\imath}$ (d) $v\hat{\imath}$ (e) $\frac{v}{4}\hat{\imath}$

Questions 8-10

A time-varying net force acting on a 4-kg particle causes the particle to have a displacement given by $x = 2t - 3t^2 + t^3$ where x is in meters and t is in seconds.

8. What is the kinetic energy of the particle as a function of time in units of joules?

(a) $2(4t^2 - 6t + 1)^2$ (b) $2(3t^2 + 3t - 2)^2$ (c) $2(3t^2 - t + 4)^2$ (d) $2(3t^2 - 6t + 2)^2$ (e) $2(5t^2 - 6t + 2)^2$

9. What is the power transferred to the particle as a function of time in units of watts?

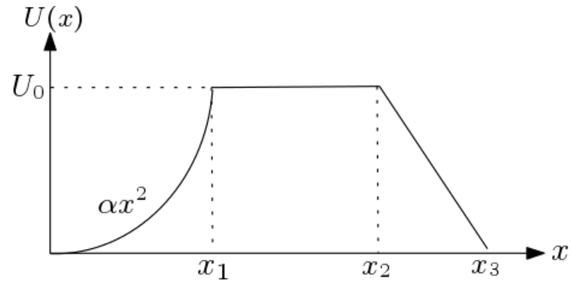
(a) $4(18t^3 - 54t^2 + 48t + 12)$ (b) $4(18t^3 - 27t^2 + 48t - 12)$ (c) $4(18t^3 - 54t^2 + 48t - 12)$ (d) $4(18t^3 - 54t^2 + 14t + 12)$ (e) $4(16t^3 - 54t^2 + 48t - 12)$

10. What is the work done on the particle in between $t = 0$ and $t = 1$ s?

(a) 8 J (b) 6 J (c) −6 J (d) 9 J (e) −8 J

Questions 11-16

An object of mass $m = 4.0\ kg$ is moving along the x-direction under the effect of a force $\vec{F}$ whose potential energy function diagram is shown in the figure: $U(x) = \alpha x^2$ (α is a constant) between $x = 0$ and x_1; it is contant between x_1 and x_2 and linearly decreasing between x_2 and x_3. At $x = 0$, the speed of the object is $v_0 = 4.0\ m/s$. There is no friction, and $x_1 = 20.0\ cm$, $x_2 = 120.0\ cm$, $x_3 = 145.0\ cm$, and $U_0 = 8.0\ J$. Take $g = 10\ m/s^2$.



11. What is the SI unit of the constant α?

(a) N/m^2 (b) $kg \cdot s/m$ (c) $kg \cdot m/s^2$ (d) N/m (e) J/m

12. Which of the following is the force $\vec{F}$ acting on the object between $x = 0$ and $x = x_1$?

(a) $-600x\hat{\imath}\,\mathrm{N}$ (b) $200x\hat{\imath}\,\mathrm{N}$ (c) $-200x\hat{\imath}\,\mathrm{N}$ (d) $-400x\hat{\imath}\,\mathrm{N}$ (e) $400x\hat{\imath}\,\mathrm{N}$

13. What is the speed of the object at $x = x_1$?

(a) $2\ m/s$ (b) $2\sqrt{3}\ m/s$ (c) $3\sqrt{2}\ m/s$ (d) $3\ m/s$ (e) $3\sqrt{3}\ m/s$

14. What is the work done by $\vec{F}$ on the object between $x = x_1$ and $x = x_2$?

(a) $10\ J$ (b) 0 (c) $8\ J$ (d) $-10\ J$ (e) $-8\ J$

15. What is the speed of the object at $x = x_3$?

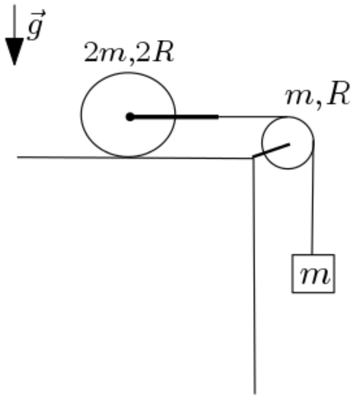
(a) $6.0\ m/s$ (b) $4.0\ m/s$ (c) $3.0\ m/s$ (d) $2.0\ m/s$ (e) 0

16. If there were friction between x_1 and x_2 ($\mu_k = 0.4$), what would be the speed of the object at $x = x_2$?

(a) $3\ m/s$ (b) $5/3\ m/s$ (c) $2\ m/s$ (d) $5/2\ m/s$ (e) $3/2\ m/s$

Questions 17-19

A uniform solid cylinder with mass $2m$ and radius $2R$ rests on a horizontal tabletop. A string is attached by a rod to a frictionless axel through the center of the cylinder so that the cylinder can rotate about the axle. The string runs over a disk shaped pulley with mass m and radius R that is mounted on a frictionless axlethrough its center. A block of mass m is suspended from the free end of the string, as shown in the figure. The string does not slip over the pulley surface, and the cylinder rolls without slipping on the tabletop. (For a solid cylinder of mass M and radius r, $I_{cm} = \frac{1}{2}Mr^2$, and for a disk of mass M and radius r, $I_{cm} = \frac{1}{2}Mr^2$.)



17. Which of the following is the magnitude of the acceleration of the block after the system is released from rest?

(a) $3g/11$ (b) $3g/7$ (c) $4g/9$ (d) $2g/11$ (e) $2g/9$

18. Which of the following is the speed of the block when it falls down a height h?

(a) $\frac{5}{3}\sqrt{gh}$ (b) $\frac{2}{7}\sqrt{gh}$ (c) $\frac{4}{3}\sqrt{gh}$ (d) $\frac{2}{5}\sqrt{gh}$ (e) $\frac{2}{3}\sqrt{gh}$

19. Which of the following is the magnitude of the friction between the table and the solid cylinder?

(a) $\frac{3mg}{11}$ (b) $\frac{2mg}{11}$ (c) $\frac{4mg}{9}$ (d) $\frac{2mg}{7}$ (e) $\frac{2mg}{9}$

20. What is the angular momentum about the origin of a particle of mass m moving along the trajectory $y = ax + b$ (a and b are constants) in the xy-plane with constant speed v?

(a) $\vec{L} = \frac{mvb}{\sqrt{1+a^2}}\hat{k}$ (b) $\vec{L} = -\frac{mvb}{\sqrt{1+a^2}}\hat{\imath}$ (c) $\vec{L} = -\frac{mvab}{\sqrt{1+b^2}}\hat{k}$ (d) $\vec{L} = -\frac{mvb}{\sqrt{1+a^2}}\hat{\jmath}$ (e) $\vec{L} = -\frac{mvb}{\sqrt{1+a^2}}\hat{k}$

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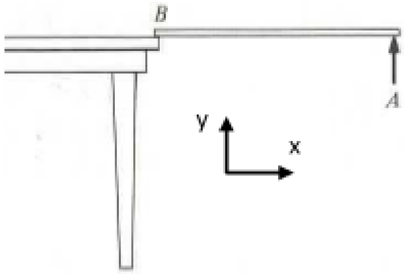
Questions 1-4

A uniform stick of mass m and length l is suspended horizontally with end B at the edge of a table and the other end A is held by hand. Point A is suddenly released. At the instant after release:



1. What is the torque about the end B on the table?
(a) $\frac{l}{2}mg(\hat{\imath}+\hat{\jmath})$ (b) 0 (c) $lmg\hat{k}$ (d) $-\frac{3}{2}mg\hat{k}$ (e) $-\frac{l}{2}mg\hat{k}$

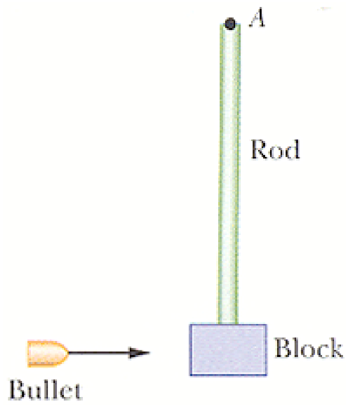
2. What is the angular acceleration about the end B on the table? (For a uniform rod of mass m and length l, $I_{cm} = \frac{1}{12}ml^2$.)
(a) $\frac{2g}{3l}$ (b) $\frac{g}{l}$ (c) $\frac{2g}{l}$ (d) $\frac{3g}{2l}$ (e) $\frac{g}{2l}$

3. What is the vertical acceleration of the center of mass?
(a) g (b) $\frac{4g}{3}$ (c) $\frac{3g}{4}$ (d) $\frac{3g}{2}$ (e) $\frac{2g}{3}$

4. What is the vertical component of the hinge force at B?
(a) $\frac{mg}{3}$ (b) mg (c) $\frac{2mg}{3}$ (d) $\frac{mg}{2}$ (e) $\frac{mg}{4}$

Questions 5-7

A bullet of mass m is fired into a block of mass M_b that is mounted on the end of a nonuniform rod of total mass M and length l. Linear mass density of the rod is $\lambda = c\,y$ where c is a constant and y is the distance from the point A.



5. Find the constant c in terms of M and length l.
(a) $\frac{M}{l}$ (b) $\frac{2\,M}{l^2}$ (c) $\frac{3\,M}{2\,l^2}$ (d) $\frac{M}{l^2}$ (e) $\frac{2\,M}{3\,l^2}$

6. The block-rod-bullet system then rotates about a fixed axis at point A. Assume the block is small enough to treat as a particle on the end of the rod. What is the rotational inertia of the block-rod-bullet system about point A?
(a) $(3M/2 + m + M_b)l^2$ (b) $(2M/3 + m + M_b)l^2$ (c) $(M/2 + m + M_b)l^2$
(d) $(M/3 + m + M_b)l^2$ (e) $(2M + m + M_b)l^2$

7. Now assume that the rod has a constant density and total mass M. If the velocity of the bullet before collision is v, find the angular speed of the rod-bullet-block system about point A after collisin. (For a uniform rod of mass m and length l, $I_{cm} = \frac{1}{12}ml^2$.)
(a) $\frac{mv}{(M+m+M_b)l/12}$ (b) $\frac{mv}{(M+m+M_b)l/3}$ (c) $\frac{mv}{(M/2+m+M_b)l}$ (d) $\frac{mv}{(M/12+m+M_b)l}$ (e) $\frac{mv}{(M/3+m+M_b)l}$

8. Find the ratio of final kinetic energy of the rod-bullet-block system just after the collision to the initial kinetic energy of the bullet just before the collision.
(a) $\frac{m}{M+m+M_b}$ (b) $\frac{m}{M/3+m+M_b}$ (c) $\frac{3m}{M+m+M_b}$ (d) $\frac{m}{M/12+m+M_b}$ (e) $\frac{12m}{M+m+M_b}$

Questions 9-10

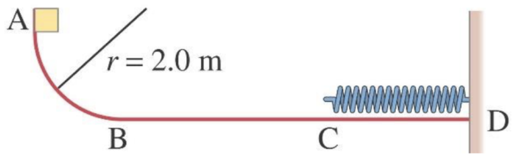
A body of mass 10.0 kg makes an elastic collision with another body at rest and continues to move in the original direction but one-third of its original speed.

9. What is the mass of the other body which is initially at rest?
(a) $5.0kg$ (b) $8.0kg$ (c) $15.0kg$ (d) $10.0kg$ (e) $3.0kg$

10. What is the speed of the two-body center of mass if the initial speed of the 10.0 kg body was 4.5 m/s?
(a) $4.5m/s$ (b) $3.0m/s$ (c) $2.5m/s$ (d) $3.5m/s$ (e) $4.0m/s$

Questions 11-14

Consider the track shown in the figure. The section AB is one quadrant of a circle of radius 2.0 m and is frictionless. B to C is a horizontal span that is 3.0 m long with a coefficient of kinetic friction $\mu_k = 0.25$. The section CD under the spring is frictionless. A block of mass 1.0 kg is released from rest at A. After sliding on the track, it compresses the spring by 0.20 m. Take the gravitational acceleration as $g = 10m/s^2$



11. What is the velocity of the block at point B?

(a) $2\sqrt{10}$ m/s (b) $2\sqrt{5}$ m/s (c) $4\sqrt{5}$ m/s (d) $\sqrt{10}$ m/s (e) $3\sqrt{10}$ m/s

12. What is the thermal energy produced as the block slides from B to C?

(a) 2.5 J (b) 0 J (c) 3 J (d) 5 J (e) 7.5 J

13. What is the the velocity of the block at point C?

(a) 10 m/s (b) 5 m/s (c) 4 m/s (d) 2 m/s (e) 6 m/s

14. What is the stiffness constant k for the spring?

(a) 625 N/m (b) 250 N/m (c) 750 N/m (d) 25 N/m (e) 500 N/m

Questions 15-16

A mass m is on a platform of mass M and height H. A spring with spring constant k, with one end fixed to the platform is used to launch the small mass horizontally. The platform is on a frictionless table, and the friction between the mass and the platform is also negligible. Initially the spring is compressed by an amount d from its natural length, and both the mass and the platform are at rest. Then the system is released.

15. What are the velocities of the mass m, $\vec{v}_m$ and of the platform, $\vec{v}_P$ at the instant the mass leaves the platform.

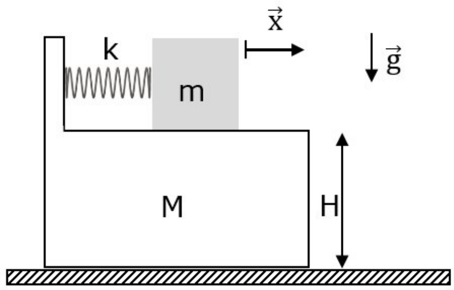
(a) $\vec{v}_m = d\sqrt{\frac{2Mk}{m(m+M)}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{2mk}{M(m+M)}}\hat{i}$

(b) $\vec{v}_m = d\sqrt{\frac{mk}{M(m+M)}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{Mk}{m(m+M)}}\hat{i}$

(c) $\vec{v}_m = d\sqrt{\frac{mk}{2M(m+M)}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{2Mk}{m(m+M)}}\hat{i}$

(d) $\vec{v}_m = d\sqrt{\frac{Mk}{m(m+M)}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{mk}{M(m+M)}}\hat{i}$

(e) $\vec{v}_m = d\sqrt{\frac{k}{m+M}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{k}{m+M}}\hat{i}$

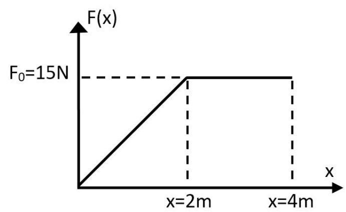


16. What is the distance between the mass and the platform when the mass hits the floor.

(a) $d\sqrt{\frac{2Hk(m+M)}{mMg}}$ (b) $d\sqrt{\frac{2MHk}{m(m+M)g}}$ (c) $d\sqrt{\frac{4Hk(m+M)}{mMg}}$ (d) $d\sqrt{\frac{Hk}{Mg}}$ (e) $d\sqrt{\frac{2mHk}{M(m+M)g}}$

Questions 17-20

A block of mass $m = 2\ kg$ is moving under the effect of a 1-dimensional force F(x) between $x = 0$ and $x = 4\ m$. The graph of the force as a function of position is given in the figure.



17. What is the work done by F between $x = 0$ and $x = 4\ m$.

(a) $40\ J$ (b) $42\ J$ (c) $50\ J$ (d) $45\ J$ (e) $35\ J$

18. If $F(x)$ is a conservative force, which of the following is the potential energy function between $x = 0$ and $x = 2\ m$ in units of joules, taking $U(0) = 2\ J$?

(a) $2 + \frac{15}{2}x^2$ (b) $2 + \frac{15}{2}x$ (c) $2 - \frac{15}{4}x$ (d) $2 - \frac{15}{4}x^2$ (e) $2 + \frac{15}{4}x^2$

19. If the block is initially at rest at $x = 0$, what is the speed of the block at $x = 2\ m$ in units of m/s?

(a) $2\sqrt{15}$ (b) $2\sqrt{30}$ (c) $\sqrt{15}$ (d) $\sqrt{30}$ (e) $3\sqrt{15}$

20. If there is friction between $x = 2\ m$ and $x = 4\ m$ with coefficient of kinetic friction $\mu_k = 0.2$, what is the speed of the block at $x = 4\ m$ in units of m/s?

(a) $\sqrt{39}$ (b) 7 (c) $\sqrt{37}$ (d) $\sqrt{41}$ (e) 6

Group Number		Name		Type
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1. The moment of inertia of a thin homogeneous disc rotating about its axis of symmetry, perpendicular to the plain of disc is given as I. One third is cut and paste as shown in figure. What is the moment of inertia of the obtained object with respect to the same rotation axis?

(a) $3I/2$ (b) $I/3$ (c) $2I/3$ (d) $4I/9$ (e) I

Questions 2-5

The potential energy of a particle is given by $U(x, y) = \frac{1}{4}(1 - x^2)^2 + \frac{1}{2}y^2 + \frac{1}{2}x^2y^2$ in joules.

2. Find the components of the force acting on the particle in N.
(a) $F_x = \frac{1}{4}(1 - x^2)^2 + \frac{1}{2}x^2y^2$, $F_y = \frac{1}{2}y^2 + \frac{1}{2}x^2y^2$
(b) $F_x = (1 - x^2)x - xy^2$, $F_y = -y(1 + x^2)$
(c) $F_x = -(1 - x^2)x$, $F_y = 0$
(d) $F_x = -(1 - x^2)x - xy^2$, $F_y = y(1 + x^2)$
(e) $F_x = (1 - x^2)x$, $F_y = 0$

3. At which position (in meters) given below, the particle is in equilibrium along the y-axis?
(a) $y = \sqrt{1 - x^2}$ (b) $y = -\sqrt{1 - x^2}$ (c) $x = -1$ (d) $x = 0$ (e) $y = 0$

4. What is F_x (in Newton) when the particle is in equilibrium along the y-axis?
(a) $F_x = (1 - x^2)x$ (b) $F_x = \frac{1}{4}(1 - x^2)^2$ (c) $F_x = 0$ (d) $F_x = -(1 - x^2)x$ (e) $F_x = \frac{1}{2}y^2$

5. What is the total work done on the particle when it moves from the initial position $\{x, y\} = \{0\text{m}, 0\text{m}\}$ to the final position $\{x, y\} = \{1\text{m}, 0\text{m}\}$?
(a) 0 (b) 1/4 J (c) -1/4 J (d) -2/3 J (e) 2/3 J

6. Which of the following is always correct?
(a) $\sum \vec{F}_{\text{ext}} = \frac{d\vec{p}}{dt}$ (b) $\sum \vec{F}_{\text{int}} = m\vec{a}$ (c) $\sum \vec{F}_{\text{int}} = \frac{d\vec{p}}{dt}$ (d) $\sum \vec{F}_{\text{ext}} = m\vec{a}$ (e) $m\vec{a} = -\frac{dm}{dt}\vec{v}$

7. Various bodies at rest are left from the top of a frictionless inclined plane. In what order will these bodies reach the bottom of the inclined? SS=Solid sphere, TS=Thin-walled hollow sphere, SC=Solid cylinder, TC=Thin-walled hollow cylinder.
(a) SC,SS,TC,TS (b) SS,SC,TS,TC (c) All at the same time (d) SS,TS,SC,TC (e) SC,TC,SS,TS

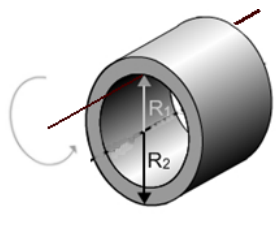
Questions 8-9

A solid cylinder rolls without slipping down a ramp, which is inclined at an angle β to the horizontal. Direction of rolling is parallel to the inclination. M is the mass and R is the radius of the cylinder, and the moment of inertia of a disc with mass M and radius R with respect to the axis of symmetry is $I = \frac{1}{2}MR^2$.

8. What is the cylinder's acceleration a_{cm} along the ramp?
(a) $a_{\text{cm}} = \frac{5}{7}g\cos\beta$ (b) $a_{\text{cm}} = \frac{5}{7}g\sin\beta$ (c) $a_{\text{cm}} = \frac{2}{3}g\sin\beta$ (d) $a_{\text{cm}} = g\sin\beta$ (e) $a_{\text{cm}} = \frac{2}{3}g\cos\beta$

9. What is the magnitude of the friction force f on the cylinder?
(a) $f = \frac{2}{7}Mg\sin\beta$ (b) $f = \frac{1}{3}Mg\cos\beta$ (c) $f = 0$ (d) $f = \frac{1}{3}Mg\sin\beta$ (e) $f = \frac{2}{7}Mg\cos\beta$

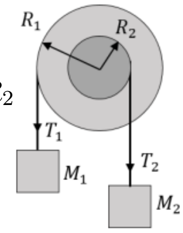
10. What is the kinetic energy of an hollow cylinder of mass M rotating with an angular speed ω about the axis passing parallel through it's inner wall as shown in figure? $R_2 = 2R$ is the radius of the outer wall and $R_1 = R$ is the radius of the inner wall (empty part) of the hollow cylinder.



(a) $\frac{9}{8}MR^2\omega^2$ (b) $\frac{5}{4}MR^2\omega^2$ (c) $\frac{7}{4}MR^2\omega^2$ (d) $\frac{17}{4}MR^2\omega^2$ (e) $\frac{1}{2}MR^2\omega^2$

Questions 11-13

A winch has a moment of inertia I passing throughout its center of symmetry. Two masses M_1 and M_2 ($M_1 > M_2$) are attached to strings which are wrapped around different parts of the winch which have radii R_1 and R_2. ($R_1 > R_2$, g is the gravitational acceleration.)



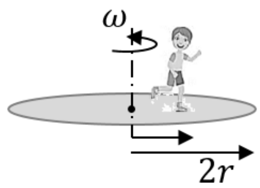
11. How are the linear acceleration a_1 and a_2 of the masses M_1 and M_2 and those with the angular acceleration α of the winch related?
(a) $\alpha = a_1/R_2 = a_2/R_1$ (b) $\alpha = a_1R_1 = a_2R_2$ (c) $\alpha = R_2/a_1 = R_1/a_2$ (d) $\alpha = a_1/R_1 = a_2/R_2$
(e) $\alpha = R_1/a_1 = R_2/a_2$

12. What is the angular acceleration α of the winch?
(a) $\alpha = g(R_2M_1 + R_1M_2)/(I + M_1{R_1}^2 + M_2{R_2}^2)$
(b) $\alpha = g(R_2M_1 - R_1M_2)/I$
(c) $\alpha = g(R_1M_1 + R_2M_2)/(I + M_1{R_1}^2 + M_2{R_2}^2)$
(d) $\alpha = g(R_1M_1 - R_2M_2)/(I + M_1{R_1}^2 + M_2{R_2}^2)$
(e) $\alpha = g(R_1M_1 - R_2M_2)/I$

13. What are the tensions T_1 and T_2 in the strings?
(a) $T_1 = M_1(g + R_1\alpha)$, $T_2 = M_2(g - R_2\alpha)$
(b) $T_1 = M_2(g - R_1\alpha)$, $T_2 = M_1(g + R_2\alpha)$
(c) $T_1 = M_1(g - R_1\alpha)$, $T_2 = M_2(g + R_2\alpha)$
(d) $T_1 = M_1(g - R_1\alpha)$, $T_2 = M_2(g - R_2\alpha)$
(e) $T_1 = M_2(g + R_1\alpha)$, $T_2 = M_1(g - R_2\alpha)$

Questions 14-18

A disc with a boy displaced a distance $r = 1$ m from the center on it, rotates around the axis of symmetry with an initial angular speed of $\omega = 6$ rad/s. The mass of the boy is $m = 12$ kg, the mass of the disc is $M = 7m$ and the radius of the disc is $R = 2r$. (The moment of inertia of a disc with mass M and radius R with respect to the axis of symmetry is $I = \frac{1}{2}MR^2$)



14. How much has the center of mass of the boy-disc system displaced along the radial direction as the boy walks straight to the rim (the edge) of the disc?
(a) $R/7$ (b) $r/4$ (c) $R/4$ (d) $r/8$ (e) $r/7$

15. The boy now stands on the rim. What is the angular speed ω in rad/s?
(a) 4 (b) 5 (c) 2/3 (d) 24/5 (e) 36/5

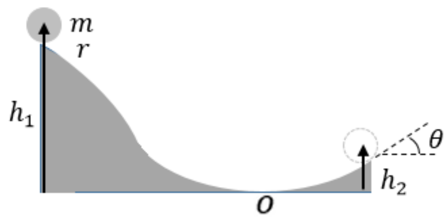
16. The boy still stands on the rim. Calculate the kinetic energy of boy-disc system.
(a) 3888 J (b) 2700 J (c) 48 J (d) 2250 J (e) 1728 J

17. A friction force 360 N is applied to the rim which causes the disc to decelerate, and eventually to stop. What is the magnitude of the angular acceleration α in rad/s^2 ?
(a) 17/3 (b) 3 (c) 4 (d) 9/2 (e) 10/3

18. What time is needed to bring the disc to stop?
(a) 3/2 s (b) 9/5 s (c) 4/3 s (d) 2 s (e) 12/5 s

Questions 19-20

A ball with mass m and radius r initially at rest rolls down the track without slipping. Moment of inertia of the ball with respect to the axis of symmetry is $I = \frac{2}{5}mr^2$. h_1 and h_2 are the heights of the center of mass with respect to point O. (assume $h = h_1 - r$, g is the gravitational acceleration)



19. What is the speed of center of mass as it arrives point O?
(a) $\sqrt{10gh/7}$ (b) $\sqrt{4gh/3}$ (c) $\sqrt{3gh}$ (d) $\sqrt{5gh/7}$ (e) $\sqrt{3gh/4}$

20. What is the maximum height with respect to height h_2 if the ball leaves the track at height h_2 with an angle θ? ($\sin\theta = 1/2$, $\cos\theta = \sqrt{3}/2$)
(a) $\frac{5}{7}(h_1 - h_2 - r)$ (b) $\frac{15}{28}(h_1 - h_2)$ (c) $\frac{5}{7}(h_1 - h_2)$ (d) $\frac{1}{4}(h_1 - h_2 + r)$ (e) $\frac{5}{28}(h_1 - h_2)$

Group Number		Name		Type
List Number		Surname		A
Student ID		Signature		
e-mail				

ATTENTION: There is only one correct answer for each question and each correct answer is equal to 1 point. Only the answers on your optical answer sheet form will be evaluated. Please be sure that you have marked all of your answers on the optical answer sheet form by using a pencil (*not* pen).

Questions 1-2

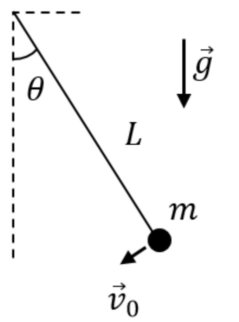
The potential energy function of a force is given as $U(x) = (ax^4 + bx^3 + cx^2 + dx + e)/12$, where a=−3 N/m^3, b=8 N/m^2, c=6 N/m, d=−24 N and e=3 Nm.

1. If the corresponding force is $\vec{F}(x) = (x + f)(x + g)(x + h)\hat{\imath}$ N/m^3, what are the constants f, g and h in meters?
(a) $+1, -1, -2$ (b) $-1, +1, +2$ (c) $-1, -1, +2$ (d) $-1, -1, -2$ (e) $+1, +1, +2$

2. What is (are) the extreme point(s) x of $U(x)$ in meters? The extreme points are the values of x where the system is in equilibrium.
(a) $-2, -1, +2$ (b) $-1, +1, +2$ (c) $+1, +2$ (d) $+1$ (e) $-1, +2$

Questions 3-5

The point-like bob of mass m of a simple pendulum of length L is observed to have a speed v_0 when the cord makes an angle θ with the vertical. (g is the magnitude of the gravitational accelereation.)



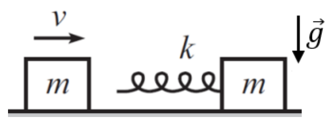
3. What is the speed of the bob when it is in its lowest position?
(a) $\sqrt{2gL\cos\theta}$ (b) $\sqrt{2gL(1+\cos\theta)+v_0^2}$ (c) $\sqrt{2gL(1-\cos\theta)+v_0^2}$ (d) $\sqrt{gL(3+2\cos\theta)}$
(e) $\sqrt{gL(3-2\cos\theta)}$

4. What is the least value that v_0 can have if the cord is to swing up to a horizontal position?
(a) $\sqrt{2gL(1-\cos\theta)+v_0^2}$ (b) $\sqrt{gL(3+2\cos\theta)}$ (c) $\sqrt{2gL(1+\cos\theta)+v_0^2}$ (d) $\sqrt{gL(3-2\cos\theta)}$
(e) $\sqrt{2gL\cos\theta}$

5. What is the least value that v_0 can have if the cord is to swing up to the highest vertical position with the cord remaining straight?
(a) $\sqrt{gL(3-2\cos\theta)}$ (b) $\sqrt{2gL(1+\cos\theta)+v_0^2}$ (c) $\sqrt{gL(3+2\cos\theta)}$ (d) $\sqrt{2gL\cos\theta}$ (e) $\sqrt{2gL(1-\cos\theta)+v_0^2}$

Questions 6-9

A massless spring with spring constant k is attached to a stationary block of mass m as shown in the figure. Another block of mass m slides to the right toward the stationary block and sticks to the left end of the spring and compresses the spring. Let v be the speed of the sliding block just before it hits the spring.



Answer the questions 6 and 7 assuming that the surface of the table is frictionless.

6. What is the common speed of the blocks at the instant when the spring gets compressed maximum?
(a) $v/4$ (b) $v/2$ (c) v (d) 0 (e) $v/8$

7. What is the maximum distance the spring gets compressed?
(a) $v\sqrt{\frac{31m}{32k}}$ (b) $v\sqrt{\frac{m}{4k}}$ (c) $v\sqrt{\frac{7m}{8k}}$ (d) $v\sqrt{\frac{m}{k}}$ (e) $v\sqrt{\frac{m}{2k}}$

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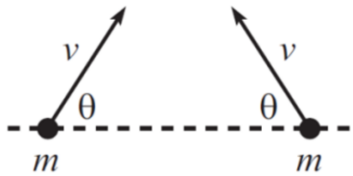
Answer the questions 8 and 9 assuming that the surface of the table is frictional with the coefficient of friction μ (both static and kinetic) between the masses and the surface.

8. What is the maximum compression distance x for which the stationary block never moves?
(a) $\mu\frac{mg}{4k}$ (b) $\mu\frac{mg}{2k}$ (c) $\mu\frac{4mg}{k}$ (d) $\mu\frac{2mg}{k}$ (e) $\mu\frac{mg}{k}$

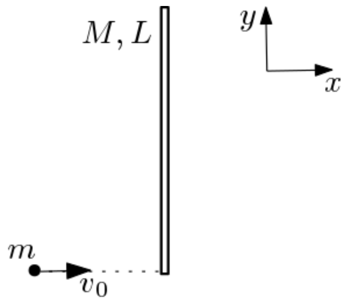
9. What is the largest value of v for which the stationary block never moves?
(a) $\frac{3}{4}\mu g\sqrt{\frac{m}{k}}$ (b) $\mu g\sqrt{\frac{3m}{k}}$ (c) $2\mu g\sqrt{\frac{2m}{k}}$ (d) $\frac{1}{2}\mu g\sqrt{\frac{5m}{k}}$ (e) $2\mu g\sqrt{\frac{6m}{k}}$

10. On a frictionless table two identical particles of mass m and speed v move toward each other, making an angle θ with the horizontal, as shown in the figure. They collide and stick together. How much kinetic energy is lost during the collision?
(a) $mv^2 \sin\theta$ (b) mv^2 (c) $mv^2 \cos^2\theta$ (d) $mv^2 \sin^2\theta$ (e) $mv^2 \cos\theta$



Questions 11-15

A uniform rod of mass $M = 4m$ and length L is initially at rest on a frictionless table. A point particle of mass m and speed v_0 hits the rod and bounces back in the opposite direction with speed $v_0/3$, as shown in the figure. (For a uniform rod of mass M and length L, $I_{cm} = \frac{1}{12}ML^2$.)



11. Which of the following is the center of mass velocity of the rod just after the collision?
(a) $\frac{1}{3}v_0\hat{\imath}$ (b) $\frac{1}{4}v_0\hat{\imath}$ (c) $-\frac{1}{3}v_0\hat{\imath}$ (d) $-\frac{1}{4}v_0\hat{\imath}$ (e) $\frac{3}{2}v_0\hat{\imath}$

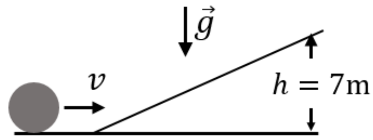
12. What is the angular speed of the rod about its center of mass just after the collision?
(a) $\frac{3}{2L}v_0$ (b) $\frac{1}{L}v_0$ (c) $\frac{1}{3L}v_0$ (d) $\frac{2}{L}v_0$ (e) $\frac{2}{3L}v_0$

13. What is the impulse transferred to the point particle m during the collision?
(a) $\frac{3}{4}mv_0\hat{\imath}$ (b) $-\frac{3}{2}mv_0\hat{\imath}$ (c) $-\frac{4}{5}mv_0\hat{\imath}$ (d) $-\frac{4}{3}mv_0\hat{\imath}$ (e) $\frac{3}{2}mv_0\hat{\imath}$

14. If the collision were completely inelastic, what would be the center of mass velocity of the system just after the collision?
(a) $\frac{3}{5}v_0\hat{\imath}$ (b) $\frac{1}{3}v_0\hat{\imath}$ (c) $-\frac{1}{5}v_0\hat{\imath}$ (d) $-\frac{1}{3}v_0\hat{\imath}$ (e) $\frac{1}{5}v_0\hat{\imath}$

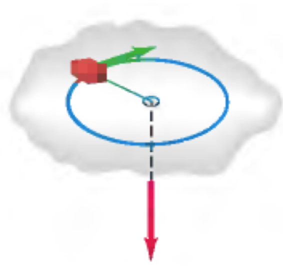
15. If the collision were completely inelastic, what would be the angular speed of the system about the new center of mass?
(a) $\frac{4}{3L}v_0$ (b) $\frac{5}{4L}v_0$ (c) $\frac{6}{5L}v_0$ (d) $\frac{1}{L}v_0$ (e) $\frac{3}{4L}v_0$

16. A solid, uniform ball rolls without slipping on a horizontal surface as shown in the figure. What is the minimum speed of the ball in order to reach to the height h on the inclined plane? (g=10 m/s^2, moment of inertia for a solid ball of mass M and radius R with respect to an axis throughout its center-of-mass is $\frac{2}{5}MR^2$)
(a) 10 m/s (b) 20 m/s (c) $\sqrt{15}$ m/s (d) 5 m/s (e) $\sqrt{10}$ m/s



Questions 17-18

A small block on a frictionless, horizontal surface has a mass of 1 kg. It is attached to a massless cord passing through a hole in the surface The block is originally revolving at a distance of 0.2 m from the hole with an angular speed of 50 RPM (Revolutions Per Minute). The cord is then pulled from below, shortening the radius of the circle in which the block revolves to the half of the original distance.

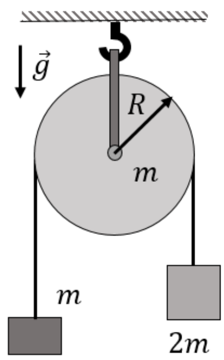


17. What is the new angular speed in RPM?
(a) 500 (b) 200 (c) 400 (d) 100 (e) 300

18. How much work was done in pulling the cord?
(a) $\pi^2/3$ J (b) 0 J (c) $2\pi^2/3$ J (d) $\pi^2/6$ J (e) $\pi^2/60$ J

Questions 19-20

Two blocks of masses m and $2m$ are connected by a very light flexible cord that runs without slipping over a pulley of mass m. The pulley is a solid uniform disk and is supported by a hook connected to the ceiling. The pulley rotates about its axle without friction. (The moment of inertia of a pulley with masss M and radius R, about its axle is given as $\frac{1}{2}MR^2$)



19. What is the acceleration of the blocks?
(a) $2g/7$ (b) $g/10$ (c) $3g/5$ (d) $2g/5$ (e) $g/5$

20. What force does the ceiling exert on the hook?
(a) $6mg$ (b) $9mg/5$ (c) $26mg/7$ (d) $18mg/5$ (e) $4mg$