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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 of the following is the unit of Power in MKS unit system?

(a) kg m/s (b) none of them (c) $\text{kg m}^2/\text{s}$ (d) $\text{kg m}^2/\text{s}^2$ (e) $\text{kg m}^2/\text{s}^3$

2. Two vectors, $\vec{a} = \hat{\imath} + 2\hat{\jmath} - \hat{k}$ and $\vec{b} = \hat{\imath} + \hat{\jmath} - 2\hat{k}$ are given. What is the magnitude of $\vec{c} \cdot (\vec{a} \times \vec{b})$ if $\vec{c} = 2\vec{a} - 3\vec{b}$ is given as a new vector?

(a) $\sqrt{35}$ (b) 0 (c) $\sqrt{29}$ (d) 5 (e) 6

3. The two non-zero vectors $\vec{a}$ and $\vec{b}$ satisfy the equation $|\vec{a} + \vec{b}| = |\vec{a} - \vec{b}|$. What is the angle between $\vec{a}$ and $\vec{b}$?

(a) $0°$ (b) $45°$ (c) $90°$ (d) $30°$ (e) $180°$

4. What is the unit vector $\hat{e}_d$ in the direction of vector $\vec{d} = -2\hat{\imath} + \hat{\jmath} - 2\hat{k}$?

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

5. Consider an object with acceleration function $a(t) = 3t\ \text{m/s}^3 - 3\ \text{m/s}^2$ with initial conditions $v(t=0) = 1$ m/s and $x(t=0) =$ 2m. What is the magnitude of the position of the object at $t = 1$ s?

(a) 2 m (b) 5 m (c) 4 m (d) 6 m (e) 3 m

6. Which step of the following derivation is wrong or includes an invalid operation for the time independent expression of motion with constant acceleration?

I. $\vec{s} = \vec{v}t$

II. $\vec{s} = \left[\frac{\vec{v}+\vec{v_0}}{2}\right] \cdot \left[\frac{\vec{v}-\vec{v_0}}{\vec{a}}\right]$

III. $2\vec{a} \cdot \vec{s} = (\vec{v} + \vec{v_0}) \cdot (\vec{v} - \vec{v_0})$

IV. $2\vec{a} \cdot \vec{s} = \vec{v} \cdot \vec{v} - \vec{v_0} \cdot \vec{v_0}$

V. $2\vec{a} \cdot \vec{s} = v^2 - v_0^2$

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

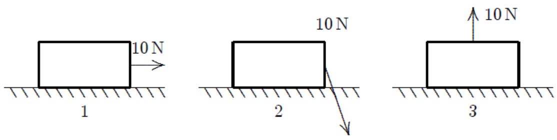
7. A cruise ship moves southward in still water at a speed of 20.0 km/h, while a passenger on the deck of the ship walks toward the east at a speed of 5.0 km/h. The passenger's velocity with respect to Earth is

(a) 20.6 km/h, west of south. (b) 25.0 km/h, east. (c) 20.6 km/h, south. (d) 25.0 km/h, south. (e) 20.6 km/h, east of south.

8. Sum of real forces acting on an astronaut who is inside a space shuttle circular orbiting the Earth is zero when the astronaut feels weightless. What can be said about the previous statement?

(a) Depends on the orbit. (b) True. (c) False. (d) If centrifugal force cancels the weight of the astronaut then it is true. (e) Depends on the kind of planet, e.g. Earth.

9. A box is pulled with a 10 N force by a woman, the crate moves 10 m to the right. Rank the situations shown below according to the work done by her force, least to greatest.



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

10. During a soccer game, a soccer ball is hit high into the upper rows of the tribunes. Over its entire flight the work done by gravity and the work done by air resistance, respectively, are:

(a) unknown, insufficient information (b) negative; positive (c) negative; negative (d) positive; negative (e) positive; positive

Questions 11-13

A rabbit runs in a garden such that the $x-$ and $y-$ components of its displacement as function of times are given by $x(t) = (5.0\ \text{m/s})t + (6.0\ \text{m/s}^2)t^2$ and $y(t) = (7.0\ \text{m}) - (3.0\ \text{m/s}^3)t^3$ (Both x and y are in meters and t is in seconds.)

11. Calculate the rabbit's velocity vector (m/s) at $t = 3.0$ s.

(a) $41\hat{\imath} - 81\hat{\jmath}$ (b) $41\hat{\imath} + 81\hat{\jmath}$ (c) $31\hat{\imath} - 81\hat{\jmath}$ (d) $31\hat{\imath} + 81\hat{\jmath}$ (e) $55\hat{\imath}$

12. Calculate the rabbit's acceleration vector (m/s^2) at $t = 3.0$ s

(a) $54\hat{\imath} - 12\hat{\jmath}$ (b) $54\hat{\imath} + 12\hat{\jmath}$ (c) $12\hat{\imath} + 54\hat{\jmath}$ (d) $12\hat{\imath} - 54\hat{\jmath}$ (e) $54\hat{\imath}$

13. Calculate the rabbit's position vector at $t = 3.0$ s.

(a) $69\hat{\imath} - 20\hat{\jmath}$ (b) $69\hat{\imath} + 71\hat{\jmath}$ (c) $69\hat{\imath} + 74\hat{\jmath}$ (d) $69\hat{\imath} - 74\hat{\jmath}$ (e) $69\hat{\imath} - 71\hat{\jmath}$

Questions 14-15

A golf ball is kicked with an initial velocity of v_0 from the ground and initial angle of θ with respect to the horizontal. Assume the golf ball leaves the foot at ground level, and ignore air resistance and rotation of the ball.

14. How high will the golf ball be at the highest point of its trajectory?

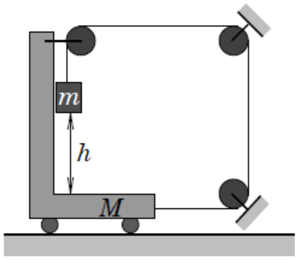
(a) $\frac{(v_0\cos\theta)^2}{2g}$ (b) $\frac{(v_0\cos\theta)^2}{g}$ (c) $\frac{(2v_0\sin\theta)^2}{g}$ (d) $\frac{(v_0\sin\theta)^2}{2g}$ (e) $\frac{\sqrt{v_0\sin\theta}}{g}$

15. Where will the golf ball fall back to the ground?

(a) $\frac{v_0^2\sin\theta}{2g}$ (b) $\frac{v_0^2\cos\theta}{2g}$ (c) $\frac{v_0^2\sin 2\theta}{g}$ (d) $\frac{v_0^2\cos 2\theta}{g}$ (e) $\frac{v_0^2\sin\theta\cos\theta}{g}$

Questions 16-20

The mass m is at rest at the beginning of the motion when it is h above the surface of M. The friction in all of the surfaces and the weight of pulleys will be neglected in this question. (Two pulleys at the right hand side are fixed and the pulley at left hand side is moving with M during the motion.)



16. What is the relationship between the x-component of the acceleration of m a_{mx} and the x-component of the acceleration of M a_{Mx}?

(a) $a_{mx} = a_{Mx}$ (b) $a_{mx} = 3a_{Mx}$ (c) $a_{mx} = 2a_{Mx}$ (d) $a_{mx} = a_{Mx}/3$ (e) $a_{mx} = a_{Mx}/2$

17. What is the relationship between the y-component of the acceleration of m a_{my} and the x-component of the acceleration of M a_{Mx}?

(a) $a_{my} = 3a_{Mx}$ (b) $a_{my} = a_{Mx}/3$ (c) $a_{my} = a_{Mx}/2$ (d) $a_{my} = 2a_{Mx}$ (e) $a_{my} = a_{Mx}$

18. Express the y-component of the acceleration of m a_{my} in terms of m, M and g.

(a) $4m\,g/(5m + M)$ (b) $5m\,g/(3m + 2M)$ (c) $5m\,g/(4m + M)$ (d) $2m\,g/(5m + M)$ (e) $4m\,g/(3m + M)$

19. Express the tension in the string in terms of m, M and g.

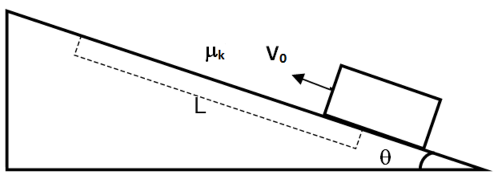
(a) $m\,g\,(m + M)/(5m + M)$ (b) $m\,g\,(m + M)/(4m + M)$ (c) $m\,g\,(m + M)/(3m + 2M)$ (d) $2m\,g\,(m + M)/(4m + M)$ (e) $2m\,g\,(m + M)/(5m + M)$

20. Express the time for mass m to reach the surface if M in terms of the acceleration of m, h and g.

(a) $\sqrt{2h\,g/a_{my}}$ (b) $\sqrt{2h/a_{mx}}$ (c) $\sqrt{2h\,g/a_{mx}}$ (d) $\sqrt{g\,h/2a_{my}}$ (e) $\sqrt{2h/a_{my}}$

Questions 21-25

A box drops down from a lorry while moving with a speed of 10 m/s on the road with inclination $\theta°$, where mass of the box and kinetic friction coefficient are 10 kg and μ_k, respectively. For the moment that the box slides up and reaches possible maximum height (L), find;
(take $g = 10\text{m/s}^2$)



21. Work done on the box by the net force

(a) 0.5 kJ (b) -0.5 kJ (c) -1 kJ (d) 0 kJ (e) 1 kJ

22. The distance that the box has taken during the slide

(a) $W_{net}/mg(\sin\theta - \mu_k\cos\theta)$ (b) $W_{net}/mg(\sin\theta + \mu_k\cos\theta)$ (c) $W_{net}/(\sin\theta - \mu_k\cos\theta)$ (d) $W_{net}/mg(\cos\theta + \mu_k\sin\theta)$ (e) $W_{net}/(\sin\theta + \mu_k\cos\theta)$

23. Work done on the box by gravitation

(a) $-mgL\mu_k\cos\theta$ (b) $mgL\sin\theta$ (c) $-mgL\tan\theta$ (d) $-mgL\sin\theta$ (e) $-mgL\cos\theta$

24. Work done on the box by normal force

(a) $mg(\cos\theta - \mu_k\sin\theta)$ (b) $mgL\sin\theta$ (c) 0 (d) $mg(\cos\theta + \mu_k\sin\theta)$ (e) $-mgL\mu_k\cos\theta$

25. Work done on the box by friction

(a) $-mg\mu_k L\sin\theta$ (b) mgL (c) $-mg\mu_k\cos\theta$ (d) $-mg\mu_k L\cos\theta$ (e) $-mgL\cos\theta$

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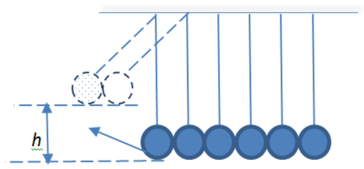
1. Which one of the following is not a unit of energy?

(a) J (b) N m (c) dyn cm (d) $\text{kg}\,\text{m}^3/\text{s}^2$ (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?

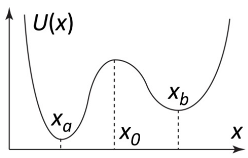


(a) One ball on the far right end rises up to $2h$ (b) Two balls on the far right end rise up to $h/2$ (c) Two balls on the far right end rise up to $2h$ (d) One ball on the far right end rises up to h (e) Two balls on the far right end rise up to h

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) $-(kx^2_{max})/2$ (d) None of them (e) $(kx^2_{max})/2$

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) $\vec{v}/2$

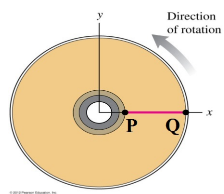
6. A sudden interaction changes the velocity of a particle of mass m from $-v\hat{j}$ to $v\hat{i}$. What is the net impulse that the particle experienced?

(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?

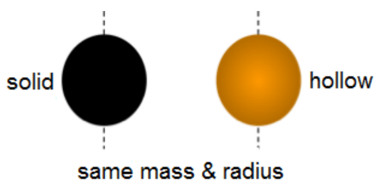


(a) Q has a greater a_{rad} and a greater a_{tan} than P. (b) P and Q have the same a_{rad}, but Q has a greater a_{tan} than P. (c) not enough information given to decide. (d) Q has a smaller a_{rad} and a greater a_{tan} than P. (e) P and Q have the same a_{rad} and a_{tan}.

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?



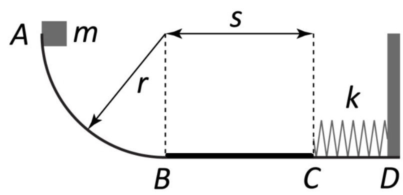
(a) solid aluminum = (1/2) hollow gold (b) solid aluminum (c) hollow gold (d) hollow gold = (1/2) solid aluminum (e) same

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?

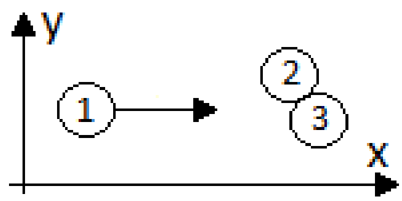
(a) 20 N/m (b) 400 N/m (c) 50 N/m (d) 100 N/m (e) 200 N/m

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?

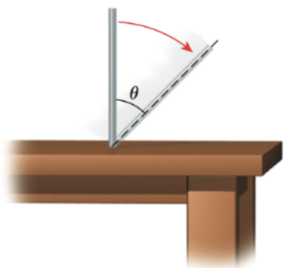
(a) $3\,\hat{i}$ (b) $10/3\,\hat{i}$ (c) $8/3\,\hat{i}$ (d) $2\,\hat{i}$ (e) $7/3\,\hat{i}$

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 skater spins with extended arms. (Assume no frictional torque.) Upon pulling his arms towards his chest, the skater's rotational velocity doubles. Which of the following is INCORRECT?

(a) The increased angular velocity occurs without applying a torque. (b) the skater's moment of inertia decreases to half its original value. (c) Muscle's of the skater perform work. (d) the rotational kinetic energy doubles (e) The angular momentum doubles

2. Five objects of mass m move at velocity **v** at a distance r from an axis of rotation perpendicular to the page through point A, as shown in figure page. At which one the angular momentum is zero about that axis?

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

3. A solid cylinder has a moment of inertia of 2 kg $\cdot$ m^2. It is at rest at time zero when a net torque given by $\tau = 6t^2 + 6$ (SI units) is applied. Find angular velocity of the cylinder after 2s.

(a) 14 rad/s (b) 28 rad/s (c) 3.0 rad/s (d) 12 rad/s (e) 24 rad/s

4. A solid ball of radius "R_1", and mass "M_1" (I_1=(2/5)M_1 R_1^2) and a hollow ball of mass "M_2" and radius "R_2". (I_2=(3/5)M_2 R_2^2) are released from the top of an inclined plane at the same time with zero initial velocity. Which ball will reach the bottom of the incline first? (Neglect air friction and assume balls are rolling without slipping.)

(a) Both at the same time (b) The ball with larger radius (c) Hollow ball, (d) Heavier ball, (e) Solid ball,

5. Which of the following(s) is/are true?
i. $\sum_i \vec{F}_i = 0$ is sufficient for static equilibrium to exist.
ii. $\sum_i \vec{F}_i = 0$ is necessary for static equilibrium to exist.
iii. In static equilibrium, the net torque about any point is zero.

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

6. A cylinder is placed by a frictionless surface formed by a plane inclined at angle θ to the horizontal on the left as shown in the figure. In which θ $\vec{F}$ has the largest value? (Look at the figures page)

(a) 60° (b) 45° (c) 40° (d) 80° (e) 30°

7. A mass m is hung from a clothesline stretched between two poles. As a result, the clothesline sags slightly as shown in figure. The tension on the clothesline is

(a) considerably greater than mg/2 (b) slightly greater than mg/2 (c) mg (d) mg/2 (e) considerably less than mg/2

8. Which is stronger, Earth's pull on the Moon, or the Moon's pull on Earth?

(a) the Moon pulls harder on the Earth (b) they pull on each other equally (c) the Earth pulls harder on the Moon (d) there is no force between the Earth and the Moon (e) it depends upon where the Moon is in its orbit at that time

9. If the distance to the Moon were doubled, then the force of attraction between Earth and the Moon would be:

(a) the same (b) two times (c) one quarter (d) one half (e) four times

10. Two satellites A and B of the same mass are going around Earth in concentric orbits. The distance of satellite B from Earth's center is twice that of satellite A. What is the ratio of the centripetal force acting on B compared to that acting on A?

(a) 1/8 (b) it's the same. (c) 2 (d) 1/4 (e) 1/2

Questions 11-15

An open door of mass M is hinged to a wall and at rest. A ball of putty (macun) of mass m (m<<M) strikes the door at a point that is a distance D from an axes through the hinges (see figure a). The initial velocity, $\vec{V}$, of the putty makes an angle θ with a normal to the door, and the putty sticks to the door after the collision (see figure b). The door has a uniform mass density and width ℓ. Neglect friction in the hinges during the time interval of the collision.

11. Find the total angular momentum of the system (door plus putty) about the hinge before the collosion?

(a) $L_i = \ell mV \sin\theta$ (b) $L_i = DmV \cos\theta$ (c) $L_i = DmV \sin\theta$ (d) $L_i = DmV$ (e) $L_i = \ell mV$

12. Find the total moment of inertia of the system about the hinge.

(a) $I = M\ell^2/3$ (b) $I = \ell^2(2m + M/3)$ (c) $I = mD^2 + M\ell^2/3$ (d) $I = m\ell^2$ (e) $I = 2mD^2/3 + M\ell^2$

13. Find the total angular momentum of the system about the hinge after the collosion?

(a) $L_f = \omega(M\ell^2)$ (b) $L_f = \omega\ell^2(2m + M/3)$ (c) $L_f = \omega(m\ell^2/3)$ (d) $L_f = \omega(mD^2 + M\ell^2/3)$ (e) $L_f = \omega(M\ell^2/3)$

14. Determine an expression for the resulting angular speed ω of the door in terms of the quantities introduced.

(a) $\omega = DmV/(mD^2 + M\ell^2/3)$ (b) $\omega = DmV\sin\theta/(mD^2)$ (c) $\omega = lmV\cos\theta/(M\ell^2/3)$ (d) $\omega = DmV\cos\theta/(mD^2 + M\ell^2/3)$ (e) $\omega = DmV\sin\theta/\ell^2(m + M/3)$

15. Find the change in kinetic energy of the system.

(a) $\Delta K = (V^2/2)[(D^2m^2\cos^2\theta/(mD^2 + M\ell^2/3)) - m]$ (b) $\Delta K = V^2[(D^2m^2\sin^2\theta/(M\ell^2/3)) - m]$ (c) $\Delta K = (V^2/2)[(\ell^2m/D^2) - m]$ (d) $\Delta K = (V^2/2)[(D^2m^2/(mD^2 + M\ell^2/3)) - m]$ (e) $\Delta K = (V^2/2)[(D^2m/\ell^2) - m]$

Questions 16-18

A rigid rod of mass m_3 is pivoted at point A, and masses m_1 and m_2 are hanging from it, and they are stayed in equilibrium as shown in the figure.

16. What is the magnitude of the normal force acting on the pivot point?

(a) 0 (b) $\frac{2m_2+m_3}{2m_1+m_3}g$ (c) m_3g (d) $(m_1 + m_2)g$ (e) $(m_1 + m_2 + m_3)g$

17. What is the ratio of L_1 to L_2, where these are the distances from the pivot point to m_1 and m_2, respectively?

(a) $\frac{2m_2+m_3}{2m_1+m_3}$ (b) 1 (c) $\frac{m_2+m_3}{m_1+m_3}$ (d) $\frac{m_1+m_2}{m_1+m_2+m_3}$ (e) $\frac{m_3}{m_1+m_2+m_3}$

18. What is the tension in rope holding the mass m_1.

(a) m_1g (b) $(m_1 + m_3)g$ (c) $\frac{m_1m_2}{m_1+m_2}g$ (d) $(m_1 - m_2)g$ (e) m_3g

Questions 19-20

A massless uniform board and a length of L, is supported by two vertical ropes, as shown in the figure. Rope A is connected to one end of the board, and rope B is connected at a distance of d from the other end of the board. A box with a weight M is placed on the board with its center of mass at d from rope A.

19. What is the tension in rope B?

(a) $Mg/2$ (b) $\frac{d}{(L-d)}Mg$ (c) $\frac{(L-d)}{(L+d)}g$ (d) $\left(\frac{(L-2d)(2M)}{(2L-d)}\right)g$ (e) Mg

20. What is the tension in rope A?

(a) $\frac{(M)(L-2d)g}{(L-d)}$ (b) $\frac{(2M)(L-2d)g}{2(L+d)}$ (c) $\frac{(M)(L-2d)g}{(2L-d)}$ (d) Mg (e) $\left(M - \frac{(L-2d)(2M)}{2(L-d)}\right)g$

Questions 21-25

Four masses are arranged as shown in figure.

21. Determine the gravitational force on (m) exerted by $(2m)$

(a) $\vec{F} = G\frac{(2m)m}{{y_0}^2}\hat{\mathbf{i}}$ (b) $\vec{F} = G\frac{(2m)m}{x_0}\hat{\mathbf{j}}$ (c) $\vec{F} = G\frac{(2m)m}{{x_0}^2}\hat{\mathbf{i}}$ (d) $\vec{F} = G\frac{(m)m}{x_0}\hat{\mathbf{i}}$ (e) $\vec{F} = G\frac{(m)m}{{x_0}^2}\hat{\mathbf{i}}$

22. Determine the gravitational force on (m) exerted by $(3m)$

(a) $\vec{F} = G\frac{(3m)m}{{x_0}^2}\cos\theta\,\hat{\mathbf{j}} + G\frac{(3m)m}{{x_0}^2+{y_0}^2}\sin\theta\hat{\mathbf{i}}$ (b) $\vec{F} = G\frac{(3m)m}{{x_0}^2+{y_0}^2}\cos\theta\,\hat{\mathbf{i}} + G\frac{(3m)m}{{x_0}^2+{y_0}^2}\sin\theta\,\hat{\mathbf{j}}$ (c) $\vec{F} = G\frac{(3m)m}{{x_0}^2}\hat{\mathbf{i}}$ (d) $\vec{F} = G\frac{(3m)m}{{x_0}^2}\sin\theta\hat{\mathbf{i}}$ (e) $\vec{F} = G\frac{(2m)m}{{x_0}^2}\hat{\mathbf{j}}$

23. Determine the gravitational force on (m) exerted by $(4m)$

(a) $\vec{F} = G\frac{(4m)m}{{x_0}^2}\cos\theta\hat{\mathbf{i}}$ (b) $\vec{F} = G\frac{(4m)m}{y_0}\hat{\mathbf{i}}$ (c) $\vec{F} = G\frac{(4m)m}{x_0}\sin\theta\hat{\mathbf{j}}$ (d) $\vec{F} = G\frac{(4m)m}{{y_0}^2}\hat{\mathbf{j}}$ (e) $\vec{F} = G\frac{(4m)m}{x_0}\cos\theta\hat{\mathbf{j}}$

24. Determine the x and y components of the gravitational <u>field</u> on the mass at the origin (m).

(a) $g = \left(G\frac{2m^2}{{x_0}^2} + G\frac{3m^2}{{x_0}^2+{y_0}^2}\frac{x_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{j}} + \left(G\frac{4m^2}{{y_0}^2} + G\frac{3m^2}{{x_0}^2+{y_0}^2}\frac{y_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{i}}$

(b) $g = \left(G\frac{2m^2}{{x_0}^2} + G\frac{3m^2}{{x_0}^2+{y_0}^2}\right)\hat{\mathbf{i}} + \left(G\frac{4m^2}{{y_0}^2} + G\frac{3m^2}{{x_0}^2+{y_0}^2}\right)\hat{\mathbf{j}}$

(c) $g = \left(G\frac{2m}{{x_0}^2} + G\frac{3m}{{x_0}^2+{y_0}^2}\frac{x_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{i}} + \left(G\frac{4m}{{y_0}^2} + G\frac{3m}{{x_0}^2+{y_0}^2}\frac{y_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{j}}$

(d) $g = \left(G\frac{2m}{{x_0}^2} + G\frac{3m^2}{{x_0}^2+{y_0}^2}\frac{y_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{i}} + \left(G\frac{4m}{{y_0}^2} + G\frac{3m}{{x_0}^2+{y_0}^2}\frac{x_0}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{j}}$

(e) $g = \left(G\frac{2m}{{x_0}^2} + G\frac{3m}{{x_0}^2+{y_0}^2}\frac{1}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{i}} + \left(G\frac{4m}{{y_0}^2} + G\frac{3m}{{x_0}^2+{y_0}^2}\frac{1}{\sqrt{{x_0}^2+{y_0}^2}}\right)\hat{\mathbf{j}}$

25. What is the angle with x-axis of force between (m) and $(3m)$?

(a) $\theta = \tan^{-1}\frac{x_0}{y_0}$ (b) $\theta = \sin^{-1}\frac{x_0}{y_0}$ (c) $\theta = \tan^{-1}\frac{y_0}{x_0}$ (d) $\theta = \tan\frac{y_0}{x_0}$ (e) $\theta = \cos^{-1}\frac{x_0}{y_0}$

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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. What is the unit of angular momentum?

(a) kgm^2/s^2 (b) Nm (c) Nms (d) kgm/s^2 (e) none of them

2. In which among the following center of mass does not coincide with the center of gravity?

(a) An airplane which is flying close to surface of the Earth. (b) An airplane which is flying 30 km above surface of the Earth. (c) A skyscraper. (d) A 3 km long train travelling in a horizontal plateau. (e) A human being.

3. What can be said about this statement?: "If the total force acting on an object is zero but the total torque is not zero than the object can still be in equilibrium."

(a) Not true. (b) True. (c) More information is needed to decide if it is true or not. (d) Can be true depending on the situation. (e) True if we ignore the friction.

4. Planet 1 has radius R_1 and density ρ_1. Planet 2 has radius $R_2 = 2R_1$ and density $\rho_2 = \rho_1\ /2$. Identical objects of mass m are placed on the surfaces of the planets. What is the relationship of the gravitational potential energy U_2 on planet 2 to U_1 on planet 1? (U_∞=0)

(a) $U_2 = U_1$ (b) $U_2 = U_1/2$ (c) $U_2 = U_1/4$ (d) $U_2 = 4U_1$ (e) $U_2 = 2U_1$

5. Which of the following statements about the motion of planets about the sun is NOT correct?

(a) At perihelion, the speed of an orbiting planet is maximal (b) Planets orbiting farther from the sun move with larger orbital speeds (c) Total mechanical energy of an orbiting planet remains constant during its motion. (d) Angular momentum of an orbiting planet with respect to the sun does not change during its motion (e) Each planetary orbit lies in a plane

6. A satellite of mass m is in circular orbit of radius R around earth (mass M). What is its mechanical energy? (U_∞=0)

(a) -GMm /2R (b) GMm/R (c) 0 (d) -GMm/R (e) GMm/2R

7. In gravitational problems U_∞ is taken as 0 because of

(a) Conserving mechanical energy (b) Conserving angular momentum (c) Conserving kinetic energy (d) Conserving potential energy (e) Convenience

Questions 8-14

There is log of mass "M", radius "R".You can consider it as a uniform solid cylinder ($I=MR^2/2$).It rolls down a hill of height "H". After the hill it rolls on a flat surface and climbs the hill on the opposite side. The gravitational acceleration is "g", the angle of the second hill is ϕ.The coefficient of friction "μ" is sufficient to prevent sliding and there are no rolling losses.

8. What is the conserved quantity in this motion?

(a) Angular momentum (b) Kinetic energy (c) Linear momentum (d) Potential energy (e) Mechanical energy

9. What is the kinetic energy of the log at the bottom?

(a) MgH (b) 0 (c) 2/3MgH (d) 3/2MgH (e) 1/2MgH

10. What is the linear speed of the log at the bottom?

(a) 2gH (b) $\sqrt{1/2\text{gH}}$ (c) $\sqrt{4/3\text{gH}}$ (d) gH/2 (e) $\sqrt{2\text{gH}}$

11. What is the magnitude of the static frictional force in the flat section?

(a) μ (b) μMg/2 (c) 2/3μMg (d) μMg (e) 0

12. Is the angular momentum of the log around its axis conserved in the uphill part? If not what is the source of the external torque?

(a) No, F_{static} (b) No, angular velocity (c) No, gravity (d) Yes (e) No, inertia

13. How high will the log roll in the uphill part?

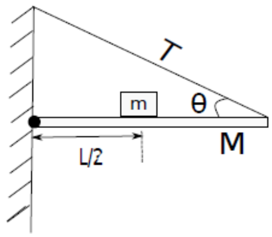
(a) 0 (b) 2/3 H (c) H (d) R (e) 2/3 R

14. What is the magnitude and direction of the static frictional force in the uphill part?

(a) Uphill, Mgsin(ϕ)/3 (b) Downhill, μMgcos(ϕ) (c) Upward, Mgcos(ϕ) (d) Downward, Mgsin(ϕ)/2 (e) Upward, μMgcos(ϕ)

Questions 15-19

A rod of length L with non-uniform mass distribution is hinged horizontally to a vertical wall from one end. The rod is supported by a rope from the other end as shown in the figure such that the rope makes an angle of 30° with the horizontal. The linear mass density (mass per unit of length) of the rod is $\lambda(x)=8Cx^3/L^4$ where x is the distance from the hinge ($x \leq L$) and C is a constant. The unit of C is kg. The distance between point mass m and the hinge is L/2.



15. What is mass M of the rode?

(a) 8C/3 (b) 2C (c) C/2 (d) C (e) 2C/3

16. Find distance L_G between the hinge and the centre of gravity of the rode (do not take into account point mass m).

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

17. Find the tension in the rope (as mass m is much smaller than the mass of the rode M neglect mass m)

(a) $gML_G/L\tan(30)$ (b) $gML_G/L\cos(30)$ (c) $gML_G\sin(30)/L$ (d) $gML_G/L\sin(30)$ (e) $gML/L_G\sin(30)$

18. What is moment of inertia of the rode (I_0) with respect to the hinge (neglect m)?

(a) $4CL^2/5$ (b) $7CL^2/3$ (c) CL^2 (d) C/L^2 (e) $4CL^2/3$

19. The rope breaks off at t = 0. What is the magnitude of the normal force that the rode applies to mass m for $t \to 0^+$?

(a) mg (b) $mg(1-(LL_GM/2I_0))$ (c) $mg(1+(LL_GM/2I_0))$ (d) 0 (e) mgL_G/L

Questions 20-25

A satellite of mass "m" is in an elliptic orbit. Its apogee (farthest point from earth) "A" is at $R_A=6R_E$ and perigee (closest point to earth) "P" is at $R_P=2R_E$ from the center of earth. (Note that at these points its velocity is tangential.) Its velocity at apogee is V_A. The mass and radius of earth are M_E and R_E.

20. What are the conserved quantities in its orbital motion?

(a) P and kinetic energy (b) Linear momentum P only (c) L only (d) L and kinetic energy (e) Angular momentum "L" and mechanical energy "ME"

21. What is its angular momentum L at apogee?

(a) 0 (b) $L=6mR_EV_A$ (c) $6mR_AV_A$ (d) $6MR_EV_A$ (e) $6mR_EV_A^2$

22. What is its kinetic energy at apogee

(a) $KE_A=P^2/2m(R_P+R_A)^2$ (b) $KE_A=P^2/2mR_A^2$ (c) $KE_A=L^2/2mR_A^2$ (d) $KE_A=P^2/2mR_P^2$ (e) $KE_A=L^2/2mR_P^2$

23. How much work is done by gravity while the satellite is moving from apogee to perigee

(a) $W=GMm/R_E$ (b) $W=Mm/3R_E$ (c) $W=GMm/3R_E$ (d) $W=GMm/3R_A$ (e) 0

24. What is its kinetic energy at perigee?

(a) $KE_P=L^2/2mR_A^2$ (b) $KE_P=L^2/2mR_P^2$ (c) $KE_P=P^2/2m(R_P+R_A)^2$ (d) $KE_P=P^2/2mR_A^2$ (e) $KE_P=P^2/2mR_P^2$

25. What is V_A in terms of R_E?

(a) $V_A=\sqrt{GM/12R_E}$ (b) $V_A=\sqrt{Gm/6R_E}$ (c) $V_A=\sqrt{Gm/12R_E}$ (d) $V_A=\sqrt{GMm/12R_E}$ (e) $V_A=\sqrt{GM/6R_E}$

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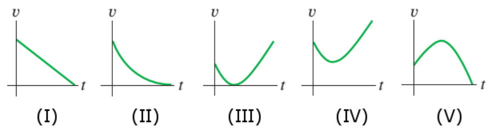
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. A simple pendulum (a mass swinging at the end of a string) starts swinging from right to left. What is the direction of the acceleration of the mass when it is at the left end of the swing?

(a) to the left (b) centrifugal (c) to the rotation axis (d) the tangential to the path (e) zero

2. A stone is thrown into the air at an angle above the horizontal and feels negligible air resistance. Which graph in the figure best depicts the stone's speed as a function of time t while it is in the air?



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

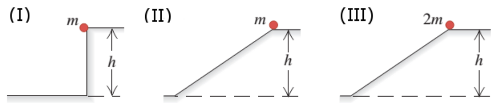
3. In uniform circular motion, how does the acceleration change when the speed is increased by a factor of 3 and the radius is decreased by factor 2?

(a) 18 (b) 36 (c) 1/18 (d) 9 (e) 1/36

4. An elevator is hoisted by its cables at constant speed. What is the total work done by cables and gravity on the elevator?

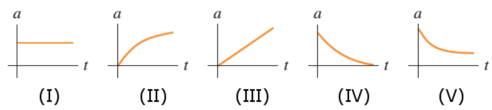
(a) Positive (b) Zero (c) Depends on number of cables (d) Negative (e) Undeterminable

5. Which statement is true for the masses sliding down from the various inclines shown in figure? There is no friction or air resistance!



(a) I will have the largest speed.
(b) They all have different speeds. (c) III will have the largest speed.
(d) They all have the same speed.
(e) I and II will have the same speed and it is going to be different from III.

6. A ball is dropped from rest and feels air resistance as it falls. Which of the graphs in figure best represents its acceleration as a function of time?

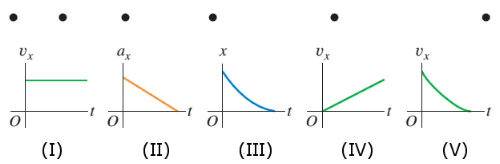


(a) V (b) IV (c) III (d) II (e) I

7. Which of the following statements is correct?
(1) The work done by any force might be positive or negative depending on the choice of the frame of reference.
(2) Any friction force will decrease the speed of the body in any reference frame.
(3) No friction force can do a positive work in any reference frame.

(a) 2,3 (b) 3 (c) 1 (d) None of them (e) 2

8. The top diagram in figure represents a series of highspeed photographs of an insect flying in a straight line from left to right (in the positive x-direction). Which of the graphs in figure most plausibly depicts this insect's motion?



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

Questions 9-11

$\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$ and $\vec{B} = a\hat{i} - \hat{j} - 2\hat{k}$ vectors are given.

9. What should be the value of a to make $\vec{B}$ perpendicular to $\vec{A}$?

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

10. What is the unit vector in the direction of $\vec{A}$?

(a) $\frac{2\hat{i}+3\hat{j}-\hat{k}}{\sqrt{14}}$ (b) $\frac{2\hat{i}+3\hat{j}+\hat{k}}{\sqrt{12}}$ (c) $\frac{2\hat{i}-3\hat{j}-\hat{k}}{\sqrt{12}}$ (d) $\frac{-2\hat{i}+3\hat{j}-\hat{k}}{\sqrt{14}}$ (e) $\hat{i}+\hat{j}+\hat{k}$

11. What is the magnitude of the projection of $\vec{B}$ vector on $\vec{A}$ vector if a=1?

(a) $1/\sqrt{12}$ (b) $1/\sqrt{14}$ (c) $\sqrt{12}$ (d) $\sqrt{14}$ (e) $1/\sqrt{84}$

Questions 12-16

A balloon having 20 m/s constant velocity is rising up from ground vertically. When the balloon reaches 160 m height, an object is thrown horizontally with a velocity of 20 m/s with respect to balloon. Assume the mass of the object is small compared to the mass of the balloon. Take $g = 10\ m/s^2$.

12. What is the horizontal distance travelled by the object before it hits the ground.

(a) 80 m (b) 160 m (c) 40 m (d) 200 m (e) 240 m

13. What are the velocity components ($|V_x|, |V_y|$) of the object when it hits the ground?

(a) (60 $\frac{m}{s}$,20 $\frac{m}{s}$) (b) (20 $\frac{m}{s}$,30 $\frac{m}{s}$) (c) (20 $\frac{m}{s}$,40 $\frac{m}{s}$) (d) (20 $\frac{m}{s}$,20 $\frac{m}{s}$) (e) (20 $\frac{m}{s}$,60 $\frac{m}{s}$)

14. How high is the balloon when the object hits the ground?

(a) 320 m (b) 220 m (c) 280 m (d) 260 m (e) 240 m

15. What is the maximum height of the object with respect to ground?

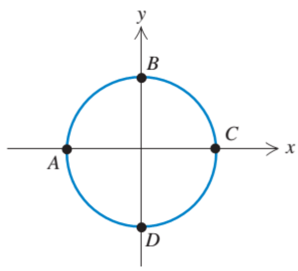
(a) 160 m (b) 180 m (c) 320 m (d) 240 m (e) 90 m

16. Find such a time that the displacement of the object and the balloon are the same after ejecting the object.

(a) 14 s (b) 16 s (c) 10 s (d) 4 s (e) 12 s

Questions 17-19

An athlete starts at point A and runs at a constant speed of 6.0 m/s around a circular track 200 m in diameter clockwise, as shown in figure. Take $\pi = 3$.



17. What is the average velocity of the runner for a complete turn (a lap) ?

(a) 0 $\frac{m}{s}$ (b) 6 $\frac{m}{s}$ (c) 4 $\frac{m}{s}$ (d) 5 $\frac{m}{s}$ (e) 200/6 $\frac{m}{s}$

18. What are the x and y components of the runner's average velocity between A and B ?

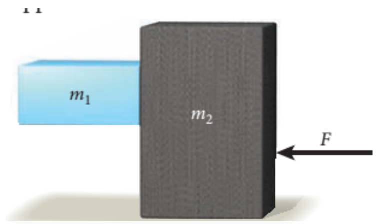
(a) (6 $\frac{m}{s}$, -4 $\frac{m}{s}$) (b) (6 $\frac{m}{s}$, 6 $\frac{m}{s}$) (c) (8 $\frac{m}{s}$, -8 $\frac{m}{s}$) (d) (-4 $\frac{m}{s}$, 6 $\frac{m}{s}$) (e) (4 $\frac{m}{s}$, 4 $\frac{m}{s}$)

19. What are the x and y components of the runner's average acceleration $(a_x, a_y)_{av}$ between A and B ?

(a) (12 $\frac{m}{s^2}$,4 $\frac{m}{s^2}$) (b) (4 $\frac{m}{s^2}$,4 $\frac{m}{s^2}$) (c) ($\frac{6}{25}$ $\frac{m}{s^2}$,$\frac{-6}{25}$ $\frac{m}{s^2}$) (d) (6 $\frac{m}{s^2}$,-4 $\frac{m}{s^2}$) (e) (-6 $\frac{m}{s^2}$,4 $\frac{m}{s^2}$)

Questions 20-23

A block of mass m_1=2.00 kg is placed in front of a block of mass m_2=7.00 kg as shown in the figure. An F=360 N force is applied to the large object as seen in the figure. The coefficient of static friction between the blocks is 0.5 and there is no friction between the larger block and the tabletop. Take $g = 10\ m/s^2$.



20. What is the magnitude of the acceleration of the smaller block?

(a) 30 m/s^2 (b) 15 m/s^2 (c) 20 m/s^2 (d) 40 m/s^2 (e) 10 m/s^2

21. What is the magnitude of the normal force between the two blocks?

(a) 40 N (b) 70 N (c) 60 N (d) 80 N (e) 30 N

22. What is the magnitude of the friction force between the two blocks?

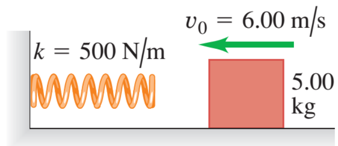
(a) 20 N (b) 25 N (c) 40 N (d) 35 N (e) 15 N

23. What is the magnitude of the normal force exerted by the table to the larger block?

(a) 10 N (b) 70 N (c) 180 N (d) 15 N (e) 90 N

Questions 24-25

A 5 kg block is moving at V_0 = 6.00 m/s along a frictionless, horizontal surface toward a spring with force constant k=500 N/m that is attached to a wall. The spring has negligible mass.



24. What is the maximum distance the spring will be compressed?

(a) 5 m (b) 1 m (c) $\frac{5}{3}$ m (d) $\frac{3}{5}$ m (e) 2 m

25. What is the speed of the block when it leaves the spring?

(a) $\sqrt{12.00}$ $\frac{m}{s}$ (b) $\sqrt{6.00}$ $\frac{m}{s}$ (c) 3.00 $\frac{m}{s}$ (d) 12.0 $\frac{m}{s}$ (e) 6.00 $\frac{m}{s}$

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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. 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 $-2Cy$

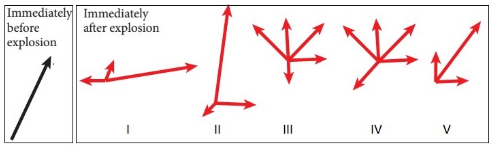
4. You use your hand to stretch a spring to a displacement x from its equilibrium position and then slowly bring it back to that position. Which is true for the whole process?

(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

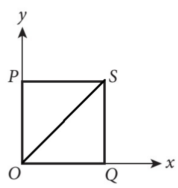
(a) increases by a factor of 2. (b) decreases by a factor of 4. (c) decreases by a factor of 2. (d) increases by a factor of 4. (e) remains the same.

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 ?

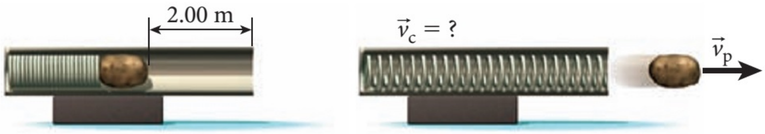
(a) 18 J (b) 9 J (c) 36 J (d) 0.9 J (e) 27 J

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?

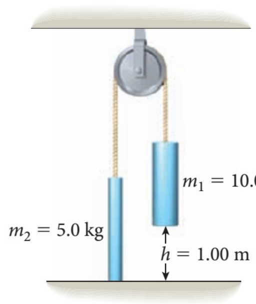
(a) To left with $\sqrt{38/11}$ m/s (b) To the right with $\sqrt{19/11}$ m/s (c) To the left with $\sqrt{19/11}$ m/s (d) To the left with $\sqrt{28/11}$ m/s (e) Cannon does not move

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?

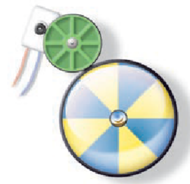
(a) $\sqrt{20/3}$ m/s (b) $\sqrt{2/3}$ m/s (c) 2/3 m/s (d) 4/3 m/s (e) $\sqrt{4/3}$ m/s

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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1. Which of the following statements is always correct?
I. A force acting on a body is the negative value of the x derivative of the potential energy function of this force.
II. The magnitude of a force acting on a body is the negative value of the x derivative of the potential energy function of this force.
III. The undefined constant in the potential energy will allow defining this energy to be zero at any desired point.
IV. The derivative of the potential energy function is equal to the conservative force in both magnitude and direction.

(a) IV and III (b) only IV (c) only I (d) I and III (e) only III

2. The physical quantity 'impulse' has the same dimensions as that of:

(a) momentum (b) power (c) work (d) energy (e) force

3. There are two planets whose masses M and m and their centre-to-centre separation is r. What is the value of the gravitational field (kütle çekim alanı) produced by M at the location of mass m?

(a) $G.M.m/r^2$ (b) $G.m/r^2$ (c) $4\pi r^2$ (d) $G.M/r^2$ (e) $g.m.M/r^2$

4. Which of the following is correct? In uniform circular motion I. $\vec{v}$ is constant, II. v is constant, III. a is constant, IV. $\vec{a}$ is constant.

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

5. Which of the following statements is true?

(a) The change in kinetic energy is equal to the net work done. (b) The change in potential energy is equal to the work done. (c) If non-conservative forces are doing work, **total** energy is not conserved. (d) The change in potential energy is equal to the negative of the work done. (e) Mechanical energy is always conserved.

6. Which of the following is the unit of Power in MKS unit system?

(a) $\mathrm{kg\,m^2/s}$ (b) none of them (c) $\mathrm{kg\,m/s}$ (d) $\mathrm{kg\,m^2/s^3}$ (e) $\mathrm{kg\,m^2/s^2}$

7. Consider an object with acceleration function $a(t) = 3t\,(m/s^3) - 3\,(m/s^2)$ with initial conditions v(t=0)=1 m/s and x(t=0)=2 m. What is the magnitude of the position of the object at t=1 s?

(a) 2 m (b) 6 m (c) 4 m (d) 3 m (e) 5 m

8. The position of a point mass 2.0 kg is given as a function of time by $\vec{r} = 6\hat{i}\,(m) + 5t\hat{j}\,(m/s)$. What is the angular momentum of this mass about the origin in $kg\,m^2$/s at t=1 s?

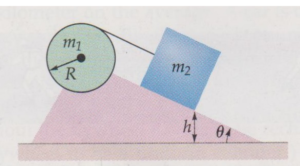
(a) $30\hat{k}$ (b) $30\hat{j}$ (c) $6\hat{j}$ (d) $6\hat{i} + 5\hat{j}$ (e) $25\hat{k}$

9. There are two blocks on top of one another. All surfaces are frictionless. The bottom block is pulled with force F. If the mass of the top block is doubled, the force necessary to pull the bottom block with the same acceleration as before, should be;

(a) 2F (b) F (c) None of them (d) F/2 (e) 0

Questions 10-13

A uniform cylinder of mass $m_1 = 0.5kg$ and radius $R = 10cm$ is pivoted on frictionless bearings. A string wrapped around the cylinder connects to a mass $m_2 = 1.0kg$, which is on a frictionless incline of angle θ as shown in Figure. The system is released from rest with m_2 at height $h = 1.0m$ above the bottom of the incline. Take $\theta = 30^0$ and $I = \frac{M.R^2}{2}$.



10. What is the acceleration of m_2? (a) 0.4 m/s^2 (b) 40 m/s^2 (c) 4 m/s^2 (d) 2 m/s^2 (e) 0.2 m/s^2

11. What is the angular acceleration of the disk? (a) 2 rad/s^2 (b) 4 rad/s^2 (c) 0.4 rad/s^2 (d) 0.2 rad/s^2 (e) 40 rad/s^2

12. What is the tension in the string? (a) 10 N (b) 0.5 N (c) 5 N (d) 0.1 N (e) 1 N

13. What is the speed of the m_2 at the bottom of the incline? (a) $\frac{\sqrt{10}}{3}$ (b) $\frac{\sqrt{40}}{3}$ (c) 4 (d) $\frac{\sqrt{4}}{3}$ (e) $\frac{\sqrt{20}}{3}$

Questions 14-18

In a tape recorder, the magnetic tape moves at a constant linear speed of approximately 5 cm/s. To maintain this constant linear speed, the angular speed of the driving spool (the take-up spool) has to change accordingly. Mass of the rotating parts are negligable except the tape and the linear mass density of the tape is λ=1.0 gr/m and $I = \frac{1}{2}m(r_1^2 + r_2^2)$

14. What is the angular speed of the take-up spool when it is empty, with radius $r_1 = 1.00$ cm? (a) 0.05 rad/s (b) 50 rad/s (c) 500 rad/s (d) 0.5 rad/s (e) 5 rad/s

15. If the total length of the tape is 100.0 m, what is the average angular acceleration of the take-up spool while the tape is being played? (When the spool is full, $r_2 = 2$ cm.) (a) 0.125 10^{-6} (b) 12.5 10^{-6} (c) 0.0125 10^{-6} (d) 125 10^{-6} (e) 1.25 10^{-6}

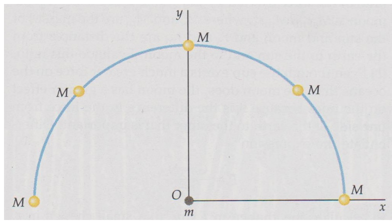
16. What is the moment of inertia of the tape when one spool is empty the other one is full? (a) 10 10^{-6} kgm^2 (b) 20 10^{-6} kgm^2 (c) 25 10^{-6} kgm^2 (d) 15 10^{-6} kgm^2 (e) 5 10^{-6} kgm^2

17. What is the total moment of inertia of the tape when it is equally distributed between the spools? (a) 10.0 10^{-6} kgm^2 (b) 12.5 10^{-6} kgm^2 (c) 7.50 10^{-6} kgm^2 (d) 17.5 10^{-6} kgm^2 (e) 15 10^{-6} kgm^2

18. In which case the rotational kinetic energy of the tape is highest? (a) When one spull have $1/4^{th}$ of the tape and the other one has $3/4^{th}$ of the tape. (b) When one spool is full, the other one is empty. (c) Not enough information is given. (d) When both spools shares the tape equally. (e) The rotational kinetic energy is the same in all cases.

Questions 19-21

Five equal masses M are equally spaced on the arc of a semicircle of radius R as shown in figure. A mass m is located at the center of the curvature of the arc. G is the gravitational constant.



19. What is the direction of the gravitational force on the mass m?

(a) both +x and +y (b) -y (c) +x (d) +y (e) -x

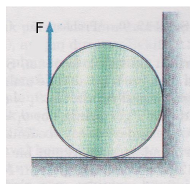
20. What is the magnitude of the gravitational force on the mass m?

(a) $\frac{G.M.m}{R}(1+\sqrt(2))$ (b) $\frac{G.M.m}{R^2}$ (c) $\frac{G.M.m}{R^2}(1-\sqrt(2))$ (d) 0 (e) $\frac{G.M.m}{R^2}(1+\sqrt(2))$

21. What is the magnitude of the gravitational potential energy of the mass m? (a) $5\frac{G.M.m}{R}(1+2\sqrt{2})$ (b) $5\frac{G.M.m}{R}(1-2\sqrt{2})$ (c) $5\frac{G.M.m}{R}$ (d) 0 (e) $5\frac{G.M.m}{R}(1+4\sqrt{2})$

Questions 22-25

A vertical F force is applied tangentially to a uniform solid cylinder with mass m=8 kg as shown in the figure. The static friction coefficient between the cylinder and all of the surfaces is given as μ=0.5. F force is applied with maximum possible magnitude that, the cylinder holds its position without rotating. Take $g = 10\,m/s^2$.



22. What should be the magnitude of the F force?

(a) 30 N (b) 0.3 N (c) 300 N (d) 3 N (e) 0.03 N

23. What is the magnitude of the normal force acting on the cylinder at the bottom position?

(a) 40 N (b) 400 N (c) 0.4 N (d) 4 N (e) 0.04 N

24. What is the magnitude of the normal force on the cylinder due to the side wall?

(a) 0.2 N (b) 200 N (c) 0.02 N (d) 2 N (e) 20 N

25. What is the magnitude and the direction of the friction force on the side wall?

(a) 100 N up (b) 1 N down (c) 10 N up (d) 100 N down (e) 1 N up

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1. A CD-player turntable initially rotating at 1.50 rev/s ($1\,rev = 2\pi\,rad = 360^0$), slows down and stops in 30 s. The magnitude of its average angular acceleration in rad/s^2 for this process is:

(a) 3.0 (b) 1.50 (c) 3.0π (d) $\pi/20$ (e) $\pi/10$

2. The unit kg·m^2/s can be used for:

(a) power (b) rotational kinetic energy (c) rotational inertia (d) angular momentum (e) torque

3. Which of the following can be considered as a type of a conservative force?
I. Friction force II. Fluid resistance III. Gravity IV. Spring force

(a) II, III, IV (b) III, IV (c) III only (d) I, II, III (e) IV only

4. The position vector of a particle with mass, $m = 2$ kg, is given as $\vec{r}(t) = 3t^2\hat{\imath} - 5t\hat{\jmath} + 8t^3\hat{k}$. What is the x component of the force (F_x) acting on the particle at time, $t = 1$ s. (t is measured in seconds and r is measured in meters.)

(a) 96 N (b) 48 N (c) 108 N (d) 0 N (e) 12 N

5. Magnitude of the drag force is given by $F = bv + cv^2$, where b and c are constants, v is the speed of the particle. The unit of b in basic units (kg, m, s) is,

(a) $kg\,s^2/m$ (b) kg/m (c) kg/s (d) $kg\,s/m$ (e) $kg/(m\,s)$

6. Kepler's 1^{st} law states that the planets follow closed ellipses. (The same path is followed in each orbit.) This indicates that

(a) The gravitational force is conservative and kinetic energy is constant. (b) The gravitational force is conservative and potential energy is constant. (c) The gravitational force is NOT conservative and mechanical energy is NOT constant. (d) The gravitational force is conservative and mechanical energy is constant. (e) The gravitational force is conservative and linear momentum is constant.

7. K: kinetic energy and p: linear momentum; which of the following is the linear momentum in terms of kinetic energy?

(a) $p = 2Km$ (b) $p = \sqrt{2Km}$ (c) $p = \sqrt{2K}m$ (d) $p = 2K/m$ (e) $p = \sqrt{2K/m}$

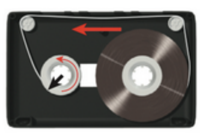
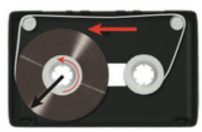
8. The coordinates of a point mass $m_1 = 4\ g$ is given as $(x, y) = (-1, 2)$ and the coordinates of another point mass $m_2 = 2\ g$ is given as $(x, y) = (2, 3)$. For this system, what is the ratio of the center of mass coordinates, $\frac{x_{cm}}{y_{cm}}$?

(a) 7/3 (b) 4/15 (c) 5/12 (d) 4/9 (e) 0

9. Moment of inertia of a rotating object about its center of mass is related to? (a) only to its mass (b) its angular velocity and its mass (c) its radius of rotation and its angular velocity (d) force on it and application point of this force (e) its mass and its radius of rotation about its center of mass

Questions 10-14

In a tape recorder, the magnetic tape moves at a constant linear speed of approximately 5 cm/s. To maintain this constant linear speed, the angular speed of the driving spool (the take-up spool) has to change accordingly. Mass of the rotating parts are negligable except the tape. The mass of the tape is 100g and the moment of inertia of a rotating hallow disk is $I = \frac{1}{2}m(r_1^2 + r_2^2)$ where r_1 is the inner and r_2 is the outer radii.

10. What is the angular speed (in rad/s) of the take-up spool when it is empty.

(a) 500 (b) 0.5 (c) 50 (d) 5 (e) 0.05

11. What is the angular speed (in rad/s) of the take-up spool when it is full.

(a) 250 (b) 0.025 (c) 25 (d) 0.25 (e) 2.5

12. What is the magnitude of the average angular acceleration (in rad/s^2) of one of the take-up spool while the tape is being played? (Remember, the spool is empty initially and it is full at the end!)

(a) $1.25\ 10^{-3}$ (b) $1.25\ 10^{-2}$ (c) $1.25\ 10^{-6}$ (d) $1.25\ 10^{-4}$ (e) $1.25\ 10^{-5}$

13. What is the moment of inertia of the tape when one spool is empty the other one is full?

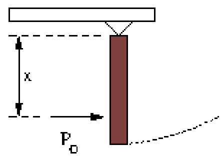
(a) $2.0\ 10^{-5}\ kgm^2$ (b) $2.5\ 10^{-5}\ kgm^2$ (c) $1.5\ 10^{-5}\ kgm^2$ (d) $1.0\ 10^{-5}\ kgm^2$ (e) $5\ 10^{-5}\ kgm^2$

14. What is the total moment of inertia of the tape when it is equally distributed between the spools?

(a) $17.5\ 10^{-6}\ kgm^2$ (b) $7.50\ 10^{-6}\ kgm^2$ (c) $12.5\ 10^{-6}\ kgm^2$ (d) $10.0\ 10^{-6}\ kgm^2$ (e) $15\ 10^{-6}\ kgm^2$

Questions 15-19

A uniform rod of mass M and length L is pivoted at one end and hangs as shown in figure such that it is free to rotate about its pivot without friction. It is struck by a horizontal force that delivers an impulse $P_0 = F_{av}.\Delta t$ at a distance x below the pivot as shown. $I_{cm} = ML^2/12$



15. What is the moment of inertia of the rod about the pivot?

(a) $I = \frac{1}{4}ML^2$ (b) $I = \frac{1}{2}ML^2$ (c) $I = \frac{3}{5}ML$ (d) $I = \frac{1}{3}ML^2$ (e) $I = \frac{2}{5}ML^2$

16. What is the magnitude of the net torque on the rod about the axis of rotation generated by the horizontal force?

(a) $\frac{P_0 x}{\Delta t}$ (b) $\frac{P_0 L}{\Delta t}$ (c) $\frac{P_0 L^2}{x\Delta t}$ (d) $\frac{P_0}{\Delta t}$ (e) $\frac{x}{\Delta t}$

17. What is the initial angular frequency of the rod after the strike? (Hint: $\vec{\tau}_{net} = I\vec{\alpha}$ and $\alpha = \frac{\Delta\omega}{\Delta t}$)

(a) $\frac{3P_0 x}{ML^2}$ (b) $\frac{2P_0 x}{ML^2}$ (c) $\frac{6P_0 x}{ML^2}$ (d) $\frac{12P_0 x}{ML^2}$ (e) 0

18. What is the speed of the center of mass after the strike?

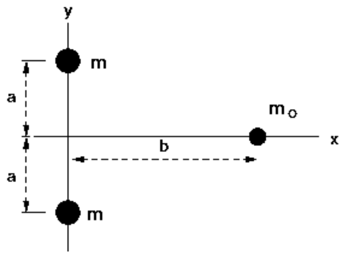
(a) $\frac{3P_0 x}{2mL}$ (b) $\frac{3x}{mL}$ (c) $\frac{3P_0}{mL^2}$ (d) $\frac{3P_0 x}{mL^2}$ (e) $\frac{3P_0}{2mL^2}$

19. How high the center of mass of the rod will go up?

(a) $\frac{21\, P_0^2\, x^2}{8\, g\, M^2\, L^2}$ (b) $\frac{21\, P_0\, x}{8\, g\, M\, L}$ (c) $\frac{21\, P_0\, x^2}{8\, g\, M^2\, L^2}$ (d) $\frac{21\, P_0^2\, x}{8\, g\, M^2\, L^2}$ (e) $\frac{21\, P_0^2\, x^2}{8\, g\, M\, L}$

Questions 20-22

Two particles with masses m has been placed at points $y = +a$ and $y = -a$ on y-axis as shown in the figure.



20. What is the force exerted by these two particles on the third particle of mass m_0 located on the x-axis at a distance b from the origin?

(a) 0 (b) $\vec{F} = -\frac{G\ m\ m_0\ b}{(b^2+a^2)^{(3/2)}}\hat{i}$ (c) $\vec{F} = -\frac{2\ G\ m\ m_0\ b}{(b^2+a^2)^{(1/2)}}\hat{i}$ (d) $\vec{F} = \frac{2\ G\ m\ m_0\ b}{(b^2+a^2)^{(1/2)}}\hat{i}$ (e) $\vec{F} = -\frac{2\ G\ m\ m_0\ b}{(b^2+a^2)^{(3/2)}}\hat{i}$

21. What is the gravitational field $\vec{g}$ at m_0 location due to particles on the y-axis?

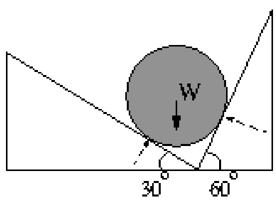
(a) $\vec{g} = -\frac{2\ G\ m\ b}{(b^2+a^2)^{(3/2)}}\hat{i}$ (b) $\vec{g} = -\frac{2\ G\ m_0\ b}{(b^2+a^2)^{(1/2)}}\hat{i}$ (c) *nullvector* (d) $\vec{g} = -\frac{G\ m\ b}{(b^2+a^2)^{(3/2)}}\hat{i}$ (e) $\vec{g} = -\frac{2\ G\ m\ b}{(b^2+a^2)^{(1/2)}}\hat{i}$

22. The maximum value of $|\ g_x\ |$ (x-component of the gravitational field) occurs at points;

(a) $x = \pm a$ (b) $x = \pm\frac{a}{\sqrt{2}}$ (c) $x = \pm a\sqrt{2}$ (d) 0 (e) $x = \pm 2a$

Questions 23-25

A cylinder of weight W=21.2 N is supported by frictionless trough formed by a plane inclined at 30^0 to the horizontal on the left and one inclined at 60^0 on the right as shown in figure. Take $\sin(30^0)=\cos(60^0)=0.5$ and $\sin(60^0)=\cos(30^0)=0.9$ for your calculations.



23. What is the force exerted by the left wedge on the cylinder?

(a) 9 N (b) 10 N (c) 18 N (d) 1.8 N (e) 1 N

24. What is the force exerted by the left wedge on the cylinder?

(a) 1.8 N (b) 5 N (c) 10 N (d) 1 N (e) 18 N

25. What is the net force on the cylinder?

(a) 27 N (b) 28 N (c) 0 N (d) 23 N (e) 15 N

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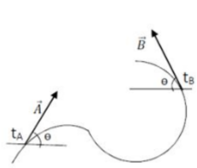
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

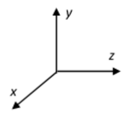
1. The position of a toy locomotive on a straight track along the x-axis is given by the equation $x(t) = t^3 - 6t^2 + 9t$, where x in meters and t is in seconds. When the path taken is the maksimum?
(a) $5s$ (b) $1s$ (c) $2s$ (d) $zero$ (e) $4s$

2. An object travels along a path shown in the figure, with changing velocity as indicated by vectors $\overrightarrow{A}$ and $\overrightarrow{B}$ with the same magnitude.Which vector best represents the average acceleration of the object from time t_A to t_B?
(a) ↙ (b) ↘ (c) ⟵ (d) ⟶ (e) ↖

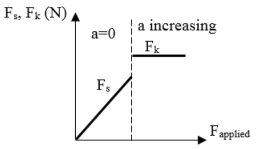


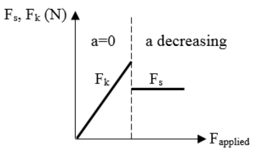
3. Which of the following is correct for the normal forces?
(a) its magnitude is always equal to the weight. (b) the value of the normal forces is different for static and kinetic frictions. (c) it is not determined if there is no friction. (d) the magnitude is higher than the weight if the surface is inclined. (e) it is always perpendicular to the surface.

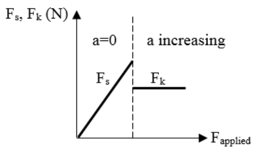
4. Which of the following is incorrect for the reference frame shown in figure. Here $\widehat{i}$, $\widehat{j}$, and $\widehat{k}$ are the unit vectors for x, y, and z axis, respectively.
(a) $(\widehat{j} \times \widehat{i}) \bullet \widehat{k} = +1$ (b) $(\widehat{j} \times \widehat{k}) \bullet \widehat{i} = -1$ (c) $\widehat{i} \times \widehat{k} = \widehat{j}$ (d) $(\widehat{j} \times \widehat{i}) \times \widehat{k} = 0$ (e) $\widehat{i} \times \widehat{j} = \widehat{k}$

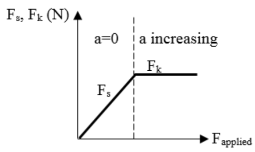


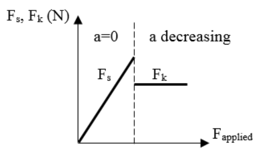
5. Which graph of the following is correct for F_s (static friction), and F_k (kinetic friction)?

(a)


(b)


(c)


(d)


(e)


6. If the air resistance is negligible, the sum of the potential and the kinetic energies of a freely falling body ....
(a) decreases (b) increases (c) is zero (d) first increases and then decreases (e) remains the same

7. Which of the following are correct?

1. Spring force is a conservative force.
2. Work done by a conservative force is always zero.
3. Frictional force is a conservative force for a closed orbit.
4. The work done by a conservative force for a closed orbit is zero.

(a) 1,2 and 4 (b) 2 and 4 (c) 1 and 4 (d) All are true (e) only 1

8. Which of the following statement is false?
(a) The total energy is preserved in the friction environment.
(b) Change in the potential energy equals to negative of the work done by a conservative force.
(c) Change in the potential energy equals to the work done by a conservative force.
(d) Change in the kinetic energy is equal to the work done.
(e) Mechanical energy is conserved in a frictionless environment.

9. Which of the following is wrong about the uniform circular motion?
(a) Angular speed is constant. (b) Magnitude of the velocity vector is constant. (c) None. (d) Acceleration vector is constant. (e) Angular frequency is constant.

10. An object is thrown with horizontal speed $v_0 = 10\,m/s$ from a height H. If the range of the object is also equal to H, which of the following is the time passing until the object hit the ground? (Take $g = 10\,m/s^2$.)
(a) $1\ s$ (b) $2\ s$ (c) $3\ s$ (d) $1/2\ s$ (e) $1/3\ s$

11. Assume that the air pressure is calculated with the formula $P = \alpha h^x g^y d^z$ where α is a dimensionless constant, P is the pressure, h is the height, g is the gravitational acceleration, and d is the density of the air; x, y, and z are also numerical constants. What is the value of x?
(a) 1 (b) 3 (c) 2 (d) 3/2 (e) 1/2

Questions 12-16

For $\vec{A}$ and $\vec{B}$ vectors given as $\vec{A} = 2\hat{i} - 3\hat{j} + 4\hat{k}$ and $\vec{B} = -3\hat{i} - 4\hat{j} + \hat{k}$

12. Find a unit vector in the same direction with $\vec{B}$.
(a) $-3\hat{i} - 4\hat{j} + \hat{k}$ (b) $\frac{-3\hat{i}-4\hat{j}+\hat{k}}{\sqrt{8}}$ (c) $\frac{+3\hat{i}+4\hat{j}-\hat{k}}{\sqrt{8}}$ (d) $\frac{-3\hat{i}-4\hat{j}+\hat{k}}{\sqrt{26}}$ (e) $\frac{-3\hat{i}-4\hat{j}+\hat{k}}{2}$

13. Calculate $\vec{A} \bullet \vec{B}$?
(a) -14 (b) 4 (c) -12 (d) 10 (e) -16

14. Calculate $\vec{A} \times \vec{B}$?
(a) $14\hat{i} - 17\hat{j} - 10\hat{k}$ (b) $14\hat{i} - 13\hat{j} - 17\hat{k}$ (c) $13\hat{i} - 14\hat{j} - 17\hat{k}$ (d) $-13\hat{i} + 14\hat{j} - 17\hat{k}$ (e) $-13\hat{i} + 14\hat{j} + 17\hat{k}$

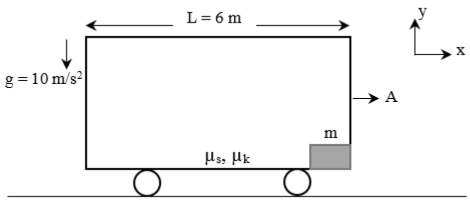
15. Find a unit vector, $\hat{c}$, which is perpendicular to the plane formed by $\vec{A}$ and $\vec{B}$ vectors.

(a) $\hat{c} = \pm\frac{14\hat{i}-13\hat{j}-17\hat{k}}{\sqrt{(13)^2+(-14)^2+(-17)^2}}$ (b) $\hat{c} = \pm\frac{13\hat{i}+14\hat{j}-17\hat{k}}{\sqrt{(13)^2+(-14)^2+(-17)^2}}$ (c) $\hat{c} = \pm\frac{14\hat{i}-17\hat{j}-10\hat{k}}{\sqrt{(13)^2+(-14)^2+(-17)^2}}$ (d) $\hat{c} = \pm\frac{13\hat{i}-14\hat{j}-17\hat{k}}{\sqrt{(13)^2+(-14)^2+(-17)^2}}$
(e) $-13\hat{i} + 14\hat{j} + 17\hat{k}$

16. Calculate the cosine of the angle between $\vec{A}$ and $\vec{B}$ vectors.
(a) $\frac{-14}{\sqrt{29}\cdot\sqrt{26}}$ (b) $\frac{10}{\sqrt{29}\cdot\sqrt{26}}$ (c) $\frac{-16}{\sqrt{29}\cdot\sqrt{26}}$ (d) $\frac{-4}{\sqrt{29}\cdot\sqrt{26}}$ (e) $\frac{-12}{\sqrt{29}\cdot\sqrt{26}}$

Questions 17-21

A truck of length $L = 6\ m$, initially at rest, starts moving with a constant acceleration A at $t = 0$. A block of mass $m = 2\ kg$ inside the truck is initially at rest and *barely touching* the front wall of the truck. The coefficient of static and kinetic frictions between the block and the truck are $\mu_s = 0.8$ and $\mu_k = 0.6$, respectively ($g = 10\ m/s^2$).



17. Which of the following is the minimum value of the A such that the block m starts sliding?
(a) $5\ m/s^2$ (b) $7\ m/s^2$ (c) $9\ m/s^2$ (d) $6\ m/s^2$ (e) $8\ m/s^2$

18. If $A = 9\ m/s^2$, which of the following is the acceleration vector of the block with respect to the truck?
(a) $2\hat{i}\ m/s^2$ (b) $3\hat{i}\ m/s^2$ (c) $-3\hat{i}\ m/s^2$ (d) $-2\hat{i}\ m/s^2$ (e) $-3/2\hat{i}\ m/s^2$

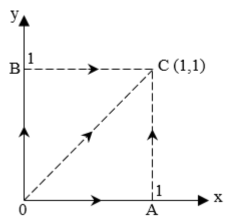
19. If $A = 6\ m/s^2$, which of the following is the magnitude of the friction force acting on the block?
(a) $10\ N$ (b) $12\ N$ (c) $8\ N$ (d) $14\ N$ (e) $16\ N$

20. If $A = 9\ m/s^2$, which of the following is the time required for the block to reach the back side of the truck?
(a) $2\ s$ (b) $3\ s$ (c) $\sqrt{3}\ s$ (d) $\sqrt{2}\ s$ (e) $1\ s$

21. If $A = 9\ m/s^2$, which of the following is the velocity vector of the block with respect to the ground when it reaches the back side?
(a) $12\hat{i}\ m/s$ (b) $-10\hat{i}\ m/s$ (c) $-8\hat{i}\ m/s$ (d) $10\hat{i}\ m/s$ (e) $8\hat{i}\ m/s$

Questions 22-25

A variable force acting on a particle of mass m moving in the xy-plane is given by $\vec{F}(x, y) = ax^2\hat{i} + by^2\hat{j}$ where a and b are constants. This particle moves from origin to point C with coordinates $(1, 1)$ through the three different paths: $O \to A \to C$, $O \to B \to C$, and $O \to C$.



22. Find the work done by $\vec{F}$ when the particle takes the path $O \to A \to C$, W_{OAC}=?
(a) $(2a + b)/3$ (b) $(a + 2b)/3$ (c) $(a - b)/3$ (d) $(2a - b)/3$ (e) $(a + b)/3$

23. Find the work done by $\vec{F}$ when the particle takes the path $O \to B \to C$, W_{OBC}=?
(a) $(a + b)/3$ (b) $(2a - b)/3$ (c) $(2a + b)/3$ (d) $(a + 2b)/3$ (e) $(a - b)/3$

24. Find the work done by $\vec{F}$ when the particle takes the path $O \to C$, W_{OC}=?
(a) $(a - b)/3$ (b) $(2a + b)/3$ (c) $(a + 2b)/3$ (d) $(a + b)/3$ (e) $(2a - b)/3$

25. Which of the followings are true?
1. This force can be a conservative force. **2.** This force can be a kind of frictional force. **3.** $W_{OACBO} = 0$.
4. $W_{OBCO} = b - a$.
(a) 2 (b) 1, 4 (c) 2, 4 (d) 1, 3 (e) 3, 4

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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 of the following statements are correct about the direction of the unit vector in the Universal Law of Gravitation defined as $\overrightarrow{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$.
1. From the source to the object. **2.** From the object to the source. **3.** How it is selected does not matter.
(a) Only 3 (b) All are correct (c) None of this is true (d) Only 2 (e) Only 1

2. The expression $a_c R^2 = k$ was found to be valid for each of the planets around the Sun. Here a_c and R are the centripetal acceleration and the average radius, respectively, and k is a constant. Which of the Newton's laws should be considered in conjunction with this statement to obtain the universal law of gravitation?
1. Action-reaction law **2.** The second law **3.** The law of inertia
(a) 1 and 2 (b) Only 2 (c) 1 and 3 (d) All are true (e) 2 and 3

3. The statement "A planet around the Sun sweeps equal areas in equal time intervals" (Kepler's law) can be proved by..
(a) Conservation of the energy (b) Conservation of the angular momentum (c) Conservation of the momentum (d) Newton's second law (e) Newton's law of inertia

4. While recognizing that the planets around the Sun can turn in nearly circular orbits, which of the followings expresses the linear velocity of the planet in terms of the radius of the orbit, R and the return period of the planet, T?
(a) $\frac{2\pi R^2}{T^2}$ (b) $\frac{R}{T}$ (c) $\frac{4\pi^2 R^2}{T^3}$ (d) $\sqrt{\frac{4\pi^2 R^2}{T^3}}$ (e) $\frac{2\pi R}{T}$

5. Which of the following is true for a planet rotating around the Sun in elliptical orbits.
(a) The planet's orbital speed does not change. (b) The speed of the planet is maximum when the planet is farthest from the sun. (c) The speed of the planet is minimum when the planet is closest to the sun. (d) Planets closer to the Sun orbital speed increases. (e) Planets closer to the Sun orbital speed decreases.

6. Which of the following is wrong about the rotational inertia of a rigid body?
(a) It depends on the shape of the object. (b) Increases with increasing speed. (c) Increases with increasing distance to the rotation axis. (d) It does not depend on angular speed. (e) Increases with increasing mass.

7. A particle of mass m moves along a straight line with an acceleration that is non-zero. Where can an axis be located such that the angular momentum of the particle is not constant?
(a) Any point on the path of the particle. (b) Initial point of the particle. (c) Any point not on the path of the particle. (d) There are no such points. (e) A point that is instantaneously at the location of the particle.

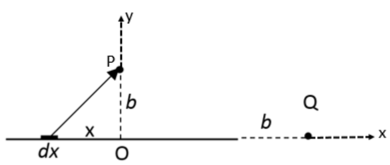
8. For a rigid body in equilibrium which of the following is wrong?
(a) It may have a constant angular velocity. (b) The only point with respect to which the net torque is zero is the center of mass of the body. (c) The net external force acting on the object is zero. (d) The angular acceleration is zero. (e) It may have a constant velocity.

9. The escape speed from a planet of mass M and radius R is v. What is the escape speed from a planet of mass $2M$ and radius $R/2$?
(a) v (b) $2v$ (c) $4v$ (d) $v/2$ (e) $\sqrt{2}v$

10. If the total momentum of a system of particles is zero, which of the following is wrong?
(a) The net impuls is zero. (b) All of the particles in the system can be at rest. (c) Center of mass velocity of the system is zero. (d) The total kinetic energy of the system is certainly zero. (e) The net external force acting on the system is zero.

Soru 11-15

A thin wire of the length L and the mass M is fitted to the x-axis as shown in the figure. The mid-point of the wire is located at the center, O, of the coordinate system, The point P is located at a distance $y = b$ above the midpoint of the wire. And the point Q is located at a distance b from the rigth end of the wire.



11. Which of the following expresses the mass, dm, of an infinitesimal length, dx, choosen along the wire?
(a) $dm = \frac{2M}{3L}dx$ (b) $dm = \frac{M}{L}dx$ (c) $dm = \frac{2M}{L}dx$ (d) $dm = \frac{M}{2L}dx$ (e) $dm = \frac{3M}{2L}dx$

12. What is the gravitational field of $d\vec{g}$ created by dm at the point P? Here dm is choosen at a distance x at the left of the point O as shown in the figure.
(a) $d\vec{g} = -G\frac{bdm}{(x^2+b^2)}\hat{j}$ (b) $d\vec{g} = -G\frac{dm}{(x^2+b^2)}(x\hat{i} + b\hat{j})$ (c) $d\vec{g} = -G\frac{dm}{(x^2+b^2)^{3/2}}(x\hat{i} - b\hat{j})$ (d) $d\vec{g} = -G\frac{dm}{(x^2+b^2)^{3/2}}(x\hat{i} + b\hat{j})$
(e) $d\vec{g} = -G\frac{xdm}{(x^2+b^2)^{3/2}}\hat{i}$

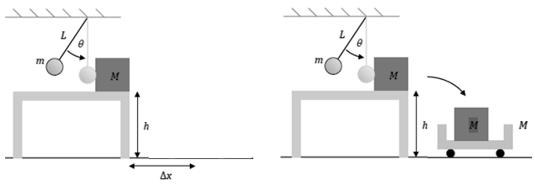
13. What is the net gravitational field created by the wire at the point P?
(a) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{x\,dx}{(x^2+b^2)^{3/2}}\hat{j}$ (b) $\vec{g} = -\frac{GM}{L}\int_{0}^{+L/2}\frac{x\,dx}{(x^2+b^2)^{3/2}}\hat{i}$ (c) $\vec{g} = -\frac{GM}{L}\int_{0}^{L}\frac{b\,dx}{(x^2+b^2)^{3/2}}\hat{j}$ (d) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{b\,dx}{\sqrt{x^2+b^2}}\hat{j}$
(e) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{b\,dx}{(x^2+b^2)^{3/2}}\hat{j}$

14. What is the net gravitational field at a distance b from the right end of the wire, the point Q?
(a) $\vec{g} = -\frac{GM}{L}\int_{0}^{L}\frac{dx}{(x+b)^{3/2}}\hat{i}$ (b) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{x\,dx}{(x+b)^2}\hat{i}$ (c) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{L/2}\frac{dx}{(\frac{L}{2}+b-x)^2}\hat{i}$ (d) $\vec{g} = -\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{dx}{(x+b)^2}\hat{i}$
(e) $\vec{g} = -\frac{GM}{L}\int_{0}^{L}\frac{b\,dx}{(x+b)^2}\hat{i}$

15. What is the gravitational force on a small particle of mass m located at the point P?
(a) $\vec{g} = -\frac{GMm}{L}\int_{0}^{L}\frac{b\,dx}{(x^2+b^2)}\hat{j}$ (b) $\vec{g} = -\frac{GMm}{L}\int_{-L/2}^{+L/2}\frac{b\,dx}{\sqrt{x^2+b^2}}\hat{j}$ (c) $\vec{g} = -\frac{GMm}{L}\int_{-L/2}^{+L/2}\frac{x\,dx}{(x^2+b^2)}\hat{j}$ (d) $\vec{g} = -\frac{GMm}{L}\int_{-L/2}^{+L/2}\frac{b\,dx}{(x^2+b^2)^{3/2}}\hat{j}$
(e) $\vec{g} = -\frac{GMm}{L}\int_{0}^{+L/2}\frac{x\,dx}{(x^2+b^2)^{3/2}}\hat{i}$

Soru 16-20

A pendulum of length $L = 1.0\ m$ and bob with mass $m = 1.0\ kg$ is released from rest at an angle $\theta = 30^o$ from the vertical. When the pendulum reaches the vertical position, the bob strikes a mass $M = 3.0\ kg$ that is resting on a frictionless table that has a height $h = 20\ m$, in the figure. $Cos30 = 0.8$, $Sin30 = 0.5$, $g = 10\ m/s^2$



16. When the pendulum reaches the vertical position, calculate the speed of the bob (m/s) just before it strikes the box.
(a) 2 (b) 3 (c) 1 (d) 5 (e) 4

17. Calculate the speed of the box (m/s) just after they collide elastically.
(a) −2 (b) 2 (c) 1 (d) −1 (e) 0

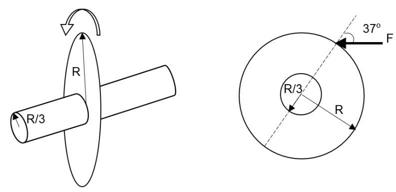
18. Calculate the speed of the the bob (m/s) just after they collide elastically.
(a) −1 (b) 1 (c) −2 (d) 2 (e) 0

19. Determine how far away from the bottom edge of the table, Δx (m), the box will strike the floor.
(a) 2 (b) 4 (c) 5 (d) 1 (e) 3

20. At the location where the box would have struck the floor, now a small cart of mass $M = 3.0\ kg$ and negligible height is placed. The box lands in the cart and sticks to the cart in a perfectly inelastic collision. Calculate the horizontal velocity of the cart (m/s) just after the box lands in it.
(a) 2/3 (b) 1/2 (c) 2 (d) 1 (e) 1/3

Questions 21-25

A disk of mass M and radius R is mounted on a rough horizontal cylindrical axle of radius $R/3$, as shown in the figure. There is a friction force between the disk and the axle. A constant force of magnitude F is applied to the edge of he disk at an angle of 37.0^o. After $3.00\ s$, the force is reduced to $F/5$, and the disk spins with constant angular speed after this instant. (For a disk of inner radius R_1 and outer radius R_2, $I_{cm} = \frac{1}{2}M(R_2^2 - R_1^2)$. $sin37 = 3/5$.)



21. What is the magnitude of the torque with respect to the center of the disk due to friction between the disk and the axle?
(a) $4FR/25$ (b) $3FR/25$ (c) $3FR/23$ (d) $4FR/27$ (e) $3FR/17$

22. What is the angular velocity of the disk at $t = 3.00\ s$?
(a) $\frac{81}{25}\frac{F}{MR}$ (b) $\frac{75}{26}\frac{F}{MR}$ (c) $\frac{81}{29}\frac{F}{MR}$ (d) $\frac{63}{25}\frac{F}{MR}$ (e) $\frac{67}{25}\frac{F}{MR}$

23. What is the kinetic energy of the disk at $t = 2.00\ s$?
(a) $\frac{457}{625}\frac{F^2}{M}$ (b) $\frac{677}{625}\frac{F^2}{M}$ (c) $\frac{648}{625}\frac{F^2}{M}$ (d) $\frac{717}{625}\frac{F^2}{M}$ (e) $\frac{217}{625}\frac{F^2}{M}$

24. What is the rate of change of the angular momentum of the system with respect to the center of mass of the disk, $\frac{d\vec{L}}{dt}$, at $t = 2.00\ s$?
(a) $\frac{113}{25}FR$ (b) $\frac{4}{5}FR$
(c) $\frac{11}{25}FR$ (d) $\frac{12}{25}FR$ (e) $\frac{17}{25}FR$

25. What is the rate of change of the angular momentum of the system with respect to the center of mass of the disk, $\frac{d\vec{L}}{dt}$, at $t = 4.00\ s$?
(a) $2FR/5$ (b) $3FR/5$ (c) FR (d) $4FR/5$ (e) 0

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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 of the following is not one of the fundamental physical quantities in the SI system?

(a) force (b) length (c) mass (d) time (e) All of the these are fundamental physical quantities.

Questions 2-5

Time dependent position vectors of two particles are given by $\vec{a} = t\hat{i} + 2\hat{j} + \hat{k}$ and $\vec{b} = \hat{i} - t\hat{j} + 2\hat{k}$. Here t represents time in seconds and the magnitudes of vectors $\vec{a}$ and $\vec{b}$ are in meters.

2. At which instant in time $\vec{a}$ is perpendicular to $\vec{b}$?

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

3. Which of the following is a unit vector, that is perpendicular to the plane spanned by vectors $\vec{a}$ and $\vec{b}$, at t=0?

(a) $\frac{2\hat{i}-3\hat{j}+5\hat{k}}{\sqrt{36}}$ (b) $\frac{4\hat{i}+3\hat{j}+2\hat{k}}{\sqrt{23}}$ (c) $\frac{2\hat{i}+4\hat{j}-2\hat{k}}{\sqrt{24}}$ (d) $\frac{4\hat{i}+\hat{j}-2\hat{k}}{\sqrt{21}}$ (e) $\frac{\hat{i}+\hat{j}-2\hat{k}}{\sqrt{6}}$

4. Which of the following is the distance between the two particles at t=3 s?

(a) 30 m (b) 28 m (c) $\sqrt{30}$ m (d) $\sqrt{29}$ m (e) $\sqrt{28}$ m

5. Which of the following is the position vector of the first particle relative to the second one at t=3 s?

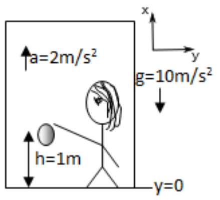
(a) $2\hat{i} + 5\hat{j} - \hat{k}$ (b) $3\hat{i} + 4\hat{j} - 1\hat{k}$ (c) $4\hat{i} + 5\hat{j} - 3\hat{k}$ (d) $4\hat{i} + 3\hat{j} + 2\hat{k}$ (e) $2\hat{i} - 3\hat{j} + 5\hat{k}$

6. A ball is thrown vertically upward, reaches its highest point and falls back down. Which of the following statements is true?

(a) The acceleration is always in the direction of motion. (b) The acceleration is always directed down. (c) At the highest point the velocity and acceleration of the particle are both nonzero. (d) The acceleration is always directed up. (e) The acceleration is always opposite to the velocity.

Questions 7-11

A girl is holding a ball as she steps onto a tall elevator on the ground floor of a building. She holds the ball at a height of 1 meter above the elevator floor. The elevator begins accelerating upward from rest at 2 m/s^2 in +y direction. After the elevator accelerates for 10 seconds (Take g = 10 m/s^2, $6^{-1/2}$ = 0.4),



7. Find the speed of the elevator.

(a) 25 m/s. (b) 15 m/s. (c) 20 m/s. (d) 5 m/s. (e) 30 m/s.

8. Find the height of the floor of the elevator above the ground.

(a) 75 m. (b) 100 m. (c) 200 m. (d) 150 m. (e) 50 m.

At the end of 10 s, the girl releases the ball from a height of 1 meter above the floor of the elevator. If the elevator continues to accelerate upward at 2 m/s^2,

9. Find the acceleration of the ball relative to the elevator.

(a) -8 m/s^2 (b) -12 m/s^2 (c) 12 m/s^2 (d) -10 m/s^2 (e) 8 m/s^2

10. What is the time needed the ball hits the floor after the ball is released ?

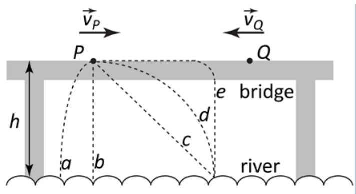
(a) 0.4 s (b) 0.2 s (c) 2 s (d) 2.5 s (e) 0.3 s

11. What is the elevator's approximate height (h) above the ground when the ball hits the elevator's ground?

(a) 8 m. (b) 4 m. (c) 174 m. (d) 100 m. (e) 108 m.

Questions 12-15

Harry is running with a constant speed $v_P = 3$ m/s across a horizontal bridge of height $h = 5$ m as shown in the figure. When he passes point P, he opens his hand and drops a rock into the river. In the following calculations, take $g = 10\ m/s^2$.



12. If you are standing at point P, which one of the trajectories shown in the figure best describes the path of the rock you are observing?

(a) Path b (b) Path a (c) Path e (d) Path d (e) Path c

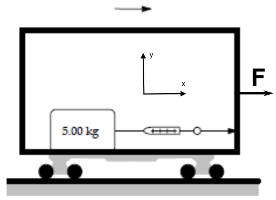
13. What horizontal distance does the rock travel from point P to the point where it hits the river?
(a) 6 m (b) 3 m (c) 10 m (d) 5 m (e) 1.5 m

14. What is the speed of the rock at the point where it hits the river?
(a) $\sqrt{109}$ m/s (b) 3 m/s (c) 13 m/s (d) 10 m/s (e) 5 m/s

15. Suppose Sally is running in the direction opposite to Harry with a constant speed $v_Q = 2$ m/s . She passes point Q located 2 m to the right of point P at the same time when Harry passes point P, opens her hand, and drops another rock into the river. What is the horizontal distance between the points where the two rocks dropped by Harry and Sally hit the river?
(a) 3 m (b) 2 m (c) 0 (d) 5 m (e) 1 m

Questions 16-18

A 5kg mass attached to a spring scale rest on a frictionless, horizontal surface. The spring scale attached to the front end of a boxcar, reads 20 N when the car is in motion and 0 N when it is at rest. The mass of boxcar is 10 kg.



16. In which type of frame of reference is Newton's first law obeyed?

I. Noninertial frame of reference. II. Inertial frame of reference. III. Frame of reference that is accelerating. IV. Frame of reference that is moving along a curve.

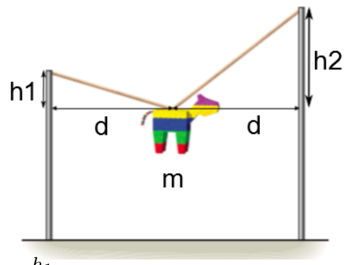
(a) none of them (b) only III (c) only II (d) I and III (e) II and III

17. Determine the acceleration of the car.
(a) $-\frac{4}{3}\hat{i}$ m/s^2 (b) $\frac{4}{3}\hat{i}$ m/s^2 (c) $4\hat{i}$ m/s^2 (d) $2\hat{i}$ m/s^2 (e) $-4\hat{i}$ m/s^2

18. What will the spring scale read if the car moves with constant velocity?
(a) 0 N (b) 10 N (c) 4 N (d) 6 N (e) -20 N

Questions 19-20

A toy horse of mass m is attached to a rope of negligible mass that is strung between the tops of two vertical poles as shown in the figure.



19. What is the relation between the tensions in the left (T_1) and right (T_2) sides of the rope?

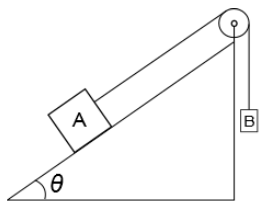
(a) $T_1 = T_2\frac{h_2^2}{h_1^2}$ (b) $T_1 = T_2\sqrt{\frac{h_1^2+d^2}{h_2^2+d^2}}$ (c) $T_1 = T_2\frac{h_1^2}{h_2^2}$ (d) $T_1 = T_2$ (e) $T_1 = T_2\sqrt{\frac{h_2^2+d^2}{h_1^2+d^2}}$

20. What is T_1?

(a) $T_1 = 2mg\frac{\sqrt{h_1^2+d^2}}{h_1+h_2}$ (b) $T_1 = mgh_1$ (c) $T_1 = mg\frac{\sqrt{h_1^2+d^2}}{h_1+h_2}$ (d) $T_1 = \sqrt{\frac{h_1^2+d^2}{h_2^2+d^2}}$ (e) $T_1 = mg\frac{h_1}{h_2}$

Questions 21-24

Block A of mass 2.0 kg is on an inclined plane with inclination $\theta = 37^o$ ($\sin\theta = 3/5$). It is attached with a string passing over a massless and frictionless pulley to block B of mass 1.0 kg. The coefficients of static and kinetic friction between block A and the inclined plane are μ_s=0.6 and μ_k=0.5, respectively. Gravitational acceleration is assumed to be 10 m/s^2. The system is released from rest. Assume that the static friction case holds:



21. What is the static friction force on block A?

(a) 9.6 N downhill (b) 9.6 N uphill (c) 0 (d) 2 N downhill (e) 2 N uphill

22. Is the static friction assumption valid or not and why?

(a) Yes, $f_s < \mu_s$N (b) Yes, $f_s = \mu_s$N (c) Yes, $f_s > \mu_s$ (d) No, $f_s > \mu_s$ (e) No, $f_s < \mu_s$

Now the blocks are given an initial velocity (hanging block downward, 2.0 kg block upward) of 1.0 m/s.

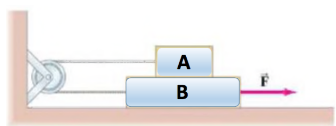
23. What is the acceleration of the hanging block in m/s^2

(a) 13/3 upward (b) 10/3 downward (c) 13/3 downward (d) 0 (e) 10/3 upward

24. How much will the blocks move until they stop (in meters)?

(a) 1 (b) they will not stop (c) 1/2 (d) 13/6 (e) 3/26

25. Consider the system shown in figure on the right. Block A sits on top of block B which is on a horizontal surface. The block B is pulled to the right with a force F. The coefficient of kinetic friction between all surfaces is μ_k. What is the acceleration of the system? Hint: Assume that the force is enough to move the system.



(a) $\mu_k(3m_A + m_B)g$ (b) $\frac{F-\mu_k(m_A+3m_B)g}{(m_A+3m_B)}$ (c) $\frac{2F-\mu_k(m_A+m_B)g}{(m_A+m_B)}$ (d) $\frac{F-\mu_k(3m_A+m_B)g}{(m_A+m_B)}$ (e) $\mu_k(m_A + 3m_B)g$

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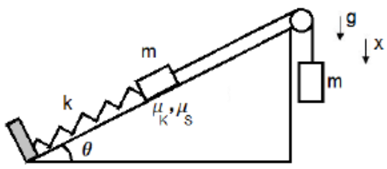
Questions 1-4

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?

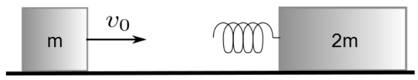
(a) 56 W (b) 14 W (c) 28 W (d) 42 W (e) 70 W

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?

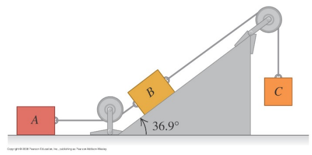
(a) $3mv_0^2/2$ (b) mv_0^2 (c) $mv_0^2/2$ (d) 0 (e) v_0^2

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

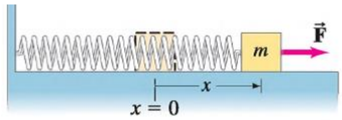
12. Find the work done by the force in first 2 seconds.

(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 $g = 10\,\mathrm{m/s^2}$.

(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?

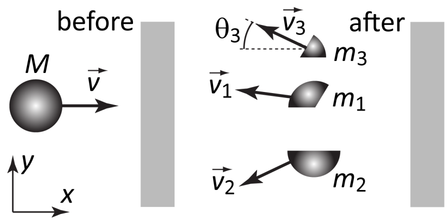
(a) $-\frac{1}{3}\hat{\imath} + \frac{1}{6}\hat{\jmath}$ (b) $\frac{1}{2}\hat{\imath} + \hat{\jmath}$ (c) $\frac{1}{6}\hat{\imath} + \frac{4}{3}\hat{\jmath}$ (d) $\frac{5}{6}\hat{\imath} + \frac{5}{6}\hat{\jmath}$ (e) $\frac{1}{6}\hat{\imath} + \frac{7}{6}\hat{\jmath}$

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.

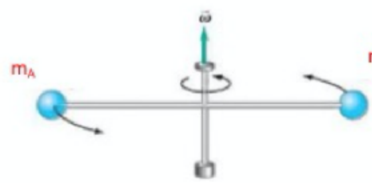
(a) 30° (b) 45° (c) −30° (d) −45° (e) −60°

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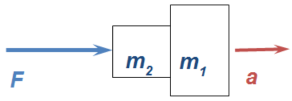
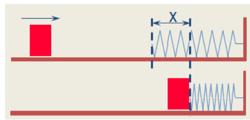
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. A force F acts on mass m_1 giving acceleration a_1. The same force acts on a different mass m_2 giving acceleration $a_2 = 2a_1$. If m_1 and m_2 are glued together and the same force F acts on this combination, what is the resulting acceleration?



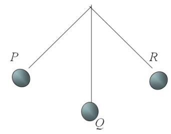
(a) $4/3\ a_1$ (b) $3/4\ a_1$ (c) $2/3\ a_1$ (d) $1/2\ a_1$ (e) $3/2\ a_1$

2. A box sliding on a frictionless flat surface runs into a fixed spring, which is compressed a distance x until the box stops. If the initial speed of the box were doubled, how much would the spring compress in this case?



(a) $\sqrt{2}$ times as much (b) The same amount (c) Half as much (d) Four times as much (e) Twice as much

3. A pendulum of length L with a bob of mass m swings back and forth. At the low point of its motion (point Q), the tension in the string is (3/2)mg. What is the speed of the bob at this point?



(a) $\frac{\sqrt{gL}}{2}$ (b) $2\sqrt{gL}$ (c) $\sqrt{gL}$ (d) $\sqrt{2gL}$ (e) $\sqrt{\frac{gL}{2}}$

4. One car has twice the mass of a second car, but only half as much kinetic energy. When both cars increase their speed by 7 m/s, they then have the same kinetic energy. What were the original speeds of two cars?

(a) $v_1 = \frac{7.0}{\sqrt{2}}$ m/s; $v_2 = v_1$ (b) $v_1 = 7\sqrt{2}$ m/s; $v_2 = v_1$ (c) $v_1 = 7\sqrt{2}$ m/s; $v_2 = 2v_1$ (d) $v_1 = 7\sqrt{2}$ m/s; $2v_2 = v_1$ (e) $v_1 = \frac{7.0}{\sqrt{2}}$ m/s; $v_2 = 2v_1$

5. A particle is moving along the x-axis subject to the potential energy function $U(x) = \frac{a}{x} + bx^2 + cx - d$, where $a = 3.00$ J m, $b = 12.0$ J/m^2, $c = 7.00$ J/m, and $d = 20.0$ J. Determine the x-component of the net force on the particle at the coordinate $x = 1$ m.

(a) $-2.8\,10^6$ g.cm/s^2 (b) $2.8\,10^6$ N (c) $-2.8\,10^6$ N (d) 0 (e) $2.8\,10^6$ g.cm/s^2

Questions 6-9

Two blocks shown in the figure are of mass "m" and rest on a flat frictionless air track. A spring of force constant "k" is attached to block (2). Block (1) has initial velocity in the +x direction. Block (2) is initially at rest. Block (1) also becomes attached when it hits the spring.

6. What is the center of mass velocity of the system?

(a) $v_0/2$ (b) 0 (c) v_0 (d) $2v_0$ (e) $v_0/4$

7. What is the minimum total kinetic energy consistent with the conservation laws?

(a) 0 (b) $mv_0^2/4$ (c) $2mv_0^2$ (d) mv_0^2 (e) $mv_0^2/2$

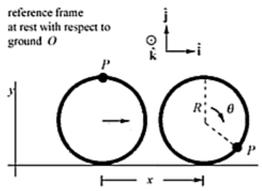
8. What is the maximum compression of the spring?

(a) $(m/2k)v_0$ (b) 0 (c) $(2k/m)v_0^2$ (d) $(m/2k)^{1/2}v_0$ (e) $(k/m)^{1/2}v_0$

9. What is the maximum velocity of block (1) after the collision?

(a) $v_0/\sqrt{2}$ (b) v_0 (c) $v_0/2$ (d) $2v_0$ (e) 0

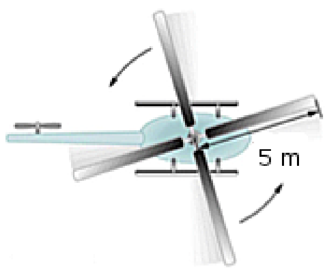
10. If a wheel of radius R rolls without slipping through an angle θ, what is the relationship between the distance the wheel rolls, x, and the product $R\theta$?



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

Questions 11-13

A typical small rescue helicopter has four blades as shown in the figure on right. Each is 5.00 m long and has a mass of 60.0 kg. The blades can be approximated as thin rods that rotate about one end of an axis perpendicular to their length. The helicopter has a total loaded mass of 2000 kg.



11. Calculate the rotational kinetic energy in the blades when they rotate at 300 rpm.

(a) $1.00\text{x}10^6$ J (b) $2.00\text{x}10^5$ J (c) $1.00\text{x}10^5$ J (d) $4.00\text{x}10^6$ J (e) $2.00\text{x}10^6$J

12. When the helicopter flies at 20.0 m/s, what is the ratio of the translational kinetic energy of the helicopter with respect to the rotational energy in the blades?

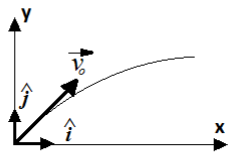
(a) 5.0 (b) 0.8 (c) 2.5 (d) 0.4 (e) 1

13. To what height could the helicopter be raised if all of the rotational kinetic energy could be used to lift it?

(a) 500.0 m (b) 50.0 m (c) 5.0 m (d) 25.0 m (e) 100.0 m

Questions 14-17

A projectile of mass m= 1 kg is fired from the ground with an initial position $\vec{r_o} = \vec{0}$ and initial velocity of $\vec{v_o} = 8\ (m/s)\hat{i} + 15\ (m/s)\hat{j}$. Acceleration due to gravity is $\vec{g} = -10\ (m/s^2)\hat{j}$. Answer the following for t=2 s.



14. Which of the following is the linear momentum of the particle in kg m/s?

(a) $5\hat{i} + 8\hat{j}$ (b) $8\hat{i} - 10\hat{j}$ (c) $5\hat{i} - 8\hat{j}$ (d) $8\hat{i} + 5\hat{j}$ (e) $8\hat{i} - 5\hat{j}$

15. Which of the following is the angular momentum of the particle in kg m^2/s?

(a) $160\hat{k}$ (b) $-80\hat{k}$ (c) $-160\hat{k}$ (d) $80\hat{i} - 80\hat{j}$ (e) $-80\hat{j}$

16. Which of the following is the rate of change of angular momentum of the particle in kg m^2/s^2?

(a) $-160\hat{k}$ (b) $-80\hat{k}$ (c) $-80\hat{j}$ (d) $80\hat{i} - 80\hat{j}$ (e) $160\hat{k}$

17. Which of the following is the net torque acting on the particle in N m?

(a) $-80\hat{k}$ (b) $160\hat{k}$ (c) $-160\hat{k}$ (d) $-80\hat{j}$ (e) $80\hat{i} - 80\hat{j}$

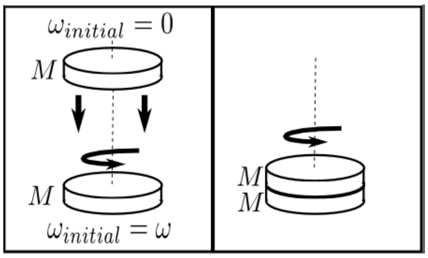
Questions 18-21

A uniform disk of mass "M", radius "R" and moment of inertia $I = MR^2/2$ is spining around its axis with angular speed ω. The system is frictionless.

18. What is its angular momentum L?

(a) $MR^2\omega^2$ (b) $MR^2\omega$ (c) $2MR^2\omega$ (d) $MR\omega^2/2$ (e) $MR^2\omega/2$

A second, identical disk is on the same axis, which is initially not spinning. It is allowed drop on the first disk. The two disks soon start turning together.



19. What quantity / quantities is /are conserved during the collision?

(a) L only. (b) Mechanical energy only. (c) Kinetic energy only. (d) L and mechanical energy. (e) L and kinetic energy.

20. What is the angular momentum L_f after the collision?

(a) $MR\omega^2/2$ (b) $MR^2\omega/2$ (c) $MR^2\omega$ (d) 0 (e) $2MR^2\omega$

21. What is the final kinetic energy KE_f after the collision?

(a) $MR^2\omega^2/2$ (b) 0 (c) $MR^2\omega^2/4$ (d) $MR^2\omega^2/8$ (e) $MR^2\omega^2$

22. Using Kepler's laws of planetary motion, decide which of the following statements are correct:
I) It takes the earth less time to complete one full revolution in its orbit around the sun than it takes Jupiter.
II) A planet moving in an orbit around the sun experiences zero net external torque.
III) Time needed by a planet to complete one full revolution around the sun increases with the mass of the planet.

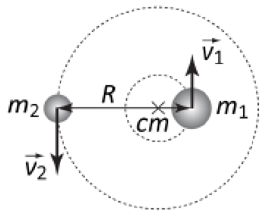
(a) Only II (b) I and II (c) I and III (d) II and III (e) I, II, and III

23. What is the magnitude of the angular momentum, L, of a satellite of mass m is in a circular orbit of radius $R = 2R_E$? The mass and radius of Earth are M_E and R_E. The universal gravitational constant is G and the magnitude of the gravitational acceleration on the earth surface is g.

(a) $L = M_E\sqrt{2gR_E^3}$ (b) $L = m\sqrt{GgR_E^3}$ (c) $L = 0$ (d) $L = (m + M_E)\sqrt{2gR_E^3}$ (e) $L = m\sqrt{2gR_E^3}$

Questions 24-25

Consider a binary star system with stars of masses $m_1 = 3M$ and $m_2 = M$, separated by distance R (see figure). The stars are in circular orbits around the center of mass of the system labeled "cm", with respective orbital speeds v_1 and v_2.



24. What is the ratio of orbital speeds v_1/v_2 of the two stars?

(a) 1/3 (b) 1/9 (c) 3 (d) 9 (e) 1

25. What is the orbital period of each star (symbol G stands for the gravitational constant)?

(a) $\frac{1}{2\pi}\frac{GM^2}{R^2}$ (b) $\frac{2\pi GM}{R}$ (c) $\sqrt{\frac{\pi^2 R^3}{GM}}$ (d) $3\sqrt{\frac{\pi^2 R^3}{GM}}$ (e) $\frac{1}{3}\sqrt{\frac{\pi^2 R^3}{GM}}$

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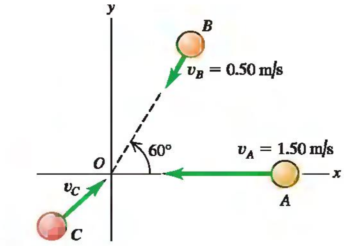
Questions 1-4

Three particles A (mass 0.020 kg), B (mass 0.030kg), and C (mass 0.050 kg) are approaching the origin as they slide on a frictionless air table shown in figure. The initial velocities of A and B are given in the figure. All three particles arrive at the origin at the same time and stick together. If all three particles are to end up moving at 0.50 m/s in the +x direction after the collision; (cos60=0.5 and sin60=0.86)



1. Which quantity(ies) will be conserved during this collision?
(a) nothing (b) x and y components of momentum (c) kinetic energy (d) x component of momentum (e) y component of momentum

2. What must the x component of the initial velocity of particle C ?
(a) 0 (b) 3 (c) 1.75 (d) 2.5 (e) 0.5

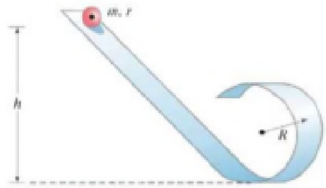
3. What must the y component of the initial velocity of particle C ?
(a) 1.5 (b) 2.5 (c) 0.26 (d) 3 (e) 0.9

4. What is the change in the kinetic energy of particle B as a result of the collision?
(a) 0.77 (b) 1.77 (c) -1.5 (d) 0 (e) 0.092

5. If the net force acting on a system is zero, is the net torque also zero? If the net torque acting on a system is zero, is the net force zero?
(a) No, No (b) Yes, No (c) None (d) No, Yes (e) Yes, Yes

Questions 6-8

A marble of mass m and radius r rolls along the looped rough track of Figure in the right:



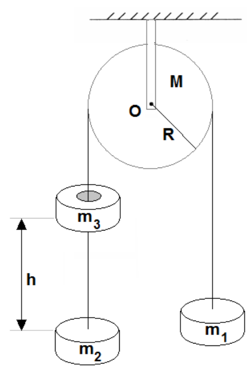
6. Assuming r << R, what is the minimum value of the vertical height h that the marble must drop if it is to reach the highest point of the loop without leaving the track?
(a) 2.6R (b) 2.8R (c) 2.9R (d) 2.7R (e) 2.5R

7. By what factor of R would provide half of the vertical height?
(a) 5/27 (b) 10/27 (c) 5/54 (d) 54/5 (e) 27/5

8. Without the assumption, what is the minimum value of the vertical height h that the marble must drop if it is to reach the highest point of the loop without leaving the track?
(a) 2.5(R-r) (b) 2.7(R-r) (c) 2.8(R-r) (d) 2.9(R-r) (e) 2.6(R-r)

Questions 9-12

While the Atwood machine shown in the figure is at rest, mass m_3 is released from a height h=0.2 m above the mass m_2. m_2 and m_3 stick together after collision. Acceleration due to gravity is g=10 m/s^2, $m_1 = m_2 = m_3 = 3$ kg, the mass and radius of the pulley are M=6 kg and R=0.15 m. The pulley rotates about a frictionless axle and has a moment of inertia $I_o = MR^2/2$. The cord does not slip on the pulley.



9. Which of the following is/are the conserved quantity/quantities during the collision?
(a) total angular momentum with respect to point O and the mechanical energy
(b) total angular momentum with respect to point O
(c) total angular momentum with respect to point O and the linear momentum
(d) mechanical energy
(e) linear momentum

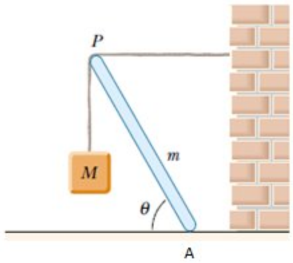
10. What is the speed of m_1 just after the collision?
(a) 2 m/s (b) 2/3 m/s (c) 1 m/s (d) 0.4 m/s (e) 0.5 m/s

11. Just after the collision, what is the magnitude of the angular momentum of m_1 with respect to m_2?
(a) 1.2 kg m^2/s (b) 0.9 kg m^2/s (c) 0.225 kg m^2/s (d) 1.8 kg m^2/s (e) 0.72 kg m^2/s

12. What is the acceleration of m_1 after the collision?
(a) 6 m/s^2 (b) 5 m/s^2 (c) 2 m/s^2 (d) 2.5 m/s^2 (e) 10/3 m/s^2

Questions 13-16

A uniform beam of mass m and length L is inclined at an angle θ to the horizontal. Its upper end produces a 90° bend in a very rough rope tied to a wall, and its lower end rest on a rough floor.



13. What is the value of torque about point A?

(a) (M+m)sinθL (b) MgLcosθ-mgLcosθ/2 (c) MgL+mgl/2 (d) 0 (e) Mgsinθ-mgcosθ

14. Determine an expression for the maximum mass M that can be suspended from the top before the beam slips, when the coefficient of static friction between the beam and the floor is $\mu_s < \cot\theta$.

(a) $\frac{m\mu_s}{2}$ (b) $\frac{m}{2}\left(\frac{2\mu_s\cos\theta-\sin\theta}{\mu_s\sin\theta}\right)$ (c) $\frac{m}{4}\left(\frac{2\mu_s\sin\theta}{\cos\theta-\mu_s\sin\theta}\right)$ (d) $\frac{m}{4}$ (e) $\frac{m}{2}\left(\frac{2\mu_s\sin\theta-\cos\theta}{\cos\theta-\mu_s\sin\theta}\right)$

15. Determine an expression for the maximum mass M that can be suspended from the top before the beam slips, when the coefficient of static friction between the beam and the floor is $\mu_s > \cot\theta$.

(a) M can increase without limit (b) $\frac{m}{2}\left(\frac{2\mu_s\cos\theta-\sin\theta}{\mu_s\sin\theta}\right)$ (c) m (d) $\frac{m}{2}\left(\frac{2\mu_s\sin\theta-\cos\theta}{\cos\theta-\mu_s\sin\theta}\right)$
(e) $\frac{m}{4}\left(\frac{2\mu_s\sin\theta}{\cos\theta-\mu_s\sin\theta}\right)$

16. Determine the magnitude of the reaction force at the floor in terms of m, M, and μ_s, when the coefficient of static friction between the beam and the floor is $\mu_s < \cot\theta$.

(a) $g\sqrt{m^2+\mu_s^2(M+m)^2}$ (b) $g\sqrt{M^2\sin\theta+\mu_s^2(M+m)^2\cos\theta}$ (c) $g\sqrt{Mm+\mu_s^2(M+m)^2}$ (d) $g\sqrt{M^2+\mu_s^2(M+m)^2}$
(e) $g\sqrt{\frac{M^2\sin\theta+\mu_s^2(M+m)^2\cos\theta}{m^2\cos\theta-\mu_s^2 M\sin\theta}}$

17. What is the relation between the total mechanical energy E and potential energy U of a satellite revolving in a circular orbit around the earth? Ignore the sky objects other than the earth and the rotation of the satellite about its own axis.

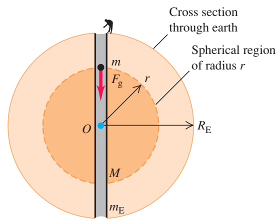
(a) $E=U$ (b) $U=2E$ (c) $E=-2U$ (d) $U=-2E$ (e) $E=2U$

18. Your personal spacecraft is in a low-altitude circular orbit around the earth. Air friction from the atmosphere does negative work on the spacecraft, causing the orbital radius to decrease slightly. What happens to the speed of your spacecraft?

(a) The answer depends on the original radius of the orbit (b) The answer depends on the ratio of masses of the spacecraft and the earth (c) It decreases (d) It remains the same (e) It increases

Questions 19-20

Imagine that you drill a hole through the earth along a diameter and drop a ball down the hole as shown in the figure. Assume that the earth's density is uniform and the earth is perfectly spherical. m_{E} and R_{E} are the mass and radius of the earth respectively, m is the mass of the ball, r is the distance from the center, M is the mass in the spherical region of radius r.



19. What is the expression for the gravitational force F_g on the ball as a function of its distance from the earth's center?

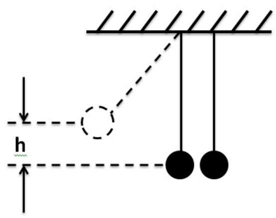
(a) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{R_{\mathrm{E}}}{r}$ (b) $F_g=0$ (c) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{r^2}{R_{\mathrm{E}}^2}$ (d) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{r}{R_{\mathrm{E}}}$ (e) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{R_{\mathrm{E}}^2}{r^2}$

20. What is the acceleration a of the ball at the instant when the ball reached the center of the earth? Assume that there isn't any friction force exerting on the ball.

(a) $a=9.8\,\mathrm{km/s^2}$ (b) Infinitely large (c) $a=0$ (d) Cannot be known since the initial speed of the ball is not given (e) $a=9.8\,\mathrm{m/s^2}$

Questions 21-25

In Figure, both balls have the same mass. The ball on the left is displaced to the outlined position and released; it collides with the stationary ball and sticks to it.



21. How fast are the balls moving just after collision?

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

22. What fraction of its kinetic energy did the first ball lose in the collision?

(a) %100 (b) %75 (c) %25 (d) %40 (e) %50

23. Suppose the two balls in figure have different masses; the ball on the left has m_1. When it is let go from the height shown, it hits the second ball and sticks to it. The combination then swings to a height h/9. Find the mass m_2 of second ball in terms of m_1

(a) $m_2=2m_1$ (b) $m_2=4m_1$ (c) $m_2=3m_1$ (d) $m_2=(1/2)m_1$ (e) $m_2=(3/2)m_1$

24. In figure, these two balls having different masses are displaced to a height h, one to the left and the other to the right. They are released simultaneously and undergo a perfectly elastic collision (it is assumed) at the bottom. How high does each swing after the collision?

(a) $V_{1f}=2\sqrt{2gh}$, $V_{2f}=\sqrt{2gh}$ (b) $V_{1f}=-(5/3)\sqrt{2gh}$, $V_{2f}=(1/3)\sqrt{2gh}$ (c) $V_{1f}=(4/3)\sqrt{2gh}$, $V_{2f}=\sqrt{2gh}$
(d) $V_{1f}=\sqrt{2gh}$, $V_{2f}=\sqrt{2gh}$ (e) $V_{1f}=-(2/3)\sqrt{2gh}$, $V_{2f}=\sqrt{2gh}$

25. Using the result of (23), the mass on the left (m_1) in figure is pulled aside and released. Its velocity at the bottom is v_0 just as it collides with the ball on the right (m_2) in a perfectly elastic collision. Find the velocities of two balls just after collision.

(a) $V_{1f}=-(1/3)v_0$, $V_{2f}=(2/3)v_0$ (b) $V_{1f}=-v_0$, $V_{2f}=v_0$ (c) $V_{1f}=-2v_0$, $V_{2f}=(1/3)v_0$ (d) $V_{1f}=-(1/2)v_0$, $V_{2f}=(1/3)v_0$ (e) $V_{1f}=-(1/3)v_0$, $V_{2f}=(1/3)v_0$

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Questions 1-3

Two vectors are given as $\vec{A} = a\hat{\imath} - 2\hat{k}$ and $\vec{B} = b\hat{\jmath} - 2\hat{k}$ where a and b are positive real numbers.

1. If the magnitudes of vectors are $A = 3$ and $B = 4$, find magnitude of the vector $\vec{A} - \vec{B}$.

(a) -4 (b) $\sqrt{17}$ (c) 12 (d) 5 (e) -$\sqrt{17}$

2. Angle between the vectors $\vec{A}$ and $\vec{B}$ is

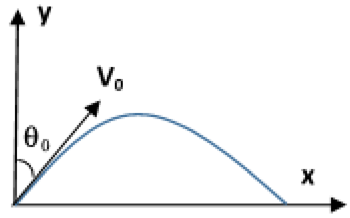
(a) $\arctan\sqrt{5/12}$ (b) $\arccos 1/3$ (c) $\arctan\sqrt{12/5}$ (d) 37° (e) 53°

3. Find a unit vector which is perpendicular to both vectors $\vec{A}$ and $\vec{B}$.

(a) $(\sqrt{12}\hat{\imath} + \sqrt{5}\hat{\jmath} + \sqrt{15}\hat{k})/\sqrt{32}$ (b) $(3\hat{\imath} + 4\hat{\jmath})/5$ (c) $2(\hat{\imath} + \hat{\jmath} - \hat{k})$ (d) $-\sqrt{5}\hat{\imath} + \sqrt{12}\hat{\jmath}$ (e) $(-\sqrt{5}\hat{\imath} + \sqrt{12}\hat{\jmath})/\sqrt{17}$

Questions 4-9

An object is thrown from ground with initial speed $V_0 = 10$ m/s at an angle $\theta_0 = 30°$ with the vertical axis as shown in the figure. (Ignore air resistance and take, g $\approx$ 10 m/s^2, $\sin 30° = 1/2$)



4. What is the acceleration of the object at the highest point?

(a) $\vec{a} = g\hat{\jmath}$ (b) $\vec{a} = g\hat{\imath}$ (c) $\vec{a} = -g\hat{\jmath}$ (d) $\vec{a} = 0$ (e) $\vec{a} = 2g\hat{\jmath}$

5. What is the maximum height that the object can reach?

(a) 15m (b) 5/4m (c) 1/2m (d) 15/4m (e) 5m

6. What is the time for the object to reach the maximum height?

(a) 15/4s (b) 5/4s (c) 1/2s (d) 2s (e) $\sqrt{3}$/2s

7. What is the horizontal range that the object can reach?

(a) 10m (b) 20$\sqrt{3}$m (c) 10$\sqrt{3}$m (d) 5m (e) 5$\sqrt{3}$m

8. A little time after the take-off, the object passes from point (x=$\sqrt{3}$m, y). What is y?

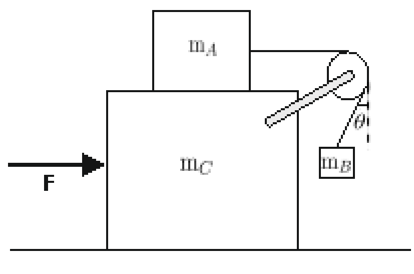
(a) 3$\sqrt{3}$m (b) $(\sqrt{3} - 1)$m (c) $\sqrt{3}$/2m (d) 12/5m (e) 1m

9. What is the velocity (in m/s) of the object when it hits the ground?

(a) $-5\hat{\imath} + 5\sqrt{3}\hat{\jmath}$ (b) $5\sqrt{3}\hat{\imath} + 5\hat{\jmath}$ (c) $5\hat{\imath} + 5\sqrt{3}\hat{\jmath}$ (d) $5\hat{\imath} - 5\sqrt{3}\hat{\jmath}$ (e) $-5\hat{\imath} - 5\sqrt{3}\hat{\jmath}$

Questions 10-14

A block of mass m_A=3 kg rests on another block of mass m_C=5 kg. Block m_A is connected by a thin string that passes over a pulley to a third block of mass m_B=1 kg. A force $\vec{\mathbf{F}}$ is exerted on the large block m_C so that the mass m_A does not move relative to m_C. Ignore all friction. Assume m_B does not make contact with m_C. g = 10 m/s^2.



10. What is the tension (in units of N) in the string in terms of the acceleration (a) of the system?

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

11. What is the tension (in units of N) in the string?

(a) $\frac{10}{\cos\theta}$ (b) 40 (c) 20 (d) 10 (e) $\frac{10}{\sin\theta}$

12. What is the value of $\sin\theta$?

(a) 3/5 (b) 1/3 (c) 0.5 (d) $\frac{\sqrt{3}}{2}$ (e) 2/5

13. What is the magnitude of $\vec{\mathbf{F}}$ in units of N?

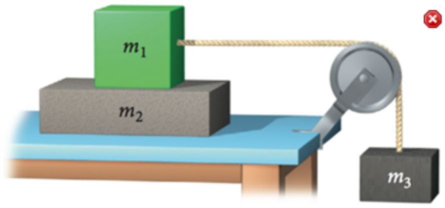
(a) 120 (b) 30 (c) $\frac{90}{\sqrt{8}}$ (d) 50 (e) 60

14. What is the acceleration (in m/s^2) of the block of mass m_B?

(a) $\frac{10}{3}$ (b) $\frac{20}{3}$ (c) $\frac{10}{\sqrt{8}}$ (d) $\frac{40}{3}$ (e) $\frac{50}{\sqrt{8}}$

Questions 15-19

Two blocks with masses m_1 and m_2 ($m_1\mu_s < m_2$) are on a frictionless table, and the blocks with masses, m_1 and m_3 are connected by a string as shown in the figure. The coefficients of static and kinetic friction between m_1 and m_2 are μ_s and μ_k, respectively. The three blocks are initially at rest and then left free to move.



15. If block m_1 slips on block m_2 what is the force of kinetic friction?

(a) $\frac{(-\mu_k m_1 - m_3)g}{m_1 - m_3}$ (b) $\frac{(-\mu_k m_1 - \mu_k m_2 + m_3)g}{m_1+m_2+m_3}$ (c) $\frac{\mu_k m_1 g}{m_1+m_2+m_3}$ (d) $\mu_k m_1 g$
(e) $\frac{(-\mu_k m_1 - \mu_k m_2 + m_3)g}{m_1+m_2-m_3}$

16. If block m_1 slips on block m_2 what is the acceleration of m_2?

(a) $\mu_k g \frac{m_1-m_2}{m_2}$ (b) $\mu_k g \frac{m_1}{m_2}$ (c) $\mu_k g \frac{m_2}{m_1+m_2}$ (d) $\mu_k g \frac{m_1+m_2}{m_2}$ (e) $\mu_k g \frac{m_1}{m_1+m_2}$

17. If block m_1 slips on block m_2 what is the acceleration of m_3?

(a) $\frac{(-\mu_k m_1 - \mu_s m_2 + m_3)g}{m_1+m_2+m_3}$ (b) $\frac{(-\mu_k m_1 - \mu_k m_2 + m_3)g}{m_1+m_2+m_3}$ (c) $\frac{(-\mu_k m_1 - m_3)g}{m_1-m_3}$ (d) $\frac{(-\mu_k m_1 + m_3)g}{m_1+m_3}$ (e) $\frac{(-\mu_k m_1 - \mu_k m_2 + m_3)g}{m_1+m_2-m_3}$

18. If block m_1 slips on block m_2 what is the tension in the string?

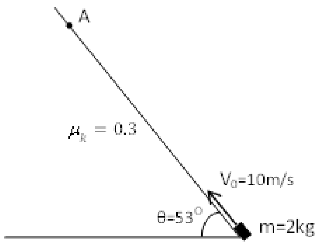
(a) $\frac{m_1 m_3 g}{m_1+m_3}(1+\mu_k)$ (b) $\frac{m_1 m_3 g}{m_2}(1+\mu_s)$ (c) $\frac{m_3 g}{m_1+m_3}(1+\mu_s)$ (d) $\frac{m_1 g}{m_1+m_3}(1+\mu_s)$ (e) $\frac{m_1 m_2 m_3 g}{m_1+m2+m_3}(1+\mu_k)$

19. What is the condition to be satisfied for the blocks with masses m_1 and m_2 move together without slipping?

(a) $m_3 \le \mu_s \frac{m_2}{m_1}(-m_1+m_2)$ (b) $m_3 \le \frac{m_1(m_1+m_2)\mu_s}{m_2 - m_1\mu_s}$ (c) $m_3 \le \mu_s(m_1+m_2)$ (d) $m_3 \le \mu_k \frac{m_1}{m_2}(m_1+m_2)$ (e) $m_3 \le \mu_k \frac{m_2}{m_1}(-m_1+m_2)$

Questions 20-25

An object of mass m=2kg is thrown up with the speed 10 m/s on an inclined surface of angle 53° as shown in the figure. The kinetic friction coefficient between the object and the surface is 0.3. (Take cos53° = 0.6, sin53° =0.8 and gravitational acceleration g=10 m/s^2)



20. What is the work (in Joule, J) done by the friction when the object reaches the point A, at a distance of 2 m from its initial point?

(a) +12 (b) +9.6 (c) -3.6 (d) 0 (e) -7.2

21. What is the work (in Joule) done by normal force up to the point A?

(a) +12 (b) 0 (c) +7.2 (d) +3.6 (e) -3

22. What is the work (in Joule) done by the net force up to the point A?

(a) -39.2 (b) -10.8 (c) +10.8 (d) +39.2 (e) -32

23. What is the speed (in m/s) of the object at the point A?

(a) $\sqrt{10.8}$ (b) $\sqrt{39.2}$ (c) $\sqrt{32}$ (d) $\sqrt{60.8}$ (e) $\sqrt{89.2}$

24. What is the approximate value of the distance (in m) that the object can travel on the inclined surface?

(a) 5.1 (b) 10.2 (c) 4.0 (d) 3.6 (e) 7.2

25. When the object turns back to its shooting point what is the speed (in m/s) of the object approximately?

(a) 5 (b) 6 (c) $\sqrt{63.3}$ (d) $\sqrt{36.7}$ (e) $\sqrt{18.4}$

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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?

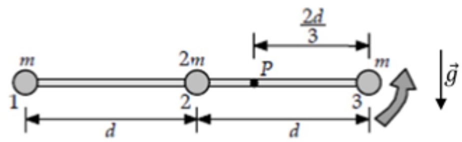
(a) 1.5 (b) 5 (c) 2 (d) 2.5 (e) 3

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. If the total angular momentum about a point P for a system of objects is conserved, which of the following statements about that system is always correct.

(a) Net torque created by external forces about point P is zero (b) Net torque created by internal forces about point P (c) Net external force is zero is nonzero (d) Net force acting on point P is zero (e) Net internal force is nonzero

2. Which of the following is true for Kepler's law of areas (planets sweep equal areas at equal times)

(a) This law is a result of conservation of linear momentum (b) This law is a result of work-energy theorem (c) This law is not valid for elliptical orbits (d) This law is a result of conservation of angular momentum (e) This law is not valid for circular orbits

Questions 3-5

An atomic nucleus of mass m traveling (along +x) with speed v collides elastically with a target particle of mass 2m (initially at rest) and is scattered at 90° relative to x axis.

3. What is the angle between the directions of atomic nucleus and the target particle after the collision?

(a) 90° (b) 135° (c) 120° (d) 150° (e) 180°

4. What is the final speed of the atomic nucleus?

(a) $\sqrt{\frac{3}{2}}v$ (b) $\frac{1}{\sqrt{3}}v$ (c) $\sqrt{\frac{2}{3}}v$ (d) $\sqrt{\frac{2}{5}}v$ (e) $\frac{2}{\sqrt{3}}v$

5. What is the final speed of the target particle?

(a) $\frac{2}{3}v$ (b) $2v$ (c) $\frac{5}{2}v$ (d) $\frac{1}{\sqrt{3}}v$ (e) $\frac{3}{4}v$

Questions 6-10

Suppose you are a 60 kg passenger in an elevator. The elevator is accelerating upward from rest at a = 1.0 m/s^2 for t=2 s, moves at the resulting velocity for 10 s,and then decelerates at a = -1.0 m/s^2 for 2 s.(g = 10 m/s^2)

6. For the entire trip, what is the work done by the normal force exerted on you by the elevator floor?

(a) 14.4 kJ (b) -8.4 kJ (c) -12.4 kJ (d) 10.4 kJ (e) -28.8 kJ

7. For the entire trip, what is the work done on you by the gravitational force?

(a) -10.4 kJ (b) 8.4 kJ (c) -14.4 kJ (d) 12.4 kJ (e) 28.8 kJ

8. What average power is delivered by the normal force for the whole motion that lasts 14.0 seconds approximately?

(a) 284 W (b) 1029 W (c) 1000 W (d) 514 W (e) 950 W

9. What instantaneous power is delivered by the normal force at 7.0 s?

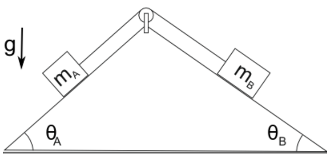
(a) 900 W (b) 400 W (c) 1100 W (d) 1200 W (e) 500 W

10. What instantaneous power is delivered by the normal force at 13.0 s?

(a) 110 W (b) 540 W (c) 220 W (d) 270 W (e) 440 W

Questions 11-15

The masses m_A =1.0 kg and m_B = 1.1 kg slide on the smooth (frictionless) triangular block as shown in the figure. The pulley and the cord have a negligible mass. The triangular block is fixed to the bottom. $\sin\theta_A = 0.60$, $\cos\theta_A = 0.80$,$\sin\theta_B = 0.50$,$\cos\theta_B = 0.87$ and g = 10 m/s^2.



11. What is the acceleration of the object of mass m_B in units of m/s^2 ?

(a) 5.75 left upwards (b) 0.24 left upwards (c) 5 right downwards (d) 5 left upwards (e) 5.75 right upwards

12. What is the tension on the cord approximately?

(a) 5.76 N (b) 11 N (c) 6.2 N (d) 11.75 N (e) 12 N

13. What is the vertical component (the direction of $\vec{g}$) of the force acting on the triangular block due to m_A ?

(a) 10 N (b) 5 N (c) 6.4 N (d) 9 N (e) 8 N

For the questions 14 and 15: θ_A and θ_B are not known.

14. When the system at rest, what would be the ratio of $\sin\theta_A/\sin\theta_B$?

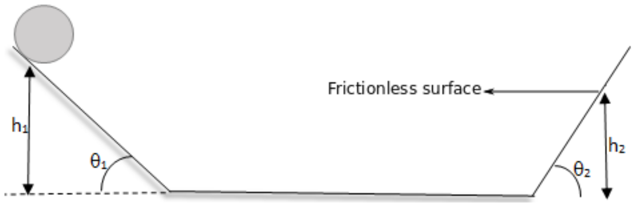
(a) 1.3 (b) 1.1 (c) 0.9 (d) 1.2 (e) 1

15. When the system is at rest, what is the tension on the cord?

(a) 6.2 N (b) It can't be determined (c) 5.8 N (d) 11 N (e) 12 N

Questions 16-20

Consider that a uniform solid ball, having mass M and radius R, starts rolling without slipping until it reaches the second inclined surface which is frictionless. $I_{cm} = \frac{2}{5}MR^2$



16. What is the minimum value of the coefficient of static friction, μ_s, between the ball and the first inclined surface so that the ball will roll down the inclined surface without slipping?

(a) $\frac{2}{7}\sin\theta_1$ (b) $\frac{2}{5}\sin\theta_1$ (c) $\frac{2}{7}\tan\theta_1$ (d) $\frac{2}{5}\tan\theta_1$ (e) $\frac{2}{5}\cot\theta_1$

17. What is the linear acceleration of the center of mass of the ball, while it is rolling down without slipping?

(a) $\frac{5}{7}g\sin\theta_1$ (b) $\frac{5}{7}g\tan\theta_1$ (c) $\frac{2}{7}g\sin\theta_1$ (d) $g\sin\theta_1$ (e) $\frac{3}{7}g\sin\theta_1$

18. What is the translational speed of the center of mass of the ball when it reaches the bottom of the first inclined surface?

(a) $\sqrt{\frac{5gh_1}{7}}$ (b) $\sqrt{\frac{3gh_1}{7}}$ (c) $\sqrt{10gh_1}$ (d) $\sqrt{\frac{10gh_1}{7}}$ (e) $\sqrt{\frac{10gh_1}{3}}$

19. What is the angular speed of the ball about its center of mass when it reaches the bottom of the first inclined surface?

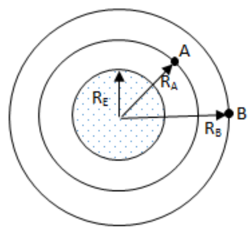
(a) $\sqrt{\frac{10gh_1}{R^2}}$ (b) $\sqrt{\frac{3gh_1}{7R^2}}$ (c) $\sqrt{\frac{10gh_1}{3R^2}}$ (d) $\sqrt{\frac{5gh_1}{7R^2}}$ (e) $\sqrt{\frac{10gh_1}{7R^2}}$

20. How high does the ball rise on the second inclined surface? (h_2=?)

(a) $\frac{5}{9}h_1$ (b) $\frac{3}{7}h_1$ (c) $\frac{10}{7}h_1$ (d) $\frac{3}{5}h_1$ (e) $\frac{5}{7}h_1$

Questions 21-25

Two satellites of masses m_A and m_B are moving in circular orbits around the Earth (mass and the radius of the Earth are M_E ve R_E, respectively). The radii of the orbits of satellites A and B are R_A and R_B, respectively. The periods of satellites A and B are T and 2T, respectively. (neglect the gravitational effect between Satellite A and Satellite B)



21. Find the R_B/R_A?

(a) $2^{1/3}$ (b) $3^{2/3}$ (c) $4^{1/3}$ (d) $2^{-1/3}$ (e) $4^{-1/3}$

22. Find the V_B/V_A?

(a) $3^{-2/3}$ (b) $2^{-2/3}$ (c) $2^{2/3}$ (d) $4^{2/3}$ (e) $2^{-1/3}$

23. What is the mechanical energy of satellite A?

(a) 0 (b) $\frac{gM_Em_A}{2R_A}$ (c) $-\frac{GM_Em_A}{2R_A}$ (d) $\frac{GM_Em_A}{2R_A}$ (e) $-\frac{gM_Em_A}{2R_A}$

24. Find the escape speed of satellite A from its orbit ?

(a) $\sqrt{\frac{GM_E}{2R_E}}$ (b) $\sqrt{\frac{GM_E}{2R_A}}$ (c) $\sqrt{\frac{GM_E}{R_A}}$ (d) $\sqrt{\frac{2GM_E}{R_E}}$ (e) $\sqrt{\frac{2GM_E}{R_A}}$

25. What is the work that must be done to move the satellite A from the orbit of radius R_A to the orbit of radius R_B?

(a) $\frac{1}{2}GM_Em_A(\frac{1}{R_B} - \frac{1}{R_E})$

(b) $\frac{1}{2}GM_Em_A(\frac{1}{R_A} - \frac{1}{R_B})$

(c) $-\frac{1}{2}GM_Em_A(\frac{1}{R_B})$

(d) $\frac{1}{2}GM_Em_A(\frac{1}{R_E} - \frac{1}{R_B})$

(e) $\frac{1}{2}GM_Em_A(\frac{1}{R_B} - \frac{1}{R_A})$

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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 small piece of packing material with m = 3 kg is dropped from a height of 2 m above the ground. Until it reaches terminal speed, the magnitude of its acceleration is given by $a = g - bV$. After falling 0.5 m the material reaches its terminal speed, and then takes 3 s more to reach the ground. ($g = 10\text{m/s}^2$)

1. What is the terminal speed of the material?

(a) 0.3 m/s (b) 0.2 m/s (c) 0.5 m/s (d) 1 m/s (e) 0.4 m/s

2. What is the value of the constant b?

(a) 40 s^{-1} (b) 4 s^{-1} (c) 5 s^{-1} (d) 20 s^{-1} (e) 10 s^{-1}

3. What is the acceleration at t=0?

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

4. What is the acceleration when the speed is 0.15 m/s?

(a) 7 m/s^2 (b) 6 m/s^2 (c) 10 m/s^2 (d) 4 m/s^2 (e) 5 m/s^2

5. What is the net force acted on the material when the speed is 0.15 m/s?

(a) 21 N (b) 15 N (c) 18 N (d) 30 N (e) 12 N

Questions 6-10

A block of mass m is placed in front of a spring which is compressed as x (between points A and B) and the system is set on an inclined surface as in the figure. The rail between A and B, and the circular part (of radius R) between C and E are frictionless (no friction). The region between B and C is considered as a completely flat surface of kinetic friction constant , μ_k. When the spring is released the block leaves the spring and moves along the rail between the points A and E. It passes the point E without falling down. (Take the gravitational acceleration as g)

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

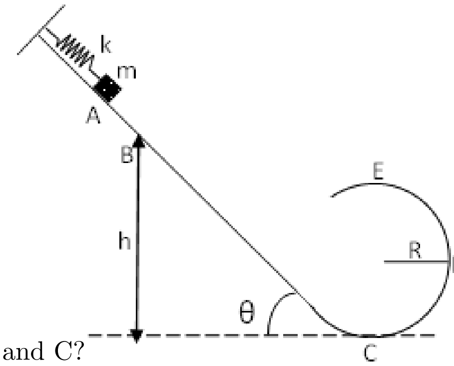
(a) $v = \sqrt{2gx\sin\theta}$

(b) $v = \sqrt{\frac{1}{2}kx}$

(c) $v = \sqrt{\frac{2}{m}(mgx\sin\theta - \frac{1}{2}kx^2)}$

(d) $v = \sqrt{\frac{2}{m}(mgx\sin\theta + \frac{1}{2}kx^2)}$

(e) $v = \sqrt{\frac{2}{m}(\frac{1}{2}kx^2 - mgx\sin\theta)}$



7. What is the energy lost in the mechanical energy of the block between the points B and C?

(a) zero (b) $\mu_k mgh\cot\theta$ (c) $\mu_k mgh\tan\theta$ (d) $\mu_k\frac{1}{2}kx^2$ (e) $\mu_k mgh\sin\theta$

8. What is the kinetic energy of the block at point C?

(a) $\sqrt{mgh(1-\mu_k) + \frac{1}{2}kx^2}$ (b) mgh (c) $mgh(1-\mu_k) - \frac{1}{2}kx^2$ (d) $mgh(1+\mu_k) + \frac{1}{2}kx^2$ (e) $mg(h + x\sin\theta - \mu_k h\cot\theta) + \frac{1}{2}kx^2$

9. What is the kinetic energy of the block at point E?

(a) $\frac{1}{2}(mgh(1-\mu_k) + \frac{1}{2}kx^2 + mg2R)$ (b) $\frac{1}{2}(mgh(1+\mu_k) + \frac{1}{2}kx^2 + mg2R)$ (c) $\frac{1}{2}(mgh(1-\mu_k) - \frac{1}{2}kx^2 - mg2R)$ (d) $mg(h + x\sin\theta - \mu_k h\cot\theta - 2R) + \frac{1}{2}kx^2$ (e) $\frac{1}{2}(mgh(1+\mu_k) + \frac{1}{2}kx^2 - mg2R)$

10. What is the normal force on the block applied by the rail at the point E?

(a) $\frac{m}{2R}(mgh(1-\mu_k) - \frac{1}{2}kx^2 - mg2R) - mg$ (b) $\frac{2}{R}(mg(h + x\sin\theta - \mu_k h\cot\theta - 2R) + \frac{1}{2}kx^2) - mg$ (c) $\frac{m}{2R}(mgh(1-\mu_k) + \frac{1}{2}kx^2 - mg2R) + mg$ (d) $\frac{m}{2R}(mgh(1-\mu_k) + \frac{1}{2}kx^2 + mg2R) - mg$ (e) $\frac{m}{2R}(mgh(1+\mu_k) + \frac{1}{2}kx^2 - mg2R) - mg$

Questions 11-15

A 3.0 kg object has the following two forces acting on it: $\vec{F_1} = (16\hat{\imath} + 12\hat{\jmath})$ N and $\vec{F_2} = (-10\hat{\imath} + 21\hat{\jmath})$ N. The object is initially at rest at a point given by the coordinates (x = 3 m, y = 4 m).

11. What is the magnitude of acceleration of the object?

(a) 6 m/s^2 (b) 12 m/s^2 (c) $5\sqrt{5}$ m/s^2 (d) 11.75 m/s^2 (e) 11 m/s^2

12. What is the momentum change in 4 s?

(a) $(8\hat{\imath}+44\hat{\jmath})$ N·s (b) $(3\hat{\imath}+4\hat{\jmath})$ N·s (c) $(6\hat{\imath}+33\hat{\jmath})$ N·s (d) $(24\hat{\imath}+132\hat{\jmath})$ N·s (e) $(2\hat{\imath}+44\hat{\jmath})$ N·s

13. What is the velocity of the object at t = 2 s?

(a) $(2\hat{\imath}+44\hat{\jmath})$ m/s (b) $(4\hat{\imath}+22\hat{\jmath})$ m/s (c) $(3\hat{\imath}+4\hat{\jmath})$ m/s (d) $(6\hat{\imath}+33\hat{\jmath})$ m/s (e) $(8\hat{\imath}+24\hat{\jmath})$ m/s

14. What is the position vector of the object at t = 2 s?

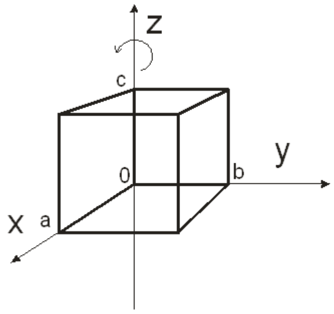
(a) $(7\hat{\imath}+26\hat{\jmath})$ m (b) $(10\sqrt{5}\hat{\imath}+10\hat{\jmath})$ m (c) $(4\hat{\imath}+72\hat{\jmath})$ m (d) $(4\hat{\imath}+88\hat{\jmath})$ m (e) $(8\hat{\imath}+132\hat{\jmath})$ m

15. What is the average velocity of the object between t = 2 s and t = 3 s?

(a) $(12\hat{\imath}+66\hat{\jmath})$ m/s (b) $(5\hat{\imath}+27.5\hat{\jmath})$ m/s (c) $(4\hat{\imath}+88\hat{\jmath})$ m/s (d) $(8\hat{\imath}+24\hat{\jmath})$ m/s (e) $(6\hat{\imath}+8\hat{\jmath})$ m/s

Questions 16-20

A rectangular prism with a mass M = 3 kg rotates in a coordinate system as shown in the figure. The lengths of the sides are a = 1 m, b = 2 m, and c = 3 m. The prism has an angular velocity w = 2 + 3 t^2 – 2 t^3 about +z-axis in units of rad/s.



16. Find the rotational inertia about z-axis in kgm^2?

(a) 21 (b) 7 (c) 5 (d) 10 (e) 42

17. Find the rotational inertia about axis through the center of mass and parallel to the z-axis.

(a) 10 kgm^2 (b) 21 kgm^2 (c) 5/4kgm^2 (d) 12 kgm^2 (e) 14 kgm^2

18. What is the angular displacement of the point given by the coordinates (x = 1 m, y = 2 m, z = 3 m) between t = 0 s and t = 2 s?

(a) 3 rad (b) 0 rad (c) 5 rad (d) 4 rad (e) 2 rad

19. What is the magnitude of the tangential acceleration of the point given by the coordinates (x = 1 m, y = 2 m, z = 3 m) at t = 2 s in m/s^2?

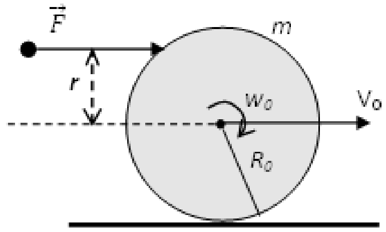
(a) $4\sqrt{5}$ (b) $4\sqrt{2}$ (c) $12\sqrt{5}$ (d) $18\sqrt{5}$ (e) $8\sqrt{5}$

20. What is the kinetic energy of the rectangular prism at t = 2 s?

(a) 14 J (b) 21 J (c) 16 J (d) 18 J (e) 10 J

Questions 21-25

A force $\vec{F} = F\hat{\imath}$ is applied only for a short time at a point above the center of a sphere and transfers a net linear momentum $\vec{p} = p\hat{\imath}$ to the sphere in the x-direction. Ignore any frictional force during the application of the force $\vec{F} = F\hat{\imath}$, and consider that the only force is the frictional force for t≥0. The sphere has a mass m and radius R_0. The sphere is at rest initially. The point to which the force applied is $r = \frac{3}{10}R_0$ above the center of mass of the sphere. The magnitude of the net frictional force for the sphere is $F_k = \mu mg$ where μ is the kinetic friction coefficient between the surfaces. The moment of inertia about an axis passing through the center of mass of the sphere is given by $I = \frac{2}{5}mR_0^2$. The directionof +z-axis is out of the page.



21. What is the speed of the center of mass of the sphere just after the application of the force? ($V_0 = V(t=0) =$?)

(a) $\frac{2p}{m}$ (b) $\frac{p}{m}$ (c) $\frac{m}{p}$ (d) $\frac{p^2}{2m}$ (e) $\frac{p}{2m}$

22. What is the angular speed about the axis passing through the center of mass just after the application of the force? ($w_0 = w(t=0) =$?)

(a) $\frac{4mR_0}{3p}$ (b) $\frac{3}{4}\frac{p}{mR_0}$ (c) $\frac{mR_0}{p}$ (d) $\frac{4}{3}\frac{p}{mR_0}$ (e) $\frac{p}{mR_0}$

23. What is the velocity of the center of mass as function of time? ($\vec{V}(t) =$?)

(a) $\left(\frac{p}{2m} - \mu gt\right)\hat{\imath}$ (b) $\left(\frac{p}{2m} - 2\mu gt\right)\hat{\imath}$ (c) $\left(\frac{2p}{m} - \mu gt\right)\hat{\imath}$ (d) $\left(\frac{p}{m} - 2\mu gt\right)\hat{\imath}$ (e) $\left(\frac{p}{m} - \mu gt\right)\hat{\imath}$

24. What is the angular velocity about the axis passing through the center of mass as function of time? ($\vec{w}(t) =$?)

(a) $-\left(\frac{3}{4}\frac{p}{mR_0} + \frac{5\mu g}{2R_0}t\right)\hat{k}$ (b) $-\left(\frac{p}{mR_0} + \frac{5\mu g}{4R_0}t\right)\hat{k}$ (c) $-\left(\frac{4}{3}\frac{p}{mR_0} + \frac{4\mu g}{5R_0}t\right)\hat{k}$ (d) $-\left(\frac{3}{4}\frac{p}{mR_0} + \frac{\mu g}{R_0}t\right)\hat{k}$ (e) $-\left(\frac{4mR_0}{3p} + \frac{5\mu g}{4R_0}t\right)\hat{k}$

25. At t=0 the sphere is slipping on the surface. Find the value of t for the sphere to start rolling without slipping?

(a) $\frac{p}{\mu g}$ (b) $\frac{p}{14m\mu g}$ (c) $\frac{p}{m\mu g}$ (d) $\frac{p}{m\mu}$ (e) $\frac{9p}{m\mu g}$

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Questions 1-11

1. Given the two vectors $\vec{A} = 2\hat{\imath} - 3\hat{\jmath}$ and $\vec{B} = -\hat{\imath} + y\hat{\jmath}$, find the value of y such that $\vec{A}$ and $\vec{B}$ are orthogonal?
(a) -3/2 (b) -2/3 (c) 2/3 (d) 1/3 (e) 3/2

2. Pressure is force per unit area, its SI unit is Pascal (Pa). Therefore;
(a) 1Pa=1J m (b) 1Pa=1J/ m^2 (c) 1Pa=1J m^3 (d) 1Pa=1J/m^3 (e) 1Pa=1J m^2

3. In uniform circular motion, velocity is (a) perpendicular to acceleration vector. (b) parallel to acceleration vector. (c) in the opposite direction to position. (d) radially outward. (e) radially inward.

4. Which of the following is true for the instantaneous velocity?
(a) The instantaneous velocity is also called as average velocity.
(b) It equals the instaneous rate of change of its acceleration vector.
(c) It equals the limit of the average velocity as the time interval goes to infinity.
(d) The instantaneous velocity is tangent to the particle's path.
(e) Each component of a particle's instantaneous velocity is equal to each other.

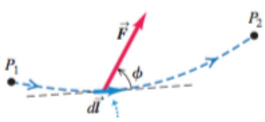
5. For motion with acceleration, which of the following is correct?
(a) A body with constant acceleration can not remain stationary. (b) If the speed is negative then the acceleration is negative. (c) A body with constant acceleration can remain stationary. (d) If the speed is positive then the acceleration is positive. (e) If the speed is zero then the acceleration is zero.

6. Consider a rock dropped from rest and falling through a fluid (e.g. water) with a fluid resistance. Which of the following is correct?
(a) The speed is always constant and is equal to the terminal speed.
(b) The speed decreases until terminal speed is reached.
(c) The speed first decreases than increases until terminal speed is reached.
(d) The speed first increases than decreases until terminal speed is reached.
(e) The speed increases until terminal speed is reached.

7. A man in an elevator drops the bag he is holding. If the bag does not fall to the floor of the elevator which of the following may be true?
I. Elevator is in free fall. II. Elevator is at constant speed. III. Elevator is accelerating downward with acceleration g. IV. Elevator is accelerating upward with g.
(a) I and IV (b) II and III (c) I and III (d) I and II (e) II and IV

8. A 10000 N automobile is pushed along a level road by four students who apply a total forward force of 500 N. Neglecting friction and taking $g = 10$ m/s^2, the acceleration of the automobile is:
(a) 0.5 m/s^2 (b) 10 m/s^2 (c) 5 m/s^2 (d) 20 m/s^2 (e) 2 m/s^2

9. According to the figure for motion along a curve, the corresponding work from P_1 to P_2 can be calculated as:
(a) $W = \int_{P_2}^{P_1} F \mathrm{d}l$ (b) $W = -\int_{P_1}^{P_2} F \sin\phi \mathrm{d}l$ (c) $W = -\int_{P_1}^{P_2} F \cos\phi \mathrm{d}l$
(d) $W = \int_{P_1}^{P_2} F \sin\phi \mathrm{d}l$ (e) $W = \int_{P_1}^{P_2} F \cos\phi \mathrm{d}l$

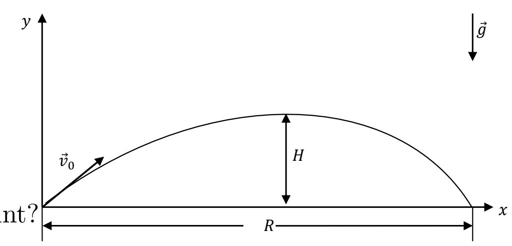


10. An elevator is pulled upward with a cable at constant velocity. The work done by the cable on the elevator
(a) is zero. (b) is positive. (c) is equal to the total work done on the elevator. (d) is negative. (e) is equal two times the total work done on the elevator.

11. Two objects interact only with each other. Initial speeds at the starting point are 5m/s for object A and 10m/s for object B. After some time, while they pass from their starting positions, A has a speed of 4m/s and B has a speed of 7m/s. What can be concluded?
(a) mechanical energy was increased by nonconservative force
(b) mechanical energy was increased by conservative forces
(c) mechanical energy was decreased by conservative forces
(d) the potential energy changed from the beginning to the end of the trip
(e) mechanical energy was decreased by nonconservative forces

Questions 12-16

A ball is thrown with an initial velocity $\vec{v}_0$, directed at an angle θ with the ground. The velocity vector of the ball at a height 5 m from the ground is given as $\vec{v} = (10\hat{\imath} - \sqrt{44}\hat{\jmath})$ m/s. (Take $g = 10$ m/s^2.)



12. What is the initial velocity $\vec{v}_0$ of the ball in m/s?

(a) $5\hat{\imath} + 12\hat{\jmath}$ (b) $5\hat{\imath} + 10\hat{\jmath}$ (c) $12\hat{\imath} + 5\hat{\jmath}$ (d) $10\hat{\imath} + 12\hat{\jmath}$ (e) $12\hat{\imath} + 10\hat{\jmath}$

13. What is the position vector of the ball in m when it reaches the highest point?

(a) $24\hat{\imath} + 7.2\hat{\jmath}$ (b) $12\hat{\imath} + 14.4\hat{\jmath}$ (c) $12\hat{\imath} + 7.2\hat{\jmath}$ (d) $24\hat{\imath} + 14.4\hat{\jmath}$ (e) $12\hat{\imath} + 24\hat{\jmath}$

14. What is the equation of the trajectory of the ball?

(a) $y = 1.2x - x^2/20$ (b) $y = 12x - x^2/100$ (c) $y = 12x - x^2/20$ (d) $y = 10x - x^2/20$ (e) $y = 1.2x - x^2/100$

15. How many seconds does it take for the ball to reach a height of $y = 63/20$ m?

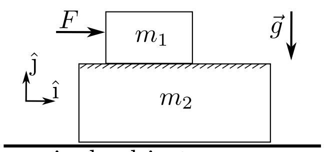
(a) 1 and 2 (b) 0.3 and 0.6 (c) 2.1 and 4.2 (d) 0.6 and 4.2 (e) 0.3 and 2.1

16. When the ball reaches the point $x = 3$ m and $y = 63/20$ m over the time interval, what is the average velocity $\Delta\vec{v}$ of the ball in m/s from the initial point?

(a) $10\hat{\imath} + 10.5\hat{\jmath}$ (b) $1.5\hat{\imath} + 1.5\hat{\jmath}$ (c) $1.6\hat{\imath} + 1.75\hat{\jmath}$ (d) $5\hat{\imath} + 5.25\hat{\jmath}$ (e) $10\hat{\imath} + 10\hat{\jmath}$

Questions 17-21

A block of $m_1 = 2.0\ kg$ is initially at rest on a slab of mass $m_2 = 4.0\ kg$, and a constant horizontal force F is applied on m_1, as shown in the figure. There is no friction between the ground and the slab but the coefficient of static and kinetic friction between the blocks are $\mu_s = 0.8$ and $\mu_k = 0.6$, respectively. (Take $g = 10.0\ m/s^2$.)



17. Find the maximum value of the force F for which m_1 will not slide off m_2 and they move as a single object.
(a) 16 N (b) 22 N (c) 24 N (d) 18 N (e) 26 N

18. If $F = 18\ N$, find the accelerations of the blocks in m/s^2.
(a) $a_1 = 2$ and $a_2 = 4$ (b) $a_1 = a_2 = 3$ (c) $a_1 = a_2 = 2$ (d) $a_1 = 3$ and $a_2 = 2$ (e) $a_1 = a_2 = 4$

19. If $F = 18\ N$, which of the following is the force applied by m_1 on m_2?
(a) $14\hat{\imath} - 18\hat{\jmath}\ N$ (b) $-12\hat{\imath} - 18\hat{\jmath}\ N$ (c) $-16\hat{\imath} + 18\hat{\jmath}\ N$ (d) $-12\hat{\imath} - 16\hat{\jmath}\ N$ (e) $12\hat{\imath} - 20\hat{\jmath}\ N$

20. If $F = 21\ N$, find the magnitude of the friction between the blocks.
(a) 16 N (b) 15 N (c) 14 N (d) 12 N (e) 13 N

21. If $F = 26\ N$, find the acceleration of m_1 relative to m_2.
(a) $-3\hat{\imath}\ m/s^2$ (b) $2\hat{\imath}\ m/s^2$ (c) $4\hat{\imath}\ m/s^2$ (d) $3\hat{\imath}\ m/s^2$ (e) $-2\hat{\imath}\ m/s^2$

Questions 22-25

22. Stretching a non-linear spring requires an amount of work given by the equation $U(x) = 15x^2 - 10x^3$, where U is in Joules and x is in meters units. How much force is required to hold this spring stretch out 2.0 m from its equilibrium position?

(a) 400 N (b) 5 N (c) 20 N (d) 120 N (e) 60 N

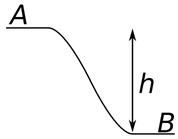
23. The behavior of a non-linear spring is described by the relationship $F = -2kx^3$, where x is the displacement from the equilibrium position and F is the force exerted by the spring. How much potential energy is stored when it is displaced a distance x from its equilibrium position?

(a) $kx^4/2$ (b) $6kx^2$ (c) $kx^3/3$ (d) $kx^4/32$ (e) $2kx^2/3$

24. An object of mass m moves horizontally, increasing in speed from 0 to v in time t. The constant power necessary to accelerate the object during this time period is

(a) $mv^2/(2t)$ (b) $v\sqrt{m/(2t)}$ (c) $2mv^2$ (d) $mv^2/2$ (e) $mv^2t/2$

25. A 55 kg skier is at the top of a slope, as shown in the figure. At the initial point A, the skier is $h = 10.0$m vertically above the final point B. Set the zero level for gravitational potential energy at A, write the gravitational potential energies of the skier at A and B, U_A and U_B respectively. (Take $g = 10$ m/s^2.)



(a) $5500\,J, 0\,J$ (b) $0\,J, -55\,J$ (c) $0\,J, -5500\,J$ (d) $0\,J, 5500\,J$ (e) $-5500\,J, 5500\,J$

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Questions 1-2

1. A ball collides with a second ball at rest. After the collision, the first ball comes to rest and the second ball moves off. Which of the following is *always* correct?
(a) If the masses are equal both total momentum and total kinetic energy are conserved.
(b) Total kinetic energy is not conserved.
(c) Total momentum is conserved but total kinetic energy is not conserved.
(d) Total momentum is not conserved.
(e) Total momentum is not conserved but total kinetic energy is conserved.

2. The center of mass of Earth's atmosphere is:
(a) near the outer boundary of the atmosphere
(b) a little more than halfway between Earth's surface and the outer boundary of the atmosphere
(c) near the center of Earth
(d) a little less than halfway between Earth's surface and the outer boundary of the atmosphere
(e) near the surface of Earth

Questions 3-4

A car including the driver and some objects has total mass M and is moving with speed V on a straigth road. What is the speed of the car immediately after the driver throws an object of mass m *backwards* with speed V

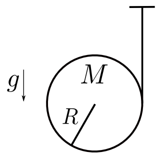
3. *with respect to the ground*?
(a) $(M+m)V/M$ (b) $MV/(M+m)$ (c) $MV/(M-m)$ (d) $(M+m)V/(M-m)$ (e) MV/m

4. *with respect to the car*?
(a) $(M+m)V/M$ (b) MV/m (c) $(M+m)V/(M-m)$ (d) $MV/(M+m)$ (e) $MV/(M-m)$

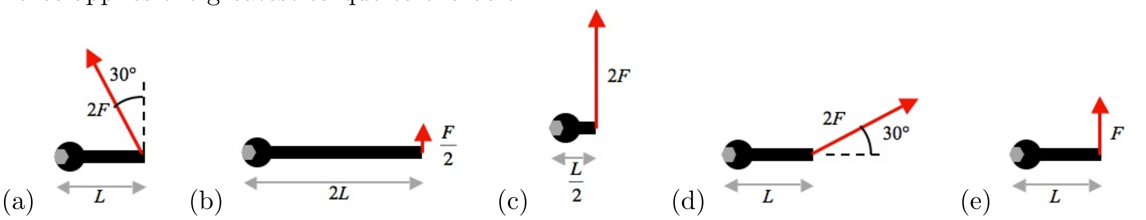
Questions 5-10

5. A wheel of radius 0.5 m rolls without slipping on a horizontal surface. Starting from rest, the wheel moves with constant angular acceleration 6 rad/s^2. What is the distance travelled by the center of the wheel from t=0 to t=3 s?
(a) 18 m (b) 0 m (c) 27 m (d) 13.5 m (e) 9 m

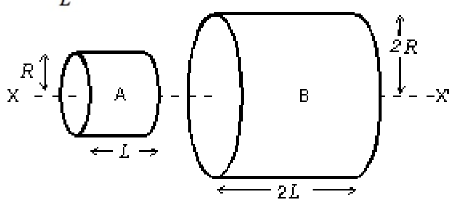
6. What is the tension in the string for the basic yo-yo in the figure?
(a) $Mg/3$ (b) $3Mg/2$ (c) $2Mg$ (d) $3Mg$ (e) Mg



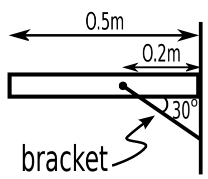
7. A series of wrenches of different lengths is used on a bolt, as shown below, Which combination of wrench length and Force applies the greatest torque to the bolt?



8. A and B are two solid cylinders made of aluminum. Their dimensions are shown in the figure. The ratio of the rotational inertia of B to that of A about the common axis X-X' is:
(a) 32 (b) 2 (c) 24 (d) 8 (e) 4



9. A uniform shelf having a weight of 40 N and of depth 0.50 m is supported by a bracket, as shown in the figure. What is the vertical component of the force exerted by the bracket exert on the shelf?
(a) 80 N (b) 50 N (c) 40 N (d) 120 N (e) 60 N



10. An object at the surface of Earth (at a distance R_E from the center of Earth) weighs 90 N. Its weight at a distance $3R_E$ from the center of Earth is: (a) 810 N (b) 270 N (c) 10 N (d) 30 N (e) 90 N

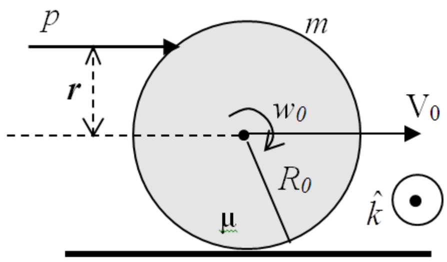
Questions 11-15

A force parallel to the x-axis is applied in a very short time at a point r above the center of a sphere and transfers a net momentum p to the sphere in the x-direction. The sphere has mass m and radius R_0 and is initially at rest. The point to which the force applied is $r = 3R_0/10$ above the center of mass of the sphere. The coefficient of kinetic friction on the surface is μ. The moment of inertia of the sphere is $I = 2mR_0^2/5$. The direction of the z-axis is out of the page.

11. What is the initial speed of the center of mass of the sphere?
(a) $2p/m$ (b) $p^2/2m$ (c) $p/2m$ (d) p/m (e) p^2/m

12. What is the initial angular speed of the sphere?
(a) $3p/2mR_0$ (b) p/mR_0 (c) $4p/3mR_0$ (d) $3p/4mR_0$ (e) p^2/mR_0

13. What is the velocity of the center of mass of the sphere as function of time?
(a) $(p/m-\mu gt)\hat{\imath}$ (b) $(p/m-\mu gt/2)\hat{\imath}$ (c) $(p/2m-\mu gt)\hat{\imath}$ (d) $(2p/m-\mu gt)\hat{\imath}$
(e) $(p/m - 2\mu gt)\hat{\imath}$



14. What is the angular velocity about the center of mass as function of time?
(a) $-(3p/4mR_0+5\mu gt/2R_0)\hat{k}$ (b) $(3p/4mR_0+5\mu gt/2R_0)\hat{k}$ (c) $-(p/mR_0+2\mu gt/5R_0)\hat{k}$ (d) $(4p/3mR_0+5\mu gt/2R_0)\hat{k}$
(e) $-(4p/3mR_0 + 5\mu gt/2R_0)\hat{k}$

15. The sphere both rotates and slides at the same time in the beginning, therefore slips on the surface for some amount of time. How long does it take until it starts rolling without slipping?
(a) $p/m\mu g$ (b) $p/14\mu g$ (c) $p/14m\mu g$ (d) $14p/mg$ (e) $14p/m\mu g$

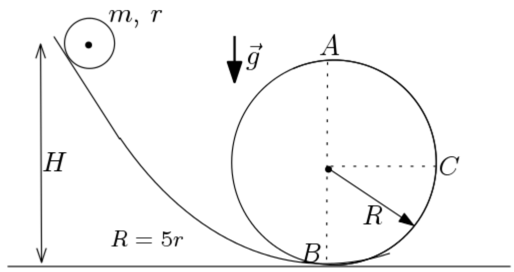
Questions 16-20

A uniform disk of mass m and radius r *rolls without slipping* through a loop of radius $R = 5r$, as shown in the figure. The disk is initially at rest at height H. (For the given disk $I_{cm} = mr^2/2$.)

16. What is the minimum value of H, H_{min}, in order to make it through the loop without falling off the track?
(a) $12r$ (b) $14r$ (c) $13r$ (d) $16r$ (e) $17r$

17. If $H = 15r$, what is the speed of the center of the disk at point A?
(a) $\sqrt{5gr/3}$ (b) $\sqrt{8gr}$ (c) $\sqrt{7gr/4}$ (d) $\sqrt{5gr}$ (e) $\sqrt{8gr/5}$

18. If $H = 15r$, what is the normal force on the object at point A?
(a) $4mg/3$ (b) $3mg/2$ (c) $2mg$ (d) $10mg/3$ (e) mg



19. If $H = 15r$, what is the normal force on the object at point C?
(a) $2mg$ (b) $10mg/3$ (c) $4mg/3$ (d) mg (e) $3mg/2$

20. What is the direction and magnitude of the friction force on the disk at point C?
(a) $3mg/4$, downward (b) $mg/3$, upward (c) $2mg/3$, downward (d) $2mg/3$, upward (e) $mg/3$, downward

Questions 21-25

Suppose you want to place a weather satellite with mass m into a circular orbit $R_E/20$ above Earth's surface, R_E being Earth's radius. Take the potential energy reference to be zero at infinity and give yor answers in terms of the parameter $\lambda = GM_E/R_E$ with G_E and M_E being the universal gravitational constant and Earth's mass, respectively.

21. What speed must the satellite have?
(a) $\sqrt{20\lambda/21}$ (b) $\sqrt{20\lambda}$ (c) $\sqrt{10\lambda/11}$ (d) $\sqrt{\lambda}$ (e) $\sqrt{10\lambda}$

22. What radial acceleration must the satellite have?
(a) $100\lambda/R_E$ (b) λ/R_E (c) $400\lambda/R_E$ (d) $(10/11)^2\lambda/R_E$ (e) $(20/21)^2\lambda/R_E$

23. What is the total mechanical energy of the satellite when it is in orbit?
(a) $-\lambda m$ (b) $-5\lambda m/11$ (c) $-10\lambda m$ (d) $-5\lambda m$ (e) $-10\lambda m/21$

24. How much work has to be done to place this satellite in orbit?
(a) $6\lambda m/11$ (b) $11\lambda m$ (c) $2\lambda m$ (d) $11\lambda m/21$ (e) $10\lambda m$

25. How much additional work would have to be done to make this satellite escape the earth?
(a) $5\lambda m/11$ (b) $10\lambda m$ (c) $6\lambda m/11$ (d) $11\lambda m$ (e) $10\lambda m/21$

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Student Number		Signature		

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 of the followings is/are true for any $\vec{A}$ and $\vec{B}$ vectors?

i. If these two vectors are perpendicular to each other, the magnitude of vector product is maximum value.
ii. If these two vectors are parallel to each other, scalar product gives the maximum value.
iii. The vector founded by the vector product of these vectors, is perpendicular to the plane constructed by these two vectors.

(a) i and ii (b) only i (c) All of them (d) i and iii (e) ii and iii

2. Which of the followings is/are always true for any $\vec{A}$, $\vec{B}$ and $\vec{C}$ vectors?

i. $\vec{A} \times (\vec{B} \times \vec{C}) = 0$
ii. $\vec{A} \times (\vec{B} \times \vec{A}) = 0$
iii. $\vec{A} \cdot (\vec{B} \times \vec{A}) = 0$

(a) All of them (b) None of them (c) Only i (d) Only iii (e) Only ii

Questions 3-5

The position of a mouse and the acceleration of a cat are given as functions of time as $\vec{r}_{mouse} = At^2\ \hat{\imath} + Bt\ \hat{\jmath}$ and $\vec{a}_{cat} = C\ \hat{\imath} + Dt\ \hat{\jmath}$. The constants are $A = 1$ m/s^2, $B = 2$ m/s, $C = 2/3$ m/s^2, $D = 2$ m/s^3. The cat is initially at rest.

3. What is the velocity of the mouse in (m/s) at t = 2 s?
(a) $4\ \hat{\imath} + 2\ \hat{\jmath}$ (b) $8\ \hat{\imath} + 2\ \hat{\jmath}$ (c) $8\ \hat{\imath} + 8\ \hat{\jmath}$ (d) $2\ \hat{\imath} + 8\ \hat{\jmath}$ (e) $2\ \hat{\imath} + 2\ \hat{\jmath}$

4. What is the velocity of the mouse in (m/s) relative to the cat at t = 2 s?
(a) $2/3\ \hat{\imath} - 6\ \hat{\jmath}$ (b) $8/3\ \hat{\imath} - 6\ \hat{\jmath}$ (c) $-2/3\ \hat{\imath} + 6\ \hat{\jmath}$ (d) $8/3\ \hat{\imath} - 2\ \hat{\jmath}$ (e) $4\ \hat{\imath} - 2\ \hat{\jmath}$

5. The cat catches the mouse at the position $\vec{r} = 9$ (m) $\hat{\imath} + 6$ (m) $\hat{\jmath}$. Find the initial position of the cat in meters (m).
(a) $23/3\ \hat{\imath} - 2\ \hat{\jmath}$ (b) $8\ \hat{\imath} - 3\ \hat{\jmath}$ (c) $6\ \hat{\imath} - 3\ \hat{\jmath}$ (d) $19/3\ \hat{\imath} - 10\ \hat{\jmath}$ (e) $7\ \hat{\imath} - 10\ \hat{\jmath}$

Questions 6-10

A ball is thrown straight up in the air with an initial speed of 20 m/s. Ignore air resistance and take $g = 10$m/s^2.

6. What is the maximum height the ball can reach?
(a) 20 m (b) $5\sqrt{2}$ m (c) 5 m (d) 10 m (e) 400 m

7. What is the speed of the ball when it reaches 5 m above the ground?
(a) 5 m/s (b) $10\sqrt{3}$ m/s (c) 300 m/s (d) $5\sqrt{3}$ m/s (e) $10\sqrt{5}$ m/s

8. How long will it take for the ball to reach 5 m above its initial position on the way up?
(a) $(2+\sqrt{5})$ s (b) $(2-\sqrt{3})$ s (c) 2 s (d) $(5+\sqrt{2})$ s (e) $(5-\sqrt{2})$ s

9. How long will it take for the ball to reach 5 m above its initial position on the way down?
(a) 4 s (b) $2\sqrt{3}$ s (c) $(\sqrt{3}+2)$ s (d) $2\sqrt{5}$ s (e) $(\sqrt{3}-2)$ s

10. What will be its final speed just before it hits the ground?
(a) 20 m/s (b) 40 m/s (c) $40\sqrt{3}$ m/s (d) 5 m/s (e) 30 m/s

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11. A particle with mass m is moving on a vertical circle with radius R under an external force F that keeps the particle speed v constant during the motion. What is the total (net) work done on the particle in completing one full revolution?
(a) mv^2/R (b) $2\pi RF$ (c) $2mgR$ (d) $mv^2/2$ (e) 0

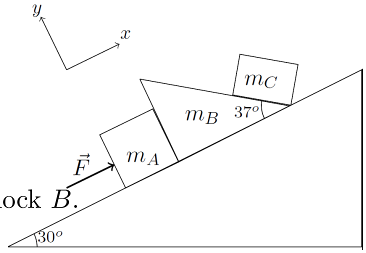
12. You can build a windmill on one of the two hills A and B. On hill A, the wind blows with a constant speed v for 24 hours every day. On hill B, the wind blows with a constant speed $2v$ for 12 hours every day. What would you expect for the relation of daily average work of mill A to mill B?
(a) Work A > Work B (b) Work B > Work A (c) There is no difference (d) It depends on the direction of the wind (e) The question can not be answered with available information

13. A father pulls his son, whose mass is m and who is sitting on a swing with ropes of length L, backward until the ropes make an angle of θ_0 with respect to the vertical. He then releases his son from rest. What is the speed of the son at the bottom of the swinging motion?

(a) $\sqrt{mgL\cos\theta_0}$ (b) $\sqrt{2gL\cos\theta_0}$ (c) $\sqrt{mgL(1-\cos\theta_0)}$ (d) $\sqrt{gL(1-\cos\theta_0)}$ (e) $\sqrt{2gL(1-\cos\theta_0)}$

Questions 14-16

Three blocks (A, B, C) on a frictionless inclined plane are in contact with each other as shown in the figure. Assume that there is no friction between the blocks. A force $\vec{F}$ parallel to the plane is applied to block A . The masses are $m_A = 5$ kg, $m_B = 2$ kg and $m_C = 1$ kg. Take $g = 10\text{m/s}^2$. ($\sin(37°) = 0.6$, $\cos(37°) = 0.8$, $\cos(30°) = 0.87$, $\sin(30°) = 0.5$)



14. What should be the magnitude of the force so that the objects remain motionless?

(a) 80 N (b) 35 N (c) 70 N (d) 40 N (e) 48 N

15. When the magnitude of the force is $36N$, find the acceleration of the blocks.

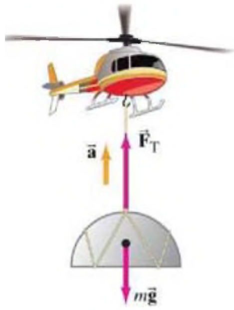
(a) 0.125 m/s^2 (b) -1.5 m/s^2 (c) -5.5 m/s^2 (d) -0.5 m/s^2 (e) -4.5 m/s^2

16. When the magnitude of the force is $36N$, find the magnitude of the force on block A due to block B.

(a) 16.5 N (b) 13.5 N (c) 8.5 N (d) 6.5 N (e) 15 N

Questions 17-19

A 7650-kg helicopter accelerates upward at 1.20 m/s^2 while lifting a 1250-kg frame at a construction site, shown in the figure at right. Take $g = 9.8\ \text{m/s}^2$.



17. What is the lift force exerted by the air on the helicopter rotors?

(a) 9.80×10^3 N (b) 8.90×10^4 N (c) 9.87×10^4 N (d) 9.79×10^3 N (e) 9.79×10^4 N

18. What is the tension in the cable (ignore its mass) that connects the frame to the helicopter?

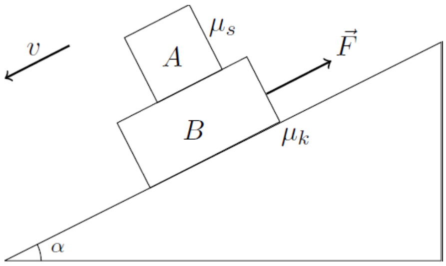
(a) 1.33×10^4 N (b) 1.375×10^3 N (c) 1.375×10^4 N (d) 1.25×10^3 N (e) 1.25×10^4 N

19. What force (and direction) does the cable exert on the helicopter?

(a) 1.25×10^3 N down (b) 1.375×10^4 N down (c) 1.33×10^4 N up (d) 1.25×10^4 N up (e) 1.375×10^4 N up

Questions 20-23

In order that two boxes, one on top of the other, are sliding down the ramp, together with the same constant speed, a force F is applied to the box B in the opposite direction of the motion, as shown in the figure. The coefficient of static friction between the two boxes is μ_s and the coefficient of kinetic friction between the box B and the ramp is μ_k. ($m_A = 1$ kg, $m_B = 9$ kg, $\mu_k = 0.5$, $\mu_s = 0.9$, $g = 10\ \text{m/s}^2$, $\cos(30°) = 0.87$, $\sin(30°) = 0.5$)



20. Find the kinetic friction force if the angle is $\alpha = 30°$.

(a) 8 N (b) 10 N (c) 50 N (d) 43.5 N (e) 6.5 N

21. Find the force F if the angle is $\alpha = 30°$.

(a) 50 N (b) 8 N (c) 6.5 N (d) 15 N (e) 11 N

22. Find the static friction force between the two boxes if the angle is $\alpha = 30°$.

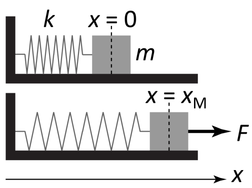
(a) 5 N (b) 45 N (c) 5.5 N (d) 2.4 N (e) 11 N

23. Find the maximum value of α such that the mass A does not move with respect to B.

(a) $\alpha_{max} = \tan^{-1}(\mu_s \cdot \mu_k)$ (b) $\alpha_{max} = \tan^{-1}(\mu_s/\mu_k)$ (c) $\alpha_{max} = \tan^{-1}(\mu_k^2/\mu_s)$
(d) $\alpha_{max} = \tan^{-1}(\mu_k)$ (e) $\alpha_{max} = \tan^{-1}(\mu_s)$

Questions 24-25

The block of mass m shown in the figure lies on a horizontal frictionless surface, and the spring constant is k. Initially, the spring is at its relaxed length and the block is stationary at position $x = 0$. Then an applied constant force F pulls the block in the positive x-direction, stretching the spring until the block stops at position $x = x_\text{M}$.



24. What is the work done by the constant force F in the pulling process?

(a) 0 (b) kx_M^2 (c) $2F^2/k$ (d) $2kx_\text{M}^2$ (e) F^2/k

25. In the pulling process, kinetic energy of the block constantly changes. What is the maximal value of kinetic energy the block will have as it moves from $x = 0$ to $x = x_\text{M}$?

(a) $kx_\text{M}^2/4$ (b) $kx_\text{M}^2/2$ (c) $2F^2/k$ (d) mgx_M (e) $F^2/(2k)$

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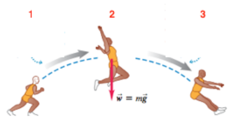
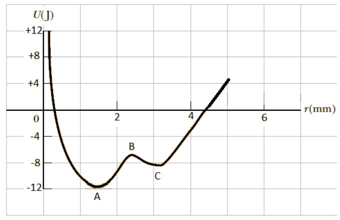
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

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?

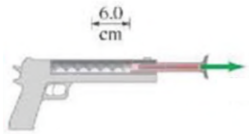


(a) A, B and C (b) A and C (c) none of them (d) only A (e) only B

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?

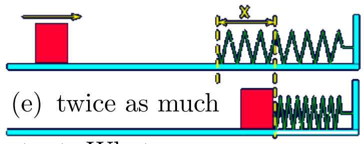
(a) 50% (b) 15% (c) 75% (d) 25% (e) 5%

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?

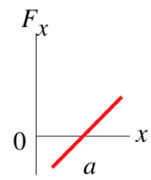


(a) half as much (b) the same amount (c) four times as much (d) $\sqrt{2}$ times as much (e) twice as much

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?

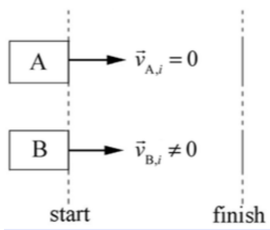


(a) U is a minimum at $x = a$ (b) Any of the above could be correct (c) U is neither a minimum or a maximum at $x = a$ (d) $U = 0$ at $x = a$ (e) U is a maximum at $x = a$

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)

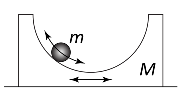


(a) Object A has a larger change in momentum (b) Object B experiences larger impulse than object A (c) Both objects have the same change in momentum (d) Not enough information is given to decide (e) Object B has a larger change in momentum

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?

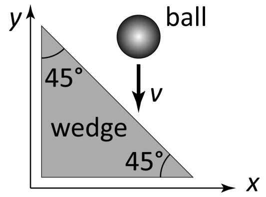


(a) both horizantal and vertical components of total momentum (b) neither horizontal nor vertical components of total momentum (c) horizontal component of total momentum (d) vertical component of total momentum (e) not enough information to decide

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



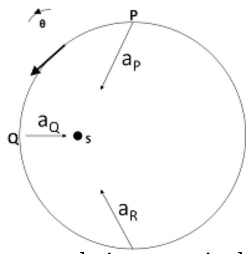
A ball of mass m falls straight down onto a 45° wedge and collides with it completely elastically. At the instant when the ball hits the wedge, it is moving with a downward speed v (see the figure). In the following, assume the wedge is solidly attached to the ground and does not move during the collision.

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) $mv/2$

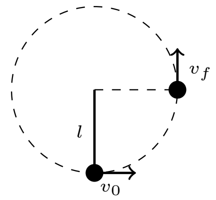


15. An object moves counter-clockwise along the circular path as shown in the figure. As it moves along the path, its acceleration vector continuously points toward the point S. The object

(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.

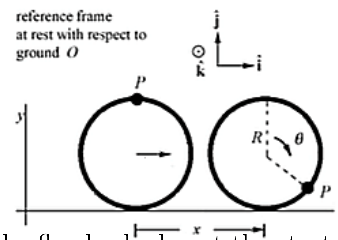


16. What is the tension in the string when the string is horizontal and the ball is moving with the speed v_f?

(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 .

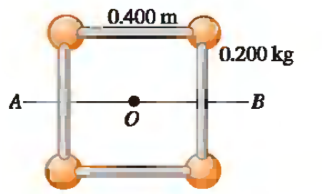
19. Compute the magnitude of the tangential acceleration and the radial acceleration of a point on the flywheel edge at the start. (π=3)

(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

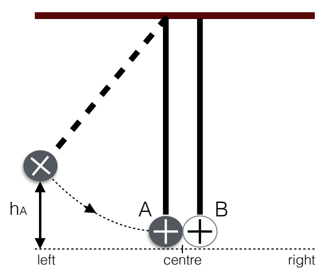
22. about an axis bisecting two opposite sides of the square (an axis along the line AB in the figure)

(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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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. 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) $\theta/2$ (b) 2θ (c) 4θ (d) $\theta/4$ (e) θ

2. An object at rest begins to rotate with a constant angular acceleration. If this object has angular velocity ω at time t, what was its angular velocity at the time $t/2$?

(a) $\omega/2$ (b) 2ω (c) $\omega/8$ (d) 4ω (e) $\omega/4$

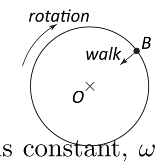
3. A force $\vec{F} = 4\hat{\imath} + 3\hat{\jmath}$ N acts on an object at a point located at the position $\vec{r} = 6\hat{k}$. What is the torque that this force applies about the origin?

(a) $24\hat{\imath} + 18\hat{\jmath}$ N.m (b) 0 (c) $-18\hat{\imath} + 24\hat{\jmath}$ N.m (d) $24\hat{\imath} - 18\hat{\jmath}$ N.m (e) $-18\hat{\imath} - 24\hat{\jmath}$ N.m

4. Disks A and B are identical and roll across a floor with equal speeds v. Disk A then rolls up an incline with angle α without slipping, reaching a maximum height h_A. Disk B moves up an incline that is identical (i.e. it has the same angle α) except that it is frictionless, reaching a maximum height h_B. What is the relationship between h_A and h_B?

(a) It depends on the value of v (b) $h_B > h_A$ (c) $h_B < h_A$ (d) It depends on the value of α (e) $h_B = h_A$

5. A beetle B sits on the rim of a small disk that rotates about its center O (see the picture). If the beetle starts walking toward the center of the disk (in the direction of the arrow), what happens to the total moment of inertia I, angular momentum L, and angular speed ω of the system "beetle + disk" (each quantity relative to the point O)?



(a) I decreases, L is constant, ω decreases (b) I increases, L is constant, ω decreases (c) I increases, L is constant, ω increases (d) I decreases, L is constant, ω increases (e) I, L, and ω are constant

6. A massive uniform ball is hung by a string from a fixed support (simple pendulum) on the earth and is in equilibrium position. Assume that the earth is perfect sphere in spite of its rotation about its own axis. Which of the following statements is/are then correct?

i) Independent of the latitude, the tip of the pendulum always points exactly the centre of gravity of the earth.

ii) The magnitude of the tension in the string depends on the latitude.

iii) The magnitude of the weight of the ball depends on the latitude.

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

7. What is the relation between the total mechanical energy E and kinetic energy K of a satellite revolving in a circular orbit around the earth? Ignore the sky objects other than the earth and the rotation of the satellite about its own axis.

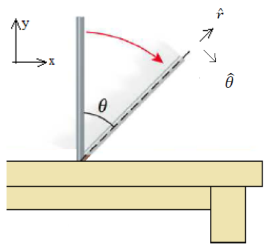
(a) $E = K/2$ (b) $E = -K$ (c) $E = K$ (d) $E = -2K$ (e) $E = 2K$

8. Your personal spacecraft is in a low-altitude circular orbit around the earth. Air resistance from the atmosphere on your spacecraft would lead your spacecraft to

(a) slow down and approach to the earth (b) speed up and recede from the earth (c) speed up and approach to the earth (d) slow down by preserving its altitude (e) slow down and recede from the earth

Questions 9-10

A uniform rod of mass M = 1 kg stands vertically on a horizontal table. It is released from rest to fall. Assume that acceleration due to gravity g=10 m/s^2 and coefficient of static friction between the table and the rod is 0.6. ($\sin 37° = 0.6$, $\cos 37° = 0.8$) ($I_{cm} = \frac{1}{12}MR^2$)



9. Calculate the normal force exerted by the table on the rod as it makes an angle $\theta = 37^o$ with respect to the vertical.

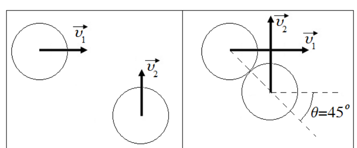
(a) 6 N (b) 9 N (c) 4.9 N (d) 4.4 N (e) 10 N

10. Calculate the force of static friction exerted by the table on the rod as it makes an angle $\theta = 37^o$ with respect to the vertical.

(a) 5.4 N (b) 3.6 N (c) 2.64 N (d) 6 N (e) 1.8 N

Questions 11-13

Two uniform identical disks of mass M and radius R collide on a frictionless table. Initial velocities of the disks are $\vec{v}_1 = v_1\hat{\imath}$ and $\vec{v}_2 = v_2\hat{\jmath}$ respectively. When the disks collide they instantly stick to each other and move as a single object. ($I_{cm} = \frac{1}{2}MR^2$)



11. Which quantities are conserved during the collision?

(a) Mechanical energy and angular momentum (b) Angular momentum and kinetic energy (c) Linear momentum and mechanical energy (d) Linear momentum and kinetic energy (e) Linear momentum and angular momentum

12. What is the velocity of center of mass of the combined disks?

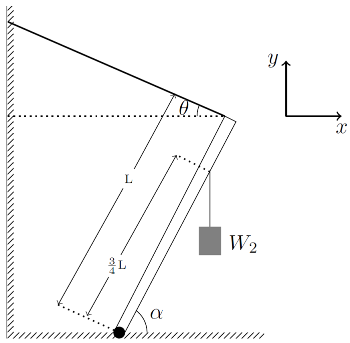
(a) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})\sqrt{2}$ (b) $(v_1\hat{\imath}-\mathrm{v}_2\hat{\jmath})/2$ (c) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})/2$ (d) $(v_1\hat{\imath}-\mathrm{v}_2\hat{\jmath})\sqrt{2}$ (e) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})/\sqrt{2}$

13. What is the angular velocity of the combined disks?

(a) $\frac{(v_2+v_1)}{R}\hat{k}$ (b) $\frac{(v_2-v_1)}{2R}\hat{k}$ (c) $\frac{(v_2-v_1)}{3\sqrt{2}R}\hat{k}$ (d) $\frac{2(v_2-v_1)}{R}\hat{k}$ (e) $\frac{(v_2+v_1)}{2R}\hat{k}$

Questions 14-16

A $W_1 = 1150$ N uniform rod with length L is supported by a cable perpendicular to the rod, as seen in the figure below. The rod is hinged at the bottom, and a $W_2 = 2100$ N weight hangs from its 3/4 L part. Assume the angle to be $\alpha = 60.0°$ and $\theta + \alpha = 90.0°$. The rod is in static equilibrium ($\cos 30° = 0.86$, $\sin 30° = 0.5$).



14. What is the correct statement with regard to the equilibrium of this situation?

(a) The system is in torque equilibrium but not force equilibrium.
(b) The system is in both force and torque equilibrium.
(c) The question cannot be answered with available information.
(d) The system is in force equilibrium but not torque equilibrium.
(e) The system is in neither force nor torque equilibrium.

15. What is the tension in the cable?

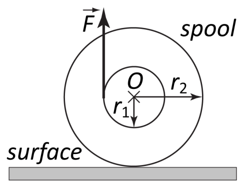
(a) 1055 N (b) 1075 N (c) 1060 N (d) 1065 N (e) 1070 N

16. What are the horizontal (H_x) and vertical (H_y) components of the force exerted on the rod by the hinge?

(a) $H_x = 924.5$ N, $H_y = 2012.5$ N (b) $H_x = 924.5$ N, $H_y = 2712.5$ N (c) $H_x = 944.5$ N, $H_y = 2712.5$ N (d) $H_x = 934.5$ N, $H_y = 2812.5$ N (e) $H_x = 944.5$ N, $H_y = 2612.5$ N

Questions 17-18

The spool shown in the picture has total mass M, inner radius r_1, outer radius r_2, and moment of inertia I about the axis through its center O. When a vertical force $\vec{F}$ is applied to the spool by pulling on a string wrapped around the spool, the spool starts rolling on the horizontal surface without slipping.



17. What is the magnitude of the static friction force acting on the spool?

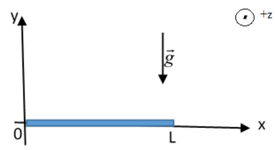
(a) $\frac{Fr_1}{r_2}$ (b) $\frac{F[I/(r_1M)+r_1]}{r_2}$ (c) $\frac{F[I/(r_2M)+r_2]}{r_1}$ (d) $\frac{Fr_2}{I/(r_1M)+r_1}$ (e) $\frac{Fr_1}{I/(r_2M)+r_2}$

18. What is the linear acceleration of the spool along the horizontal surface?

(a) $\frac{Fr_1}{Mr_2}$ (b) $\frac{F[I/(r_2M)+r_2]}{Mr_1}$ (c) $\frac{Fr_1}{M[I/(r_2M)+r_2]}$ (d) $\frac{F[I/(r_1M)+r_1]}{Mr_2}$ (e) $\frac{Fr_2}{M[I/(r_1M)+r_1]}$

Questions 19-23

A thin rod having length L and mass M is pinned at point O, so that it is free to rotate in the vertical plane. The rod is non-uniform with mass density varying as $\lambda = \lambda_0(1+\alpha x)$, where λ_0 and α are constant and limit values are known as $\lambda_{(x=0)} = \lambda_0$ and $\lambda_{(x=L)} = 2\lambda_0$.



19. Find the total mass of rod.

(a) $3\lambda_0 L/2$ (b) $2\lambda_0 L/5$ (c) $\lambda_0 L/2$ (d) $5\lambda_0 L/2$ (e) $\lambda_0 L$

20. Find the center of mass of the rod.

(a) $5L/9$ (b) $L/3$ (c) $2L/3$ (d) $3L/2$ (e) $L/2$

21. The rod is released from rest in the horizontal position at $t = 0$ s. Compute its moment of inertia.

(a) $M(\frac{5L}{9})^2 + \int_{-\frac{5L}{9}}^{\frac{4L}{9}} \lambda x^2 dx$ (b) $M(\frac{5L}{9})^2 + \int_0^L \lambda x^2 dx$ (c) $M(\frac{3L}{2})^2 + \int_0^L \lambda x^2 dx$ (d) $\int_0^L \lambda x^2 dx$ (e) $\int_{\frac{5L}{9}}^{\frac{4L}{9}} \lambda x^2 dx$

22. Find the torque about point O at $t = 0$ s.

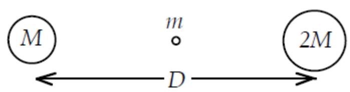
(a) $-(5MgL/9)\hat{k}$ (b) $-(MgL/3)\hat{k}$ (c) $-(3MgL/2)\hat{k}$ (d) $-(MgL/2)\hat{k}$ (e) $-(2MgL/3)\hat{k}$

23. Find the maximum kinetic energy of the system.

(a) $3MgL/2$ (b) $2MgL/3$ (c) $MgL/3$ (d) $5MgL/9$ (e) $MgL/2$

Questions 24-25

Two spherical stars with masses of M and $2M$ are positioned a distance D apart (measured from the center of one star to the center of the other star) as shown. A small spherical asteroid with mass m is located with its center exactly halfway between the two stars.



24. Find the magnitude and direction of the total gravitational force acting on the asteroid.

(a) $\frac{3GMm}{D^2}$, to the right (b) $\frac{GMm}{D^2}$, to the right (c) $\frac{2GMm}{D^2}$, to the right (d) $\frac{4GMm}{D^2}$, to the right (e) $\frac{2GMm}{D^2}$, to the left

25. Find the gravitational potential energy of the system.

(a) $-\frac{GM(3m+2M)}{D}$ (b) $-\frac{GM(m+2M)}{D}$ (c) $-\frac{GM(4m+3M)}{D}$ (d) $-\frac{GM(6m+2M)}{D}$ (e) $-\frac{GM(3m+M)}{D}$

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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. Given $\vec{A} = \hat{\imath} + \hat{\jmath}$ and $\vec{B} = 2\,\hat{\imath} - 2\,\hat{k}$ vectors. Find the unit vector perpendicular to both $\vec{A}$ and $\vec{B}$ vectors.

(a) $\frac{-\hat{\imath}+\hat{\jmath}-\hat{k}}{\sqrt{3}}$ (b) $\frac{-4\,\hat{\imath}+\hat{\jmath}-2\,\hat{k}}{\sqrt{21}}$ (c) $\frac{-2\,\hat{\imath}+\hat{\jmath}-\hat{k}}{\sqrt{6}}$ (d) $\frac{-\hat{\imath}+5\,\hat{\jmath}-\hat{k}}{\sqrt{27}}$ (e) $\frac{-\hat{\imath}+\hat{\jmath}-\hat{k}}{\sqrt{6}}$

2. The position of a particle is given by $\vec{x} = 3t^2\ \hat{\imath}$ (m). What is the acceleration of the particle after 3 s?

(a) $9\,m/s^2$ (b) $18\,m/s^2$ (c) $0\,m/s^2$ (d) $6\,m/s^2$ (e) $3\,m/s^2$

3. A block of mass m is sliding along a friction-free inclined plane with a slope angle of θ. The reaction force exerted by the plane on the block is

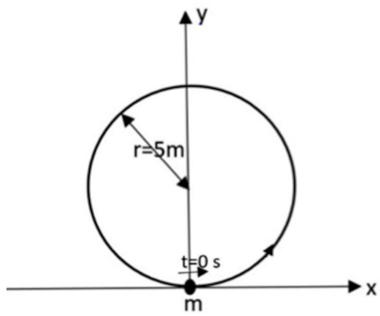
(a) mg (b) 0 (c) $mg\cos\theta\sin\theta$ (d) $mg\cos\theta$ (e) $mg\sin\theta$

4. The rocket starting its motion with speed 5 m/s on a straight way, moves for a 20 seconds with an acceleration of $a_t = 1+2t+3t^2$ (m/s^2). Find the speed of the rocket at the end of 20 seconds.

(a) 8000 m/s (b) 8420 m/s (c) 8425 m/s (d) 1260 m/s (e) 8400 m/s

Questions 5-8

A particle of mass m moves in a circle of radius 5 m at constant speed taking time 40 s for each revolution (Period: T = 40 s). Particle passes from the origin (x = 0, y = 0) at time t = 0 s.



5. Find the displacement vector of the particle between 20 s and 30 s.

(a) 0 (b) $(-5\,\hat{\imath} - 5\,\hat{\jmath})$ m (c) $(-5\,\hat{\jmath})$ m (d) $(5\,\hat{\imath} - 5\,\hat{\jmath})$ m (e) $(5\,\hat{\imath} + 5\,\hat{\jmath})$ m

6. Find the average velocity of the particle between 20 s and 30 s.

(a) $\frac{1}{2}(\hat{\imath} - \hat{\jmath})$ m/s (b) $-\frac{1}{2}(\hat{\imath} + \hat{\jmath})$ m/s (c) $-\frac{1}{2}(\hat{\imath})$ m/s (d) 0 (e) $\frac{1}{2}(\hat{\imath} + \hat{\jmath})$ m/s

7. Find the average acceleration of the particle between 20 s and 30 s. (take $\pi = 3$)

(a) $\frac{3}{40}(\hat{\imath} - \hat{\jmath})\,m/s^2$ (b) $\frac{3}{40}(\hat{\imath} + \hat{\jmath})\,m/s^2$ (c) $\frac{3}{20}(\hat{\imath} - \hat{\jmath})\,m/s^2$ (d) 0 (e) $9,8\,\hat{\jmath}\,m/s^2$

8. Find the instant acceleration at 30 s. (take $\pi = 3$)

(a) $\frac{3}{80}(\hat{\imath} - \hat{\jmath})\,m/s^2$ (b) $\frac{9}{80}(\hat{\imath} + \hat{\jmath})\,m/s^2$ (c) $9,8\,\hat{\jmath}\,m/s^2$ (d) $\frac{9}{80}(\hat{\imath})\,m/s^2$ (e) $\frac{9}{80}(\hat{\jmath})\,m/s^2$

9. A stock person at the local grocery store has a job consisting of the following five segments:

i. picking up boxes of tomatoes from the stockroom floor
ii. accelerating to a comfortable speed
iii. carrying the boxes to the tomato display at constant speed
iv. decelerating to a stop
v. lowering the boxes slowly to the floor.

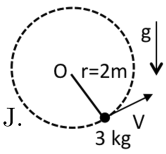
During which of the five segments of the job, does the stock person do positive work on the boxes?

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

10. Two men, Joel and Jerry, push against a wall. Jerry stops after 10 min, while Joel is able to push for 5.0 min longer. Compare the work they do.

(a) Both men do positive work, but Joel does 25 % more work than Jerry.
(b) Both men do positive work, but Joel does 75 % more work than Jerry.
(c) Both men do positive work, but Jerry does 50 % more work than Joel.
(d) Neither of them does any work.
(e) Both men do positive work, but Joel does 50 % more work than Jerry.

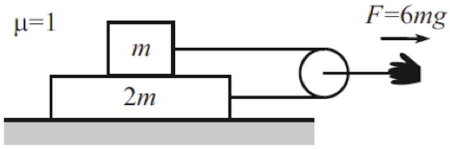
11. 3.00 kg ball swings rapidly in a complete vertical circle of radius 2.00 m by a light string that is fixed at one end. The ball moves so fast that the string is always straight and perpendicular to the velocity of the ball. As the ball swings from its lowest point to its highest point ($g=10\ m/s^2$)



(a) the work done on it by gravity is +120 J and the work done on it by the tension in the string is -120 J.
(b) the work done on it by gravity is -120 J and the work done on it by the tension in the string is zero.
(c) the work done on it by gravity and the work done on it by the tension in the string are both equal to zero.
(d) the work done on it by gravity and the work done on it by the tension in the string are both equal to -120 J.
(e) the work done on it by gravity is -120J and the work done on it by the tension in the string is +120 J.

Questions 12-16

A block of mass m sits on top of a block of mass 2m which sits on a table. The coefficient of kinetic friction between all surfaces is $\mu = 1$. A massless string is connected to each mass and wraps halfway around a massless pulley, as shown. Assume that you pull on the pulley with a force of 6mg.



12. What is the magnitude of friction force between mass m and mass 2m?

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

13. What is the magnitude of the friction force between ground and mass 2m?

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

14. What is the magnitude of the acceleration of mass m?

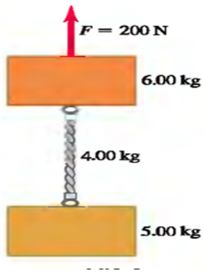
(a) 2g (b) g/2 (c) g/3 (d) g (e) 3g

15. What is the magnitude of the acceleration of mass 2m?

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

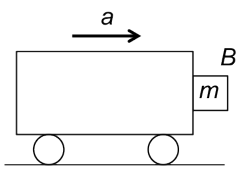
16. What is the acceleration of your hand?

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



17. The two blocks shown in figure are connected by a heavy uniform rope with a mass of 4.00 kg. An upward force of 200 N is applied as shown. What is the tension at the midpoint of the rope? (g = 10 m/s^2)

(a) 120 N (b) 45 N (c) 70 N (d) 93 N (e) 62 N



18. What is the minimum acceleration of mass m that is required to prevent block B from falling? Where the coefficient of static friction between the block and mass m is μ.

(a) 2gμ (b) gμ/2 (c) g/μ (d) gμ (e) 2g/μ

Questions 19-21

19. What work is done by a force $\vec{F} = (2.0x)\,\hat{\imath} - (3.0y^2)\,\hat{\jmath}$ (N), that moves a particle from a position $\vec{r_i} = 2.0\,\hat{\imath} + 3.0\,\hat{\jmath}$ (m) to a position $\vec{r_f} = -4.0\,\hat{\imath} - 3.0\,\hat{\jmath}$ (m), where $\vec{r}$, x and y are in meters? The mass of the particle is 2 kg.

(a) 66 J (b) 86 J (c) 76 J (d) 67 J (e) 42 J

20. If the initial velocity of the particle is 3.0 m/s, what is the final kinetic energy of the particle?

(a) 85 J (b) 79 J (c) 75 J (d) 81 J (e) 77 J

21. What is the magnitude of the acceleration of the particle at the position $\vec{r} = 2.0\,\hat{\imath} + 1.0$m $\hat{\jmath}$?

(a) 3.0 m/s^2 (b) 2.5 m/s^2 (c) 3.5 m/s^2 (d) 1.5 m/s^2 (e) 2.0 m/s^2

Questions 22-24

A speeding motorcyclist is traveling at a constant speed of 36 m/s when he passes a police car parked on the side of the road. At the instant the motorcycle passes the police car, the police officer starts to chase the motorcyclist with a constant acceleration of 4 m/s^2.

22. How long will it take the police officer to catch the motorcyclist?

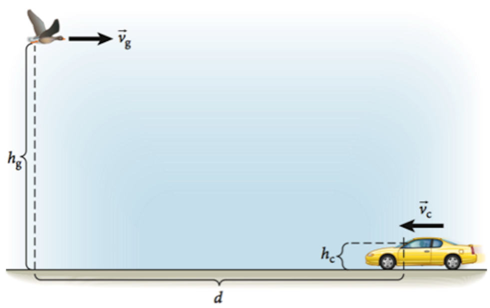
(a) 36 s (b) 24 s (c) 18 s (d) 9 s (e) 27 s

23. What is the speed of the police car when it catches up to the motorcycle?

(a) 72 m/s (b) 108 m/s (c) 36 m/s (d) 144 m/s (e) 96 m/s

24. How far will the police car be from its original position when it catches up to the motorcycle?

(a) 1296 m (b) 648 m (c) 324 m (d) 162 m (e) 972 m



25. One goose is flying northward at a level altitude of h_g = 46 m above a north-south highway, when it sees a car ahead in the distance moving in the southbound lane and decides to deliver (drop) an "egg." The goose is flying at a speed of v_g = 15 m/s, and the car is moving at a speed of v_c = 97.2 km/h. The separation between the goose and the center of the front window of the car, is d = 126 m, at the instant when the goose takes action. (The center of the front window is h_c = 1.00 m off the ground.) When the "egg" strikes the front window, what is the relative velocity of the "egg" with respect to the car at the moment of the impact? (assume g = 10 m/s^2).

(a) $\vec{V} = 15\hat{\imath} - 30\hat{\jmath}$ m/s (b) $\vec{V} = 42\hat{\imath} - 25\hat{\jmath}$ m/s (c) $\vec{V} = 12\hat{\imath} - 30\hat{\jmath}$ m/s (d) $\vec{V} = 42\hat{\imath} - 30\hat{\jmath}$ m/s (e) $\vec{V} = 15\hat{\imath} + 30\hat{\jmath}$ m/s

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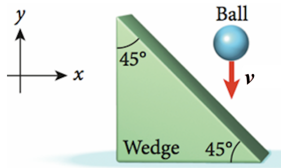
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

Questions 1-2

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?

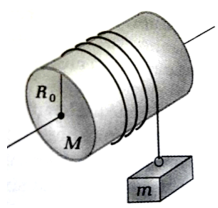
(a) $-\hat{k}$ (b) $+\hat{\jmath}$ (c) $+\hat{\imath}$ (d) $+\hat{k}$ (e) $-\hat{\imath}$

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

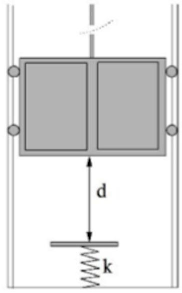
11. A stone is tied to a string and rotate in a horizontal plane at constant angular velocity. During the motion,

(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) $12\omega_0$

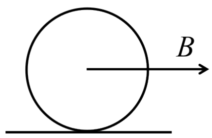
21. While the system is rotating, objects move towards the center of the rod until they are half as far from the center as before. What is the resulting angular speed in terms of ω_0?

(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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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 wrong?

(a) The planets follow elliptical orbits in which one of their focuses is the Sun. (b) The torque applied by the solar gravitational field to the planets is zero. (c) The period of a planet in a gravitational field is directly proportional to the square of the radius of its orbit. (d) Planets have equal areas at equal time intervals along their orbit in the gravitational field of a star. (e) The gravitational force between two masses is inversely proportional to the square of the distance between them.

2. Consider the circular motion of a satellite around the earth. Which one of the following is wrong?

(a) The square of the velocity of a satellite is inversely proportional to the distance from the center of the earth. (b) The centripetal acceleration is provided by the Earth's gravitational force. (c) Escape velocity from the orbit is the same as the speed in orbit. (d) The square of the period of a satellite is proportional to the cube of distance from the earth. (e) Angular momentum is preserved in circular motion of a satellite.

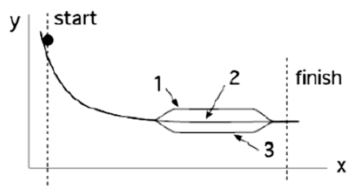
3. What is the conditions for a static equilibrium of rigid bodies?

(a) None of them. (b) Bodies should be both in the translational and in the rotational equilibrium. (c) Bodies should be only in translational equilibrium. (d) Bodies should be only rotational equilibrium. (e) Bodies should be neither in translational nor rotational equilibrium.

4. A force $\vec{F} = 174\text{N}\ \hat{\imath} + 203\text{N}\ \hat{\jmath} - 166\text{N}\ \hat{k}$ is exerted on an object at a point located by the position vector $\vec{r} = 1.0\text{m}\ \hat{\imath} - 1.0\text{m}\ \hat{\jmath}$ from a reference point O. Evaluate the torque exerted by this force about point O.

(a) $166\ \hat{\imath} + 166\ \hat{\jmath} + 377\ \hat{k}$ (b) 0 (c) $166\ \hat{\imath} + 377\ \hat{k}$ (d) $-166\ \hat{\imath} - 166\ \hat{\jmath} - 377\ \hat{k}$ (e) $-166\ \hat{\imath} + 166\ \hat{\jmath} + 377\ \hat{k}$

5. An object starts from rest and slides down on frictionless hill. Which path leads to the highest speed at the finish?



(a) can not be known (b) 3 (c) 1 (d) 2 (e) all results in the same final speed

6. Which one of the following is equivalent to the torque unit in SI unit system?

(a) kg/m^2s^2 (b) kgm^2/s (c) kgm^3/s^2 (d) kgm^2/s^2 (e) kg/ms^2

7. A stream of water from a hose is sprayed on the wall. If the speed of the water is 6 m/s and the hose sprays 450 cm^3/s, what is the average force exerted on the wall by stream of water in N? Assume that the water does not spatter back appreciably. The density of water is 1.0 g/cm^3.

(a) 4.1 (b) 6.5 (c) 2.7 (d) 3.4 (e) 5.8

8. A massless string is wrapped around a pulley with a radius of 2.0 cm and no appreciable friction in its axle. The pulley is initially not turning. A constant force of 50 N is applied to the string, which does not slip, causing the pulley to rotate and the string to unwind. If the string unwinds 1.2 m in 4.9 s, what is the moment of inertia of the pulley?

(a) 1.7 kgm^2 (b) 0.2 kgm^2 (c) 0.017 kgm^2 (d) 0.17 kgm^2 (e) 1.4 kgm^2

Questions 9-10

A 1200 kg car is moving along a straight highway at 5 m/s. Another car with mass 1800 kg and speed 30 m/s ahead of the previous one.

9. What is the speed of the center of mass of the two-car system in m/s?

(a) 30 (b) 10 (c) 40 (d) 5 (e) 20

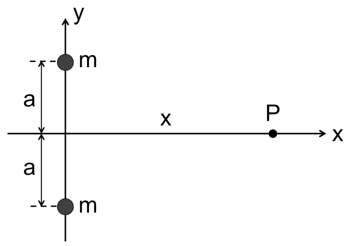
10. Find the magnitude of the total momentum of the system in kg.m/s.

(a) 6×10^4 (b) 9×10^4 (c) 12×10^4 (d) 3×10^4 (e) 1.5×10^4

11. A bicycle is traveling north at 5.0 m/s. The mass of the wheel, 2.0 kg, is uniformly distributed along the rim, which has a radius of 20 cm. What are the magnitude and direction of the angular momentum of the wheel about its axle?

(a) 5.0 kgm^2/s vertically upwards (b) 2.0 kgm^2/s towards the east (c) 2.0 kgm^2/s towards the west (d) 5.0 kgm^2/s towards the east (e) 5.0 kgm^2/s towards the west

12. Two particles with masses m are placed at the (0, a) and (0, -a) points on y-axis. Find the magnitude of gravitational acceleration (g) at the point P(x,0) on x-axis.



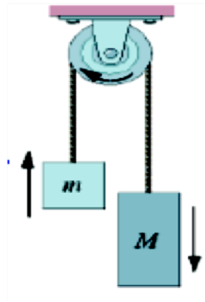
(a) $\frac{4Gmx}{(x^2+a^2)^{1/2}}$ (b) 0 (c) $\frac{2Gmx}{(x^2+a^2)^{3/2}}$ (d) $\frac{4Gmx}{(x^2+a^2)^{3/2}}$ (e) $\frac{2Gmx}{(x^2+a^2)^{1/2}}$

13. Let us assume a planet with a radius of 500 km with a gravitational acceleration of 4 m/s^2. What is the threshold value of the escape speed for a rocket on this planet?

(a) 3000 m/s (b) $\sqrt{3000}$ m/s (c) $\sqrt{2000}$ m/s (d) 2000 m/s (e) 1000 m/s

Questions 14-18

In the figure, a block has mass M= 0.50 kg, the other has mass m = 0.40 kg, and the pulley, which is mounted in horizontal frictionless bearings, has a radius of R = 5.00 cm. When released from rest, the heavier block falls 125.0 cm in 5.0 s (without the cord slipping on the pulley). Take g = 10 m/s^2.



14. What is the magnitude of the blocks' acceleration?

(a) 1.0 m/s^2 (b) 0.02 m/s^2 (c) 0.1 m/s^2 (d) 0.15 m/s^2 (e) 0.01 m/s^2

15. What is the tension in the part of the cord that supports the heavier block?

(a) 4.90 N (b) 5.05 N (c) 5.10 N (d) 5.00 N (e) 4.95 N

16. What is the tension in the part of the cord that supports the lighter block?

(a) 4.00 N (b) 4.04 N (c) 4.10 N (d) 3.96 N (e) 3.90 N

17. What is the magnitude of the pulley's angular acceleration?

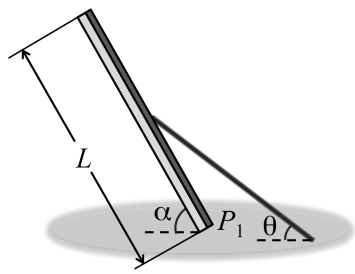
(a) 200.0 rad/s^2 (b) 1.0 rad/s^2 (c) 0.2 rad/s^2 (d) 2.0 rad/s^2 (e) 20.0 rad/s^2

18. What is its rotational inertia?

(a) 0.200 kgm^2 (b) 0.027 kgm^2 (c) 0.300 kgm^2 (d) 0.030 kgm^2 (e) 0.225 kgm^2

Questions 19-21

The figure shows a 18 kg, uniform ladder of length L hinged to a horizontal platform at point P_1 and anchored with a steel cable attached at the ladder's midpoint. At the equilibrium, the angle α between the ladder and the floor is 60.0°, and the angle θ between the rope and the floor is 30.0°. (cos(60°)=0.5, sin(60°)=0.86, sin(30°)=0.5, cos(30°)=0,86 and g = 10 m/s^2).



19. Calculate the tension in the cable when a 76-kg person is standing three-quarters of the way up the ladder.

(a) 1880 N (b) 2611 N (c) 1093 N (d) 1320 N (e) 2186 N

20. Calculate the horizontal force component in the hinge when a 76-kg person is standing three-quarters of the way up the ladder.

(a) 2200 N (b) 2602 N (c) 1560 N (d) 1100 N (e) 1135 N

21. Calculate the vertical force component in the hinge when a 76 kg person is standing three-quarters of the way up the ladder.

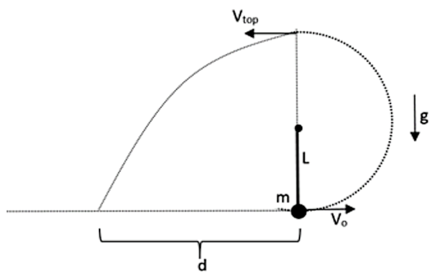
(a) 940 N (b) 1593 N (c) 1220 N (d) 1600 N (e) 2590 N

22. A 120 kg refrigerator, 2.00 m tall and 85.0 cm wide, has its center of mass at its geometrical center. You are attempting to slide it along the floor by pushing horizontally on the side of the refrigerator. The coefficient of static friction between the floor and the refrigerator is 0.300. Depending on where you push, the refrigerator may start to tip over before it starts to slide along the floor. What is the highest distance above the floor that you can push the refrigerator so that it won't tip before it begins to slide?

(a) 1.63 m (b) 0.71 m (c) 1.00 m (d) 1.21 m (e) 1.42 m

Questions 23-25

A ball of mass m hangs from a string of length L. It is hit in such a way that it then travels in a vertical circle. The initial speed of the ball after being struck is V_0. (Assume that there is no frictional forces doing work on the ball and massless string. g is the magnitude of the gravitational acceleration.)



23. Find the speed of ball at the highest point of the circle, (V_{top}=?).

(a) $\sqrt{V_0^2+4gL}$ (b) $\sqrt{V_0^2-2gL}$ (c) $\sqrt{V_0^2+2gL}$ (d) $\sqrt{V_0^2-4gL}$ (e) $\sqrt{V}$

24. Find the tension in the string when the ball is at the top of the circle.

(a) $\frac{mV_0^2}{L}-3mg$ (b) $\frac{m(V_0^2-4gL)}{L}$ (c) $\frac{mV_0^2}{L}$ (d) $\frac{mV_0^2}{L}+3mg$ (e) $\frac{mV_0^2}{L}-5mg$

25. Find the distance d when the ball left the string at the top of the circle.

(a) $2\sqrt{\frac{(V_0^2-4gL)L}{g}}$ (b) $\sqrt{\frac{(V_0^2-4gL)L}{g}}$ (c) $2\sqrt{\frac{(V_0^2+4gL)L}{g}}$ (d) $4\sqrt{\frac{(V_0^2-4gL)L}{g}}$ (e) $2\sqrt{\frac{(V_0^2-2gL)L}{g}}$

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Questions 1-4

The position of a particle moving along the x-axis is given by $x(t) = 3 + Bt^3 - Ct^2$ where x is in meters and t is in seconds, B and C are constants.

1. What is the SI unit of the constant B?
(a) m^2/s^2 (b) m^2/s^3 (c) m/s^2 (d) m/s (e) m/s^3

2. If the particle comes to rest at $x = 24\ m$ when $t = 3\ s$, what are the numerical values of the constants B and C?
(a) $-12/7$ and 3 (b) 4 and -5 (c) $-14/9$ and -7 (d) 6 and 5 (e) $13/6$ and -3

3. When is the particle's acceleration zero?
(a) at $3.0\ s$ (b) at $1.5\ s$ (c) at $1.0\ s$ (d) at $2.0\ s$ (e) at $2.5\ s$

4. Which of the following is the average acceleration vector $\vec{a}_{av}$ between $t = 1\ s$ and $t = 3\ s$?
(a) $-8\hat{\imath}\ m/s^2$ (b) $-24/5\ \hat{\imath}\ m/s^2$ (c) $-14/3\ \hat{\imath}\ m/s^2$ (d) $8\hat{\imath}\ m/s^2$ (e) $25/4\ \hat{\imath}\ m/s^2$

Questions 5-7

A particle starts moving from the origin with an initial velocity $\vec{v}_0 = -8\hat{\jmath}\ m/s$ and its acceleration $\vec{a} = (4\hat{\imath}+2\hat{\jmath})\ m/s^2$.

5. What is the velocity of the particle as a function of time?
(a) $\vec{v}(t) = [(4t)\hat{\imath} + (3t)\hat{\jmath}]\ m/s$ (b) $\vec{v}(t) = [(2t)\hat{\imath} + (6t-8)\hat{\jmath}]\ m/s$ (c) $\vec{v}(t) = [(4t)\hat{\imath} + (2t-8)\hat{\jmath}]\ m/s$
(d) $\vec{v}(t) = [(3t)\hat{\imath} + (2t^2-8)\hat{\jmath}]\ m/s$ (e) $\vec{v}(t) = [(2t)\hat{\imath} + (4t-8)\hat{\jmath}]\ m/s$

6. When does the particle reach its minimum y-coordinate?
(a) $t = 6\ s$ (b) at $t = 4\ s$ (c) $t = 3\ s$ (d) $t = 5\ s$ (e) $t = 8\ s$

7. Assuming that there is a second particle moving with constant velocity $\vec{v}_2 = 2\hat{\imath} + 3\hat{\jmath}\ m/s$, what is the velocity of the *first particle relative to the second particle* at $t = 2\ s$?
(a) $-6\hat{\imath} + 7\hat{\jmath}\ m/s$ (b) $5\hat{\imath} - 4\hat{\jmath}\ m/s$ (c) $6\hat{\imath} - 7\hat{\jmath}\ m/s$ (d) $6\hat{\imath} - 8\hat{\jmath}\ m/s$ (e) $6\hat{\imath} + 6\hat{\jmath}\ m/s$

Questions 8-10

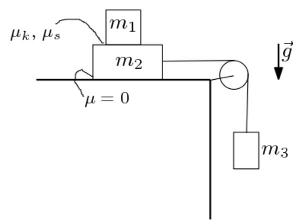
A particle is moving along the x-axis under the action of a variable force $\vec{F}(x) = (Cx - 3x^2)\hat{\imath}\ N$, where x is in meters and C is a constant. There is no friction.

8. What is the *dimension* of the constant C?
(a) $[ML/T^3]$ (b) $[ML/T^2]$ (c) $[M/T^3]$ (d) $[M/T^2]$ (e) $[ML^2/T^2]$

9. What is the work done by the force to move the particle from $x = 0$ to $x = 3\ m$?
(a) $(9C/2 + 24)\ J$ (b) $(7C/2 - 25)\ J$ (c) $(9C/2 - 27)\ J$ (d) $(9C/2 - 25)\ J$ (e) $(5C/2 + 27)\ J$

10. At $x = 0$, the particle's kinetic energy is $20\ J$ and at $x = 3\ m$ it is $11\ J$. What is the numerical value of the constant C?
(a) 3 (b) 5 (c) 2 (d) 7 (e) 4

Questions 11-13



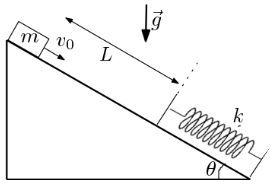
Consider the system shown in the figure: The coefficient of kinetic and static frictions between $m_1 = 2\ kg$ and $m_2 = 4\ kg$ are $\mu_k = 0.5$ and $\mu_s = 0.7$, respectively, and there is no friction between m_2 and the table. Take $g = 10\ m/s^2$.

11. If the blocks are moving in such a way that m_1 and m_2 are not sliding relative to each other (that is, they are moving as a single block), what is the magnitude of the force of friction between m_1 and m_2? Take $m_3 = 8\ kg$.
(a) $75/7\ N$ (b) $80/7\ N$ (c) $85/7\ N$ (d) $82/7\ N$ (e) $78/7\ N$

12. What is the **maximum** value of m_3 such that m_1 and m_2 does not slide relative to each other, that is, they move as a single object?
(a) 12 kg (b) 15 kg (c) 10 kg (d) 14 kg (e) 11 kg

13. If $m_3 = 21\ kg$, what are the accelerations of the blocks relative to the observer at rest on the table? (a_1 is the acceleration of m_1 and a_2 is the acceleration of m_2 and m_3.)
(a) $a_1 = 4\ m/^2$ and $a_2 = 15/2\ m/^2$ (b) $a_1 = 5\ m/^2$ and $a_2 = 8\ m/^2$ (c) $a_1 = 5\ m/^2$ and $a_2 = 17/2\ m/^2$
(d) $a_1 = 5\ m/^2$ and $a_2 = 7\ m/^2$ (e) $a_1 = 4\ m/^2$ and $a_2 = 10\ m/^2$

Questions 14-17



Consider the system shown in the figure: The coefficient of kinetic and static frictions between the block $m = 3\ kg$ and the inclined plane, of angle $\theta = 53^0$, are $\mu_k = 0.6$ and μ_s, respectively. The massles spring of force constant $k = 300\ N/m$ is fastened to the bottom of the inclined plane and it is initially unstretched. The block starts sliding down the incline with an initial speed v_0 and the initial distance between the block and the spring is $L = 70\ cm$. The amount of maximum compression of the spring by the block is $d = 30\ cm$. Take $g = 10\ m/s^2$. ($\sin 37 = \cos 53 = 3/5$ and $\cos 37 = \sin 53 = 4/5$.)

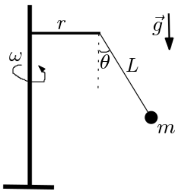
14. What is the *work done by the spring* until the block comes to rest at the maximum compression?
(a) $27/2\ J$ (b) $-27/2\ J$ (c) $-29/2\ J$ (d) $25/2\ J$ (e) $-25/2\ J$

15. What is the *work done by the friction* until the block comes to rest at the maximum compression?
(a) $-57/5\ J$ (b) $-59/5\ J$ (c) $-64/5\ J$ (d) $-51/5\ J$ (e) $-54/5\ J$

16. What is the value of v_0?
(a) $\sqrt{7}/5\ m/s$ (b) $\sqrt{3}/5\ m/s$ (c) $\sqrt{7}\ m/s$ (d) $\sqrt{5}/5\ m/s$ (e) $\sqrt{5}\ m/s$

17. What is **minimum** value of the μ_s such that the block can not rebound up the incline after the maximum compression?
(a) 11/4 (b) 12/5 (c) 13/3 (d) 11/3 (e) 13/6

Questions 18-20



A block of mass m is connected by a massless cord of length $L = 1\ m$ to a horizontal rod of length $r = 60\ cm$ which is being rotated about a vertical central shaft with a constant angular speed ω, as shown in the figure. Take $g = 10\ m/s^2$ and $\theta = 37^0$. ($\sin 37 = \cos 53 = 3/5$ and $\cos 37 = \sin 53 = 4/5$.)

18. What is the linear speed of the block m?
(a) $v = 2\ m/s$ (b) $v = 3\ m/s$ (c) $v = 3.5\ m/s$ (d) $v = 4.5\ m/s$ (e) $v = 4\ m/s$

19. What is angular speed ω of the rotating assembly?
(a) $\omega = 7/2\ rad/s$ (b) $\omega = 7\ rad/s$ (c) $\omega = 5/2\ rad/s$ (d) $\omega = 4\ rad/s$ (e) $\omega = 5\ rad/s$

20. If $m = 2\ kg$ and the maximum tension that the cord can stand without breaking is $T_{max} = 64\ N$, what is the maximum value that the ω can take without the cord breaks?
(a) $\omega_{max} = 5\ rad/s$ (b) $\omega_{max} = 3\ rad/s$ (c) $\omega_{max} = 8\ rad/s$ (d) $\omega_{max} = 6\ rad/s$ (e) $\omega_{max} = 4\ rad/s$

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Questions 1-3

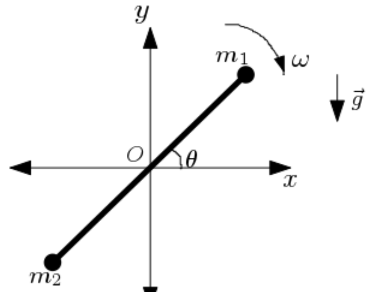
The angular position of a rigid body rotating about a fixed-axis is given as $\theta(t) = a + bt - ct^3$ with t is in seconds and θ in radians, a, b, c are constants. At $t = 0$ the object has angular speed 2 rad/s and at $t = 1.5$ s it has angular acceleration of 18 rad/s^2

1. Which of the following is the constant b with its SI unit?
(a) 2 rad/s (b) 3 rad/s^2 (c) 2 rad/s^2 (d) 3 rad/s (e) 1.5 rad/s

2. If the angular momentum of the object at $t = 0$ is 12 kgm^2/s, what is the rotational inertia of the object relative to the given rotation axis?
(a) 7.5 kgm^2 (b) 7 kgm^2 (c) 6 kgm^2 (d) 8 kgm^2 (e) 5 kgm^2

3. What is the torque on the object relative to the rotation axis at $t = 1.5$ s?
(a) 108 Nm (b) 72 Nm (c) 63 Nm (d) 54 Nm (e) 90 Nm

Questions 4-6



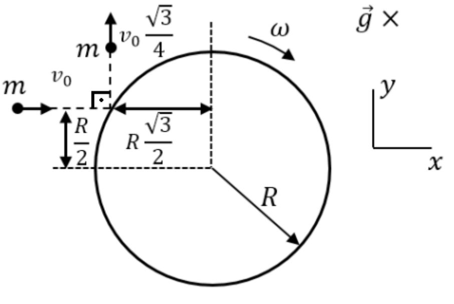
A uniform rigid rod of mass M and length ℓ rotates in the vertical plane about a frictionless pivot passing through its center. Two point masses m_1 and m_2 are attached at the ends of the rod, as shown in the figure. (For a uniform rigid rod of mass M and length ℓ, $I_{cm} = \frac{1}{12}M\ell^2$.)

4. What is the angular momentum of the system relative to the center of mass of the rod, if the whole assembly is rotating about this point with an angular speed ω?
(a) $(M + m_1 + m_2)\frac{\omega\ell^2}{2}$
(b) $\left(\frac{M}{3} + m_1 + m_2\right)\frac{\omega\ell^2}{4}$ (c) $\left(\frac{M}{12} + m_1 + m_2\right)\frac{\omega\ell^2}{2}$ (d) $\left(\frac{M}{2} + m_1 + m_2\right)\frac{\omega\ell^2}{4}$ (e) $(M + m_1 + m_2)\frac{\omega\ell^2}{4}$

5. What is the magnitude of the angular acceleration of the system when the rod makes an angle θ with the horizontal, assuming $m_2 > m_1$?
(a) $\frac{2(m_2-m_1)}{\left(\frac{M}{3}+m_1+m_2\right)}\frac{g\cos\theta}{\ell}$ (b) $\frac{2(m_2-m_1)}{\left(\frac{M}{2}+m_1+m_2\right)}\frac{g\cos\theta}{\ell}$
(c) $\frac{(2m_2-m_1)}{\left(\frac{M}{2}+m_1+m_2\right)}\frac{g\cos\theta}{\ell}$ (d) $\frac{(2m_2-m_1)}{\left(\frac{M}{3}+m_1+m_2\right)}\frac{g\cos\theta}{\ell}$ (e) $\frac{2(m_2-m_1)}{(M+m_1+m_2)}\frac{g\cos\theta}{\ell}$

6. What is the kinetic energy of the system when its angular speed is ω?
(a) $\frac{1}{8}\left(\frac{M}{3} + m_1 + m_2\right)\omega^2\ell^2$ (b) $\frac{1}{6}(M + m_1 + m_2)\omega^2\ell^2$
(c) $\frac{1}{2}\left(\frac{M}{6} + m_1 + m_2\right)\omega^2\ell^2$ (d) $\frac{1}{2}\left(\frac{M}{3} + m_1 + m_2\right)\omega^2\ell^2$ (e) $\frac{1}{2}\left(\frac{M}{12} + m_1 + m_2\right)\omega^2\ell^2$

Questions 7-10



A disk of mass M and radius R is located on a frictionless table and pivoted at its center, and initially at rest. A point mass of m with an initial speed v_0 hits and scatters from the disk as shown in the figure. (For a disk of mass M and radius R, $I_{cm} = \frac{1}{2}MR^2$.)

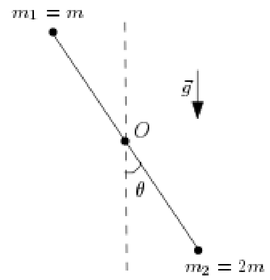
7. What are the conserved quantites in this collision?
(a) $\vec{L}$ relative to the center of mass of the disk (b) $\vec{p}$ and $\vec{L}$ relative to the every point in space (c) $\vec{L}$ relative to the point of collision (d) $\vec{p}$ and $\vec{L}$ relative to the point of collision (e) $\vec{p}$

8. What is the magnitude of the angular speed of the disk just after the collision?
(a) $\frac{3mv_0}{4MR}$ (b) $\frac{mv_0}{4MR}$ (c) $\frac{mv_0}{2MR}$ (d) $\frac{3mv_0}{5MR}$ (e) $\frac{2mv_0}{5MR}$,

9. What is the impulse transferred to the mass m during the collision?
(a) $-mv_0\hat{j}/2)$ (b) $mv_0\hat{i}$ (c) $mv_0(\hat{i} + \hat{j}/2)$ (d) $-2mv_0(2\hat{i} - \hat{j})$ (e) $-mv_0(\hat{i} - \sqrt{3}\hat{j}/4)$

10. If the disk were not pivoted at the beginning, what would be the center of mass velocity, v_{cm}, of the disk just after the collision?
(a) $\frac{mv_0}{M}(\hat{i} - \hat{j})$ (b) $\frac{mv_0}{2M}(\hat{i} - \hat{j})$ (c) $\frac{mv_0}{3M}(2\hat{i} - \hat{j})$ (d) $\frac{mv_0}{M}(\hat{i} - \sqrt{3}\hat{j}/4)$ (e) $\frac{2mv_0}{M}(\hat{i} - \hat{j})$

Questions 11-13



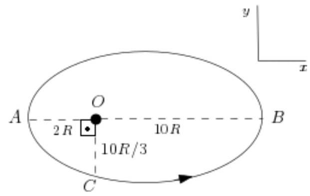
A uniform rod of mass $M = 3m$ and length L is pinned to a wall at its center of mass O in the vertical plane. It is free to be able to rotate about this point. Two point masses $m_1 = m$ and $m_2 = 2m$ are attached to the ends of the rod, as shown in the figure.

11. What is the rotational inertia of the system about the point O?
(a) $2mL^2/3$ (b) $2mL^2/5$ (c) $3mL^2/2$ (d) mL^2 (e) $3mL^2/4$

12. Which of the following is the period of the system for small oscillations?
(a) $2\pi\sqrt{\frac{3L}{g}}$ (b) $2\pi\sqrt{\frac{2L}{g}}$ (c) $2\pi\sqrt{\frac{2L}{3g}}$ (d) $2\pi\sqrt{\frac{3L}{2g}}$ (e) $2\pi\sqrt{\frac{3L}{4g}}$

13. If the system starts oscillation from an initial angle θ_{max}, which of the following is the required time to reach $\theta_{max}/2$, in terms of the period T of the small oscillations?
(a) $T/8$ (b) $T/5$ (c) $T/12$ (d) $T/10$ (e) $T/6$

Questions 14-18



A planet of mass m is moving on an elliptical path about a star of mass M ($m << M$) at point O, as shown in the figure. The point A is the closest and the point B is the farthest point of the planet from the star. The distance between the planet and the star is $2R$ when the planet is at point A, and $10R$ when it is at point B.

14. What is the length of the semimajor axis (half of long axis of the ellipse) of the elliptical orbit?
(a) $9R$ (b) $8R$ (c) $12R$ (d) $6R$ (e) $10R$

15. What is the total mechanical energy of the system?
(a) $-\frac{GMm}{8R}$ (b) $-\frac{GMm}{6R}$ (c) $-\frac{GMm}{10R}$ (d) $-\frac{GMm}{9R}$ (e) $-\frac{GMm}{12R}$

16. What is the speed of the planet at point C?
(a) $\sqrt{\frac{3GM}{4R}}$ (b) $\sqrt{\frac{5GM}{21R}}$ (c) $\sqrt{\frac{7GM}{9R}}$ (d) $\sqrt{\frac{14GM}{27R}}$ (e) $\sqrt{\frac{13GM}{30R}}$

17. What is the acceleration vector of the planet at point C?
(a) $\frac{3GM}{10R^2}\hat{i}$ (b) $\frac{9GM}{10R^2}\hat{i}$ (c) $-\frac{3GM}{10R^2}\hat{j}$ (d) $\frac{7GM}{100R^2}\hat{j}$ (e) $\frac{9GM}{100R^2}\hat{j}$

18. What is the time to reach from A to B on this elliptical orbit?
(a) $8\pi\sqrt{\frac{4R^3}{GM}}$ (b) $6\pi\sqrt{\frac{3R^3}{GM}}$ (c) $8\pi\sqrt{\frac{6R^3}{5GM}}$ (d) $12\pi\sqrt{\frac{6R^3}{5GM}}$ (e) $6\pi\sqrt{\frac{6R^3}{GM}}$

Questions 19-20

A spring-mass system is composed of a mass $m = 200\ g$ and a massless spring of force constant k obeying Hooke's Law, and the whole system is located on a horizontal frictionless table. The mass m makes oscillations about the equilibrium position $x = 0$ according to the relation $x(t) = (15\ cm)\sin 2\pi t$. (You can take $\pi = 3$.)

19. What is the force constant k of the spring?
(a) $36/5\ N/m$ (b) $36\ N/m$ (c) $54\ N/m$ (d) $72/5\ N/m$ (e) $54/4\ N/m$

20. What is the total mechanical energy of the system?
(a) $9/50\ J$ (b) $81/1000\ J$ (c) $8/25\ J$ (d) $81/130\ J$ (e) $2/25\ J$

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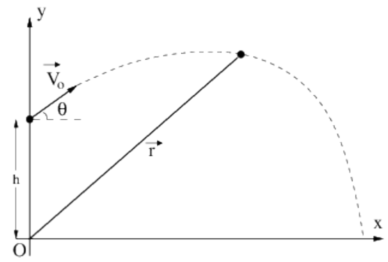
ATTENTION: Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. For what value of d is the vector $\vec{A} = 2\hat{\imath} + 2\hat{\jmath} + \mathrm{d}\hat{k}$ perpendicular to the vector $\vec{B} = 4\hat{\imath} + 4\hat{\jmath} - 2\hat{k}$?

(a) 4 (b) 8 (c) -4 (d) -1 (e) 0

2. A particle is projected from y_0=h at t=0 with $\vec{V_0}$ velocity making an angle θ with the horizontal as shown in the figure. Take the magnitude of the gravitational acceleration as g. What is its maximum height of the object with respect to origin?

(a) $h + \frac{V_0^2 sin(2\theta)}{2g}$ (b) h (c) $\frac{V_0^2 sin(2\theta)}{2g}$ (d) $h + \frac{V_0^2 sin^2\theta}{2g}$ (e) $\frac{V_0^2 sin^2\theta}{2g}$



Questions 3-6

An object on a horizontal plane has an initial velocity $\vec{V_0} = 4.0\hat{\imath} + 1.0\hat{\jmath}$ (m/s) at a point where its position vector is $\vec{r_0} = 10\hat{\imath} - 4.0\hat{\jmath}$ (m) relative to an origin. The object moves with constant acceleration and after t=20 s, its velocity becomes $\vec{V} = 20\hat{\imath} - 5.0\hat{\jmath}$ (m/s).

3. What is the magnitude of its acceleration in m/s^2?

(a) -0.3 (b) 1.0 (c) $\sqrt{1.16}$ (d) 0.8 (e) $\sqrt{73}/10$

4. What is its position vector at $t = 2$ s?

(a) $18\hat{\imath} - 2\hat{\jmath}$ (b) $-18\hat{\imath} + 2\hat{\jmath}$ (c) $19.6\hat{\imath} - 2.6\hat{\jmath}$ (d) $9.6\hat{\imath} + 1.4\hat{\jmath}$ (e) $19.6\hat{\imath}$

5. What is the velocity of the object at $t = 2$ s?

(a) $0.6\hat{\imath} + 1.6\hat{\jmath}$ (b) $1.6\hat{\imath} - 0.6\hat{\jmath}$ (c) $1.6\hat{\imath} + 0.6\hat{\jmath}$ (d) $5.6\hat{\imath} + 2.6\hat{\jmath}$ (e) $5.6\hat{\imath} + 0.4\hat{\jmath}$

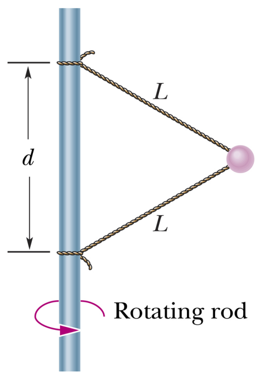
6. At what time, x coordinate of the object becomes zero?

(a) 2 s (b) 5 s (c) $\sqrt{5/2.2}$ s (d) never (e) ∞

Questions 7-10

In Fig, a 1.5 kg ball is connected by means of two massless strings, each of length L= 2.0 m, to a vertical, rotating rod. The strings are tied to the rod with separation d = 2.0 m and are taut. The tension in the upper string is 35 N.

Take $g = 10$ m/s^2, $sin30 = 0.5$, $cos30 = 0.9$, $tan30 = 0.6$.



7. What is the tension in the lower string?

(a) 5.0 N (b) 16.4 N (c) 13.6 N (d) 18.3 N (e) 5.8 N

8. What is the magnitude of the net force on the ball?

(a) 36.0 N (b) 18.6 N (c) 26.6 N (d) 48.0 N (e) 54.6 N

9. What is the speed of the ball?

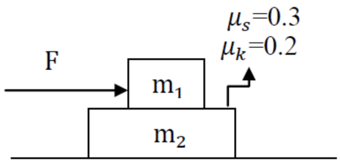
(a) $\sqrt{14.2}$ m/s (b) $\sqrt{32.4}$ m/s (c) $\sqrt{24.3}$ m/s (d) $\sqrt{26.7}$ m/s (e) $\sqrt{40.0}$ m/s

10. What is the direction of the net force on the ball?

(a) downward (b) radially towards the rod (c) upward (d) none of these (e) radially away from the rod

Questions 11-14

Two blocks of masses $m_1 = 4$ kg and $m_2 = 6$ kg are standing one on the top of the other, as shown in the figure. The coefficients of static and kinetic friction between the blocks are $\mu_s = 0.3$ and $\mu_k = 0.2$ respectively. The surface between m_2 and the floor is frictionless. A horizontal force F is applied on the m_1 as shown in the figure. ($g = 10$ m/s^2)



11. What is the maximum value for F so that m_1 and m_2 move together, without m_1 sliding on the surface of m_2?

(a) 50 N (b) 40 N (c) 15 N (d) 20 N (e) 25 N

12. If $F = 16$ N, what are the accelerations a_1 and a_2 for m_1 and m_2, respectively?

(a) $a_1 = a_2 = 1.6$ m/s^2 (b) $a_1 = a_2 = 1$ m/s^2 (c) $a_1 = a_2 = 2$ m/s^2 (d) $a_1 = a_2 = 0.16$ m/s^2 (e) $a_1 = a_2 = 3.2$ m/s^2

13. If $F = 16$ N, what is the magnitude of the static frictional force?

(a) 10 N (b) 16 N (c) 20 N (d) 30 N (e) 48/5 N

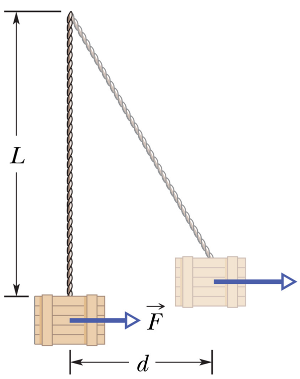
14. If $F = 24$ N, what are the accelerations a_1 and a_2?

(a) $a_1 = 10$ m/s^2 ; $a_2 = 4/3$ m/s^2
(b) $a_1 = 4$ m/s^2 ; $a_2 = 10/3$ m/s^2
(c) $a_1 = 4$ m/s^2 ; $a_2 = 4/3$ m/s^2
(d) $a_1 = 2$ m/s^2 ; $a_2 = 2/3$ m/s^2
(e) $a_1 = 5$ m/s^2 ; $a_2 = 5/3$ m/s^2

Questions 15-17

A 280 kg crate hangs from the end of a rope of length $L = 15.0$ m. You push the crate horizontally with a varying force F to move it a distance of $d = 5.0$ m to the side. The crate is at rest before and after its displacement.

Take $g = 10$ m/s^2, $\sqrt{2} = 1.4$.



15. What is the magnitude of F when the crate is in this final position?

(a) 1000 N (b) 1200 N (c) 7840 N (d) 800 N (e) 2640 N

16. During the crate's displacement, what is the work done by the gravitational force on the crate?

(a) 1400 J (b) 2800 J (c) −1400 J (d) 0 J (e) −2800 J

17. What is the work done on the crate by the tension in the rope?

(a) 1400 J (b) −1400 J (c) −2800 J (d) 0 J (e) 2800 J

Questions 18-20

A net force $\vec{F} = (Ax - 6x^2)\hat{\imath}$ acts on a particle as the particle moves along the x-axis, with $\vec{F}$ in newtons, x in meters, and A a constant.

18. What is the SI unit of the constant A?

(a) N/m^2 (b) N·m (c) N/m (d) N (e) N·m^2

19. What is the work done in moving the particle from the origin, $x = 0$ to $x = 2$ m?

(a) $3A - 27$ (b) $2A - 16$ (c) $4A + 27$ (d) $10A + 27$ (e) $9A - 27$

20. At $x = 0$, the particle's kinetic energy is 12 J; at $x = 2$ m, it is 32 J. What is the value of the constant A?

(a) −16 (b) 18 (c) −12 (d) 2 (e) 6

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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.

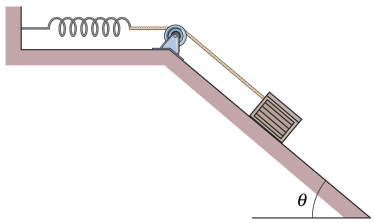
1. For what values of x, the force F_x is zero?

(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

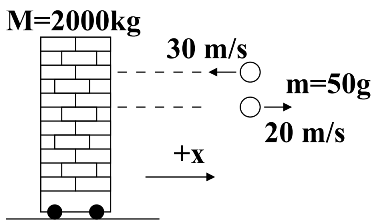
4. How far down the incline from its point of release does the box slide before momentarily stopping?

(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

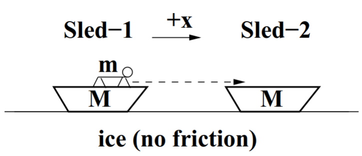
7. What is the magnitude and direction of the force acting on the ball during the collision?

(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?

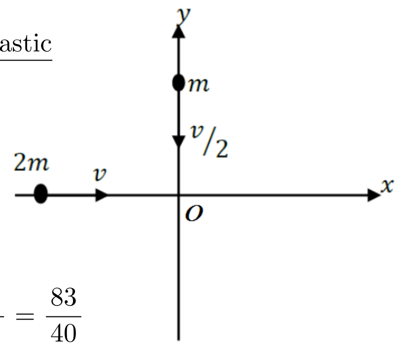
(a) $(-3$ m/s$)\hat{\imath}$ (b) $(-0.5$ m/s$)\hat{\imath}$ (c) $(0.6$ m/s$)\hat{\imath}$ (d) $(-0.6$ m/s$)\hat{\imath}$ (e) $(0$ m/s$)\hat{\imath}$

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.

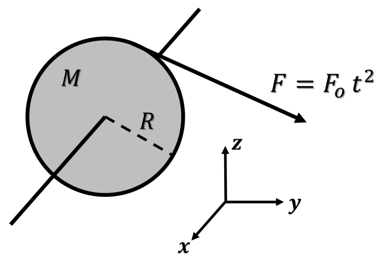
(a) $\frac{17}{\sqrt{6}}v$ (b) $\frac{\sqrt{2}}{5}v$ (c) $\sqrt{\frac{17}{6}}v$ (d) $\sqrt{\frac{2}{5}}v$ (e) $\frac{\sqrt{17}}{6}v$

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?

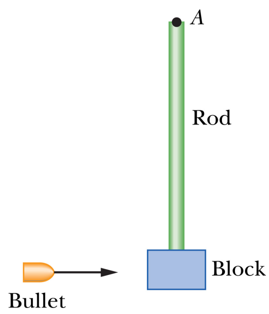
(a) $\vec{\tau} = -24t^3\hat{k}$ N·m , $\vec{L} = -24t^4\hat{k}$ J·s (b) $\vec{\tau} = 40t^3\hat{k}$ N·m , $\vec{L} = -110t^4\hat{k}$ J·s (c) $\vec{\tau} = 140t^3\hat{k}$ N·m , $\vec{L} = 200t^4\hat{k}$ J·s
(d) $\vec{\tau} = -140t^3\hat{k}$ N·m , $\vec{L} = 110t^4\hat{k}$ J·s (e) $\vec{\tau} = -40t^3\hat{k}$ 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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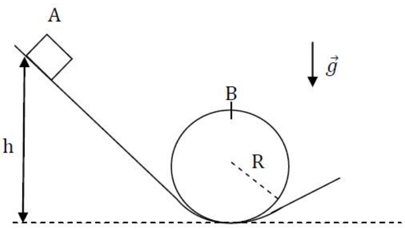
Questions 1-3

A block of mass m slides on the frictionless loop-to-loop track as shown in the figure. The block starts from rest at point A at a height h above the bottom of the loop.



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

(a) $\sqrt{2g(h+2R)}$ (b) $\sqrt{2g(h-2R)}$ (c) $\sqrt{4g(h+2R)}$ (d) $\sqrt{4g(h-2R)}$ (e) $\sqrt{4gR}$

2. What is the condition satisfied by h (in terms of R) such that the block moves around the loop without falling off at the top point B?

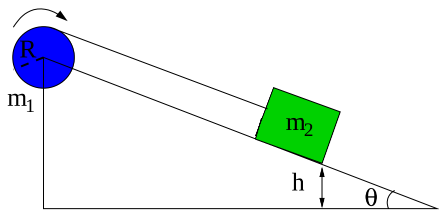
(a) $h > \frac{5}{2}R$ (b) $h > \frac{11}{5}R$ (c) $h > \frac{1}{2}R$ (d) $h > \frac{12}{5}R$ (e) $h > \frac{21}{10}R$

3. Find the normal force at point B for $h = 6R$.

(a) 15 mg (b) 7 mg (c) 9 mg (d) 11 mg (e) mg

Questions 4-6

A uniform cylinder of mass m_1=4 kg and radius R=40 cm is pivoted on frictionless bearings. A string wrapped around the cylinder connects to a mass m_2=6 kg, which is on a frictionless incline of angle θ=30^0 as shown in the figure. The system is released from rest with m_2 at height h=8 cm above the bottom of the incline. Moment of inertia of a cylinder rotating about its central axis is given as $\frac{1}{2}m_1R^2$. **(Take g=10 m/s^2, sin30=0.5)**



4. What is the acceleration of m_2 in m/s^2 after the system is released?

(a) 10 (b) 30/6.32 (c) 3.75 (d) 27/4 (e) 27/8

5. What is the tension in the string in *newton* after the system is released?

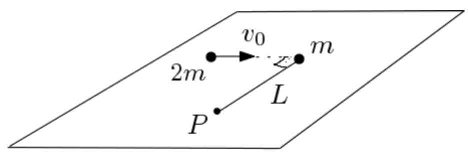
(a) 81/4 (b) 30 (c) 7.5 (d) 45 (e) 15

6. What is the angular speed of the cylinder when m_2 is at the bottom of the incline in rad/s?

(a) $\sqrt{15}$ (b) $\sqrt{60}$ (c) $\sqrt{10}$ (d) $\sqrt{7.5}$ (e) $\sqrt{30}$

Questions 7-9

A light rod of length L is fixed from one end at point P on a horizontal frictionless surface, and a point particle of mass m is attached to the other end, as shown in the figure. Another point particle of mass $2m$ with speed v_0 collides with m in a direction perpendicular to the rod.



7. If $2m$ sticks to m after the collision, what is the angular speed ω of the system just after the collision?

(a) $\frac{4v_0}{3L}$ (b) $\frac{v_0}{2L}$ (c) $\frac{v_0}{L}$ (d) $\frac{2v_0}{3L}$ (e) $\frac{v_0}{3L}$

8. If the mass $2m$ collides with speed v_0 and then bounces back with speed $v_0/2$ in the direction perpendicular to the rod, what is the angular speed ω of the rod and m just after the collision?

(a) $\frac{v_0}{3L}$ (b) $\frac{2v_0}{L}$ (c) $\frac{v_0}{4L}$ (d) $\frac{v_0}{L}$ (e) $\frac{3v_0}{L}$

9. If the rod is uniform and its mass is $M = 3m$, and $2m$ collides with speed v_0 and sticks to m after the collision, what is the angular speed ω of the system just after the collision? **(For a uniform rod of mass M and length L, $I_{cm} = \frac{1}{12}ML^2$)**

(a) $\frac{v_0}{L}$ (b) $\frac{v_0}{2L}$ (c) $\frac{4v_0}{3L}$ (d) $\frac{v_0}{5L}$ (e) $\frac{2v_0}{L}$

Questions 10-13

Suppose you want to place a weather satellite with mass m into a circular orbit of altitude $R_E/10$, where R_E is the radius of the earth. **PS:** Give your answers in terms of the parameter $\lambda = (GM_E)/R_E$ with G and M_E universal gravitational constant and the earth's mass respectively (take the potential energy to be zero at infinite distance).

10. What is the speed of the satellite in this orbit?

(a) $\sqrt{\lambda}$ (b) $\sqrt{20\lambda}$ (c) $\sqrt{\frac{20\lambda}{21}}$ (d) $\sqrt{210\lambda}$ (e) $\sqrt{\frac{10\lambda}{11}}$

11. What is the radial acceleration of the satellite in this orbit?

(a) $\frac{\lambda}{R_E}$ (b) $\left(\frac{10}{11}\right)^2\frac{\lambda}{R_E}$ (c) $100\frac{\lambda}{R_E}$ (d) $400\frac{\lambda}{R_E}$ (e) $\left(\frac{100}{21}\right)^2\frac{\lambda}{R_E}$

12. What is the total mechanical energy of the satellite when it is in this orbit?

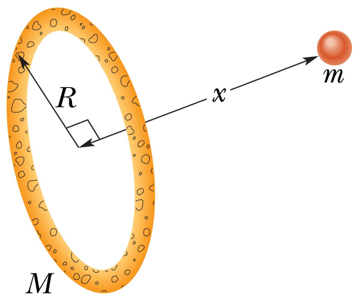
(a) $-5\lambda m$ (b) $-\frac{20}{11}\lambda m$ (c) $+\frac{5}{11}\lambda m$ (d) $+\lambda m$ (e) $-\frac{5}{11}\lambda m$

13. How much work has to be done to place this satellite in this orbit?

(a) $11\lambda m$ (b) $\frac{41}{11}\lambda m$ (c) $\frac{6}{11}\lambda m$ (d) $2\lambda m$ (e) $10\lambda m$

Questions 14-16

Consider the ring-shaped body of uniformly distributed mass M in the figure. A particle with mass m is placed a distance x from the center of the ring, along the line through the center of the ring and perpendicular to its plane.



14. What is the gravitational potential energy of this system? (Take the potential energy to be zero when the two objects are far apart.)

(a) $-\frac{GMm}{(x^2+R^2)}$ (b) $-\frac{GMm}{(x^2+R^2)^{3/2}}$ (c) $-\frac{GMm}{(x^2+R^2)^2}$ (d) $-\frac{GMm}{(x^2+R^2)^{1/2}}$
(e) $-\frac{GMm}{(x^2+R^2)^{5/2}}$

15. What is the magnitude of the gravitational force exerted by the ring on the point particle?

(a) $\frac{GMmx}{(x^2+R^2)^2}$ (b) $\frac{GMmx}{(x^2+R^2)^{3/2}}$ (c) $\frac{GMmx}{(x^2+R^2)^{1/2}}$ (d) $\frac{GMm}{(x^2+R^2)^{1/2}}$ (e) $\frac{GMmx}{(x^2+R^2)^{5/2}}$

16. What is the magnitude of the gravitational force exerted by the ring on the point particle when x is very large compared to the radius of the ring?

(a) $\frac{GMm}{x^{3/2}}$ (b) $\frac{GMm}{x}$ (c) $\frac{GMm}{x^3}$ (d) $\frac{GMm}{x^{1/2}}$ (e) $\frac{GMm}{x^2}$

Questions 17-20

A spring-mass system is composed of a block with mass m and a massless spring of force constant k obeying Hooke's Law, and the whole system is located on a horizontal frictionless table. The block makes oscillations about the equilibrium position $x = 0$. The total mechanical energy and the maximum speed of the block are 10 J and 1 m/s, respectively. The amplitude of the oscillations and the phase constant are given as 0.1 m and $\pi/4$ rad, respectively.

17. What is the spring constant?

(a) 1000 N/m (b) 100 N/m (c) 1500 N/m (d) 2000 N/m (e) 1200 N/m

18. What is the period of the oscillations?

(a) $\frac{2\pi}{5}$ s (b) $\frac{2\pi}{15}$ s (c) $\frac{\pi}{5}$ s (d) $\frac{\pi}{15}$ s (e) $\frac{4\pi}{5}$ s

19. What is the mass of the block?

(a) 200 kg (b) 120 g (c) 200 g (d) 120 kg (e) 20 kg

20. What is the initial position of the block at $t = 0$?

(a) $\frac{\sqrt{2}}{200}$ m (b) $\frac{\sqrt{2}}{120}$ m (c) $\frac{\sqrt{2}}{20}$ m (d) $\frac{3\sqrt{2}}{200}$ m (e) $\frac{5\sqrt{2}}{20}$ m

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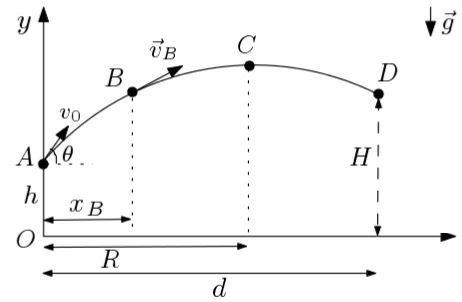
Questions 1-5

An object of mass m is thrown from point A at $t = 0$ with an initial speed $v_0 = 10\ m/s$ from a height $h = 1\ m$ over the ground making an angle $\theta = 53^o$ with the horizontal, and following the trajectory shown in the figure, it hits the point D which is at height $H = 7/4\ m$ over the ground.

Take $g = 10\ m/s^2$ **and** $\sin 53^o = \cos 37^o = 4/5$ **.**



1. In the given Cartesian coordinate system, which of the followings is the $y(t)$ of the object in meters?

(a) $1 + 8t + 5t^2$ (b) $1 + 6t - 5t^2$ (c) $1 - 8t - 5t^2$ (d) $1 + 8t - 5t^2$ (e) $1 - 6t + 5t^2$

2. What is the time to reach point D in seconds?

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

3. If C is the highest point of the trajectory over the ground, what is the ratio R/d?

(a) 4/5 (b) 3/5 (c) 7/15 (d) 8/15 (e) 11/15

4. Assuming that B and D are at the same height, what is x_B in meters?

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

5. What is the velocity $\vec{v}_B$ at point B in units of m/s?

(a) $6\hat{\imath} - 6\hat{\jmath}$ (b) $6\hat{\imath} + 7\hat{\jmath}$ (c) $8\hat{\imath} + 7\hat{\jmath}$ (d) $6\hat{\imath} - 7\hat{\jmath}$ (e) $8\hat{\imath} + 6\hat{\jmath}$

Questions 6-8

Consider a particle moving in the xy-plane with a constant acceleration. At $t = 0$ the particle's initial position is $(2\ m)\hat{\imath} - (3\ \text{m})\hat{\jmath}$ and at that instant its initial velocity is $(10\ m/s)\hat{\imath}$. At $t = 3\ s$ its velocity is $(4\ m/s)\hat{\imath} + (3\ \text{m/s})\hat{\jmath}$.

6. What is the acceleration of this particle?

(a) $(2\ m/s^2)\hat{\imath} - (1\ \text{m/s}^2)\hat{\jmath}$ (b) $(3\ m/s^2)\hat{\imath} + (2\ \text{m/s}^2)\hat{\jmath}$ (c) $(-2\ m/s^2)\hat{\imath} + (3\ \text{m/s}^2)\hat{\jmath}$ (d) $(-3\ m/s^2)\hat{\imath} + (2\ \text{m/s}^2)\hat{\jmath}$
(e) $(-2\ m/s^2)\hat{\imath} + (1\ \text{m/s}^2)\hat{\jmath}$

7. What is the position vector of the particle at $t = 3\ s$?

(a) $(5\ m)\hat{\imath} + (2\ \text{m})\hat{\jmath}$ (b) $(17\ m)\hat{\imath} + (5/2\ \text{m})\hat{\jmath}$ (c) $(23\ m)\hat{\imath} + (3/2\ \text{m})\hat{\jmath}$ (d) $(13\ m)\hat{\imath} + (5/2\ \text{m})\hat{\jmath}$
(e) $(3\ m)\hat{\imath} + (4\ \text{m})\hat{\jmath}$

8. During the time interval $t_i = 0$ and $t_f = 3\ s$ what is the average velocity of the particle?

(a) $(4\ m)\hat{\imath} + (5/2\ \text{m})\hat{\jmath}$ (b) $(7\ m)\hat{\imath} + (3/2\ \text{m})\hat{\jmath}$ (c) $(5\ m)\hat{\imath} + (5/2\ \text{m})\hat{\jmath}$ (d) $(4\ m)\hat{\imath} + (7/2\ \text{m})\hat{\jmath}$ (e) $(5\ m)\hat{\imath} + (3\ \text{m})\hat{\jmath}$

Questions 9-10

A block of mass m is at rest at the origin at $t = 0$. It is pushed with constant force F_0 from $x = 0$ to $x = L$ across a horizontal surface whose coefficient of kinetic friction is $\mu_k = \mu_0(1 - x/L)$, that is, the coefficient of friction decreases from μ_0 at $x = 0$ to zero at $x = L$.

9. What is the net work done by the net force to bring the block from $x = 0$ to $x = L$?

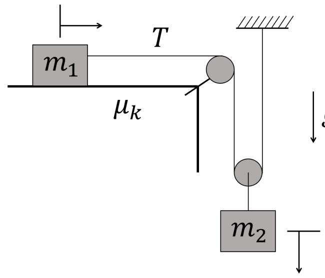
(a) $\left(F_0 - \frac{3}{2}mg\mu_0\right)L$ (b) $\left(2F_0 - \frac{1}{2}mg\mu_0\right)L$ (c) $\left(F_0 + \frac{3}{2}mg\mu_0\right)L$ (d) $\left(3F_0 + \frac{5}{2}mg\mu_0\right)L$ (e) $\left(F_0 - \frac{1}{2}mg\mu_0\right)L$

10. What is the block's speed as it reaches position L?

(a) $\sqrt{\left(\frac{F_0}{m} - 4\mu_0 g\right)L}$ (b) $\sqrt{\left(\frac{F_0}{m} - 3\mu_0 g\right)L}$ (c) $\sqrt{\left(\frac{2F_0}{m} + 3\mu_0 g\right)L}$ (d) $\sqrt{\left(\frac{2F_0}{m} - 3\mu_0 g\right)L}$ (e) $\sqrt{\left(\frac{2F_0}{m} - \mu_0 g\right)L}$

Questions 11-13

Consider the system shown in the figure. The pulleys are assumed to be frictionless and massless. The coefficient of kinetic friction between m_1 and the horizontal surface is $\mu_k = 0.25$. Take $m_1 = 2\ kg$ and $m_2 = 4\ kg$, $g = 10\ m/s^2$.



11. What is the relation between the manitudes of the accelerations of the blocks?

(a) $3a_1 = 2a_2$ (b) $a_1 = a_2$ (c) $a_1 = 3a_2$ (d) $a_1 = 2a_2$ (e) $2a_1 = a_2$

12. What is the acceleration of the block m_1?

(a) $3\ m/s^2$ (b) $4.5\ m/s^2$ (c) $3.5\ m/s^2$ (d) $5\ m/s^2$ (e) $4\ m/s^2$

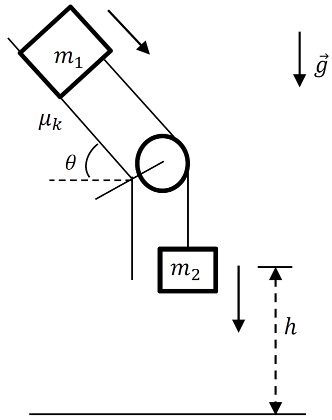
13. What is the tension T in the rope?

(a) $13\ N$ (b) $11\ N$ (c) $19\ N$ (d) $17\ N$ (e) $15\ N$

Questions 14-16

Two blocks of masses $m_1 = 5\ kg$ and $m_2 = 10\ kg$ are connected by a string of negligible mass, as shown in the figure. The coefficient of kinetic friction between the block m_1 and the inclined plane is given by $\mu_k = 0.25$ and the angle of inclanation is $\theta = 37^o$.

Take $g = 10\ m/s^2$ **and** $\sin 37^o = \cos 53^o = 3/5$ **.**



14. What is the acceleration of the blocks?

(a) $6.5\ m/s^2$ (b) $8\ m/s^2$ (c) $6\ m/s^2$ (d) $7\ m/s^2$ (e) $7.5\ m/s^2$

15. What is the tension in the string?

(a) $25\ N$ (b) $30\ N$ (c) $15\ N$ (d) $35\ N$ (e) $20\ N$

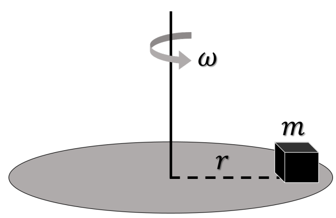
16. What is the work done by gravity when m_2 falls a distance $h = 0.5\ m$?

(a) $55\ J$ (b) $65\ J$ (c) $60\ J$ (d) $50\ J$ (e) $45\ J$

Questions 17-18

A disk shaped platform of radius R is being rotated with a constant angular speed $\omega = 3\ rad/s$ about the axis passing through its center of mass, as shown in the figure. A block of mass $m = 500\ g$ is at rest relative to the platform at a distance $r = 25\ cm$ from the axis of rotation. The coefficient of static and kinetic frictions between the block and the platform are $\mu_s = 0.7$ and $\mu_k = 0.4$, respectively.

Take $g = 10\ m/s^2$.



17. What is the magnitude and direction of the friction force on m?

(a) $11/8\ N$, away from the rotation axis
(b) $9/5\ N$, towards the rotation axis
(c) $9/8\ N$, towards the rotation axis
(d) $11/8\ N$, towards the rotation axis
(e) $9/8\ N$, away from the rotation axis

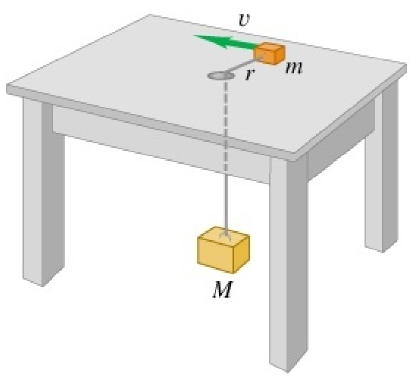
18. What is the maximum value of ω to keep the block at rest relative to the platform in units of rad/s?

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

Questions 19-20

A small block of mass $m = 0.5\ kg$ is set into a uniform circular motion on a horizontal frictionless table at a distance $r = 50\ cm$ from a hole in the center of the table, as shown in the figure. A string tied to m passes down through the hole, and a larger block of mass M is suspended from the free end of the string. If the small block m makes 4 turns in a second, the height of M is not changing.

Take $g = 10\ m/s^2$, $\pi \approx 3$.



19. For this given configuration of the system, what is the magnitude of the acceleration of m?

(a) $328\ m/s^2$ (b) $148\ m/s^2$ (c) $288\ m/s^2$ (d) $178\ m/s^2$ (e) $258\ m/s^2$

20. What is the value of M?

(a) $72/5\ kg$ (b) $18\ kg$ (c) $17\ kg$ (d) $76/7\ kg$ (e) $72/7\ kg$

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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. 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?

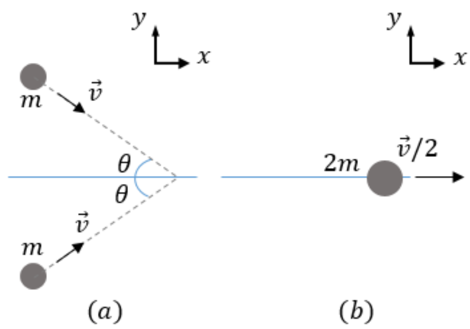
(a) $\frac{64}{15}$ J (b) $\frac{61}{13}$ J (c) $\frac{53}{15}$ J (d) $\frac{47}{15}$ J (e) $\frac{64}{19}$ J

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?

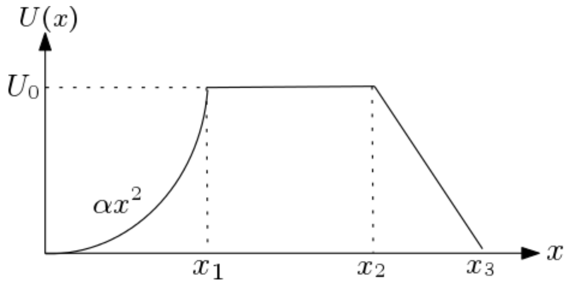
(a) $4(18t^3 - 54t^2 + 48t + 12)$ (b) $4(18t^3 - 27t^2 + 48t - 12)$ (c) $4(18t^3 - 54t^2 + 48t - 12)$ (d) $4(18t^3 - 54t^2 + 14t + 12)$
(e) $4(16t^3 - 54t^2 + 48t - 12)$

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) $-600x\hat{\imath}$ N (b) $200x\hat{\imath}$ N (c) $-200x\hat{\imath}$ N (d) $-400x\hat{\imath}$ N (e) $400x\hat{\imath}$ 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 $x = x_3$?

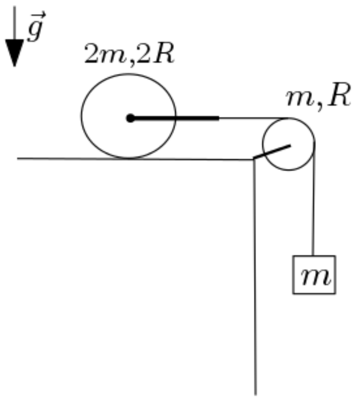
(a) $6.0\ m/s$ (b) $4.0\ m/s$ (c) $3.0\ m/s$ (d) $2.0\ m/s$ (e) 0

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 mass m attached to the end of a spring on a frictionless horizontal plane is released from rest at $t = 0$ s from an extended position x_{max}. The mass $m = 0.2$ kg and $k = 1$ N/m. At $\omega t = 5\pi/4$ with ω angular frequency of the simple harmonic motion, the speed of the mass is measured to be 1.5 m/s.

1. What is the maximum speed of the motion?

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

2. What is x_{max}?

(a) $3/\sqrt{7}$ m/s (b) $3/\sqrt{5}$ m/s (c) $\sqrt{10}/2$ m/s (d) $3/\sqrt{10}$ m (e) $\sqrt{10}/3$ m/s

3. What is the angular frequency of the simple harmonic motion?

(a) $\sqrt{7}$ rad/s (b) 5 rad/s (c) $\sqrt{3}$ rad/s (d) $\sqrt{5}$ rad/s (e) 3 rad/s

4. What is the total energy of the mass - spring system?

(a) 9/20 J (b) 9/10 J (c) 7/10 J (d) 3/20 J (e) 9/16 J

Questions 5 - 7

A physical pendulum of $m = 2$ kg oscillates at small angle around an axis at a distant of $h = 0.2$ m to it center of gravity. It has a moment of inertia $I = \frac{1}{2}mh^2$ with respect to its rotation axis.

5. What is the length of a 2 kg simple pendulum that has the same period for small amplitude oscillations?

(a) $\sqrt{2}/0.1$ m (b) $\sqrt{3}/0.1$ m (c) 0.4 m (d) 0.2 $\sqrt{2}$ m (e) 0.1 m

6. Find the maximum value of the angular acceleration if the amplitude of oscillation is 0.3 rad.

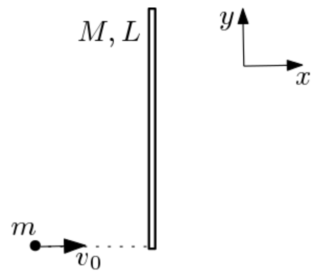
(a) 3 rad/s^2 (b) 1/30 rad/s^2 (c) 30 rad/s^2 (d) 300 rad/s^2 (e) 1/300 rad/s^2

7. What is the angular acceleration as the pendulum passed through the equilibrium position?

(a) 30 $\sqrt{2}$ rad/s^2 (b) $20/\sqrt{3}$ rad/s^2 (c) 0 rad/s^2 (d) 30 rad/s^2 (e) 150 rad/s^2

Questions 8 - 12

A uniform rod of mass $M = 3m$ 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 $v_0/2$, as shown in the figure. (For a uniform rod of mass M and length L, $I_{cm} = \frac{1}{12}ML^2$.)



8. Which of the following is the center of mass velocity of the rod just after the collision?

(a) $\frac{3v_0}{2}\hat{\imath}$ (b) $\frac{v_0}{4}\hat{\imath}$ (c) $-\frac{v_0}{2}\hat{\imath}$ (d) $\frac{v_0}{2}\hat{\imath}$ (e) $-\frac{v_0}{4}\hat{\imath}$

9. What is the angular speed of the rod about its center of mass just after the collision?

(a) $\frac{v_0}{3L}$ (b) $\frac{2v_0}{3L}$ (c) $\frac{3v_0}{2L}$ (d) $\frac{3v_0}{L}$ (e) $\frac{3v_0}{4L}$

10. What is the impulse transferred to the point particle m during the collision?

(a) $\frac{3m}{4}v_0\hat{\imath}$ (b) $\frac{3m}{2}v_0\hat{\imath}$ (c) $-\frac{3m}{2}v_0\hat{\imath}$ (d) $-\frac{3m}{5}v_0\hat{\imath}$ (e) $-\frac{3m}{4}v_0\hat{\imath}$

11. If the collision were completely inelastic, what would be the center of mass velocity of the system just after the collision?

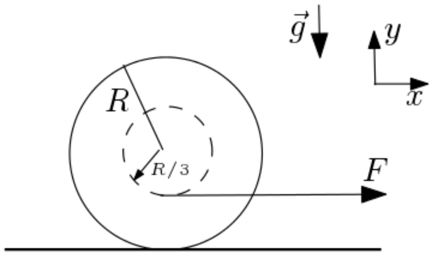
(a) $\frac{v_0}{4}\hat{\imath}$ (b) $-\frac{v_0}{3}\hat{\imath}$ (c) $-\frac{v_0}{4}\hat{\imath}$ (d) $\frac{3v_0}{4}\hat{\imath}$ (e) $\frac{v_0}{3}\hat{\imath}$

12. If the collision were completely inelastic, what would be the angular speed of the system about the new center of mass?

(a) $\frac{6v_0}{5L}$ (b) $\frac{5v_0}{6L}$ (c) $\frac{7v_0}{4L}$ (d) $\frac{5v_0}{7L}$ (e) $\frac{6v_0}{7L}$

Questions 13 - 15

A disk shaped yo-yo is being pulled by a constant horizontal force $F = 6\ N$, as shown in the figure. The mass of the yo-yo is $M = 500$ g and its radius is $R = 20$ cm, and F is pulling it at a distance $R/3$ from the center. Assume that the yo-yo is rolling without slipping under these conditions.
(For a disk of mass M and radius R, $I_{cm} = \frac{1}{2}MR^2$. Take $g = 10$ m/s^2.)



13. Which of the following is the acceleration of the center of mass of the yo-yo?

(a) $2\ m/s^2$ (b) $\frac{16}{3}\ m/s^2$ (c) $\frac{5}{2}\ m/s^2$ (d) $\frac{11}{3}\ m/s^2$ (e) $3\ m/s^2$

14. Which of the following is the angular speed of the yo-yo when its center of mass has moved a distance $1.5\ m$?

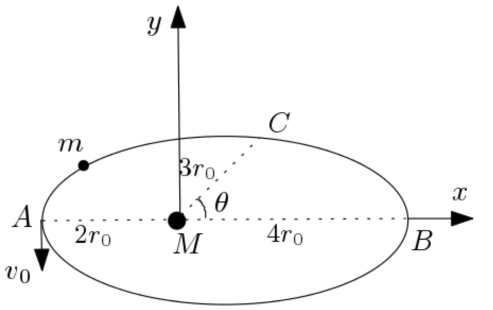
(a) $10\ rad/s$ (b) $25\ rad/s$ (c) $15\ rad/s$ (d) $30\ rad/s$ (e) $20\ rad/s$

15. Which of the following is the static friction force acting on the yo-yo?

(a) $-\left(\frac{10}{3}\ N\right)\hat{\imath}$ (b) $-\left(\frac{8}{3}\ N\right)\hat{\imath}$ (c) $-2\ N\hat{\imath}$ (d) $-4\ N\hat{\imath}$ (e) $-3\ N\hat{\imath}$

Questions 16 - 20

A planet of mass m is moving on an elliptic orbit about a star of mass M ($m \ll M$), as shown in the figure. The point A is the closest point of the planet to the star and the point B is that of farthest, and the distance of the planet to the star at point A is $2r_0$ and at B is $4r_0$. The speed of the planet at point A is $v_0 = \sqrt{\frac{2GM}{3r_0}}$.



16. Which of the following is the total energy of the system?

(a) $-\frac{2GMm}{7r_0}$ (b) $-\frac{GMm}{7r_0}$ (c) $-\frac{GMm}{8r_0}$ (d) $-\frac{3GMm}{7r_0}$ (e) $-\frac{GMm}{6r_0}$

17. Which of the following is the speed of the planet at point B?

(a) $\sqrt{\frac{2GM}{7r_0}}$ (b) $\sqrt{\frac{GM}{6r_0}}$ (c) $\sqrt{\frac{GM}{8r_0}}$ (d) $\sqrt{\frac{3GM}{8r_0}}$ (e) $\sqrt{\frac{GM}{7r_0}}$

18. Which of the following is the acceleration of the planet at point C which is at a distance $3r_0$ from the star where the radius vector makes an angle of $\theta = \pi/6\ rad$ with the x-axis? ($\sin\pi/6 = 1/2$.)

(a) $-\frac{GM}{18r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (b) $\frac{GM}{16r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (c) $-\frac{GM}{16r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (d) $-\frac{GM}{18r_0^2}(\sqrt{3}\hat{\imath}-\hat{\jmath})$ (e) $-\frac{GM}{18r_0^2}(-\sqrt{3}\hat{\imath}+\hat{\jmath})$

19. Which of the following is the length of the semimajor axis of the elliptic orbit?

(a) $7r_0/2$ (b) $3r_0$ (c) $7r_0/3$ (d) $5r_0/2$ (e) $9r_0/4$

20. Which of the following is the eccentricity of the orbit?

(a) $2/3$ (b) $1/3$ (c) $3/4$ (d) $3/5$ (e) 0

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For all questions take $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9\ N\,m^2/C^2$**.**

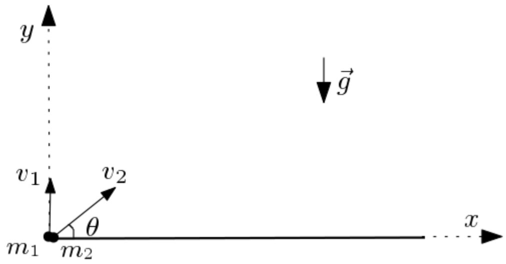
1. Which of the following is a unit vector perpendicular to both $\vec{A} = 2\hat{\imath} + \hat{\jmath}$ and $\vec{B} = 3\hat{\imath} - 2\hat{k}$?

(a) $\frac{3\hat{\imath}+2\hat{\jmath}-3\hat{k}}{\sqrt{29}}$ (b) $\frac{-3\hat{\imath}+4\hat{\jmath}-2\hat{k}}{\sqrt{29}}$ (c) $\frac{3\hat{\imath}+4\hat{\jmath}-3\hat{k}}{\sqrt{34}}$ (d) $\frac{-3\hat{\imath}+4\hat{\jmath}+3\hat{k}}{\sqrt{34}}$ (e) $\frac{-2\hat{\imath}+4\hat{\jmath}-3\hat{k}}{\sqrt{29}}$

Questions 2-4

An object of mass m_1 and another object of mass m_2 are thrown at the same instant from the ground with the same initial speeds $v_1 = v_2 = 5\ m/s$, as shown in the figure. $\theta = 53^o$ and take $g = 10\ m/s^2$.

Take $g = 10\ m/s^2$ **and** $\theta = 53^o$ **,** $\sin 53^o = 4/5$ **.**



2. What is the acceleration vector of m_1 relative to m_2?

(a) 0 (b) $\frac{1}{2}g\hat{\jmath}$ (c) $-\frac{1}{2}g\hat{\jmath}$ (d) $-g\hat{\jmath}$ (e) $g\hat{\jmath}$

3. What is the velocity of m_1 relative to m_2 when m_2 is at the heighest point of its trajectory in units of m/s?

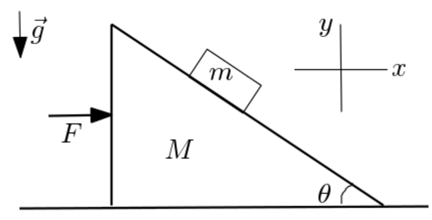
(a) $-2\hat{\imath} + \hat{\jmath}$ (b) $3\hat{\imath} - 2\hat{\jmath}$ (c) $\hat{\imath} + \hat{\jmath}$ (d) $\hat{\imath} - \hat{\jmath}$ (e) $-3\hat{\imath} + \hat{\jmath}$

4. What is the distance between m_1 and m_2 at $t = 0.5\ s$?

(a) $\sqrt{2}\ m$ (b) $3/2\ m$ (c) $\sqrt{10}/2\ m$ (d) $\sqrt{3}\ m$ (e) $\sqrt{7}/2\ m$

Questions 5-8

A constant horizontal force $F = 32\ N$ is applied on $M = 4\ kg$ and the system is moving to the right, as shown in the figure. The small block $m = 2\ kg$ is at rest relative to M during the motion. There is no friction between M and the ground, the coefficient of static friction between m and M is $\mu_s = 0.5$, and the angle of inclanation is $\theta = 53^o$. (Take $g = 10\ m/s^2$ and $\sin 53 = 4/5$.)



5. What is the acceleration of the system?

(a) $16/3\ m/s^2$ (b) $3\ m/s^2$ (c) $4\ m/s^2$ (d) $5\ m/s^2$ (e) $14/3\ m/s^2$

6. What is the magnitude of the normal force applied on m by M?

(a) $20\ N$ (b) $308/15\ N$ (c) $298/15\ N$ (d) $17\ N$ (e) $21\ N$

7. What is the magnitude of the friction force between m and M?

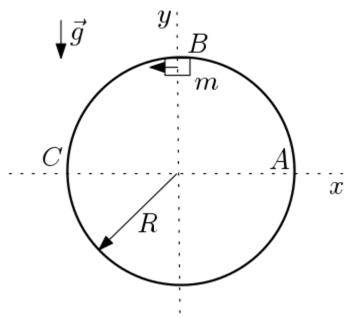
(a) $154/15\ N$ (b) $157/15\ N$ (c) $14\ N$ (d) $48/5\ N$ (e) $51/5\ N$

8. What is the minimum value of F which keeps m at rest relative to M during the motion of the system?

(a) $30\ N$ (b) $25\ N$ (c) $28\ N$ (d) $19\ N$ (e) $22\ N$

Questions 9-12

A small remote-controlled car of mass $m = 500\ g$ is moving at a constant speed $v = 6\ m/s$ in a vertical circle of radius $R = 1.5\ m$ inside a hollow metal cylinder. The object is at point A at time $t = 0$. (Take $g = 10\ m/s^2$.)



9. What is the normal force exerted on the car by the walls of the cylinder at point B?

(a) $12\ N$ (b) $11\ N$ (c) $7\ N$ (d) $5\ N$ (e) $14\ N$

10. What is the normal force exerted on the car by the walls of the cylinder at point C?

(a) $11\ N$ (b) $12\ N$ (c) $14\ N$ (d) $5\ N$ (e) $7\ N$

11. What is the average velocity of the car between $t = 0$ and $t = \pi/4\ s$ in units of m/s?

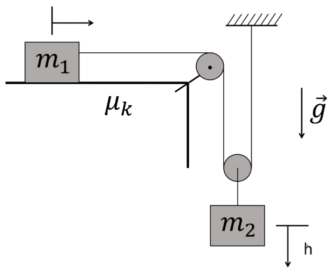
(a) $+\frac{10}{\pi}\hat{j}$ (b) $-\frac{12}{\pi}\hat{i}$ (c) $+\frac{12}{\pi}\hat{i}$ (d) $-\frac{12}{\pi}\hat{j}$ (e) $-\frac{10}{\pi}\hat{i}$

12. What is the average acceleration vector of the car between $t = 0$ and $t = \pi/4\ s$ in units of m/s^2?

(a) $-\frac{44}{\pi}\hat{j}$ (b) $+\frac{44}{\pi}\hat{i}$ (c) $+\frac{48}{\pi}\hat{i}$ (d) $-\frac{48}{\pi}\hat{j}$ (e) $-\frac{48}{\pi}\hat{i}$

Questions 13-16

The system shown in the figure starts motion from rest. The coefficient of kinetic friction between $m_1 = 1\ kg$ and the table is $\mu_k = 0.2$. Assume that the cords and the pulleys are massless. The acceleration of m_1 is a_1 and that of $m_2 = 2\ kg$ is a_2.



13. What is the relation between the accelerations of the blocks?

(a) $a_1 = 3a_2$ (b) $3a_1 = a_2$ (c) $2a_1 = a_2$ (d) $a_1 = 2a_2$ (e) $a_1 = a_2$

14. What is the tension in the rope tied to m_1?

(a) $7\ N$ (b) $22/3\ N$ (c) $21/4\ N$ (d) $21/5\ N$ (e) $8\ N$

15. What is the work done by friction when m_2 falls a distance $h = 50\ cm$?

(a) $-6\ J$ (b) $-5\ J$ (c) $-4\ J$ (d) $-2\ J$ (e) $-3\ J$

16. What is the speed of m_2 when it falls a distance $h = 50\ cm$?

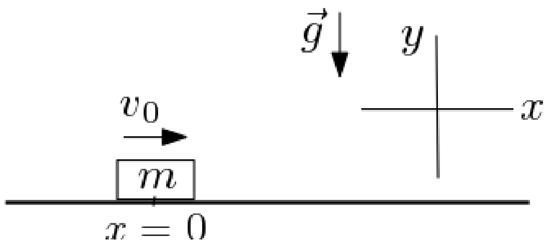
(a) $\frac{3\sqrt{2}}{3}\ m/s$ (b) $\frac{5\sqrt{3}}{3}\ m/s$ (c) $\frac{4\sqrt{2}}{3}\ m/s$ (d) $\frac{2\sqrt{3}}{3}\ m/s$ (e) $\frac{2\sqrt{6}}{3}\ m/s$

Questions 17-20

A block of mass m with initial speed v_0 enters into a region of a rough surface at $x = 0$, as shown in the figure. The coefficient of kinetic friction in this region is variable and of the form $\mu_k = bx$, where b is a constant.

17. What is the SI unit of the constant b?

(a) m (b) m/s (c) m^{-1} (d) m^{-2} (e) $m \cdot s$



18. What is the magnitude of the acceleration of the block as a function of x?

(a) $3bx$ (b) bgx (c) gx (d) $2bx$ (e) $2gx$

19. Which of the following is the work done by the friction between $x = 0$ and $x = d$?

(a) $-bmgd$ (b) $-\frac{3}{2}bmgd^2$ (c) $-\frac{3}{2}bmgd$ (d) $-\frac{1}{2}bmgd$ (e) $-\frac{1}{2}bmgd^2$

20. At which point x the block comes to rest?

(a) $\frac{3v_0}{\sqrt{g}}$ (b) $\frac{v_0}{\sqrt{bg}}$ (c) $\frac{2v_0}{\sqrt{g}}$ (d) $\frac{2v_0}{\sqrt{mg}}$ (e) $\frac{v_0}{\sqrt{b^2g}}$

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Questions 1-5

1. A mass m is revolving in a circular path of radius R with an angular acceleration $\alpha = A\,t$, where A is a positive constant. Calculate the angular speed $\omega(t)$ in terms of ω_0 (initial angular speed at $t=0$), A and time t.
(a) $\omega_0 + 2\,A\,t^2$ (b) $\omega_0 + 2\,A\,t$ (c) $\omega_0 + A\,t$ (d) $\omega_0 + \frac{1}{2}\,A\,t^2$ (e) $\omega_0 + A\,t^2$

2. Calculate the angular position $\theta(t)$ in terms θ_0 (initial angular position at $t=0$), ω_0, A and t.
(a) $\theta_0 + \omega_0\,t + A\,t^2$ (b) $\theta_0 + \omega_0\,t + \frac{1}{2}\,A\,t^2$ (c) $\theta_0 + \omega_0\,t + \frac{1}{6}\,A\,t^3$ (d) $\theta_0 + \omega_0\,t + \frac{1}{3}\,A\,t^3$ (e) $\theta_0 + \omega_0\,t + \frac{2}{3}\,A\,t^3$

3. Calculate the speed $v(t)$ of the particle in terms of ω_0, A, R and time t.
(a) $\omega_0\,R + A\,R t^2$ (b) $\omega_0\,R + 2\,A\,R t^2$ (c) $\omega_0\,R + \frac{1}{2}\,A\,R\,t^2$ (d) $\omega_0\,R + 2\,A\,R t$ (e) $\omega_0\,R + A\,R\,t$

4. Calculate the magnitude of radial acceleration $a_r(t)$ in terms of ω_0, A, R and time t.
(a) $(\omega_0 + A\,t^2)^2\,R$ (b) $(\omega_0 + \frac{1}{2}\,A\,t^2)^2\,R$ (c) $(\omega_0 + 2\,A\,t)^2\,R$ (d) $(\omega_0 + 2\,A\,t^2)^2\,R$ (e) $(\omega_0 + A\,t)^2\,R$

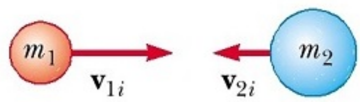
5. Calculate the magnitude of the linear acceleration $a(t)$ in terms of ω_0, A, R and time t.
(a) $R\sqrt{A^2\,t^2 + (\omega_0 + \frac{1}{2}\,A\,t^2)^4}$ (b) $R\sqrt{A^2\,t^2 + (\omega_0 + A\,t)^4}$ (c) $R\sqrt{A^2\,t^2 + (\omega_0 + 2\,A\,t^2)^4}$
(d) $R\sqrt{A^2\,t^2 + (\omega_0 + 2\,A\,t)^4}$ (e) $R\sqrt{A^2\,t^2 + (\omega_0 + A\,t^2)^4}$

Questions 6-7

Position vectors of $m_1 = 1\,kg$, $m_2 = 2\,kg$ and $m_3 = 3\,kg$ are given as $\vec{r}_1 = 2t^2\hat{\imath}$, $\vec{r}_2 = (2-3t)\hat{\imath} + 2t\hat{\jmath}$ and $\vec{r}_3 = (1-t)\hat{\jmath} - \frac{1}{6}(t^3-1)\hat{k}$ in units of meters.

6. Find the centre of mass velocity $\vec{v}_{\rm cm}$ when $t = 2$ s.
(a) $\frac{1}{6}(-3\hat{\jmath} + 2\hat{k})$ (b) $\frac{1}{2}(3\hat{\imath} - 2\hat{\jmath} + 1\hat{k})$ (c) $\frac{1}{6}(2\hat{\imath} + \hat{\jmath} - 6\hat{k})$ (d) $\frac{1}{6}(-3\hat{\imath} - 2\hat{\jmath} + 4\hat{k})$ (e) $\frac{1}{5}(-4\hat{\imath} - 2\hat{k})$

7. Find the centre of mass acceleration $\vec{a}_{\rm cm}$ when $t = 2$ s.
(a) $\frac{1}{3}(2\hat{\imath} - 3\hat{k})$ (b) $\frac{1}{2}(2\hat{\jmath} - 5\hat{k})$ (c) $\frac{1}{6}(4\hat{\imath} - 3\hat{\jmath} - 5\hat{k})$ (d) $\frac{1}{6}(4\hat{\imath} - 3\hat{\jmath})$ (e) $\frac{1}{6}(2\hat{\imath} + 3\hat{k})$



Questions 8-10

Two objects with masses $m_1 = 2\,kg$ and $m_2 = 3\,kg$ collide elastically with initial velocities given as $\vec{v}_{1i} = 4\,\hat{\imath}\,\frac{m}{s}$ and $\vec{v}_{2i} = -6\,\hat{\imath}\,\frac{m}{s}$.

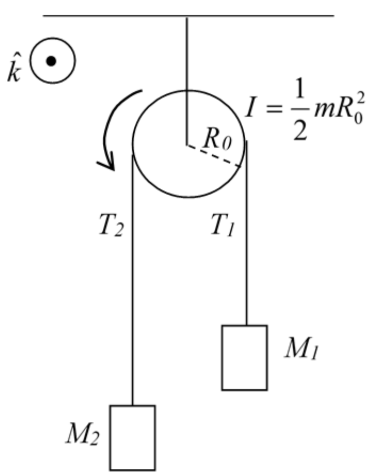
8. Calculate the centre of mass velocity $\vec{v}_{\rm cm}$ of the system **before** the collision.
(a) $+1\,\hat{\imath}\,\frac{m}{s}$ (b) $-4\,\hat{\imath}\,\frac{m}{s}$ (c) $-1\,\hat{\imath}\,\frac{m}{s}$ (d) $-2\,\hat{\imath}\,\frac{m}{s}$ (e) $-3\,\hat{\imath}\,\frac{m}{s}$

9. Calculate the velocities of m_1 and m_2 with respect to centre of mass frame (velocities relative to an observer moving with $\vec{v}_{\rm cm}$) **before** the collision.
(a) $\vec{v'}_1 = -2\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_2 = +4\,\hat{\imath}\,\frac{m}{s}$ (b) $\vec{v'}_1 = 6\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_2 = -4\,\hat{\imath}\,\frac{m}{s}$ (c) $\vec{v'}_1 = 3\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_2 = -2\,\hat{\imath}\,\frac{m}{s}$ (d) $\vec{v'}_1 = 2\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_2 = -8\,\hat{\imath}\,\frac{m}{s}$
(e) $\vec{v'}_1 = 5\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_2 = -5\,\hat{\imath}\,\frac{m}{s}$

10. Calculate the velocities of m_1 and m_2 with respect to centre of mass frame (velocities relative to an observer moving with $\vec{v}_{\rm cm}$) **after** the collision.
(a) $\vec{v'}_{1f} = -3\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_{2f} = +2\,\hat{\imath}\,\frac{m}{s}$ (b) $\vec{v'}_{1f} = -6\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_{2f} = +4\,\hat{\imath}\,\frac{m}{s}$ (c) $\vec{v'}_{1f} = -4\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_{2f} = +6\,\hat{\imath}\,\frac{m}{s}$
(d) $\vec{v'}_{1f} = +2\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_{2f} = -4\,\hat{\imath}\,\frac{m}{s}$ (e) $\vec{v'}_{1f} = -8\,\hat{\imath}\,\frac{m}{s}, \vec{v'}_{2f} = +2\,\hat{\imath}\,\frac{m}{s}$

Questions 11-13

An Atwood machine is represented in figure where the pulley is in disc form and its moment of inertia is $I = \frac{1}{2}mR_0^2$. Here, $m = 2$ kg is the mass of the pulley and $R_0 = 20$ cm is the radius of the pulley. Initially the masses $M_1 = 1$ kg and $M_2 = 3$ kg are kept at rest and released at time, $t = 0$. The direction of z-axis is out of the page. Ignore friction on the axis of rotation. Take $g = 10$ m/s^2.



11. What is the magnitude of the acceleration a of the masses in unit of m/s^2 ?
(a) 20/3 (b) 2 (c) 4 (d) 5 (e) 10/3

12. What is the ratio of the tensions, T_1/T_2, shown in the figure?
(a) 5/3 (b) 5/7 (c) 3/5 (d) 3/2 (e) 7/9

13. What is the angular speed, ω, of the pulley at $t = 2$ s, in unit of rad/s ?
(a) 40 (b) 30 (c) 10 (d) 20 (e) 5

Questions 14-15

A horizontal table in the form of a circular disk rotates around a vertical axis passing through its centre of mass without friction, with an angular speed $\omega_0 = 0.5$ rad/s. The mass of the table is 100 kg and the radius is 2 m. A child with a mass of 32 kg walks slowly from the edge of the rotating table towards the centre. The moment of inertia of the table is $I = \frac{1}{2}MR^2$.

14. What is the angular speed of the child, in rad/s, when he reaches a point 0.5 m away from the centre of the disk?
(a) 30/14 (b) 50/32 (c) 52/41 (d) 32/50 (e) 41/52

15. What is the rotational kinetic energy of the system, in N.m, when he reaches a point 0.5 m away from the centre of the disk?
(a) 2704/26 (b) 1681/26 (c) 1024/13 (d) 250/32 (e) 900/32

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16. If the escape speed from the surface of a star of mass M and radius R is v, then what it would be for a star of mass $18M$ and radius $R/2$?

(a) $3v$ (b) $9v$ (c) $1296v$ (d) $36v$ (e) $6v$

17. What is the weight w of a particle of mass m at a distance $r < R$ from the centre of a homogenous (constant density) spherical body of mass M and radius R.

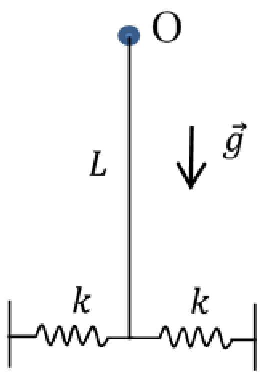
(a) $w = G\frac{mM}{r^2}$ (b) $w = 0$ (c) $w = G\frac{mM}{R^2}r$ (d) $w = G\frac{mM}{R^3}r$ (e) $w = G\frac{mM}{r^2}R$

18. Which of the following is correct for a planet revolving in an elliptical orbit around the sun? ϕ is the angle between the velocity $\vec{v}$ of the planet and the line with a length r from the sun to the planet. (Hint: Recall Kepler's Second Law. $r_{\min}$ and $r_{\max}$ are the minimum and maximum distances of the planet from the sun. $v_{\min}$ and $v_{\max}$ are the minimum and maximum speeds of the planet in its orbit.)

(a) $rv\sin\phi = r_{\min}v_{\min}$ (b) $rv = r_{\min}v_{\max}$ (c) $rv\cos\phi = r_{\min}v_{\max}$ (d) $vr = \text{constant}$ (e) $rv\sin\phi = r_{\min}v_{\max}$

Questions 19-20

A homogeneous rod of mass $M = 5$ kg and length $L = 3$ m is suspended from one end to rotate around the point O in the vertical plane. From the other end, as shown in figure, the rod is attached to two identical springs with spring constants $k = \frac{100}{6}$ N/m (take $\pi = 3\,, g = 10\,m/s^2$ and $I_{\text{cm}} = \frac{1}{12}ML^2$). For small vibrations;



19. What is the magnitude of the angular acceleration of the rod as function of θ?
(a) 25 θ (b) 125 θ (c) 120 θ (d) 5 θ (e) 2 θ

20. What is the period of the vibration in units of seconds?
(a) 3/5 (b) 5/3 (c) 5/6 (d) 6/5 (e) 7/4

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Questions 1-5

1. If ρ has a units of kg/m^3, and P has units of N/m^2, what are the units of c if $c = \sqrt{5P/3\rho}$?

(a) m^3/s (b) m/s (c) $m^2/s^{1/2}$ (d) kgm^2/s^2 (e) $s^{1/2}$

2. Drag force of the air is given by the equation $D = b\,v^2$ where $b = 4.0Ns^2/m^2$ and v is the speed of the object. An object of mass $m = 10.0kg$ is falling under the effect of constant gravity and this drag force to the ground. What is the terminal speed (the constant speed) of the object? ($g = 10\,m/s^2$)

(a) $3.0m/s$ (b) $4.0m/s$ (c) $6.0m/s$ (d) $5.0m/s$ (e) $5.5m/s$

3. Vector $\vec{a} = 2\hat{i} + 3\hat{j} - 5\hat{k}$ and vector $\vec{b} = \hat{i} - 2\hat{j} - 3\hat{k}$ are given. Find a vector $\vec{c}$ that is perpendicular to both $\vec{a}$ and $\vec{b}$.

(a) $\vec{c} = -19\hat{i} + \hat{j} + 7\hat{k}$ (b) $\vec{c} = +19\hat{i} + \hat{j} - 7\hat{k}$ (c) $\vec{c} = -19\hat{i} + \hat{j} - 7\hat{k}$ (d) $\vec{c} = 19\hat{i} + \hat{j} + 7\hat{k}$ (e) $\vec{c} = -19\hat{i} - \hat{j} - 7\hat{k}$

4. Vectors $\vec{A} = 4\hat{i} + a\hat{j} + 2\hat{k}$ and $\vec{B} = -3\hat{i} + 2\hat{j} + b\hat{k}$ are given. Find the value of $a + b$ if the angle between these two vectors is 90^o.

(a) 12 (b) 8 (c) 6 (d) 7 (e) 5

5. The period of an object making uniform circular motion on a circular trajectory of radius R is T. What is the magnitude of the centripetal acceleration?

(a) $\dfrac{4\pi^2 R^2}{T^3}$ (b) $\dfrac{4\pi^2 R}{T}$ (c) $\dfrac{2\pi^2 R^2}{T^3}$ (d) $\dfrac{\pi^2 R}{T^2}$ (e) $\dfrac{4\pi^2 R}{T^2}$

Questions 6-7

While driving along a highway at 40 m/s you see a police car 50 m ahead traveling at a constant speed of 30 m/s which is the speed limit. You apply the brakes and begin decelareting at 1.0 m/s^2.

6. After applying to the brakes, when will you reach to the police car?

(a) $10s$ (b) $14s$ (c) $8.0s$ (d) $12s$ (e) $9.0s$

7. After applying to the brakes, what is the distance covered by the car to reach the police car?

(a) $300m$ (b) $450m$ (c) $250m$ (d) $350m$ (e) $400m$

Questions 8-10

A particle starts from the origin at $t = 0$ with a velocity of $4.0\hat{j}$ and moves in the xy plane with a constant acceleration of $(2.0\hat{i} - 3.0\hat{j})m/s^2$.

8. At $t = 2.0s$, what is the distance of the particle to the origin?

(a) $2\sqrt{5}m$ (b) $4.0m$ (c) $4\sqrt{5}$ (d) $3\sqrt{3}$ (e) $5.0m$

9. Find the velocity of the particle at $t = 2.0s$ in units of m/s.

(a) $3.0\hat{i} - 2.0\hat{j}$ (b) $-4.0\hat{i} - 2.0\hat{j}$ (c) $4.0\hat{i} - 2.0\hat{j}$ (d) $4.0\hat{i} + 2.0\hat{j}$ (e) $-3.0\hat{i} + 2.0\hat{j}$

10. A second object is moving with a velocity $\vec{v} = -2\hat{i} + \hat{j}$ m/s in this coordinate system. What is the velocity of this object with respect to the first at $t = 2$ s in units of m/s?

(a) $-4.0\hat{i} + 3.0\hat{j}$ (b) $-4.0\hat{i} + 5.0\hat{j}$ (c) $6.0\hat{i} - 3.0\hat{j}$ (d) $-6.0\hat{i} + 3.0\hat{j}$ (e) $4.0\hat{i} - 3.0\hat{j}$

11. A 5.0 kg mass is suspended by a string from the ceiling of an elevator that is moving upward with a speed which is decreasing at a constant rate of 2.0 m/s in each second. What is the tension in the string supporting the mass assuming that $g = 10m/s^2$?

(a) 40 N (b) 60 N (c) 15 N (d) 45 N (e) 50 N

12. Consider a horizontal block-spring system such that the block is released from rest when the spring is stretched a distance d. The spring obeys the Hooke's Law. If the spring constant $k = 50$ N/m, the mass of the block is $m = 0.50$ kg, $d = 10$ cm, and the coefficient of kinetic friction $\mu_k = 0.25$, what is the speed of the block when it first passes through the position for which the spring is unstretched ? $(g = 10m/s^2)$

(a) $\frac{\sqrt{3}}{2}$ m/s (b) $\sqrt{\frac{3}{2}}$ m/s (c) $\frac{1}{\sqrt{3}}$ m/s (d) $\frac{\sqrt{2}}{2}$ m/s (e) $\frac{1}{2}$ m/s

Questions 13-15

A box of mass m is sitting on top of another box of mass M, which sits on a frictionless layer of ice. There is friction between the two boxes. A horizontal force of magnitude F is applied to the lower box

13. Assume that the static friction is such that the two boxes will move together. What is the acceleration of the system?

(a) $\frac{Fm}{M^2}$ (b) $\frac{F}{m}$ (c) $\frac{F}{M}$ (d) $\frac{F(m+M)}{mM}$ (e) $\frac{F}{m+M}$

14. What is the minimum coefficient of static friction μ_s between the two boxes such that they move together?

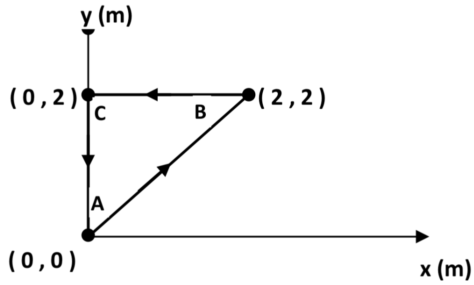
(a) $\frac{F}{g(m+M)}$ (b) $\frac{F}{gM}$ (c) $\frac{F(m+M)}{gmM}$ (d) $\frac{F}{gm}$ (e) $\frac{Fm}{gM^2}$

15. Now, assume that something is exerting an additional vertical downwards force F_2 on the upper box. What would the minimum μ_s now be such that the two boxes still move together?

(a) $\frac{MF_2}{m(m+M)(mg+F_2)}$ (b) $\frac{mF}{M(m+M)(mg+F)}$ (c) $\frac{mF}{M(m+M)(mg+F_2)}$ (d) $\frac{MF_2}{(m+M)(mg+F)}$ (e) $\frac{mF}{(m+M)(mg+F_2)}$

Questions 16-18

A force acting on a particle is given by $F = (3\hat{i} + 4x\hat{j})N$.



16. Calculate W_{AB}, the work done by the force to take the particle from $(0,0)$ to $(2,2)$.

(a) 16J (b) 10J (c) 14J (d) 8J (e) 12J

17. Calculate W_{BC}, the work done by the force to take the particle from $(2,2)$ to $(0,2)$.

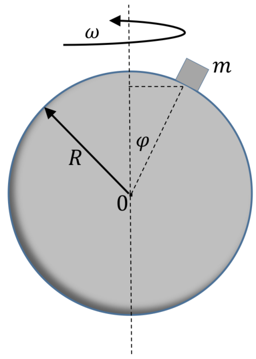
(a) 0J (b) -6J (c) 6J (d) 4J (e) -4J

18. Calculate W_{TOT}, the total work done for the complete loop.

(a) 6J (b) 8J (c) 4J (d) 2J (e) 0J

Questions 19-20

A small mass m is put on the surface of the sphere of radius R, as shown in the figure. The coefficient of static friction between the mass and the surface is μ_s. Answer the following questions, expressing your answers in terms of $\{R, m, \varphi, g, \mu_s\}$.



19. Initially the sphere and the mass are at rest. Find the minimum value of μ_s so that the mass does not slide on the sphere because of friction?

(a) φ (b) $\tan\varphi$ (c) $\cos\varphi$ (d) $\sin\varphi$ (e) $\cot\varphi$

20. If the sphere is rotating about its axis with a constant angular speed ω, as shown in the figure, what is the maximum value of ω such that the mass m is at rest? $(v = \omega r)$

(a) $\omega = \sqrt{\frac{g}{R}}$

(b) $\omega = \sqrt{\frac{g}{R}\left(\frac{\cos\varphi - \mu_s\sin\varphi}{\mu_s\sin^2\varphi}\right)}$

(c) $\omega = \sqrt{\frac{g}{R}\left(\frac{\mu_s\sin\varphi}{\mu_s\sin^2\varphi + \cos^2\varphi\sin\varphi}\right)}$

(d) $\omega = \sqrt{\frac{g}{R}\left(\frac{\cos\varphi}{\mu_s\sin^2\varphi}\right)}$

(e) $\omega = \sqrt{\frac{g}{R}\left(\frac{\mu_s\cos\varphi - \sin\varphi}{\mu_s\sin^2\varphi + \cos\varphi\sin\varphi}\right)}$

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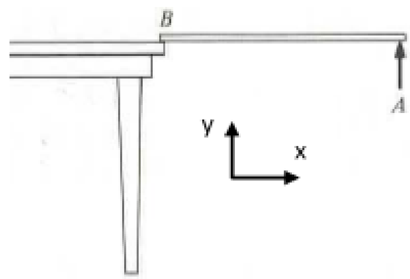
Questions 1-4

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) $-\frac{l}{2}mg\hat{k}$

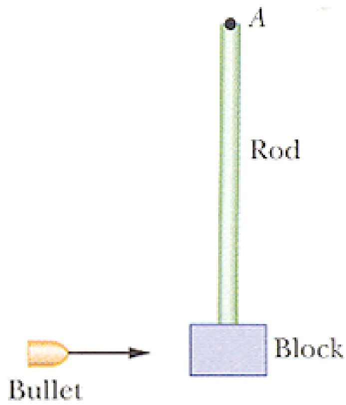
2. What is the angular acceleration about the end B on the table? (For a uniform rod of mass m and length l, $I_{cm}=\frac{1}{12}ml^2$.)
(a) $\frac{2g}{3l}$ (b) $\frac{g}{l}$ (c) $\frac{2g}{l}$ (d) $\frac{3g}{2l}$ (e) $\frac{g}{2l}$

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) $\frac{2M}{l^2}$ (c) $\frac{3M}{2l^2}$ (d) $\frac{M}{l^2}$ (e) $\frac{2M}{3l^2}$

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

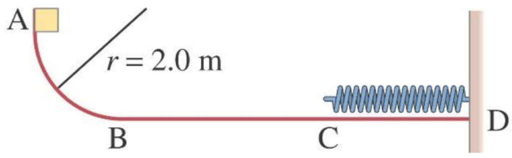
A body of mass 10.0 kg makes an elastic collision with another body at rest and continues to move in the original direction but one-third of its original speed.

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.

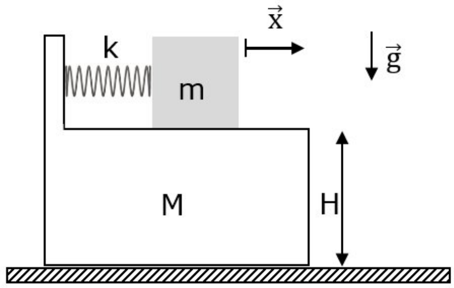
(a) $\vec{v}_m = d\sqrt{\frac{2Mk}{m(m+M)}}\hat{i}$, $\vec{v}_P = -d\sqrt{\frac{2mk}{M(m+M)}}\hat{i}$

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

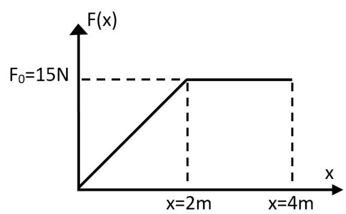


16. What is the distance between the mass and the platform when the mass hits the floor.

(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

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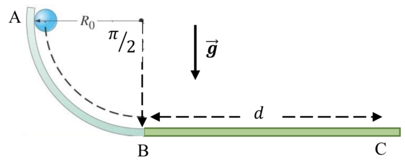
Questions 1-2

A ball of mass m and radius r (moment of inertia $I_{cm} = \frac{2}{5}mr^2$) is placed on the inside of a frictionless circular track of radius R_0 as shown in the figure. It starts from rest at the vertical edge of the track, and since there is no friction, it slides down without rotation.



1. What will be the speed of its center of mass when it reaches the lowest point B of the track?

(a) 0 (b) $\sqrt{4g(R_0 - r)}$ (c) $\sqrt{4g(R_0 + r)}$ (d) $\sqrt{2g(R_0 + r)}$ (e) $\sqrt{2g(R_0 - r)}$

2. The horizontal section of the track starting from B is a surface with coefficient of kinetic friction μ_k. If the ball starts to roll without slipping after traveling a distance d, what is the expression for the coefficient of kinetic friction in terms of the given parameters?

(a) $\frac{12(R_0-r)}{49d}$ (b) $\frac{5(R_0-r)}{49d}$ (c) $\frac{5(R_0-r)}{64d}$ (d) $\frac{24(R_0-r)}{49d}$ (e) $\frac{3(R_0-r)}{8d}$

Questions 3-6

An object with mass m is initially at rest at the origin $x = 0$. At time $t = 0$ it starts to accelerate with a changing acceleration along the $+x$ direction. At time $t = T$ it is at the point $x = x_T$ and its speed is measured as $v(T) = v_T$.

3. How much work is done by the force to accelerate the object during the time interval T?

(a) $-\frac{1}{2}mv_T^2$ (b) 0 (c) $\frac{1}{2}mv_T^2$ (d) mv_T^2 (e) $-mv_T^2$

4. What is the average power supplied by the force during the time interval T?

(a) $\frac{2mv_T^2}{T}$ (b) $\frac{mv_T^2}{2T}$ (c) 0 (d) $\frac{mv_T^2}{4T}$ (e) $\frac{mv_T^2}{T}$

5. If the force accelerating the object is of the form $F(t) = F_0\left(1 - \frac{t}{T}\right)$ for $0 \le t \le T$, what is the power supplied by the force at $t = T$?

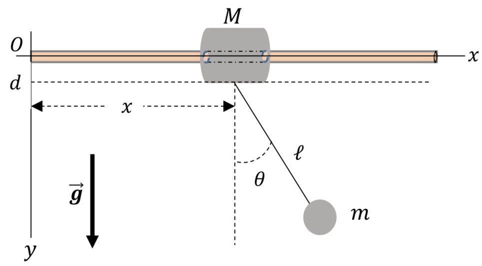
(a) $\frac{mv_T^2}{4T}$ (b) $\frac{mv_T^2}{2T}$ (c) 0 (d) $\frac{2mv_T^2}{T}$ (e) $\frac{mv_T^2}{T}$

6. Find the expressions for v_T and x_T in terms of F, m, and T.

(a) $v_T = \frac{F_0T}{2m}$, $x_T = \frac{F_0T^2}{m}$ (b) $v_T = \frac{F_0T}{m}$, $x_T = \frac{F_0T^2}{2m}$ (c) $v_T = \frac{F_0T}{2m}$, $x_T = \frac{F_0T^2}{3m}$ (d) $v_T = \frac{F_0T}{2m}$, $x_T = \frac{F_0T^2}{2m}$
(e) $v_T = \frac{F_0T}{m}$, $x_T = \frac{F_0T^2}{3m}$

Questions 7-9

A cylinder of mass M is free to slide on a frictionless horizontal shaft passing through its axis. A ball of mass m is attached to the cylinder by a massless string of length ℓ. Initially, both the cylinder and the ball are at rest, with the center of the cylinder at a perpendicular distance x_0 from the y-axis, and the ball displaced by an angle $\theta = \pi/2$ to the right relative to the vertical. Use the coordinate system indicated in the figure and assume that the motion takes place on the xy- plane.



7. What is the initial x-coordinate of the center of mass of the system?

(a) $x_{cm} = x_0 + \frac{2M\ell}{M+m}$ (b) $x_{cm} = x_0 + \frac{2m\ell}{M+m}$ (c) $x_{cm} = x_0 + \frac{m\ell}{M+m}$ (d) $x_{cm} = x_0 + \frac{M\ell}{M+m}$ (e) $x_{cm} = x_0 + \frac{m\ell}{2(M+m)}$

8. If the ball is released from its initial position $(x_0 + \ell, d)$ with zero initial velocity, what will be its coordiates (x', y') when it is at the bottom of its swing, i.e., when $\theta = 0$?

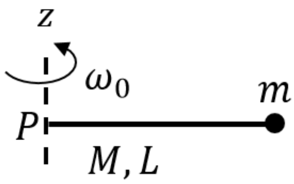
(a) $x' = x_0 + \frac{m\ell}{M+m}$, $y' = \ell + d$ (b) $x' = x_0 + \frac{M\ell}{M+m}$, $y' = \ell + 2d$ (c) $x' = x_0 + \frac{m\ell}{M+m}$, $y' = \ell + \frac{d}{2}$
(d) $x' = x_0 + \frac{2M\ell}{M+m}$, $y' = \ell + \frac{d}{2}$ (e) $x' = x_0 + \frac{2m\ell}{M+m}$, $y' = \ell + d$

9. Find the velocities of the ball v_B and the cylinder v_C when $\theta = 0$.

(a) $v_B = \sqrt{\frac{2Mg\ell}{M+m}}$, $v_C = \sqrt{\frac{2m^2g\ell}{M(M+m)}}$ (b) $v_B = \sqrt{\frac{Mg\ell}{M+m}}$, $v_C = \sqrt{\frac{m^2g\ell}{M(M+m)}}$ (c) $v_B = \sqrt{\frac{Mg\ell}{M+m}}$, $v_C = \sqrt{\frac{2m^2g\ell}{M(M+m)}}$
(d) $v_B = \sqrt{\frac{2mg\ell}{M+m}}$, $v_C = \sqrt{\frac{2M^2g\ell}{m(M+m)}}$ (e) $v_B = \sqrt{\frac{2Mg\ell}{M+m}}$, $v_C = \sqrt{\frac{2M^2g\ell}{m(M+m)}}$

Questions 10-12

A uniform rod of mass $M = 0.6\ kg$ and length $L = 1\ m$ with a point mass $m = 0.3\ kg$ attached to its free end is rotating with angular speed $\omega_0 = 10.0\ rad/s$ about the z-axis, as shown in the figure.



10. Find the rotational inertia of the system about point P in units of kgm^2. (For a uniform rod of mass M and length L, $I_{cm} = \frac{1}{12}ML^2$)
(a) 0.5 (b) 2.0 (c) 1.0 (d) 2.5 (e) 1.5

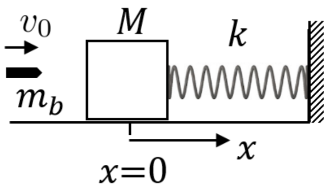
11. Another point mass $2m$ moving in the plane of rotation collides perpendicularly in the direction of the rotation of the rod and sticks to the rod at a distance $2L/3$ form point P with a linear speed $3\omega_0 L$. What is the angular momentum vector relative to point P just after the collision in units of kgm^2/s ?

(a) $19\hat{k}$ (b) $15\hat{k}$ (c) $21\hat{k}$ (d) $23\hat{k}$ (e) $17\hat{k}$

12. What is the angular speed of the system just after the collision in rad/s?
(a) $\frac{270}{17}$ (b) $\frac{510}{23}$ (c) $\frac{290}{13}$ (d) $\frac{410}{19}$ (e) $\frac{310}{29}$

Questions 13-16

A massless spring with spring constant k is attached at one end of a block of mass M that is at rest on a frictionless horizontal table. The other end of the spring is fixed to a wall. A bullet of mass m_b is fired into the block from the left with a speed v_0 and comes to rest in the block.



13. What is the speed of the block-bullet system immediately after the collision?

(a) $\frac{m_b}{m_b+M}v_0$ (b) $\sqrt{\frac{m_b}{m_b+M}}v_0$ (c) $\frac{m_b}{M}v_0$ (d) $\sqrt{\frac{m_b+M}{m_b}}v_0$ (e) $\frac{m_b+M}{m_b}v_0$

14. Find the amplitude of the resulting simple harmonic motion.

(a) $\sqrt{\frac{1}{k\,m_b}}(m_b+M)v_0$ (b) $\sqrt{\frac{1}{k(m_b+M)}}m_b v_0$ (c) $\sqrt{\frac{(m_b+M)}{m_b}}v_0$ (d) $\sqrt{\frac{1}{k\,M}}m_b v_0$ (e) $\sqrt{\frac{m_b}{(m_b+M)}}v_0$

15. How long does it take the block to first return to the position $x = 0$?

(a) $\frac{\pi}{2}\sqrt{\frac{m_b+M}{k}}$ (b) $2\pi\sqrt{\frac{m_b+M}{k}}$ (c) $\pi\sqrt{\frac{k}{m_b+M}}$ (d) $\frac{\pi}{4}\sqrt{\frac{m_b+M}{k}}$ (e) $\pi\sqrt{\frac{m_b+M}{k}}$

16. What is the maximum acceleration of the block?

(a) $\sqrt{\frac{k}{m_b+M}}v_0$ (b) $\sqrt{\frac{k\,m_b}{m_b+M}}v_0$ (c) $\sqrt{\frac{k\,m_b}{(m_b+M)^2}}v_0$ (d) $\sqrt{\frac{k\,m_b^2}{(m_b+M)^3}}v_0$ (e) $\sqrt{\frac{k\,(m_b+M))}{m_b^2}}v_0$

Questions 17-20

A small object of mass m is launched from the surface of the Earth with a speed of v_0 in a direction perpendicular to the Earths surface.

17. What is the total mechanical energy of the object at its starting point in terms of m, v_0, the radius of the Earth R, the mass of the Earth M, and the gravitational constant G ?

(a) $\frac{1}{2}mv_0^2$ (b) $\frac{1}{2}mv^2 + \frac{GMm}{R^2}$ (c) $\frac{1}{2}mv^2 - \frac{GMm}{R^2}$ (d) $\frac{1}{2}mv_0^2 + \frac{GMm}{R}$ (e) $\frac{1}{2}mv_0^2 - \frac{GMm}{R}$

18. Find an expression for the speed v of the object at a height $h = R$ (i.e., a distance $2R$ from Earth's center).

(a) $\sqrt{v_0^2 - \frac{GM}{2R}}$ (b) $\sqrt{v_0^2 - \frac{3GM}{R}}$ (c) $\sqrt{v_0^2 - \frac{2GM}{R}}$ (d) $\sqrt{v_0^2 - \frac{GM}{R}}$ (e) $\sqrt{v_0^2 - \frac{GM}{3R}}$

19. Now consider a different situation where the object is placed in a circular orbit at a height $h = R$ (i.e., a distance $2R$ from Earth's center). Find the speed the object needs to be in a circular orbit at that height.

(a) $\sqrt{\frac{2GM}{R}}$ (b) $\sqrt{\frac{GM}{3R}}$ (c) $\sqrt{\frac{3GM}{R}}$ (d) $\sqrt{\frac{GM}{2R}}$ (e) $\sqrt{\frac{GM}{R}}$

20. Find the period of the object in this circular orbit at that height.

(a) $4\pi\sqrt{\frac{R^3}{2GM}}$ (b) $4\pi\sqrt{\frac{2R^3}{GM}}$ (c) $2\pi\sqrt{\frac{R^3}{2GM}}$ (d) $\pi\sqrt{\frac{R^3}{GM}}$ (e) $2\pi\sqrt{\frac{R^3}{GM}}$

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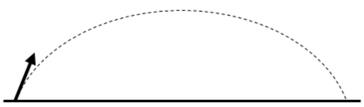
1. Which force is responsible for holding a car in the track, in an unbanked curve?
(a) The car's weight
(b) The car's engine force
(c) The kinetic friction force
(d) The static friction force
(e) The normal force

2. Which statement is always true for an object having constant $|\vec{v}|$?
(a) $a_{\text{rad}} = 0$ (b) $|a_{\tan}| \geq |a_{\text{rad}}|$ (c) $|a_{\tan}| > |a_{\text{rad}}|$ (d) $|\vec{a}| = 0$ (e) $a_{\tan} = 0$

3. Bodies A and B are thrown from the same position with the same initial speeds at angles α_{A} and α_{B}. Both bodies hit to the same point on the ground. Which of the following is always correct?
(a) $\alpha_{\text{A}} + \alpha_{\text{B}} = \pi/2$
(b) $\alpha_{\text{A}} + \alpha_{\text{B}} = \pi$
(c) $\alpha_{\text{A}} - \alpha_{\text{B}} = \pi/2$
(d) $\sqrt{\alpha_{\text{A}}^2 + \alpha_{\text{B}}^2} = \pi/2$
(e) $\alpha_{\text{A}} + \alpha_{\text{B}} = \pi/4$

4. If the weight of an object of mass 10 kg is 50 N, then what is the maximum range of the object thrown with an initial speed of 50 m/s? (Assume that there is no air resistance.)



(a) 5 m (b) 500 m (c) 250 m (d) 10 m (e) 1000 m

Questions 5-6

One of the forces acting on a particle with a mass of 1 kg is given as $\vec{F}(t) = 3t\,\hat{\imath} - 2\,\hat{\jmath}$ [Newton] and its position is given as $\vec{r}(t) = t/2\,\hat{\imath} - t^3\,\hat{\jmath}$ [meter]

5. What is the average velocity in m/s between $t = 1$ and $t = 3$ sec?

(a) $1/2\,\hat{\imath} - 3\,\hat{\jmath}$ (b) $2\,\hat{\imath} - 12\,\hat{\jmath}$ (c) $2\,\hat{\imath} + 14\,\hat{\jmath}$ (d) $1/2\,\hat{\imath} - 14\,\hat{\jmath}$ (e) $1/2\,\hat{\imath} - 13\,\hat{\jmath}$

6. What is the instantaneous power acting on this particle by the forces other than $\vec{F}$ at $t = 2$ sec?

(a) -123 W (b) 117 W (c) -120 W (d) 123 W (e) 67 W

Questions 7-9

The velocity of a particle moving in a straight line is given as $v(t) = (-t^2/2 + 3t + 3/2)$ where t is in seconds and v is in m/s.

7. Calculate the particle's acceleration at $t = 2$ s.
(a) 3 m/s^2 (b) 5 m/s^2 (c) 11/2 m/s^2 (d) 1 m/s^2 (e) 4 m/s^2

8. Compute the time when the force acting on the particle changes its direction.
(a) 19/2 s (b) 3/2 s (c) 0 s (d) 1 s (e) 3 s

9. Calculate the position r of the particle when the force acting on the particle changes its direction. Take $r(t = 0) = 0$.
(a) 27/2 m (b) 0 (c) 23/3 m (d) 17/6 m (e) 27/5 m

Questions 10-14

Position vector of an object A with mass m_{A} relative to the Earth (E) is given as $\vec{r}_{\mathrm{A/E}} = (3t^2+104)\hat{\imath} + 2t\hat{\jmath} + \hat{k}$, that of object B with mass $m_{\mathrm{B}} =$ relative to the object A is given as $\vec{r}_{\mathrm{B/A}} = (-t^2+2t-100)\hat{\imath} + (-2t+5)\hat{\jmath} - \hat{k}$. ($m_{\mathrm{A}} = 10$ kg, $m_{\mathrm{B}} = 5$ kg)

10. Find the position vector of B relative to the Earth, $\vec{r}_{\mathrm{B/E}}$.
(a) $(4t^2-2t+204)\hat{\imath} + (4t-5)\hat{\jmath} + 2\hat{k}$
(b) $(-2t^2-2t-4)\hat{\imath} - 5\hat{\jmath}$
(c) $(2t^2+2t+4)\hat{\imath} + 5\hat{\jmath} + 2\hat{k}$
(d) $(-4t^2+2t-204)\hat{\imath} + (-4t+5)\hat{\jmath} + 2\hat{k}$
(e) $(2t^2+2t+4)\hat{\imath} + 5\hat{\jmath}$

11. Find the velocity of B relative to the Earth, $\vec{v}_{\mathrm{B/E}}$.
(a) $(8t-2)\hat{\imath} + 4\hat{\jmath}$ (b) $(-4t-2)\hat{\jmath}$ (c) $(4t+2)\hat{\imath}$ (d) $(-8t+2)\hat{\imath} - 4\hat{\jmath}$ (e) $(-4t-2)\hat{\imath}$

12. Find the magnitude of the total external force exerted on B.
(a) 20 N (b) $(20t+10)$ N (c) 40 N (d) 0 N (e) -20 N

13. Find the speed of A relative to B at $t = 0$.
(a) 2 m/s (b) $2\sqrt{2}$ m/s (c) 4 m/s (d) $2\sqrt{5}$ m/s (e) 0 m/s

14. When do A and B meet each other? (Assume they are point particles)
(a) $t = \sqrt{11}$ s (b) $t = 101$ s (c) $t = 5/2$ s (d) Never (e) $t = 5/4$ s

Questions 15-17

A luggage handler pulls a 20 kg suitcase up a ramp inclined θ above the horizontal by a force of magnitude 210 N, parallel to the ramp. The coefficient of kinetic friction between the ramp and the incline is $\mu_k = 3/8$.
($\sin(\theta) = 3/5$, $\cos(\theta) = 4/5$, $g = 10$ m/s^2)
If the suitcase takes 3 m distance along the ramp;

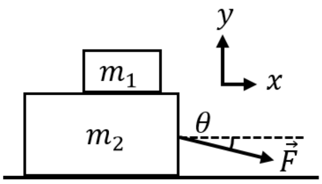
15. Calculate the work done on the suitcase by the gravitational force
(a) -180 J (b) 0 (c) 360 J (d) -360 J (e) -135 J

16. Calculate the total work done on the suitcase.
(a) 90 J (b) 480 J (c) 0 (d) 360 J (e) 300 J

17. If the speed of the suitcase is zero at the bottom of the ramp, what is the speed when it takes 3m along the ramp?
(a) $4\sqrt{2}$ m/s (b) 3 m/s (c) 0 (d) $2\sqrt{6}$ m/s (e) $\sqrt{6}$ m/s

Questions 18-20

A block of mass m_1 rests on top of another block of mass m_2, which rests on a frictionless horizontal surface. The coefficient of static and kinetic friction between the two blocks are $\mu_s = 1/2$ and $\mu_k = 1/4$, respectively. A force F is applied to m_2 as shown in figure. ($m_1 = 1$ kg, $m_2 = 2$ kg, $\sin(\theta) = 4/5$, $\cos(\theta) = 3/5$, $\vec{g} = -10$ m/s^2 $\hat{\jmath}$)



18. Which magnitude of $\vec{F}$ below ensures that the blocks accelerate together without m_1 sliding on m_2?
(a) 32 N (b) 29 N (c) 22 N (d) 26 N (e) 34 N

19. Find the acceleration of each block for $F = 15$ N.
(a) $7/2$ m/s^2 (b) 5 m/s^2 (c) 3 m/s^2 (d) 2 m/s^2 (e) $9/2$ m/s^2

20. Find the acceleration of each block for $F = 35$ N, where a_1 is the aceleration of m_1 and a_2 is the aceleration of m_2, relative to the horizontal surface.
(a) $a_1 = 5$ m/s^2, $a_2 = 8$ m/s^2
(b) $a_1 = 5/2$ m/s^2, $a_2 = 21$ m/s^2
(c) $a_1 = 5/2$ m/s^2, $a_2 = 37/4$ m/s^2
(d) $a_1 = 2$ m/s^2, $a_2 = 51/4$ m/s^2
(e) $a_1 = 1/2$ m/s^2, $a_2 = 21$ m/s^2

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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) $\sum \vec{F}_{\text{ext}} = \frac{\text{d}\vec{p}}{\text{d}t}$ (b) $\sum \vec{F}_{\text{int}} = m\vec{a}$ (c) $\sum \vec{F}_{\text{int}} = \frac{\text{d}\vec{p}}{\text{d}t}$ (d) $\sum \vec{F}_{\text{ext}} = m\vec{a}$ (e) $m\vec{a} = -\frac{\text{d}m}{\text{d}t}\vec{v}$

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

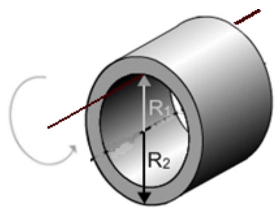
Questions 8-9

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) $f = \frac{2}{7}Mg\cos\beta$

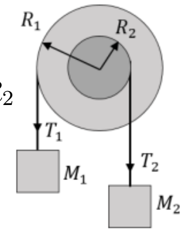
10. What is the kinetic energy of an hollow cylinder of mass M rotating with an angular speed ω about the axis passing parallel through it's inner wall as shown in figure? $R_2 = 2R$ is the radius of the outer wall and $R_1 = R$ is the radius of the inner wall (empty part) of the hollow cylinder.



(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.)



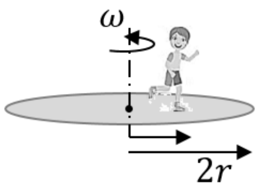
11. How are the linear acceleration a_1 and a_2 of the masses M_1 and M_2 and those with the angular acceleration α of the winch related?
(a) $\alpha = a_1/R_2 = a_2/R_1$ (b) $\alpha = a_1R_1 = a_2R_2$ (c) $\alpha = R_2/a_1 = R_1/a_2$ (d) $\alpha = a_1/R_1 = a_2/R_2$
(e) $\alpha = R_1/a_1 = R_2/a_2$

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

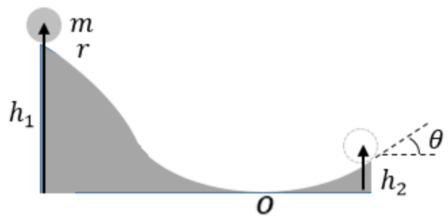
16. The boy still stands on the rim. Calculate the kinetic energy of boy-disc system.
(a) 3888 J (b) 2700 J (c) 48 J (d) 2250 J (e) 1728 J

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) $\frac{5}{28}(h_1 - h_2)$

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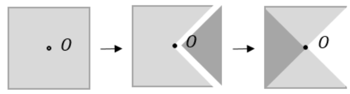
1. The moment of inertia of a thin homogeneous square rotating about its axis of symmetry O, perpendicular to the plain of square is given as I. A triangle part from it is cut and paste as shown in figure. What is the moment of inertia of the obtained object with respect to the same rotation axis?

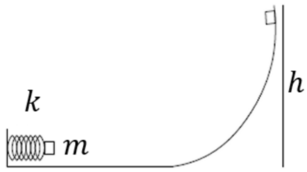


(a) I (b) $I/3$ (c) $2I/3$ (d) $3I/2$ (e) $4I/9$

2. You throw a baseball straight up. The magnitute of the drag force is proportional to the square of the speed (v^2). When the ball is moving up at half its terminal speed, what is the magnitude of its acceleration? Terminal speed is reached when gravity is balanced by the air drag force. (g is the magnitude of the acceleration due to gravity.)

(a) $3g/4$ (b) $5g/4$ (c) $3g/2$ (d) $g/2$ (e) g

3. A massless spring of spring constant $k = 7.5 \times 10^4$ N/m is used to launch a block of mass $m = 1.5$ kg up the curved track shown. The track is in a vertical plane. The maximum height observed for the block is given by $h = 0.4$ m. If the initial compression of the spring is 0.02 m, find the energy lost due to the friction. (g=10 m/s^2)



(a) 16/5 J (b) 9 J (c) 20/3 J (d) 8 J (e) 12 J

Questions 4-5

A door of width d and mass M, is hinged at one side so that it is free to rotate without friction about its vertical axis. A police officer fires a bullet with a mass of m and a speed of v into the the door, a distance $2d/3$ to the hinge (axis of rotation) in a direction perpendicular to the plane of the door. (The moment of inertia through the axis of the hinge is $I = \frac{1}{3}Md^2$.)

4. Find the angular speed of the door just after the bullet embeds itself in the door.

(a) $mv/[(M/2 + 2m/3)d]$ (b) $Mv/[(M/2 + 2m/3)d]$ (c) $mvd/(M/3 + 3m/2)d$ (d) $(mv)^2/(M + 2m)$ (e) $mv/[(m/2 + 2M/3)d]$

5. Find the kinetic energy of the bullet-door system just after the bullet embeds itself in the door.

(a) $(mv)^2/(3M/2 + 2m)$ (b) $(mv)^2/[(3M/4 + m)d]$ (c) $mvd/(3M/2 + 2m)$ (d) $(mv)^2/[(3M + 3m/2)d]$ (e) $(mv)^2/(M/2 + 2m/3)$

Questions 6-7

A comet is orbiting the sun in elliptical orbit. The distance of this comet to sun at the perihelion (nearest distance to the sun) is R and the distance of this comet to sun at the aphelion (farthest distance to the sun) is $10R$.

6. What is the ratio of K_p, the kinetic energy at the perihelion to K_a, the kinetic energy at the aphelion points?

(a) $\frac{K_p}{K_a}$=100 (b) $\frac{K_p}{K_a}$=1 (c) $\frac{K_p}{K_a}$=10 (d) $\frac{K_p}{K_a}=\frac{1}{10}$ (e) $\frac{K_p}{K_a}=\frac{1}{100}$

7. What is the ratio of ω_p, the angular velocity at the perihelion to ω_a, the angular velocity at the aphelion points?

(a) $\frac{\omega_p}{\omega_a}$=10 (b) $\frac{\omega_p}{\omega_a}$=1 (c) $\frac{\omega_p}{\omega_a}$=100 (d) $\frac{\omega_p}{\omega_a}=\frac{1}{10}$ (e) $\frac{\omega_p}{\omega_a}=\frac{1}{100}$

Questions 8-10

On a frictionless horizontal air track a cart of mass m and another of mass $3m$ collide. Initially the cart of mass $3m$ has a velocity of $v_o = 1.25$ m/s and the smaller cart has an initial velocity of zero. Take $m = 3.2$ kg.

8. If the collision is completely inelastic, calculate the final velocity in m/s.

(a) 5/6 (b) 15/16 (c) 3/4 (d) 5/3 (e) 4/3

9. If the collision is completely inelastic, how much mechanical energy is lost?

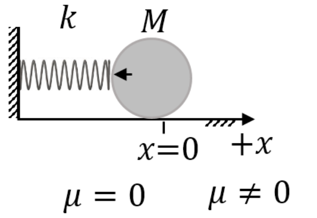
(a) 45/8 J (b) 15/8 J (c) 25/8 J (d) 5/8 J (e) 105/8 J

10. If the collision is elastic, calculate the final velocity of mass m in m/s.

(a) 15/4 (b) 18/5 (c) 5/4 (d) 16/7 (e) 15/8

Questions 11-13

A solid sphere of mass M=10 kg and radius R=1 m is held against a spring (massless) of force constant k=4000 N/m, compressed by an amount of 0.2 m. The spring is released and the sphere skids on a frictionless horizontal surface as it leaves the spring at x=0. It then enters a region with friction, so it begins to rotate and still skids, until it starts *rolling without slipping.* ($I_{\text{cm}} = \frac{2}{5}MR^2$ for solid sphere.)



11. What is the center-of-mass speed in m/s of the sphere when it leaves the spring at $x = 0$?

(a) 8 (b) 6 (c) 4 (d) 5 (e) 2

12. What is the center-of-mass speed in m/s of the sphere when it is rolling without slipping?

(a) 2/3 (b) 5/3 (c) 8/5 (d) 4/5 (e) 20/7

13. Calculate the energy lost to friction.

(a) 175/3 J (b) 175/9 J (c) 545/9 J (d) 160/7 J (e) 105/3 J

Questions 14-15

A satellite of mass m revolves in a circular orbit about the Earth at height h from the surface of the Earth. M_{E} and R_{E} are the mass and the radius of the Earth, respectively.

14. What is the total mechanical energy E of the satellite-Earth system?

(a) $E = \frac{GM_{\text{E}}m}{(R_{\text{E}}+h)}$ (b) $E = \frac{GM_{\text{E}}m}{2(R_{\text{E}}+h)}$ (c) $E = -\frac{GM_{\text{E}}m}{2(R_{\text{E}}+h)}$ (d) $E = -\frac{GM_{\text{E}}m}{(R_{\text{E}}+h)}$ (e) $E = -\frac{GM_{\text{E}}m}{2h}$

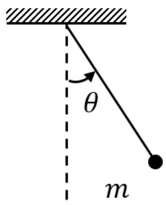
15. If the satellite is not at a high altitude, it will lose mechanical energy because of the air friction. In this case which of the following will happen?

(a) Nothing changes. (b) Its temperature decreases. (c) The satellite approaches to the Earth. (d) The satellite recedes away from the Earth. (e) The satellite slows down.

16. Consider the Earth and an astronaut at height h from the surface of the Earth. Which of the following is always correct?

(a) The potential energy of the astronaut is $U = -\frac{GM_{\text{E}}m}{R_{\text{E}}+h}$.
(b) The potential energy of the Earth-astronaut system is $U = mgh$.
(c) The potential energy of the astronaut is $U = mgh$.
(d) The potential energy of the Earth-astronaut system is $U = -\frac{GM_{\text{E}}m}{R_{\text{E}}+h}$.
(e) The potential energy of the Earth-astronaut system decreases with increasing h.

17. Which of the following is/are in fact always correct for a simple pendulum?



(i) $F_\theta = -mg\theta$ (ii) $F_\theta = -mg\sin\theta$ (iii) $T = 2\pi\sqrt{\frac{L}{g}}$ (iv) $T > 2\pi\sqrt{\frac{L}{g}}$

(a) i and iii (b) i and ii (c) i (d) ii and iv (e) i and iv

Questions 18-19

An object of a mass m is oscillating with amplitude A at the end of a spring (massless) on a frictionless horizontal surface along the x axis. The spring is unstreched as the mass is at $x = 0$.

18. What is the position of this mass when the elastic potential energy equals the kinetic energy?

(a) $x = \pm\frac{A}{\sqrt{3}}$ (b) $x = \pm\frac{A}{\sqrt{5}}$ (c) $x = \pm\frac{A^2}{\sqrt{2}}$ (d) $x = \pm\frac{A}{\sqrt{2}}$ (e) $x = \pm\frac{A}{2}$

19. What is the magnitude of the momentum of this mass when the elastic potential energy equals the kinetic energy?

(a) $p_x = \frac{1}{2}\sqrt{mk}A$ (b) $p_x = \sqrt{\frac{mk}{3}}A$ (c) $p_x = \sqrt{\frac{kmA}{2}}$ (d) $p_x = \sqrt{\frac{mk}{5}}A$ (e) $p_x = \sqrt{\frac{mk}{2}}A$

20. A block of mass M attached to a horizontal spring (massless) with force constant k is moving in simple harmonic motion with amplitude A and period T_1. A lump of putty mass m is dropped from a small height and sticks to it, when it is at $x = -A$. What is the new period T_2 of the motion?

(a) $T_2 = T_1\sqrt{\frac{M}{m}}$ (b) $T_2 = T_1\left(1 + \frac{m}{M}\right)$ (c) $T_2 = T_1\left(1 + \frac{M}{m}\right)$ (d) $T_2 = T_1\sqrt{1 + \frac{M}{m}}$ (e) $T_2 = T_1\sqrt{1 + \frac{m}{M}}$

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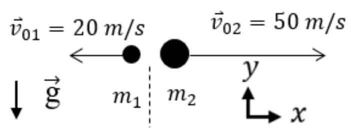
1. The fluid resistance acting on a mass m released into a liquid is given as $F = kv$ in Newtons where k is a constant, v is the velocity of the object. The buoyant force acting on this object is given as $f = A\rho g$, where A is the volume of the object, g is the gravitational acceleration and ρ is the density of the liquid. Accordingly, which of the following equations is an expression obtained from Newton's 2nd law? (buoyant force: [TR] kaldırma kuvveti)

(a) $\frac{d^2x}{dt^2} = \frac{k}{m}\frac{dx}{dt} + g\left(1 + \frac{\rho A}{m}\right)$
(b) $\frac{d^2x}{dt^2} = \frac{k}{m}\frac{dx}{dt} - g\left(1 - \frac{\rho A}{m}\right)$
(c) $\frac{d^2x}{dt^2} = -\frac{k}{m}\frac{dx}{dt} + g\left(1 + \frac{\rho A}{m}\right)$
(d) $\frac{d^2x}{dt^2} = -\frac{k}{m}\frac{dx}{dt} + g\left(1 - \frac{\rho A}{m}\right)$
(e) $\frac{d^2x}{dt^2} = -\frac{k}{m}\frac{dx}{dt} - g\left(1 - \frac{\rho A}{m}\right)$

Questions 2-5

As shown in the figure, the masses m_1 and m_2 are thrown from a high location, parallel to the ground and in opposite directions, at speeds of $v_{01} = 20$ m/s and $v_{02} = 50$ m/s. Neglect the air friction and take $g = 10$ m/s^2.



2. In which of the following option are the velocities of the masses at $t = 3$ s correctly given?

(a) $\vec{v}_1 = 20\hat{\imath} - 30\hat{\jmath}$; $\vec{v}_2 = 40\hat{\imath} - 30\hat{\jmath}$ (b) $\vec{v}_1 = -20\hat{\imath} - 30\hat{\jmath}$; $\vec{v}_2 = 50\hat{\imath} - 30\hat{\jmath}$ (c) $\vec{v}_1 = -10\hat{\imath} - 30\hat{\jmath}$; $\vec{v}_2 = 30\hat{\imath} - 30\hat{\jmath}$
(d) $\vec{v}_1 = -20\hat{\imath} - 30\hat{\jmath}$; $\vec{v}_2 = -30\hat{\imath} - 30\hat{\jmath}$ (e) $\vec{v}_1 = 10\hat{\imath} - 30\hat{\jmath}$; $\vec{v}_2 = 30\hat{\imath} - 30\hat{\jmath}$

3. What is the distance between the masses in unit of meters at $t = 3\ s$?

(a) 150 (b) 250 (c) 180 (d) 210 (e) 230

4. What is the velocity of mass m_1 with respect to mass m_2 at $t = 3\ s$?

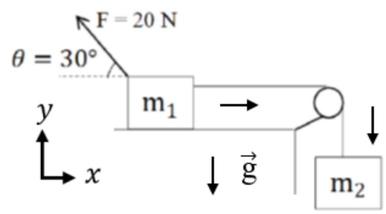
(a) $-80\hat{\imath}$ m/s (b) $-60\hat{\imath}$ m/s (c) $80\hat{\imath}$ m/s (d) $-70\hat{\imath}$ m/s (e) $75\hat{\imath}$ m/s

5. At which instant t are the velocities of masses perpendicular to each other?

(a) $\sqrt{7}$ s (b) 4 s (c) $\sqrt{12}$ s (d) 3 s (e) $\sqrt{10}$ s

Questions 6-9

Two masses $m_1 = 2.0$ kg and $m_2 = 3.0$ kg are connected by a massless string passing over a massless and frictionless pulley. Mass m_1 moves on a horizontal surface having a coefficient of kinetic friction $\mu_k = 0.50$ and is subject to a force $F = 20.0$ N. ($\cos 30° = 0.9,\ \sin 30° = 0.5,\ g = 10$ m/s^2)



6. What is the magnitude of the acceleration of m_2?
(a) 0.7 m/s^2 (b) 1.4 m/s^2 (c) 2.4 m/s^2 (d) 0.8 m/s^2 (e) 1.8 m/s^2

7. What is the tension on the string?
(a) 25.8 N (b) 15.6 N (c) 20.0 N (d) 21.4 N (e) 18.0 N

8. What is the magnitude of the frictional force on m_1?
(a) 4.0 N (b) 7.0 N (c) 5.0 N (d) 3.0 N (e) 8.0 N

9. What should be the mass m_1 if the two masses move with a constant speed?
(a) 2.6 kg (b) 4.0 kg (c) 3.4 kg (d) 1.8 kg (e) 2.0 kg

Questions 10-11

A small block of mass $m = 0.5$ kg sits 2.25 m from the center of a horizontal turntable whose frequency of rotation is f and the coefficient of static friction between the block and the turntable is $\mu_s = 0.9$. Take $g = 10$ m/s^2, $\pi \approx 3$.

10. What is the maximum value of f to keep the block at rest with respect to the turntable?
(a) $\frac{2}{3}$ Hz (b) $\frac{1}{5}$ Hz (c) 2.0 Hz (d) $\frac{1}{3}$ Hz (e) 1.0 Hz

11. If $f = 0.25$ Hz, what is the magnitude of the friction?
(a) $\frac{93}{17}$ N (b) $\frac{81}{32}$ N (c) $\frac{76}{35}$ N (d) $\frac{49}{14}$ N (e) $\frac{41}{17}$ N

Questions 12-13

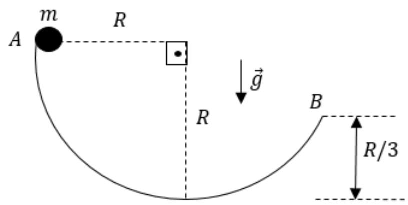
A small puck of mass $m = 0.3$ kg moves in a circle of radius $R = 1.5$ m on a table; the puck is tied with a massless string to a pin at the center of the circular path. The coefficient of kinetic friction between the puck and the table is $\mu_k = 0.2$. At $t = 0$, the puck starts rotating with an initial speed $v_0 = 10$ m/s. Take $g = 10$ m/s^2, $\pi \approx 3$.

12. What is the tension in the string at $t = 0$?
(a) 20 N (b) 10 N (c) 15 N (d) 30 N (e) 25 N

13. What is the tension in the string at the end of one revolution?
(a) 14.6 N (b) 10.6 N (c) 12.8 N (d) 11.0 N (e) 15.2 N

Questions 14-15

A block of mass m slides on a frictionless loop-to-loop track of radius R, as shown in the figure. The block starts from rest at point A.



14. What is the speed of the block at point B?
(a) $\sqrt{\frac{5gR}{2}}$ (b) $\sqrt{\frac{4gR}{3}}$ (c) $\sqrt{\frac{3gR}{5}}$ (d) $\sqrt{\frac{7gR}{3}}$ (e) $\sqrt{\frac{8gR}{5}}$

15. What is the magnitude of the normal force at point B?
(a) $1.5mg$ (b) $2.5mg$ (c) $2mg$ (d) mg (e) $3mg$

Questions 16-17

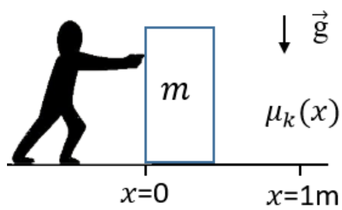
A net force $\vec{F} = (4x - 3x^2)\hat{\imath}$ acts on a particle as the particle of mass m moves along the x-axis, with $\vec{F}$ in newtons, x in meters.

16. What is the work done by the net force in moving the particle from the origin $x = 0$ to $x = 3$ m?
(a) -7 J (b) 6 J (c) 8 J (d) -8 J (e) -9 J

17. At $x = 0$ the particle's speed is $\sqrt{10}$ m/s, at $x = 3$ m, its kinetic energy is 11 J. Find the mass of the particle.
(a) 4 kg (b) 2 kg (c) 5 kg (d) 3 kg (e) 6 kg

Questions 18-20

A worker pushes a 20-kg crate straight across a 1-m-long section of horizontal floor with a constant force of $F = 20$ N. This section of the floor has the peculiarity that it becomes rougher from beginning to end, and the crate is moving at 2 m/s when it arrives at the start of this section. The coefficient of friction is 0.15 at the start and 0.25 at the finish, varying linearly with distance in between. ($g = 10$ m/s^2)



18. What is the coefficient of kinetic friction as a function of distance x?
(a) $\mu_k(x) = 0.15 + 0.10x$ (b) $\mu_k(x) = 0.15 + 0.25x$ (c) $\mu_k(x) = 0.15 + 0.15x$
(d) $\mu_k(x) = 0.20 + 0.10x$ (e) $\mu_k(x) = 0.10 + 0.25x$

19. What is the work done by the net force acting on the block?
(a) -17 J (b) 25 J (c) 17 J (d) -15 J (e) -20 J

20. What is the speed of the crate at the end of the section?
(a) $\sqrt{5}$ m/s (b) $\sqrt{3}$ m/s (c) 2 m/s (d) 3 m/s (e) $\sqrt{2}$ m/s

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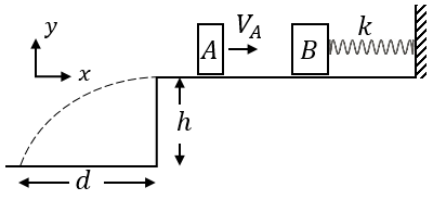
Questions 1-5



Block A of mass 0.20 kg sliding to the right over a frictionless elevated surface at a speed of 8.0 m/s. It undergoes an elastic collision with stationary block B, which is attached to a spring of spring constant 2160 N/m. (Assume that the spring does not affect the collision.) After the collision, block B oscillates in SHM with a period of 0.1 s, and block A slides off the opposite end of the elevated surface, landing a distance d from the base of that surface after falling a height h = 5.0 m. ($\pi = 3$, g=10 m/s^2)

1. What is the mass of block B?
(a) 0.7 kg (b) 0.4 kg (c) 0.6 kg (d) 0.5 kg (e) 1.0 kg

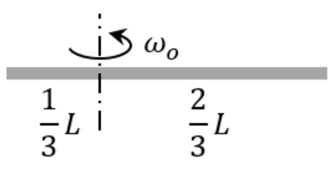
2. What are the velocities V_{Af} and V_{Bf} of the blocks in m/s, immediately after the collision? (Again, assume that the spring does not affect the collision and the collison is elastic.)
(a) V_{Af}=$-1.5\hat{\imath}$, V_{Bf}=$0.5\hat{\imath}$ (b) V_{Af}=$-4.0\hat{\imath}$, V_{Bf}=$4.0\hat{\imath}$ (c) V_{Af}=$4.0\hat{\imath}$, V_{Bf}=$1.5\hat{\imath}$ (d) V_{Af}=$-4.0\hat{\imath}$, V_{Bf}=$1.0\hat{\imath}$ (e) V_{Af}=$0.5\hat{\imath}$, V_{Bf}=$4.0\hat{\imath}$

3. What is the value of d?
(a) 5.0 m (b) 1.5 m (c) 2.5 m (d) 4.0 m (e) 0.5 m

4. What is the maximum acceleration of block B?
(a) 240 m/s^2 (b) 120 m/s^2 (c) 160 m/s^2 (d) 100 m/s^2 (e) 80 m/s^2

5. Now, consider a different situation. Block B is replaced by a 0.2 kg mass and the spring is replaced by a spring with k= 40 N/m. Assume that the collision is completely inelastic, so that after the collision the two blocks stick together. What is the amplitude of the new oscillation?
(a) 0.15 m (b) 0.2 m (c) 0.4 m (d) 0.3 m (e) 0.1 m

Questions 6-10



A homogeneous rod with a length L =3 m and mass m = 2 kg rotates on a flat, frictionless surface with an angular velocity ω_0=3 rad/s around a vertical axis at a distance $L/3$ from one side, as shown in figure. $I_{cm} = \frac{1}{12}ML^2$

6. What is the moment of inertia of the rod with respect to the rotation axis?
(a) 1/2 kg m^2 (b) 2/3 kg m^2 (c) 2 kg m^2 (d) 3/2 kg m^2 (e) 1/4 kg m^2

7. What is the magnitude of the angular momentum of the rod?
(a) 6 m^2/s (b) 2 m^2/s (c) 2/3 m^2/s (d) 3 m^2/s (e) 1/6 m^2/s

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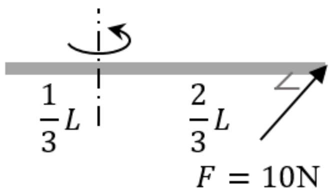


If a force F=10 N is applied, during 3 s, perpendicular to the far end of the long leg of the rod, as in the second figure, so as to increase the angular velocity of the rod.

8. What will be the final angular momentum of the rod?
(a) 36 m^2/s (b) 60 m^2/s (c) 16 m^2/s (d) 30 m^2/s (e) 66 m^2/s

9. What is the angular velocity of the rod after 3 s?
(a) 18 rad/s (b) 33 rad/s (c) 8 rad/s (d) 30 rad/s (e) 15 rad/s

10. What is the linear velocity of the end point of the short edge of the rod after 3 s?
(a) 8 m/s (b) 30 m/s (c) 15 m/s (d) 33 m/s (e) 18 m/s

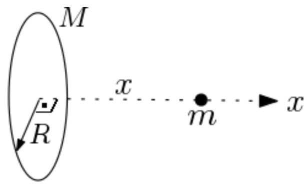
Questions 11-13

A solid sphere of radius R and mass M starts from rest and rolls without slipping down a θ incline that has a length of l . ($I_{cm} = \frac{2}{5}MR^2$ $g = 10$ m/s^2)

11. What is the speed of its center of mass (v_{cm}) when it reaches the bottom of the inclined?
(a) $\sqrt{\frac{9}{5}gl\sin\theta}$ (b) $\sqrt{\frac{2}{5}gl\sin\theta}$ (c) $\sqrt{\frac{10}{7}gl\sin\theta}$ (d) $\sqrt{\frac{2}{7}gl\sin\theta}$ (e) $\sqrt{\frac{5}{7}gl\sin\theta}$

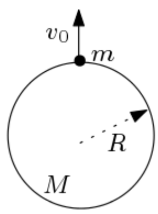
12. What is the acceleration of the center of mass (a_{cm}) of the sphere?
(a) $\frac{5}{7}g\sin\theta$ (b) $\frac{7}{9}g\sin\theta$ (c) $\frac{2}{7}g\sin\theta$ (d) $\frac{5}{9}g\sin\theta$ (e) $\frac{2}{5}g\sin\theta$

13. What is the friction force acting on the sphere?
(a) $\frac{2}{5}mg\sin\theta$ (b) $\frac{5}{7}mg\sin\theta$ (c) $\frac{9}{7}mg\sin\theta$ (d) $\frac{2}{7}mg\sin\theta$ (e) $\frac{5}{9}mg\sin\theta$



14. Which of the following is the gravitational potential energy of the system, shown in the figure? The circular wire has a uniform density.
(a) $-\frac{GMm}{\sqrt{R^2+x^2}}$ (b) $-\frac{3GMm}{2\sqrt{R^2+x^2}}$ (c) $\frac{GMm}{2\sqrt{R^2+x^2}}$ (d) $\frac{GMm}{\sqrt{R^2+x^2}}$ (e) $-\frac{GMm}{2\sqrt{R^2+x^2}}$

15. Which of the following is the force on the point mass m?
(a) $-\frac{2GMmx}{5(R^2+x^2)^{3/2}}\hat{i}$ (b) $-\frac{GMmx}{(R^2+x^2)^{3/2}}\hat{i}$ (c) $-\frac{2GMmx}{3(R^2+x^2)^{3/2}}\hat{i}$ (d) $-\frac{GMmx}{2(R^2+x^2)^{3/2}}\hat{i}$
(e) $-\frac{GMmx}{3(R^2+x^2)^{3/2}}\hat{i}$



16. An object of mass m is thrown in the upward direction with a speed $v_0 = \sqrt{\frac{3GM}{2R}}$ on a planet of mass M and radius R, as shown in the figure. Assume that the density of the planet is constant, it is a perfect sphere, and it is not rotating. What is the speed of the object at an altitude R?
(a) $\sqrt{\frac{GM}{3R}}$ (b) $\sqrt{\frac{GM}{2R}}$ (c) $\sqrt{\frac{2GM}{3R}}$ (d) $\sqrt{\frac{3GM}{4R}}$ (e) $\sqrt{\frac{GM}{4R}}$

17. Which of the following is the expression giving the time to reach for this object to the altitude R?
(a) $\int_R^{2R} \frac{dr}{\sqrt{2Gm\left(\frac{1}{r}-\frac{1}{4R}\right)}}$ (b) $\int_0^{2R} \frac{dr}{\sqrt{2GM\left(\frac{1}{r}-\frac{1}{4R}\right)}}$ (c) $\int_R^{2R} \frac{dr}{\sqrt{2Gm\left(\frac{1}{r}-\frac{1}{2R}\right)}}$
(d) $\int_0^{2R} \frac{dr}{\sqrt{2GM\left(\frac{1}{r}-\frac{1}{2R}\right)}}$ (e) $\int_R^{2R} \frac{dr}{\sqrt{2GM\left(\frac{1}{r}-\frac{1}{4R}\right)}}$

Questions 18-20

A physical pendulum of 3 kg oscillates at small angle around an axis at a distant of h=0.8 m to it center of gravity. It's moment of inertia is I=1.2 kg m^2 with respect to the oscillation axis. (g=10 m/s^2)

18. What is the length of a 1.5 kg simple pendulum that has the same period for small amplitude oscillations?
(a) 1 m (b) $\sqrt{5}/2$ m (c) 0.2 $\sqrt{2}$ m (d) 0.5 m (e) 2 $\sqrt{2}$ m

19. Find the maximum value of the angular acceleration if the amplitude of the oscillation is 0.5 rad.
(a) 1/10 rad/s^2 (b) $2\sqrt{5}$ rad/s^2 (c) 2 rad/s^2 (d) 1/20 rad/s^2 (e) 10 rad/s^2

20. What is the angular acceleration as the pendulum passed through the equilibrium position?
(a) 1/10 rad/s^2 (b) 10 rad/s^2 (c) 20 $\sqrt{2}$ rad/s^2 (d) 1/10 $\sqrt{5}$ rad/s^2 (e) 0 rad/s^2

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Questions 1-2

Two vectors $\vec{A} = 2\hat{\imath} - a\hat{\jmath} + \hat{k}$ and $\vec{B} = 3\hat{\imath} + \hat{\jmath} - 2\hat{k}$ are given. If $\vec{A} \cdot \vec{B} = 3$,

1. What is a?
(a) -1 (b) 1 (c) -2 (d) $-1/3$ (e) 2

2. What is the unit vector in the direction of $\vec{A} + \vec{B}$?
(a) $(-5\hat{\imath}+\hat{k})/\sqrt{26}$ (b) $(\hat{\imath}+\hat{\jmath}+\hat{k})/\sqrt{41}$ (c) $(5\hat{\imath}-\hat{k})/\sqrt{26}$ (d) $(\hat{\imath}+2\hat{\jmath}-\hat{k})/\sqrt{14}$ (e) $(-\hat{\imath}-2\hat{\jmath}+\hat{k})/\sqrt{14}$

Questions 3-5

An object with mass of 0.5 kg has a non-constant acceleration, given by $a(t) = 3\left(\frac{\text{m}}{\text{s}^4}\right)t^2 - 1\left(\frac{\text{m}}{\text{s}^2}\right)$ where t is measured in seconds.

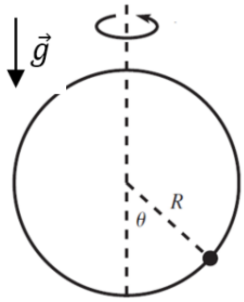
3. What is the amount of displacement the object made in 2 seconds if its initial velocity $v(t{=}0)$ is 3 m/s?
(a) 8 m (b) 9 m (c) 6 m (d) 12 m (e) 24 m

4. What is the average force applied to the object in this time interval: from 0 s to 2 s?
(a) 5 N (b) 1.5 N (c) 3 N (d) 6 N (e) 2.5 N

5. What is the acceleration of the object when its velocity is 9 m/s?
(a) 26 m/s^2 (b) 11 m/s^2 (c) 28 m/s^2 (d) 13 m/s^2 (e) 9 m/s^2

Questions 6-8

A bead of mass m is free to move around the frictionless wire hoop with radius R which is spinning at a fixed rate about its vertical axis. If the bead maintains the same position with respect to the hoop, at a constant angle θ with respect to the vertical, as shown in the figure, while it is making a uniform circular motion as the hoop spins



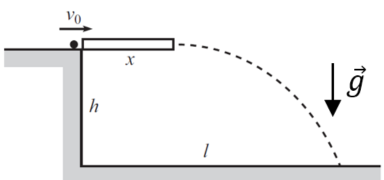
6. What is the vertical component of the normal force on the bead applied by the hoop?
(a) $mg\cot\theta$ (b) $mg\cos\theta$ (c) $mg\tan\theta$ (d) $mg\sin\theta$ (e) mg

7. What is the horizontal component of the normal force on the bead applied by the hoop?
(a) $mg\cos\theta$ (b) mg (c) $mg\sin\theta$ (d) $mg\tan\theta$ (e) $mg\cot\theta$

8. What is the speed squared: v^2 of the bead?
(a) $gR\tan\theta\sin\theta$ (b) $gR\cos\theta\sin\theta$ (c) $gR\cot\theta\sin\theta$ (d) $gR\cot\theta\cos\theta$ (e) $gR\tan\theta\cos\theta$

Questions 9-12

A particle is thrown horizontally with an initial speed v_0 from the top edge of a wall of height h. As soon as it is thrown, the particle enters a fixed tube with length x, as shown in the figure. There is friction between the particle and the tube; therefore the particle decelerates with constant acceleration $-a$ (where $a > 0$) inside the tube. After the particle exits the tube, it makes the usual projectile motion down to the ground.



9. What is the total horizontal distance l (measured from the edge of the wall) that the particle travels?
(a) $x+\sqrt{v_0^2-2ax}\sqrt{\frac{h}{g}}$ (b) $x+\sqrt{v_0^2-ax}\sqrt{\frac{2h}{g}}$ (c) $x+\sqrt{v_0^2-ax}\sqrt{\frac{h}{g}}$ (d) $x+\sqrt{v_0^2-2ax}\sqrt{\frac{2h}{g}}$
(e) $x+\sqrt{v_0^2-2ax}\sqrt{\frac{h}{2g}}$

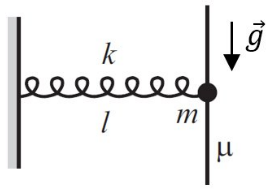
10. What is the length x of the tube which yields maximum l?
(a) $\frac{v_0^2}{2a}-\frac{ah}{2g}$ (b) $\frac{v_0^2}{2a}-\frac{ah}{g}$ (c) $\frac{v_0^2}{a}-\frac{ah}{4g}$ (d) $\frac{v_0^2}{2a}-\frac{ah}{4g}$ (e) $\frac{v_0^2}{a}-\frac{ah}{2g}$

11. What is the horizontal component of the velocity when the particle hits the ground?
(a) $\sqrt{v_0^2-ax}$ (b) $\sqrt{v_0^2-ah}$ (c) $\sqrt{v_0^2-2ah}$ (d) $\sqrt{v_0^2-4ax}$ (e) $\sqrt{v_0^2-2ax}$

12. What is the vertical component of the velocity when the particle hits the ground?
(a) $-\sqrt{2gh}$ (b) $-\sqrt{gx}$ (c) $-\sqrt{2gx}$ (d) $-\sqrt{4gh}$ (e) $-\sqrt{gh}$

Questions 13-17

One end of a spring with spring constant k and relaxed length zero is attached to a wall and the other end is attached to a ring with mass m which can move on a verticle rod of infinite length. The rod is fixed at a distance l from the wall as shown in the figure. The friction coefficient between the ring and the rod is μ (both static and kinetic). The ring is held such that the spring is horizontal as shown in the figure and then released.



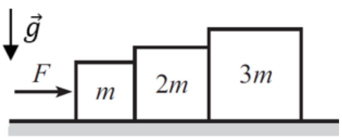
13. What is the normal force between the ring and the rod?
(a) $\sqrt{2}kl$ (b) $\sqrt{3}kl/2$ (c) $2kl$ (d) kl (e) $kl/2$

14. How far does the ring fall down on the rod before starting to move back up?
(a) $2(\frac{mg}{k}-\sqrt{2}\mu l)$ (b) $\frac{mg}{k}-\mu l$ (c) $\frac{mg}{k}-2\mu l$ (d) $2(\frac{mg}{k}-\mu l)$ (e) $2(\frac{mg}{k}-2\mu l)$

15. What is the maximum value of μ so that the ring can fall when it is released?
(a) $\frac{mg}{2kl}$ (b) $\frac{2mg}{kl}$ (c) $\frac{2mg}{3kl}$ (d) $\frac{mg}{kl}$ (e) $\frac{mg}{\sqrt{2}kl}$

16. What is the maximum value of μ so that the ring can move back up when it reaches the lowest possible position in its motion?
(a) $\frac{mg}{6kl}$ (b) $\frac{mg}{kl}$ (c) $\frac{mg}{\sqrt{2}kl}$ (d) $\frac{mg}{3kl}$ (e) $\frac{mg}{2kl}$

17. Three blocks of masses m, $2m$ and $3m$ are pushed by a force F across a frictionless horizontal surface as shown in the figure. If the normal force between the left two blocks is N_1 and the normal force between the right two blocks is N_2, what are N_1 and N_2 in terms of m and acceleration a?



(a) $N_1=5ma$, $N_2=3ma$ (b) $N_1=3ma$, $N_2=ma$ (c) $N_1=4ma$, $N_2=2ma$ (d) $N_1=6ma$, $N_2=6ma$
(e) $N_1=6ma$, $N_2=4ma$

Questions 18-20

As part of your gym training, you lie on your back and push with your feet against a platform attached to two identical stiff springs arranged side by side so that they are parallel to each other. When you push the platform, you compress the springs. You do 80 J of work when you compress the springs 0.2 m from their uncompressed length.

18. What is the value of each spring constant?
(a) 4000 N/m (b) 500 N/m (c) 200N/m (d) 1000 N/m (e) 2000 N/m

19. What magnitude of force must you apply to hold the platform in this compressed position?
(a) 1600 N (b) 200 N (c) 800 N (d) 600 N (e) 400 N

20. How much additional work must you do to move the platform 0.200 m farther from the compressed position, and what maximum force must you apply?
(a) 240 J, 400 N (b) 240 J, 1600 N (c) 240 J, 800 N (d) 180 J, 1000 N (e) 180 J, 1600 N

Group Number		Name		Type
List Number		Surname		A
Student ID		Signature		
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Questions 1-2

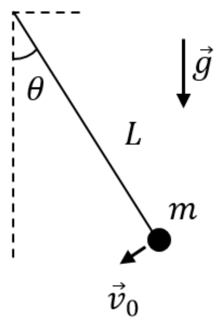
The potential energy function of a force is given as $U(x) = (ax^4 + bx^3 + cx^2 + dx + e)/12$, where a=-3 N/m^3, b=8 N/m^2, c=6 N/m, d=-24 N and e=3 Nm.

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.)



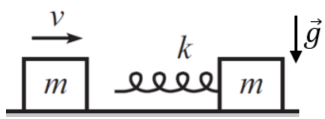
3. What is the speed of the bob when it is in its lowest position?
(a) $\sqrt{2gL\cos\theta}$ (b) $\sqrt{2gL(1+\cos\theta)+v_0^2}$ (c) $\sqrt{2gL(1-\cos\theta)+v_0^2}$ (d) $\sqrt{gL(3+2\cos\theta)}$
(e) $\sqrt{gL(3-2\cos\theta)}$

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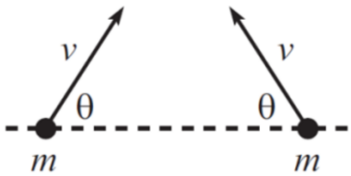
Answer the questions 8 and 9 assuming that the surface of the table is frictional with the coefficient of friction μ (both static and kinetic) between the masses and the surface.

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) $\mu\frac{mg}{k}$

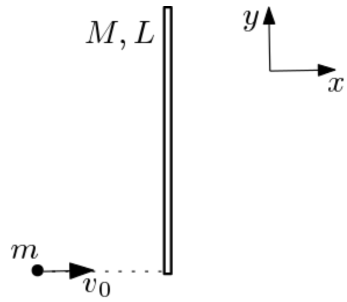
9. What is the largest value of v for which the stationary block never moves?
(a) $\frac{3}{4}\mu g\sqrt{\frac{m}{k}}$ (b) $\mu g\sqrt{\frac{3m}{k}}$ (c) $2\mu g\sqrt{\frac{2m}{k}}$ (d) $\frac{1}{2}\mu g\sqrt{\frac{5m}{k}}$ (e) $2\mu g\sqrt{\frac{6m}{k}}$

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) $\frac{3}{2}v_0\hat{\imath}$

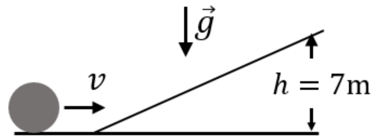
12. What is the angular speed of the rod about its center of mass just after the collision?
(a) $\frac{3}{2L}v_0$ (b) $\frac{1}{L}v_0$ (c) $\frac{1}{3L}v_0$ (d) $\frac{2}{L}v_0$ (e) $\frac{2}{3L}v_0$

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 <u>completely inelastic</u>, 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) $\frac{1}{5}v_0\hat{\imath}$

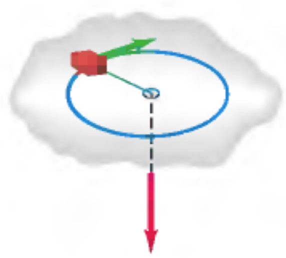
15. If the collision were <u>completely inelastic</u>, what would be the angular speed of the system about the <u>new</u> center of mass?
(a) $\frac{4}{3L}v_0$ (b) $\frac{5}{4L}v_0$ (c) $\frac{6}{5L}v_0$ (d) $\frac{1}{L}v_0$ (e) $\frac{3}{4L}v_0$

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.

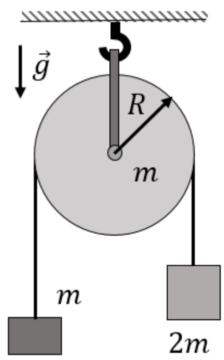


17. What is the new angular speed in RPM?
(a) 500 (b) 200 (c) 400 (d) 100 (e) 300

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) $4mg$

Group Number		Name		Type
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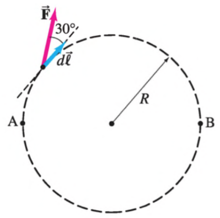
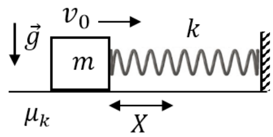
1. An object, moving along the circumference of a circle with radius R, is acted upon by a force of constant magnitude F. The force is directed at all times at a 30° angle with respect to the tangent to the circle as shown in the figure. Determine the work done by this force when the object moves along the half circle from A to B.



(a) $\sqrt{2}\pi FR/2$ (b) πFR (c) $\pi FR/2$ (d) $\sqrt{3}\pi FR$ (e) $\sqrt{3}\pi FR/2$

2. A block of mass m sliding along a rough horizontal surface is traveling at a speed v_0 when it strikes a massless spring head-on and compresses the spring a maximum distance X. If the spring has stiffness constant k, what is the coefficient of kinetic friction between block and surface?



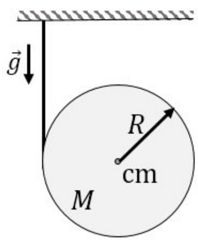
(a) $\frac{v_0^2}{2gX} - \frac{kX}{2mg}$ (b) $\frac{v_0^2}{gX} - \frac{kX}{2mg}$ (c) $\frac{v_0^2}{2gX}$ (d) $\frac{v_0^2}{gX} - \frac{kX}{mg}$ (e) $\frac{v_0^2}{2gX} - \frac{kX}{mg}$

3. In the high jump, the kinetic energy of an athlete is transformed into gravitational potential energy without the aid of a pole. With what minimum speed must the athlete leave the ground in order to lift his center of mass 2 m and cross the bar with a speed of 3 m/s? (take $g = 10$ m/s^2)
(a) 5 m/s (b) 7 m/s (c) 4 m/s (d) 2 m/s (e) 3 m/s

4. A particle constrained to move in one dimension is subject to a force with magnitude $F(x)$ that varies with position x as $\vec{F}(x) = A\sin(kx)\hat{\imath}$ where A and k are constants. What is the potential energy function $U(x)$, if we take $U = 0$ at the point $x = 0$?
(a) $A[\sin(kx) - 1]/k$ (b) $A[\cos(kx) - 1]$ (c) $A[\sin(kx) - 1]$ (d) $A[\cos(kx) - 1]/k$ (e) $A\cos(kx)/k$

Questions 5-6

A string, fixed from one end to the ceiling, is wrapped around a uniform solid cylinder of mass M and radius R. The cylinder starts falling from rest as shown in the figure. As the string unwinds the cylinder rolls without slipping. ($I_{cm} = \frac{1}{2}MR^2$.)



5. What is the acceleration of the cylinder?
(a) g/2 (b) 2g/3 (c) 3g/2 (d) 4g/3 (e) 3g/4

6. What is the tension in the string?
(a) 3Mg/2 (b) 2Mg/3 (c) 5Mg/3 (d) Mg/3 (e) 3Mg/5

7. Assume that the acceleration due to gravity on the surface of the Moon is $g/6$. Consider two identical simple pendulums of mass m and lenght l. One of the perndulums oscillates on the surface of the Moon, whereas the other oscillates on the surface of the Earth with the same amplitude. Which of the below statements is/are true?

I The ratio of the periods of the simple pendulums, T_{Moon}/T_{Earth} is $\sqrt{1/6}$

II The ratio of the speeds of masses as they pass through the vertical, v_{Moon}/v_{Earth} is $\sqrt{1/6}$

III The ratio of the total mechanical energies of the simple pendulums, E_{Moon}/E_{Earth} is 1/6

(a) II (b) I, III (c) I, II (d) III (e) II, III

Questions 8-10

A 32 N force stretches a vertical massless spring by 0.2 m. (+; above the equilibrium position, −; below the equilibrium position, U; upwards, D: downwards, $g = 10$ m/s^2)

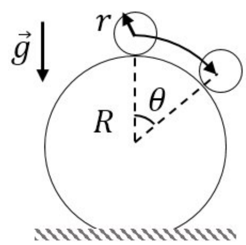
8. What mass must be suspended from the spring so that the system oscillates with a period of 0.5 s?
(a) $10/\pi^2$ kg (b) $5/\pi^2$ kg (c) $10\sqrt{2}\pi^2$ kg (d) $50/\pi^2$ kg (e) $20/\pi^2$ kg

9. If the amplitude of the oscillation is 0.1 m and the period is 0.5 s, where is the object and in what direction is it moving 5/24 s after it has passed the equilibrium position, moving downward?
(a) −0.05 m U (b) −0.05 m D (c) +0.05 m U (d) $-0.05\sqrt{3}$ m D (e) $-0.05\sqrt{3}$ m U

10. If the amplitude of the oscillation is 0.1 m and the period is 0.5 s, what is the acceleration of the object when it is 0.03 m below the equilibrium position, moving upward?
(a) $12\pi^2/25$ m/s^2 U (b) $37\pi^2/25$ m/s^2 U (c) $13\pi^2/25$ m/s^2 D (d) $12\pi^2/25$ m/s^2 D (e) $13\pi^2/25$ m/s^2 U

Questions 11-14

A small homogeneous ball of mass m and radius r is initially at rest on top of the outer surface of a large fixed sphere of radius R as shown in the figure. Let θ be the polar angle of the ball with respect to a coordinate system with origin at the center of the large sphere and the z-axis vertical. The ball starts rolling from the top of the sphere where θ =0. (Moment of inertia of the ball about an axis through its center is $I = \frac{2}{5}mr^2$.)



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Answer the questions 11 and 12 assuming that the coefficient of friction μ (both static and kinetic) between the ball and the surface of the sphere is large enough that the ball rolls without slipping with respect to the sphere for all of the time that it is in contact with the sphere.

11. What is the speed of the ball as it is rolling without slipping as a function of θ?
(a) $\sqrt{\frac{10}{7}g(R+r)(1-\cos\theta)}$ (b) $\sqrt{\frac{5}{7}g(R+r)(1-\cos\theta)}$ (c) $\sqrt{\frac{7}{5}g(R+r)(1-\cos\theta)}$ (d) $\sqrt{\frac{5}{7}g(R+r)(1-\sin\theta)}$
(e) $\sqrt{\frac{2}{5}g(R+r)(1-\sin\theta)}$

12. At what angle θ does the ball lose contact with the sphere?
(a) $\sin^{-1}(\frac{7}{10})$ (b) $\sin^{-1}(\frac{2}{5})$ (c) $\cos^{-1}(\frac{10}{17})$ (d) $\cos^{-1}(\frac{5}{7})$ (e) $\cos^{-1}(\frac{2}{5})$

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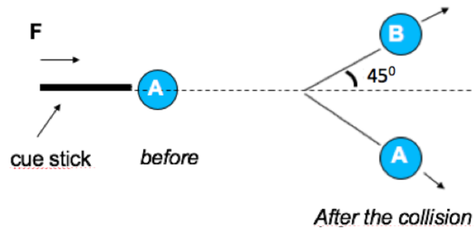
Answer the questions 13 and 14 assuming that the μ is small enough so that the ball starts slipping just after it reaches $\theta = \theta_S$ while it is rolling on the surface of the sphere.

13. What is the frictional force between the surface of the ball and the sphere at $\theta = \theta_S$?
(a) $\frac{5}{7}mg\sin\theta_S$ (b) $\frac{2}{7}mg\cos\theta_S$ (c) $\frac{2}{5}mg\cos\theta_S$ (d) $\frac{2}{5}mg\sin\theta_S$ (e) $\frac{2}{7}mg\sin\theta_S$

14. What is the coefficient of friction μ in terms of θ_S?
(a) $\frac{\sin\theta_S}{5\cos\theta_S-7}$ (b) $\frac{2\sin\theta_S}{10\cos\theta_S-7}$ (c) $\frac{\cos\theta_S}{7\sin\theta_S-5}$ (d) $\frac{2\cos\theta_S}{5\sin\theta_S-7}$ (e) $\frac{2\sin\theta_S}{17\cos\theta_S-10}$

Questions 15-16

A cue stick exerts a force of 200 N for 10^{-3} s to a stationary billiard ball (A) with mass m. Then this billiard ball (A) hits another billiard ball (B) with same mass and which is at rest initially. After the collision, the billiard ball (B) moves with a speed $v_B = \sqrt{2}$ m/s at an angle 45 degree with respect to the axis of the incoming ball (A). Assuming no friction between the billiard balls and the table, and assuming the collision is completely elastic: ($\cos 45 = \sin 45 = \sqrt{2}/2$)



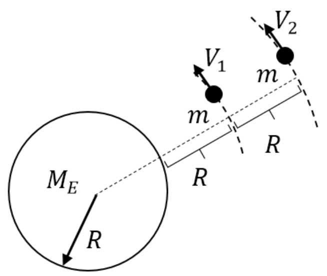
15. What is the angle between directions of two moving balls after the collision?
(a) 30° (b) 60° (c) $\sqrt{2}$ 30° (d) 0° (e) 90°

16. What is the mass m of each billiard ball?
(a) $\sqrt{200}$ kg (b) 1 kg (c) 0.2 kg (d) 0.1 kg (e) $\sqrt{2}$ kg

17. What is the maximum radius of a planet with mass 9×10^{24} kg, in order that an object thrown out from this planet with a speed c would not overcome the gravitational force? (c = 3×10^8 m/s, Universal gravitational constant G = 7×10^{-11} Nm^2/kg^2)
(a) 7 mm (b) 60 mm (c) 700 mm (d) 14 mm (e) 120 mm

Questions 18-19

A satellite orbiting around the Earth at a distance equal to the Earth's radius R from the surface, has a constant speed v_1 and period T_1. If this satellite orbited with a constant speed at a distance equal to the Earth's diameter $2R$ from the surface,



18. What would its speed be?
(a) $\sqrt{3/2}\, v_1$ (b) $v_1/2$ (c) $2\, v_1$ (d) $\sqrt{2/3}\, v_1$ (e) $4\, v_1$

19. What would its period be?
(a) $T_1/2$ (b) $(3/2)^{3/2}\, T_1$ (c) $4\, T_1$ (d) $2\, T_1$ (e) $(2/3)^{3/2}\, T_1$

20. Assume that the Earth is an ideal sphere with radius R and there is a frictionless tunnel from the North pole to the equator. If an object enters this hole from the North pole, what is the speed when it reaches the half way of the tunnel?
(a) $2\sqrt{Rg}$ (b) $\sqrt{2Rg}$ (c) $\sqrt{Rg/2}$ (d) $\frac{1}{2}\sqrt{Rg/2}$ (e) $\sqrt{Rg}$