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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 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 <u>sufficient</u> for static equilibrium to exist.
ii. $\sum_i \vec{F_i} = 0$ is <u>necessary</u> 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) $\Delta K = (V^2/2)[(\ell^2 m/D^2) - m]$ (d) $\Delta K = (V^2/2)[(D^2m^2/(mD^2 + M\ell^2/3)) - m]$ (e) $\Delta K = (V^2/2)[(D^2 m/\ell^2) - m]$

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

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

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?

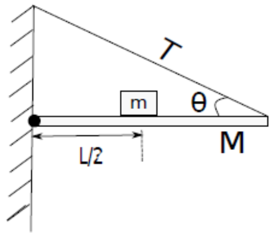
(a) 0 (b) 2/3 H (c) H (d) R (e) 2/3 R

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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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?

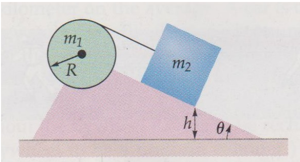
(a) $30\hat{k}$ (b) $30\hat{j}$ (c) $6\hat{j}$ (d) $6\hat{i} + 5\hat{j}$ (e) $25\hat{k}$

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}

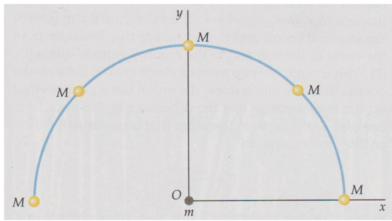
16. What is the moment of inertia of the tape when one spool is empty the other one is full? (a) 10 10^{-6} kgm^2 (b) 20 10^{-6} kgm^2 (c) 25 10^{-6} kgm^2 (d) 15 10^{-6} kgm^2 (e) 5 10^{-6} kgm^2

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

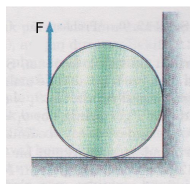
20. What is the magnitude of the gravitational force on the mass m?

(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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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 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 <u>kinetic</u> energy is constant. (b) The gravitational force is conservative and <u>potential</u> energy is constant. (c) The gravitational force is NOT conservative and mechanical energy is NOT constant. (d) The gravitational force is conservative and <u>mechanical</u> energy is constant. (e) The gravitational force is conservative and <u>linear</u> 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) $p = \sqrt{2K/m}$

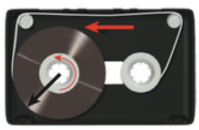
8. The coordinates of a point mass $m_1 = 4\ g$ is given as $(x, y) = (-1, 2)$ and the coordinates of another point mass $m_2 = 2\ g$ is given as $(x, y) = (2, 3)$. For this system, what is the ratio of the center of mass coordinates, $\frac{x_{cm}}{y_{cm}}$?

(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?

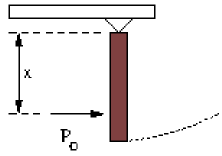
(a) $2.0\ 10^{-5}\ kgm^2$ (b) $2.5\ 10^{-5}\ kgm^2$ (c) $1.5\ 10^{-5}\ kgm^2$ (d) $1.0\ 10^{-5}\ kgm^2$ (e) $5\ 10^{-5}\ kgm^2$

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?

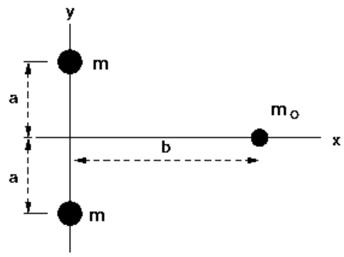
(a) $\frac{3P_0 x}{2mL}$ (b) $\frac{3x}{mL}$ (c) $\frac{3P_0}{mL^2}$ (d) $\frac{3P_0 x}{mL^2}$ (e) $\frac{3P_0}{2mL^2}$

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

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

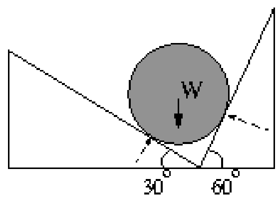
(a) $\vec{g} = -\frac{2\ G\ m\ b}{(b^2+a^2)^{(3/2)}}\hat{\imath}$ (b) $\vec{g} = -\frac{2\ G\ m_0\ b}{(b^2+a^2)^{(1/2)}}\hat{\imath}$ (c) *nullvector* (d) $\vec{g} = -\frac{G\ m\ b}{(b^2+a^2)^{(3/2)}}\hat{\imath}$ (e) $\vec{g} = -\frac{2\ G\ m\ b}{(b^2+a^2)^{(1/2)}}\hat{\imath}$

22. The maximum value of $\mid g_x \mid$ (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. 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.

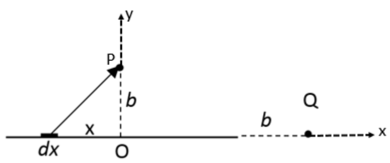
7. A particle of mass m moves along a straight line with an acceleration that is non-zero. Where can an axis be located such that the angular momentum of the particle is not constant?
(a) Any point on the path of the particle. (b) Initial point of the particle. (c) Any point not on the path of the particle. (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) $d\vec{g} = -G\frac{xdm}{(x^2+b^2)^{3/2}}\hat{i}$

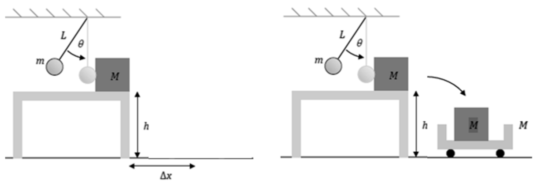
13. What is the net gravitational field created by the wire at the point P?
(a) $\vec{g}=-\frac{GM}{L}\int_{-L/2}^{+L/2}\frac{x\,dx}{(x^2+b^2)^{3/2}}\hat{j}$ (b) $\vec{g}=-\frac{GM}{L}\int_{0}^{+L/2}\frac{x\,dx}{(x^2+b^2)^{3/2}}\hat{i}$ (c) $\vec{g}=-\frac{GM}{L}\int_{0}^{L}\frac{b\,dx}{(x^2+b^2)^{3/2}}\hat{j}$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

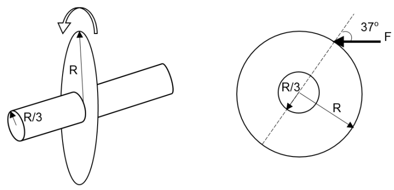
18. Calculate the speed of the the bob (m/s) just after they collide elastically.
(a) -1 (b) 1 (c) -2 (d) 2 (e) 0

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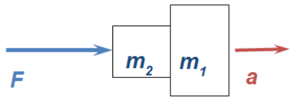
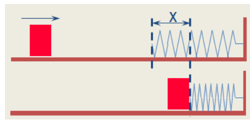
ATTENTION:Each question has only one correct answer and is worth one point. Be sure to fill in completely the circle that corresponds to your answer on the answer sheet. Use a pencil (not a pen). Only the answers on your answer sheet will be taken into account.

1. 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?



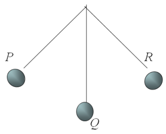
(a) 4/3 a_1 (b) 3/4 a_1 (c) 2/3 a_1 (d) 1/2 a_1 (e) 3/2 a_1

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) $mv_0^2/2$

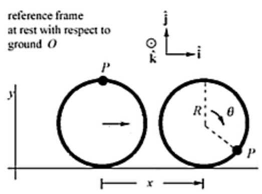
8. What is the maximum compression of the spring?

(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

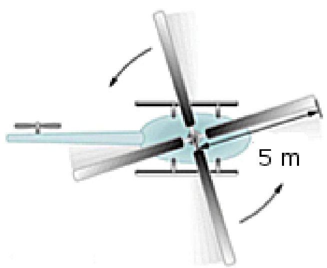
10. If a wheel of radius R rolls without slipping through an angle θ, what is the relationship between the distance the wheel rolls, x, and the product Rθ?



(a) R < xθ (b) x < Rθ (c) x > Rθ (d) x = Rθ (e) R > xθ

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) 1.00x10^6 J (b) 2.00x10^5 J (c) 1.00x10^5 J (d) 4.00x10^6 J (e) 2.00x10^6J

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?

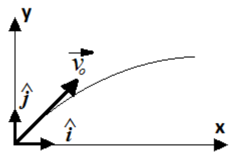
(a) 5.0 (b) 0.8 (c) 2.5 (d) 0.4 (e) 1

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) $80\hat{i} - 80\hat{j}$

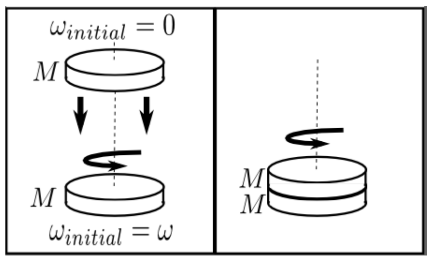
Questions 18-21

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.

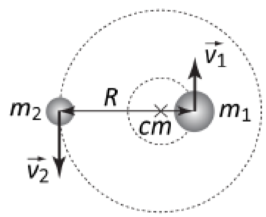
(a) Only II (b) I and II (c) I and III (d) II and III (e) I, II, and III

23. What is the magnitude of the angular momentum, L, of a satellite of mass m is in a circular orbit of radius $R = 2R_{\mathrm{E}}$? 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) $L = M_{\mathrm{E}}\sqrt{2gR_{\mathrm{E}}^3}$ (b) $L = m\sqrt{GgR_{\mathrm{E}}^3}$ (c) $L = 0$ (d) $L = (m + M_{\mathrm{E}})\sqrt{2gR_{\mathrm{E}}^3}$ (e) $L = m\sqrt{2gR_{\mathrm{E}}^3}$

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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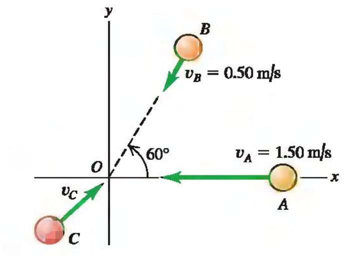
Questions 1-4

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?

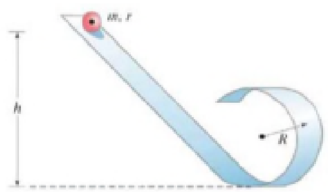
(a) 0.77 (b) 1.77 (c) -1.5 (d) 0 (e) 0.092

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?

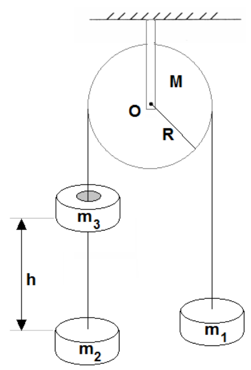
(a) 5/27 (b) 10/27 (c) 5/54 (d) 54/5 (e) 27/5

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?

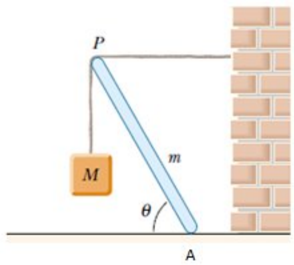
(a) 1.2 kg m^2/s (b) 0.9 kg m^2/s (c) 0.225 kg m^2/s (d) 1.8 kg m^2/s (e) 0.72 kg m^2/s

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.

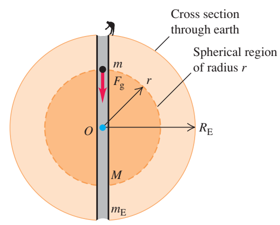
(a) $E=U$ (b) $U=2E$ (c) $E=-2U$ (d) $U=-2E$ (e) $E=2U$

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?

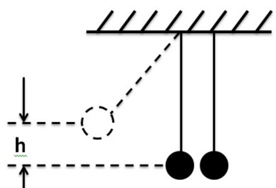
(a) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{R_{\mathrm{E}}}{r}$ (b) $F_g=0$ (c) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{r^2}{R_{\mathrm{E}}^2}$ (d) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{r}{R_{\mathrm{E}}}$ (e) $F_g=\frac{Gm_{\mathrm{E}}m}{R_{\mathrm{E}}^2}\frac{R_{\mathrm{E}}^2}{r^2}$

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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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?

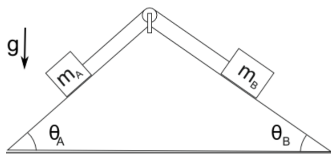
(a) 900 W (b) 400 W (c) 1100 W (d) 1200 W (e) 500 W

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 $\sin\theta_A/\sin\theta_B$?

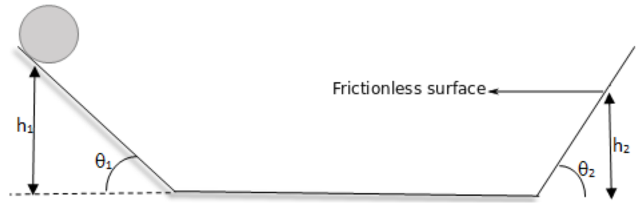
(a) 1.3 (b) 1.1 (c) 0.9 (d) 1.2 (e) 1

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?

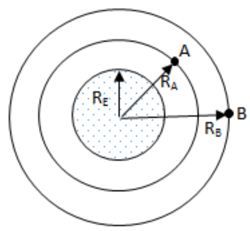
(a) $\sqrt{\frac{10gh_1}{R^2}}$ (b) $\sqrt{\frac{3gh_1}{7R^2}}$ (c) $\sqrt{\frac{10gh_1}{3R^2}}$ (d) $\sqrt{\frac{5gh_1}{7R^2}}$ (e) $\sqrt{\frac{10gh_1}{7R^2}}$

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?

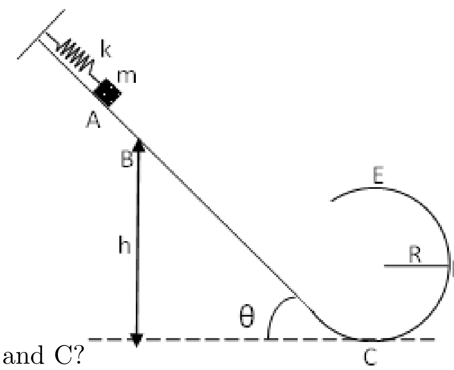
(a) 7 m/s^2 (b) 6 m/s^2 (c) 10 m/s^2 (d) 4 m/s^2 (e) 5 m/s^2

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

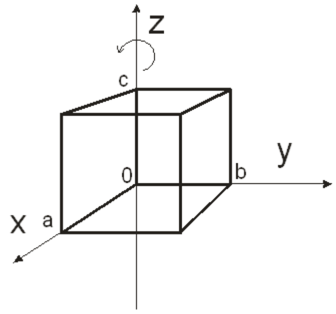
14. What is the position vector of the object at t = 2 s?

(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

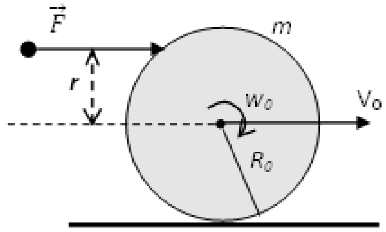
19. What is the magnitude of the tangential acceleration of the point given by the coordinates (x = 1 m, y = 2 m, z = 3 m) at t = 2 s in m/s^2?

(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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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 consideration.

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

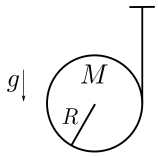
3. *with respect to the ground*?
(a) $(M+m)V/M$ (b) $MV/(M+m)$ (c) $MV/(M-m)$ (d) $(M+m)V/(M-m)$ (e) MV/m

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) $MV/(M-m)$

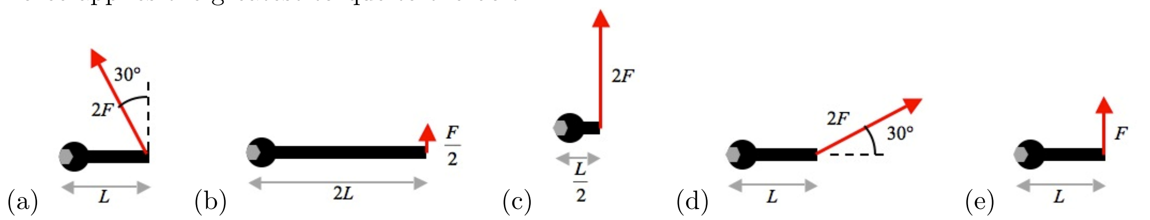
Questions 5-10

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

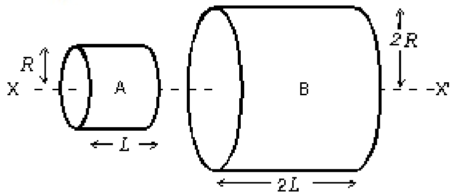
6. What is the tension in the string for the basic yo-yo in the figure?
(a) $Mg/3$ (b) $3Mg/2$ (c) $2Mg$ (d) $3Mg$ (e) Mg



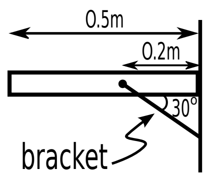
7. A series of wrenches of different lengths is used on a bolt, as shown below, Which combination of wrench length and Force applies the greatest torque to the bolt?



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



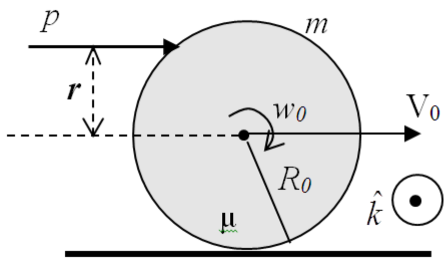
9. A uniform shelf having a weight of 40 N and of depth 0.50 m is supported by a bracket, as shown in the figure. What is the vertical component of the force exerted by the bracket exert on the shelf?
(a) 80 N (b) 50 N (c) 40 N (d) 120 N (e) 60 N



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

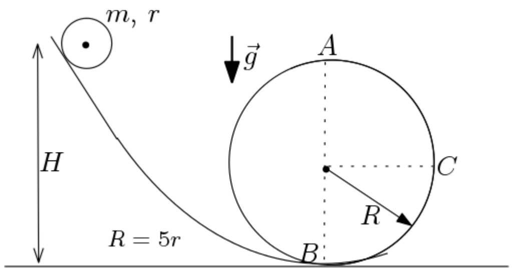
13. What is the velocity of the center of mass of the sphere as function of time?
(a) $(p/m-\mu gt)\hat{\imath}$ (b) $(p/m-\mu gt/2)\hat{\imath}$ (c) $(p/2m-\mu gt)\hat{\imath}$ (d) $(2p/m-\mu gt)\hat{\imath}$
(e) $(p/m - 2\mu gt)\hat{\imath}$

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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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) $\omega/4$

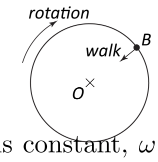
3. A force $\vec{F} = 4\hat{\imath} + 3\hat{\jmath}$ N acts on an object at a point located at the position $\vec{r} = 6\hat{k}$. What is the torque that this force applies about the origin?

(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.

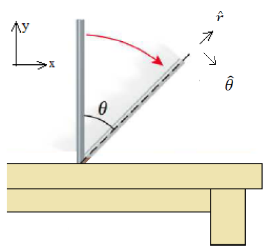
(a) $E = K/2$ (b) $E = -K$ (c) $E = K$ (d) $E = -2K$ (e) $E = 2K$

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.

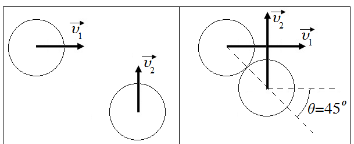
(a) 6 N (b) 9 N (c) 4.9 N (d) 4.4 N (e) 10 N

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?

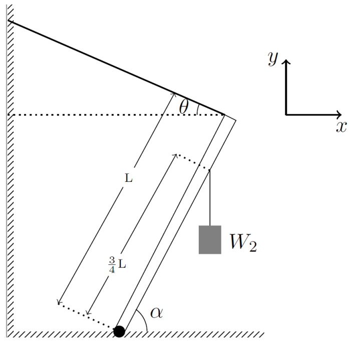
(a) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})\sqrt{2}$ (b) $(v_1\hat{\imath}-\mathrm{v}_2\hat{\jmath})/2$ (c) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})/2$ (d) $(v_1\hat{\imath}-\mathrm{v}_2\hat{\jmath})\sqrt{2}$ (e) $(v_1\hat{\imath}+\mathrm{v}_2\hat{\jmath})/\sqrt{2}$

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?

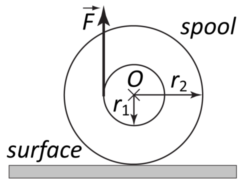
(a) 1055 N (b) 1075 N (c) 1060 N (d) 1065 N (e) 1070 N

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?

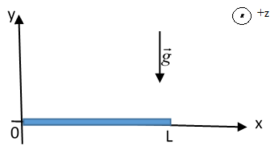
(a) $\frac{Fr_1}{r_2}$ (b) $\frac{F[I/(r_1M)+r_1]}{r_2}$ (c) $\frac{F[I/(r_2M)+r_2]}{r_1}$ (d) $\frac{Fr_2}{I/(r_1M)+r_1}$ (e) $\frac{Fr_1}{I/(r_2M)+r_2}$

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.

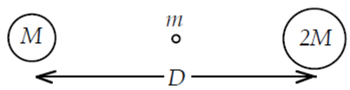
(a) $-(5MgL/9)\hat{k}$ (b) $-(MgL/3)\hat{k}$ (c) $-(3MgL/2)\hat{k}$ (d) $-(MgL/2)\hat{k}$ (e) $-(2MgL/3)\hat{k}$

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. 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.

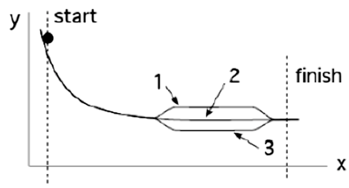
3. What is the conditions for a static equilibrium of rigid bodies?

(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) $\text{kg/m}^2\text{s}^2$ (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?

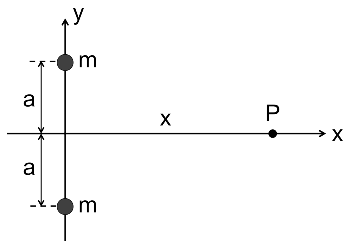
(a) 30 (b) 10 (c) 40 (d) 5 (e) 20

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



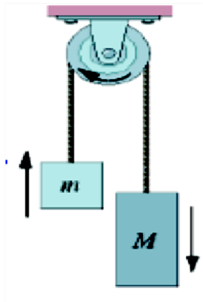
12. Two particles with masses m are placed at the (0, a) and (0, -a) points on y-axis. Find the magnitude of gravitational acceleration (g) at the point P(x,0) on x-axis.

(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

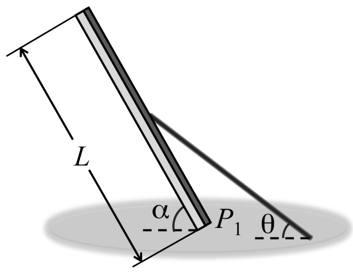
17. What is the magnitude of the pulley's angular acceleration?

(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

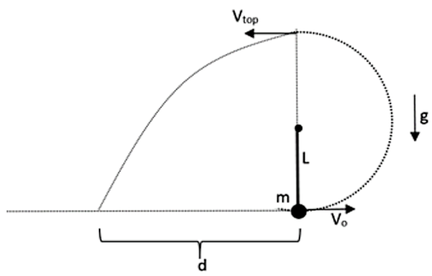
21. Calculate the vertical force component in the hinge when a 76 kg person is standing three-quarters of the way up the ladder.

(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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ATTENTION: There is normally only one correct answer for each question and each correct answer is worth the same point. Only the answers on your answer sheet will be graded. Please be sure that you have marked all of your answers on the answer sheet by using a pencil (*not* pen).

Questions 1-3

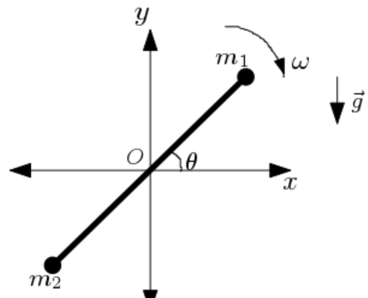
The angular position of a rigid body rotating about a fixed-axis is given as $\theta(t) = a + bt - ct^3$ with t is in seconds and θ in radians, a, b, c are constants. At $t = 0$ the object has angular speed 2 rad/s and at $t = 1.5$ s it has angular acceleration of 18 rad/s^2

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



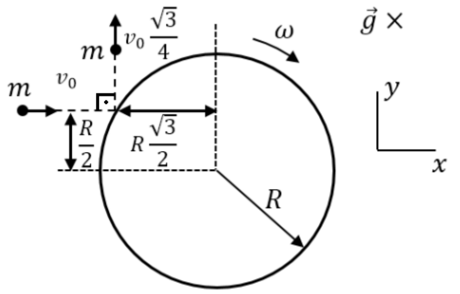
A uniform rigid rod of mass M and length ℓ rotates in the vertical plane about a frictionless pivot passing through its center. Two point masses m_1 and m_2 are attached at the ends of the rod, as shown in the figure. (For a uniform rigid rod of mass M and length ℓ, $I_{cm} = \frac{1}{12}M\ell^2$.)

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, $I_{cm} = \frac{1}{2}MR^2$.)

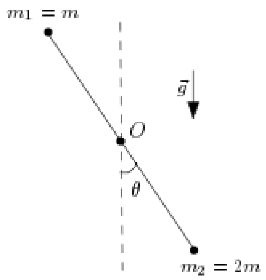
7. What are the conserved quantites in this collision?
(a) $\vec{L}$ relative to the center of mass of the disk (b) $\vec{p}$ and $\vec{L}$ relative to the every point in space (c) $\vec{L}$ relative to the point of collision (d) $\vec{p}$ and $\vec{L}$ relative to the point of collision (e) $\vec{p}$

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



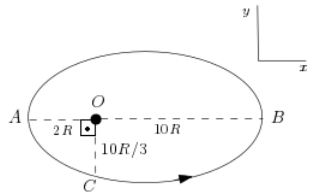
A uniform rod of mass $M = 3m$ and length L is pinned to a wall at its center of mass O in the vertical plane. It is free to be able to rotate about this point. Two point masses $m_1 = m$ and $m_2 = 2m$ are attached to the ends of the rod, as shown in the figure.

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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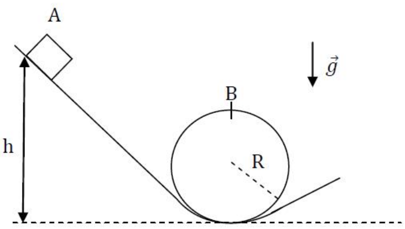
Questions 1-3

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?

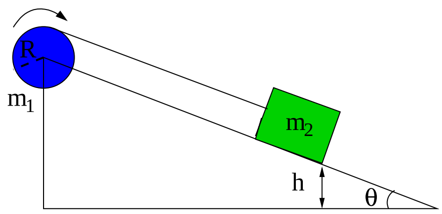
(a) $h > \frac{5}{2}R$ (b) $h > \frac{11}{5}R$ (c) $h > \frac{1}{2}R$ (d) $h > \frac{12}{5}R$ (e) $h > \frac{21}{10}R$

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?

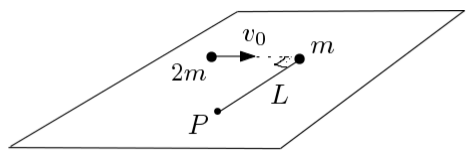
(a) 81/4 (b) 30 (c) 7.5 (d) 45 (e) 15

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) $\sqrt{\dfrac{20\lambda}{21}}$ (d) $\sqrt{210\lambda}$ (e) $\sqrt{\dfrac{10\lambda}{11}}$

11. What is the radial acceleration of the satellite in this orbit?

(a) $\dfrac{\lambda}{R_E}$ (b) $\left(\dfrac{10}{11}\right)^2 \dfrac{\lambda}{R_E}$ (c) $100\dfrac{\lambda}{R_E}$ (d) $400\dfrac{\lambda}{R_E}$ (e) $\left(\dfrac{100}{21}\right)^2 \dfrac{\lambda}{R_E}$

12. What is the total mechanical energy of the satellite when it is in this orbit?

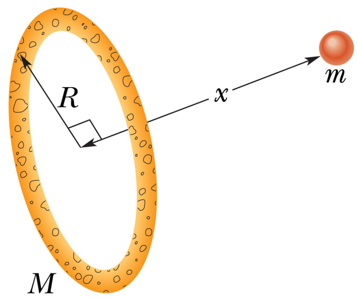
(a) $-5\lambda m$ (b) $-\dfrac{20}{11}\lambda m$ (c) $+\dfrac{5}{11}\lambda m$ (d) $+\lambda m$ (e) $-\dfrac{5}{11}\lambda m$

13. How much work has to be done to place this satellite in this orbit?

(a) $11\lambda m$ (b) $\dfrac{41}{11}\lambda m$ (c) $\dfrac{6}{11}\lambda m$ (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) $-\dfrac{GMm}{(x^2+R^2)}$ (b) $-\dfrac{GMm}{(x^2+R^2)^{3/2}}$ (c) $-\dfrac{GMm}{(x^2+R^2)^2}$ (d) $-\dfrac{GMm}{(x^2+R^2)^{1/2}}$
(e) $-\dfrac{GMm}{(x^2+R^2)^{5/2}}$

15. What is the magnitude of the gravitational force exerted by the ring on the point particle?

(a) $\dfrac{GMmx}{(x^2+R^2)^2}$ (b) $\dfrac{GMmx}{(x^2+R^2)^{3/2}}$ (c) $\dfrac{GMmx}{(x^2+R^2)^{1/2}}$ (d) $\dfrac{GMm}{(x^2+R^2)^{1/2}}$ (e) $\dfrac{GMmx}{(x^2+R^2)^{5/2}}$

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) $\dfrac{GMm}{x^{3/2}}$ (b) $\dfrac{GMm}{x}$ (c) $\dfrac{GMm}{x^3}$ (d) $\dfrac{GMm}{x^{1/2}}$ (e) $\dfrac{GMm}{x^2}$

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) $\dfrac{2\pi}{5}$ s (b) $\dfrac{2\pi}{15}$ s (c) $\dfrac{\pi}{5}$ s (d) $\dfrac{\pi}{15}$ s (e) $\dfrac{4\pi}{5}$ 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) $\dfrac{\sqrt{2}}{200}$ m (b) $\dfrac{\sqrt{2}}{120}$ m (c) $\dfrac{\sqrt{2}}{20}$ m (d) $\dfrac{3\sqrt{2}}{200}$ m (e) $\dfrac{5\sqrt{2}}{20}$ m

Group Number		Name		Type
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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.

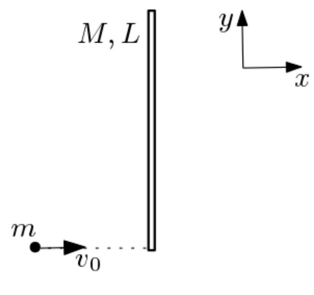
5. What is the length of a 2 kg simple pendulum that has the same period for small amplitude oscillations?
(a) $\sqrt{2}/0.1$ m (b) $\sqrt{3}/0.1$ m (c) 0.4 m (d) 0.2 $\sqrt{2}$ m (e) 0.1 m

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) $\frac{3v_0}{4L}$

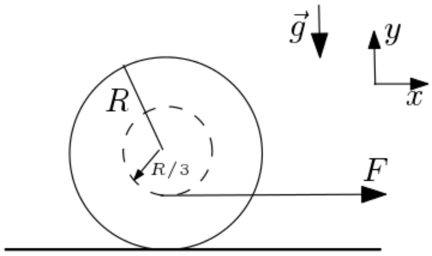
10. What is the impulse transferred to the point particle m during the collision?
(a) $\frac{3m}{4}v_0\hat{\imath}$ (b) $\frac{3m}{2}v_0\hat{\imath}$ (c) $-\frac{3m}{2}v_0\hat{\imath}$ (d) $-\frac{3m}{5}v_0\hat{\imath}$ (e) $-\frac{3m}{4}v_0\hat{\imath}$

11. If the collision were <u>completely inelastic</u>, 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 <u>completely inelastic</u>, what would be the angular speed of the system about the <u>new</u> 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) $\dfrac{16}{3}\ m/s^2$ (c) $\dfrac{5}{2}\ m/s^2$ (d) $\dfrac{11}{3}\ m/s^2$ (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 $1.5\ m$?

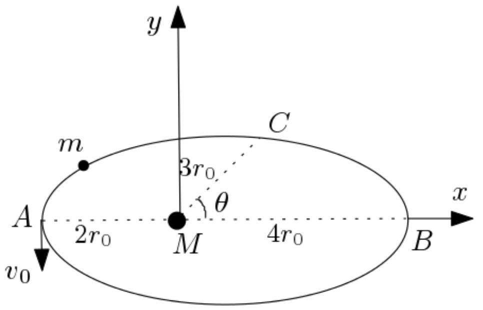
(a) $10\ rad/s$ (b) $25\ rad/s$ (c) $15\ rad/s$ (d) $30\ rad/s$ (e) $20\ rad/s$

15. Which of the following is the static friction force acting on the yo-yo?

(a) $-\left(\dfrac{10}{3}\ N\right)\hat{\imath}$ (b) $-\left(\dfrac{8}{3}\ N\right)\hat{\imath}$ (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) $-\dfrac{2GMm}{7r_0}$ (b) $-\dfrac{GMm}{7r_0}$ (c) $-\dfrac{GMm}{8r_0}$ (d) $-\dfrac{3GMm}{7r_0}$ (e) $-\dfrac{GMm}{6r_0}$

17. Which of the following is the speed of the planet at point B?

(a) $\sqrt{\dfrac{2GM}{7r_0}}$ (b) $\sqrt{\dfrac{GM}{6r_0}}$ (c) $\sqrt{\dfrac{GM}{8r_0}}$ (d) $\sqrt{\dfrac{3GM}{8r_0}}$ (e) $\sqrt{\dfrac{GM}{7r_0}}$

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) $-\dfrac{GM}{18r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (b) $\dfrac{GM}{16r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (c) $-\dfrac{GM}{16r_0^2}(\sqrt{3}\hat{\imath}+\hat{\jmath})$ (d) $-\dfrac{GM}{18r_0^2}(\sqrt{3}\hat{\imath}-\hat{\jmath})$ (e) $-\dfrac{GM}{18r_0^2}(-\sqrt{3}\hat{\imath}+\hat{\jmath})$

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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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) $\omega_0\,R + A\,Rt^2$ (b) $\omega_0\,R + 2\,A\,Rt^2$ (c) $\omega_0\,R + \frac{1}{2}\,A\,R\,t^2$ (d) $\omega_0\,R + 2\,A\,Rt$ (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 $\vec{v}_{2i} = -6\,\hat{\imath}\,\frac{m}{s}$.

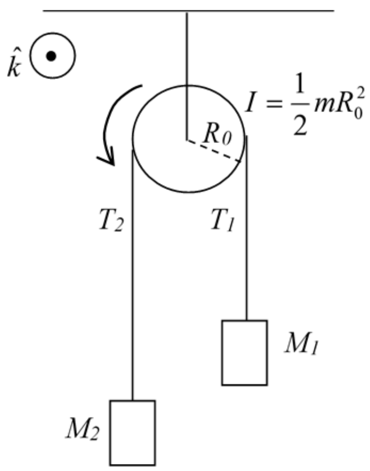
8. Calculate the centre of mass velocity $\vec{v}_{\rm cm}$ of the system **before** the collision.
(a) $+1\,\hat{\imath}\,\frac{m}{s}$ (b) $-4\,\hat{\imath}\,\frac{m}{s}$ (c) $-1\,\hat{\imath}\,\frac{m}{s}$ (d) $-2\,\hat{\imath}\,\frac{m}{s}$ (e) $-3\,\hat{\imath}\,\frac{m}{s}$

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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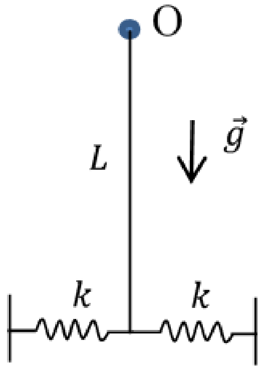
16. If the escape speed from the surface of a star of mass M and radius R is v, then what it would be for a star of mass $18M$ and radius $R/2$?
(a) $3v$ (b) $9v$ (c) $1296v$ (d) $36v$ (e) $6v$

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. $r_{\rm min}$ and $r_{\rm max}$ are the minimum and maximum distances of the planet from the sun. $v_{\rm min}$ and $v_{\rm max}$ are the minimum and maximum speeds of the planet in its orbit.)
(a) $rv\sin\phi = r_{\rm min}v_{\rm min}$ (b) $rv = r_{\rm min}v_{\rm max}$ (c) $rv\cos\phi = r_{\rm min}v_{\rm max}$ (d) $vr = $ constant (e) $rv\sin\phi = r_{\rm min}v_{\rm max}$

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 $I_{\rm cm} = \frac{1}{12}ML^2$). 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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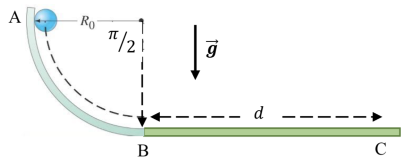
Questions 1-2

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 $t = T$?

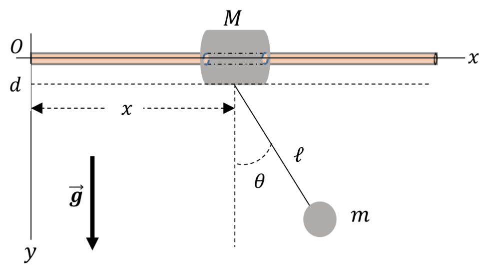
(a) $\frac{mv_T^2}{4T}$ (b) $\frac{mv_T^2}{2T}$ (c) 0 (d) $\frac{2mv_T^2}{T}$ (e) $\frac{mv_T^2}{T}$

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 $\theta = 0$?

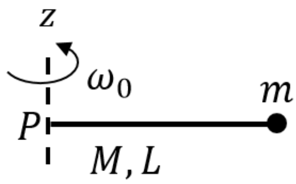
(a) $x' = x_0 + \frac{m\ell}{M+m}$, $y' = \ell + d$ (b) $x' = x_0 + \frac{M\ell}{M+m}$, $y' = \ell + 2d$ (c) $x' = x_0 + \frac{m\ell}{M+m}$, $y' = \ell + \frac{d}{2}$
(d) $x' = x_0 + \frac{2M\ell}{M+m}$, $y' = \ell + \frac{d}{2}$ (e) $x' = x_0 + \frac{2m\ell}{M+m}$, $y' = \ell + d$

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

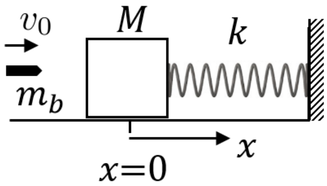
11. Another point mass $2m$ moving in the plane of rotation collides perpendicularly in the direction of the rotation of the rod and sticks to the rod at a distance $2L/3$ form point P with a linear speed $3\omega_0 L$. What is the angular momentum vector relative to point P just after the collision 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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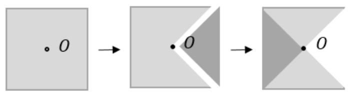
1. The moment of inertia of a thin homogeneous square rotating about its axis of symmetry O, perpendicular to the plain of square is given as I. A triangle part from it is cut and paste as shown in figure. What is the moment of inertia of the obtained object with respect to the same rotation axis?

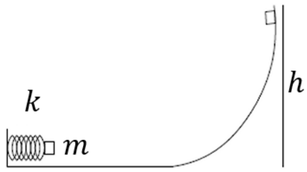


(a) I (b) $I/3$ (c) $2I/3$ (d) $3I/2$ (e) $4I/9$

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 $k = 7.5\times10^4$ 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?

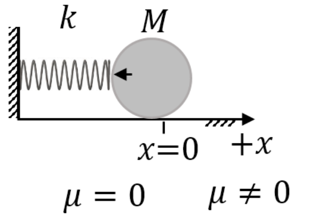
(a) 45/8 J (b) 15/8 J (c) 25/8 J (d) 5/8 J (e) 105/8 J

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.* ($I_{\mathrm{cm}} = \frac{2}{5}MR^2$ 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) $E = \frac{GM_{\mathrm{E}}m}{(R_{\mathrm{E}}+h)}$ (b) $E = \frac{GM_{\mathrm{E}}m}{2(R_{\mathrm{E}}+h)}$ (c) $E = -\frac{GM_{\mathrm{E}}m}{2(R_{\mathrm{E}}+h)}$ (d) $E = -\frac{GM_{\mathrm{E}}m}{(R_{\mathrm{E}}+h)}$ (e) $E = -\frac{GM_{\mathrm{E}}m}{2h}$

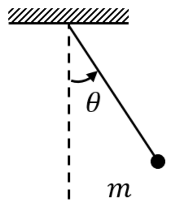
15. If the satellite is not at a high altitude, it will lose mechanical energy because of the air friction. In this case which of the following will happen?

(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 $U = -\frac{GM_{\mathrm{E}}m}{R_{\mathrm{E}}+h}$.
(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 $U = -\frac{GM_{\mathrm{E}}m}{R_{\mathrm{E}}+h}$.
(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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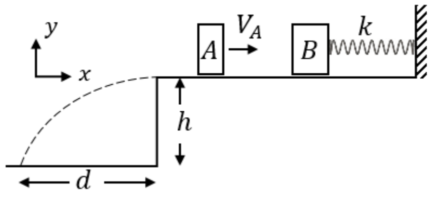
Questions 1-5

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}=$4.0\hat{\imath}$

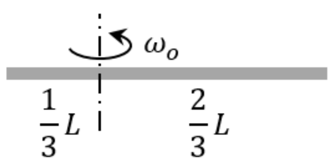
3. What is the value of d?
(a) 5.0 m (b) 1.5 m (c) 2.5 m (d) 4.0 m (e) 0.5 m

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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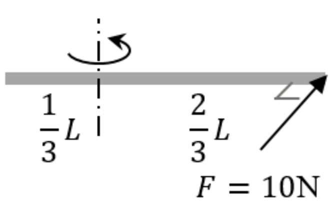
If a force F=10 N is applied, during 3 s, perpendicular to the far end of the long leg of the rod, as in the second figure, so as to increase the angular velocity of the rod.



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

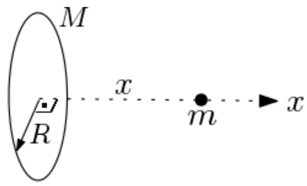
Questions 11-13

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) $\sqrt{\frac{5}{7}gl\sin\theta}$

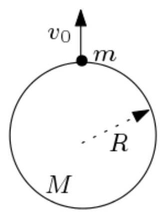
12. What is the acceleration of the center of mass (a_{cm}) of the sphere?
(a) $\frac{5}{7}g\sin\theta$ (b) $\frac{7}{9}g\sin\theta$ (c) $\frac{2}{7}g\sin\theta$ (d) $\frac{5}{9}g\sin\theta$ (e) $\frac{2}{5}g\sin\theta$

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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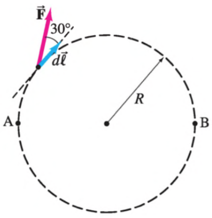
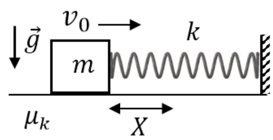
1. An object, moving along the circumference of a circle with radius R, is acted upon by a force of constant magnitude F. The force is directed at all times at a 30° angle with respect to the tangent to the circle as shown in the figure. Determine the work done by this force when the object moves along 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?



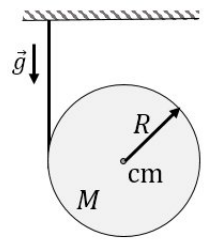
(a) $\frac{v_0^2}{2gX} - \frac{kX}{2mg}$ (b) $\frac{v_0^2}{gX} - \frac{kX}{2mg}$ (c) $\frac{v_0^2}{2gX}$ (d) $\frac{v_0^2}{gX} - \frac{kX}{mg}$ (e) $\frac{v_0^2}{2gX} - \frac{kX}{mg}$

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)

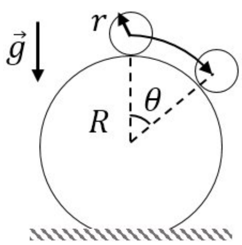
8. What mass must be suspended from the spring so that the system oscillates with a period of 0.5 s?
(a) $10/\pi^2$ kg (b) $5/\pi^2$ kg (c) $10\sqrt{2}\pi^2$ kg (d) $50/\pi^2$ kg (e) $20/\pi^2$ kg

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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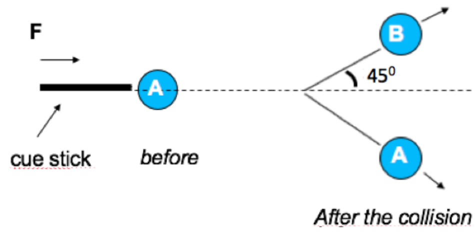
Answer the questions 13 and 14 assuming that the μ is small enough so that the ball starts slipping just after it reaches $\theta = \theta_S$ while it is rolling on the surface of the sphere.

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: $(\cos 45 = \sin 45 = \sqrt{2}/2)$



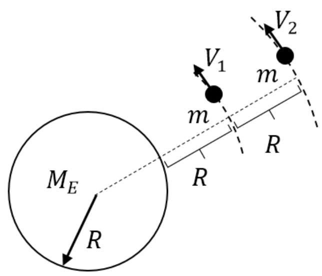
15. What is the angle between directions of two moving balls after the collision?
(a) 30° (b) 60° (c) $\sqrt{2}\,30°$ (d) 0° (e) 90°

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} $\mathrm{Nm^2/kg^2}$)
(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) $\sqrt{Rg}$