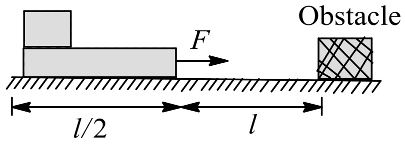
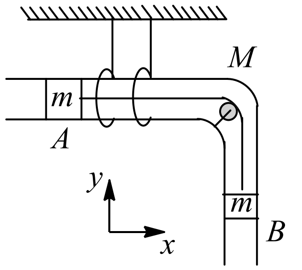
Single Correct Answer Type

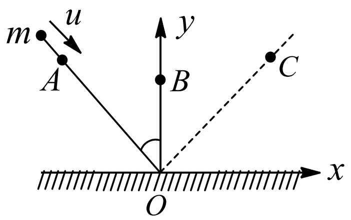
1. In problem 5, the moment of inertia of the system about one of the diagonals is
a) $\frac{2Ml^2}{3}$ b) $\frac{13Ml^2}{3}$ c) $\frac{Ml^2}{6}$ d) $\frac{13Ml^2}{6}$
2. A particle of mass m moving towards the east with speed v collides with another particle of the same mass and same speed v moving towards the north. If the two particles stick to each other, the new particle of mass $2m$ will have a speed of
a) v b) $v/2$ c) $\frac{v}{\sqrt{2}}$ d) $v\sqrt{2}$
3. In problem 29, the tangential acceleration of a point on the rim is
a) $\frac{T}{M}$ b) $\frac{MR}{T}$ c) $\frac{2T}{MR}$ d) $\frac{MR}{2T}$
4. As shown in fig., there two blocks of the same mass M, one on top of the other, lying on a frictionless horizontal surface. Both the blocks are at rest. The upper block is much smaller than the lower block. A force F is applied on the lower block and both the blocks start moving together without any relative motion. Suddenly, the lower block hits a fixed obstacle and comes to rest. The upper block continues to slide on the lower block. The upper block just manges to reach the opposite end of the lower block. What is the coefficient of friction between the two blocks?



a) F/Mg b) $2F/Mg$ c) $F/2Mg$ d) None
5. In fig., a hollow tube of mass M is free in horizontal direction. The system is released from rest. There is no friction present. Region within the box represents the system

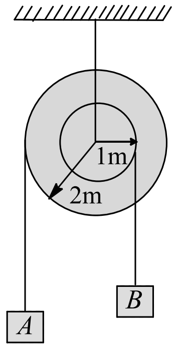


i. Momentum of the system is conserved in x -direction
ii. Speed of A w.r.t. M = speed of B w.r.t. M
iii. Trajectory of centre of mass is X –constant
iv. Centre of mass has finite acceleration
Evaluate the above statement and choose the correct option from the following:
a) Statements i, ii, are true and iii, iv are false
b) Statements i, ii are false and iii, iv are true
c) All statements are true
d) All statements are false
6. Two circular discs are of same thickness. The diameter of A is twice that of B. The moment of inertia of A as compound to that of B is
a) Twice as large b) Four times as large c) Eight times as large d) 16 times as large
7. A ball of mass moving with constant velocity u collides with a smooth horizontal surface at O as shown in Figure. Neglect gravity and friction. The y-axis is drawn normal to the horizontal surface at the point of impact O and x-axis is horizontal as shown. About which point will the angular momentum of ball be conserved?



a) Point A b) Point B c) Point C d) None of these

8. In the pullet system shown, if radii of the bigger and smaller pulley are 2 m and 1 m, respectively, and the acceleration of block A is 5 m/s^2 in the downward direction, the acceleration of block B will be

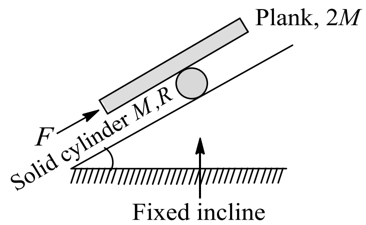


a) 0 m/s^2 b) 5 m/s^2 c) 10 m/s^2 d) $\frac{5}{2}$ m/s^2

9. A child is standing with folded hands at the centre of a platform rotating about its central axis. The kinetic energy of the system is K. The child now stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is

a) $2K$ b) $\frac{K}{2}$ c) $\frac{K}{4}$ d) $4K$

10. A solid cylinder of mass M and radius $2R$ is rolled up on an incline with the help of a plank of mass $2M$ as shown in figure. A force (constant) F is acting on the plank parallel to the incline. There is no slipping at any of the contact. The friction force between the plank and the cylinder is given by



a) $\frac{F}{2}$

b) $\frac{3F + 29Mg\sin\theta}{57}$

c) $\frac{3F + 2Mg\sin\theta}{19}$

d) Coefficient of friction value is not given and hence CANNOT be found

11. A uniform disc of mass M and radius R is mounted on an axle supported in frictionless bearings. A light cord is wrapped around the rim of the disc and a steady downward pull T is exerted on the cord. The angular acceleration of the disc is

a) $\frac{T}{MR}$ b) $\frac{MR}{T}$ c) $\frac{2T}{MR}$ d) $\frac{MR}{2T}$

12. A particle of mass m_1 moving with velocity v in a positive direction collides elastically with a mass m_2 moving in opposite direction also at velocity v. If $m_2 \gg m_1$, then

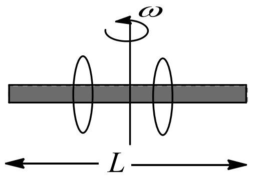
a) The velocity of m_1 immediately after collision is nearly $3v$

b) The change in momentum of m_1 is nearly $4m_1v$

c) The change in kinetic energy of m_1 is nearly $4mv_2$

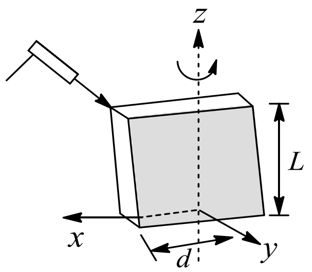
d) All of the above

13. A smooth uniform rod of length L and mass M has two identical beads (1 and 2) of negligible size, each of mass m, which can slide freely along the rod. Initially the two beads are at the centre of the rod and the system is rotating with angular velocity ω_0 about an axis perpendicular to the rod and is passing through its midpoint. There are no external forces when the beads reach the ends of the rod, the angular velocity of the system is



a) $\frac{M\omega_0}{M+6m}$ b) $\frac{M\omega_0}{m}$ c) $\frac{M\omega_0}{M+12m}$ d) ω_0

14. A thin plate of mass M, length L and width $2d$ is mounted vertically on a frictionless fixed axle along the z-axis as shown. Initially, the object is at rest. It is then tapped with a hammer to provide a torque τ, which produces an angular impulse H about the z-axis of magnitude $H = \int \tau \, dt$. What is the angular speed ω of the plate about the z-axis after the tap?



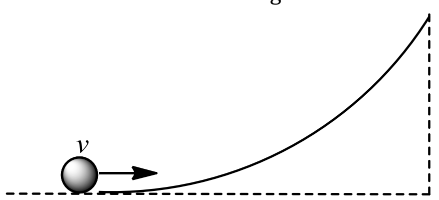
a) $\frac{H}{Md^2}$ b) $\frac{2H}{Md^2}$ c) $\frac{3H}{Md^2}$ d) $\frac{4H}{Md^2}$

15. A uniform box of height 2 m and having a square base of side 1 m, weight 150 kg , is kept on one end on the floor of a truck. The maximum speed with which the truck can round a curve of radius 20 m without causing the block to tip over is (assume that friction is sufficient so that there is no sliding)
a) 15 m/s
b) 10 m/s
c) 8 m/s
d) Depends on the value of coefficient of friction

16. In Fig, a massive rod AB is held in horizontal position by two massless strings. If the string at B breaks and if the horizontal acceleration of centre of mass, vertical acceleration and angular acceleration of rod about the centre of mass are a_x, a_y and α, respectively, then

a) $2\sqrt{3}a_y = \sqrt{3}\alpha l + 2\alpha_x$ b) $\sqrt{3}a_y = \sqrt{3}\alpha l + a_x$ c) $a_y = \sqrt{3}\alpha l + 2a_x$ d) $2a_y = \alpha l + 2\sqrt{3}a_x$

17. A small object of uniform density roll up a curved surface with an initial velocity v. If reaches up to a maximum height of $\frac{3v^2}{4g}$ with respect to the initial position. The object is



a) Ring b) Solid sphere c) Hollow sphere d) Disc

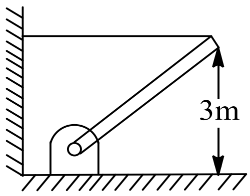
18. A uniform ring of radius R is given a back spin of angular velocity $V_0/2R$ and thrown on a horizontal rough surface with velocity of centre to be V_0. The velocity of the centre of the ring when it starts pure rolling will be

a) $\frac{V_0}{2}$ b) $\frac{V_0}{4}$ c) $\frac{3V_0}{4}$ d) 0

19. A string is wrapped around a cylinder of mass M and radius R. The string is pulled vertically upwards to prevent the centre of mass from falling as the cylinder unwinds the string. The tension in the string is

a) $\frac{Mg}{6}$ b) $\frac{Mg}{3}$ c) $\frac{Mg}{2}$ d) $\frac{2Mg}{3}$

20. A uniform rod of mass 15 kg is held stationary with the help of a light string as shown in Figure. The tension in the string is

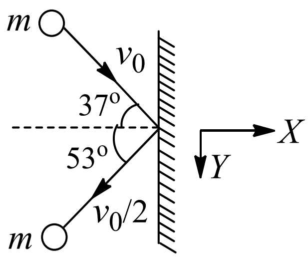


a) 150 N b) 225 N c) 100 N d) None of the above

21. A projectile is moving at 20 ms^{-1} at its highest point where it breaks into equal parts due to an internal explosion. One part moves vertically up at 30 ms^{-1} with respect to the ground. Then the other part will move at

a) 20 m/s b) $10\sqrt{13}$ m/s c) 50 m/s d) 30 m/s

22. A ball of mass m moving with velocity v_0 collides with a wall as shown in fig. After impact it rebounds with a velocity $v_0/2$. The component of impulse acting on the ball along the wall is

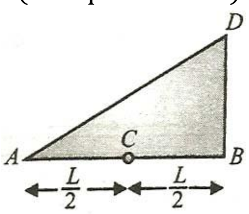


a) $\frac{mv_0}{2}\hat{j}$ b) $-\frac{mv_0}{2}\hat{j}$ c) $-\frac{mv_0}{5}\hat{j}$ d) None of these

23. A particle at rest is constrained to move on a smooth horizontal surface. Another identical particle hits the fractional particle with a velocity v at an angle $\theta = 60°$ with horizontal. If the particles move together, the velocity of the combination just after impact is equal to

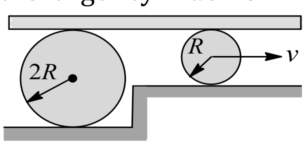
a) v b) $\frac{v}{2}$ c) $\frac{\sqrt{3}v}{4}$ d) $\frac{v}{4}$

24. A triangular plate of uniform thickness and density is made to rotate about an axis perpendicular to the plane of the paper and (a) passing through A, (b) passing through B, by the application of some force F at C(mid-point of AB) as shown in Figure. In which case is angular acceleration more?



a) In case (a) b) In case (b) c) Both (a) and (b) d) None of these

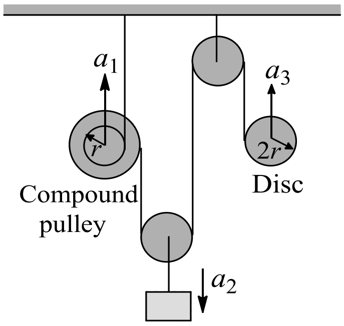
25. Velocity of the centre of a small cylinder is v. There is no slipping anywhere. The velocity of the centre of the larger cylinder is



a) $2v$ b) v c) $\frac{3v}{2}$ d) None of these

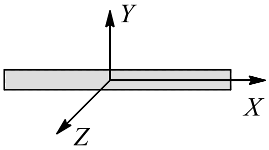
26. In the figure shown, suppose the compound pulley and the disc have the same angular acceleration in

clockwise direction. If a_1 is the upward acceleration of the compound pulley's centre (inner radius r, outer radius $3r$);a_2 is the dowmward acceleration of the block while a_3 is the upward acceleration of the centre of the disc (radius $2r$). From kinematic constraints of the thread, the relation between them is



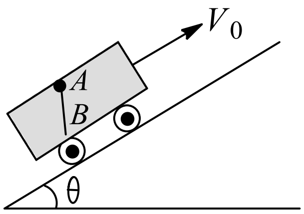
a) $\frac{a_2 - a_3}{2} = 2a_1$ b) $a_2 + a_3 = \frac{a_1}{3}$ c) $2a_2 - a_3 = 4a_1$ d) $a_2 + 2a_3 = a_1$

27. A uniform smooth rod (mass m and length l) placed on a smooth horizontal floor is hit by a particle (mass m) moving on the floor, at a distance $l/4$ from one end elasetically ($e = 1$). The distance travelled by the centre of the rod after the collision when it has completed three revolutions will be
a) $2\pi l$
b) Cannot be determined
c) πl
d) None of these
28. A block of mass 0.50 kg is moving with a speed of 2.00 m/s on a smooth surface. It strikes another stationary mass of 1.00 kg and then they move together as a single body. The energy loss during the collision is
a) 0.16 J b) 1.00 J c) 0.67 J d) 0.34 J
29. A uniform rod of mass M and length L is free to rotate in $X - Z$ plane,
i.e., $\vec{F} = (3\hat{\imath} + 2\hat{\jmath} + 6\hat{k})$ N is acting on the rod at $(L/2, 0, 0)$ in the situation shown in Figure. The angular acceleration of the rod is (Take $M = 6$ kg and $L = 4$ m)



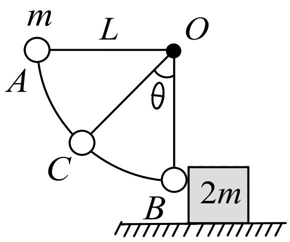
a) $-\frac{3}{2}\hat{\jmath} + 1/2\hat{k}$ b) $-\frac{3}{2}\hat{\jmath}$ c) $\frac{1}{2}$k d) $4\,\hat{\jmath}$

30. A uniform rod AB of length l and mass m hangs from point A in a car moving with velocity v_0 on an inclined plane as shown in Fiogure. The rod can rotate in vertical plane about the axis at point A. If the car suddenly stops, the angular speed with which the rod starts rotating is



a) $\frac{3}{2}\frac{v_0}{l}\cos\theta$ b) $\frac{v_0}{2}\cos\theta$ c) $\frac{3}{2}\frac{v_0}{l}\sin\theta$ d) $\frac{5}{2}\frac{v_0}{l}\sin\theta$

31. A ball of mass m is attached to a cord of length L, pivoted at point O, as shown in fig. The ball is released from rest at point A, swings down and makes an inelastic collision with a block of mass $2m$ kept on a rough horizontal floor. The coefficient of restitution of collision is $e = 2/3$ and coefficient of friction between block and surface is μ. After collision, the ball comes momentarily to rest at C when cord makes an angle of θ with the vertical and block moves a distance of $3L/2$ on rough horizontal floor before stopping. The values of μ and θ are, respectively,

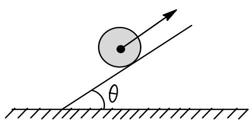


a) $\frac{50}{243}, \cos^{-1}\left(\frac{80}{81}\right)$ b) $\frac{50}{81}, \cos^{-1}\left(\frac{80}{81}\right)$ c) $\frac{2}{81}, \cos^{-1}\left(\frac{80}{243}\right)$ d) $\frac{2}{243}, \cos^{-1}\left(\frac{80}{243}\right)$

32. Two rings of same radius and mass are placed such that their centres are at a common point and their planes are perpendicular to each other. The moment of inertia of the system about an axis passing through the centre and perpendicular to the plane of one of the rings is (mass of the ring $= m$, radius $= r$)

a) $\frac{1}{2}mr^2$ b) mr^2 c) $\frac{3}{2}mr^2$ d) $2mr^2$

33. A sphere has to purely roll upwards. At an instant when the velocity of sphere is v, frictional force acting on it is



a) Downwards and $\mu mg \cos \theta$ b) Downwards and $\frac{2mg \sin \theta}{7}$

c) Upwards and $\mu mg \cos \theta$ d) Upwards and $\frac{2mg \sin \theta}{7}$

34. A car of mass 400 kg travelling at 72 km/h crashes into a truck of mass 4000 kg travelling at 9 km/h in the same direction. The car bounces back at a speed of 18 km/h. The speed of the truck after the impact is

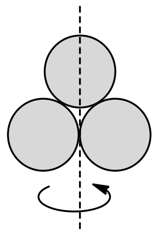
a) 9 km/h b) 18 km/h c) 27 km/h d) 36 km/h

35. A solid sphere, a hollow sphere and a disc, all having the same mass and radius, are placed at the top of an incline and released. The friction coefficients between the objects and the incline are same and not sufficient to allow pure rolling. The least time will be taken in reaching the bottom by

a) The solid sphere b) The hollow sphere

c) The disc d) All will take the same time

36. Three rings, each of mass m and radius r, are so placed that they touch each other. Find the moment of inertia about the axis as shown in Figure



a) $5mr^2$ b) $\frac{5}{7}mr^2$ c) $7mr^2$ d) $\frac{7}{2}mr^2$

37. In a system of particles 8 kg mass is subjected to a force of 16 N along +ve x-axis and another 8 kg mass is subjected to a force of 8 N along +ve y-axis. The magnitude of accleration of centre of mass and the angle made by it with x-axis are given, respectively, by

a) $\frac{\sqrt{5}}{2}\text{ms}^2, \theta = 45°$ b) $3\sqrt{5}\text{ms}^2, \theta = \tan^{-1}\left(\frac{2}{3}\right)$

c) $\frac{\sqrt{5}}{2}\text{ms}^2, \theta = \tan^{-1}\left(\frac{1}{2}\right)$ d) $1\ \text{ms}^2, \theta = \tan^{-1}\sqrt{3}$

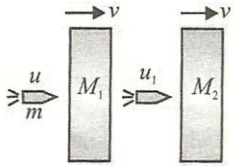
38. In the above problem, the velocity of the centre of mass after 1 s will be

a) $\frac{20}{3}$ m/s, vertically downwards b) $\frac{20}{3}$ m/s, vertically upwards

c) $\frac{70}{3}$ m/s, vertically downwards d) $\frac{70}{3}$ m/s, vertically upwards

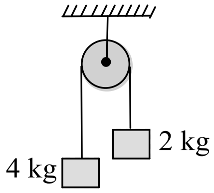
39. A 20 g bullet pierces through a plate of mass $M_1 = 1$ kg and then comes to rest inside a second plate of

mass M_2= 2.98 kg as shown in Fig. It is found that the two plates, initially at rest, now move with equal velocities. Find the percentage loss in the initial velocity of the bullet when it is between M_1 and M_2. Neglect any loss of material of the plates due to the action of bullet



a) 50% b) 25% c) 100% d) 75%

40. For the system shown in fig., the string is light and pulley is frictionless. The 4 kg block is given an upward velocity of 1 m/s



The centre of mass of the two blocks will [neglect the impulse duration]

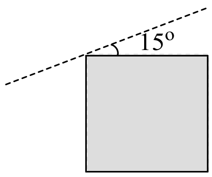
a) Accelerate down with g/3

b) Initially accelerate downwards with g and then after some time accelerate down with g/3

c) Initially accelerate with $\vec{g}$ and then the acceleration is 0

d) Initially accelerate with $\vec{g}$ and when accelerate with g/3

41. A square plate of mass M and edge L is shown in the figure. The moment of inertia of the plate about the axis in the plane of plate and passing through one of its vertex making an angle 15° horizontal is



a) $\frac{ML^2}{12}$ b) $\frac{11ML^2}{24}$ c) $\frac{7ML^2}{12}$ d) None of these

42. A ball of mass m moving with a speed u undergoes a head-on elastic collision with a ball of mass nm initially at rest. The fraction of the incident energy transferred to the second ball is

a) $\frac{n}{1+n}$ b) $\frac{n}{(1+n)^2}$ c) $\frac{2n}{(1+n)^2}$ d) $\frac{4n}{(1+n)^2}$

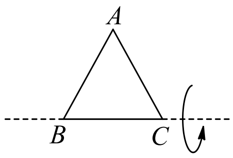
43. Four identical rods are joined end to end to form a square. The mass of each rod is M. The moment of inertia of the square about the median line is

a) $\frac{Ml^2}{3}$ b) $\frac{Ml^2}{4}$ c) $\frac{Ml^2}{6}$ d) None of these

44. A ball is let fall from a height h_0. There are n collisions with the earth. If the velocity of rebound after n collision is v_n and the ball rises to a height h_n, then coefficient of restitution e is given by

a) $e^n = \sqrt{\frac{h_n}{h_0}}$ b) $e^n = \sqrt{\frac{h_0}{h_n}}$ c) $ne = \sqrt{\frac{h_n}{h_0}}$ d) $\sqrt{ne} = \sqrt{\frac{h_n}{h_0}}$

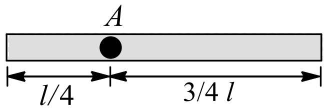
45. Three identical rods, each of mass m and length l, form an equaliteral triangle. Moment of inertia about one of the sides is



a) $\frac{ml^2}{4}$ b) ml^2 c) $\frac{3ml^2}{4}$ d) $\frac{2ml^2}{3}$

46. A uniform rod of mass m and length l is fixed from point A, which is at a distance $l/4$ from one end as

shown in the figure. The rod is free to rotate in a vertical plane. The rod is released from the horizontal position



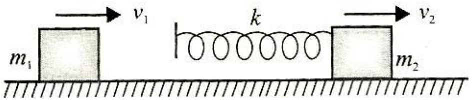
What is the reaction at the hinge, when kinetic energy of the rod is maximum?

a) $\frac{4}{7}$ b) $\frac{5}{7}mg$ c) $\frac{13}{7}mg$ d) $\frac{11}{7}mg$

47. If in the previous problem the collision is elastic, the height to which the bob will rise will be

a) $\frac{v^2}{8g}$ b) $\frac{v^2}{2g}$ c) $\frac{2v^2}{g}$ d) $\frac{v^2}{g}$

48. Two blocks of masses $m_1 = 2$ kg and $m_2 = 4$ kg are moving in the same direction with speeds $v_1 = 6$ m/s and $v_2 = 3$ m/s, respectively on a frictionless surface as shown in figure. An ideal spring with spring constant $k = 30000$ N/m is attached to the back side of m_2. Then the maximum compression of the spring after collision will be



a) 0.06 m b) 0.04 m c) 0.02 m d) None of these

49. A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass

a) Of the box remains constant
b) Of the (box + ball) system remains constant
c) Of the ball remains constant
d) Of the ball relative to the box remains constant

50. From a given sample of uniform wire, two circular loops P and Q are made, P of radius r and Q of radius nr. If the M.I of Q about its axis if four times that of P about its axis (assuming the wire to be diameter much smaller than either radius), the value of n is

a) $(4)^{\frac{2}{3}}$ b) $(4)^{\frac{1}{3}}$ c) $(4)^{\frac{1}{2}}$ d) $(4)^{\frac{1}{4}}$

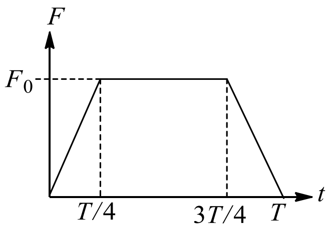
51. If we hang a body of mass m with the cord in problem 29, the tangential acceleration of the disc will be

a) $\frac{mg}{M+m}$ b) $\frac{mg}{M+2m}$ c) $\frac{2mg}{M+2m}$ d) $\frac{M+2m}{2mg}$

52. Two particle A and B start moving due to their mutual interaction only. If at any time $'t'$, $\vec{a}_A$ and $\vec{a}_B$ are their respective accelerations, $\vec{v}_A$ and $\vec{v}_B$ are their respective velocities, and up to that time W_A and W_B are the work done on A and B, respectively, by the mutual force, m_A and m_B are their masses, respectively, then which of the following is always correct?

a) $\vec{v}_A + \vec{v}_B = 0$ b) $m_A\vec{v}_A + m_B\vec{v}_B = 0$ c) $W_A + W_B = 0$ d) $\vec{a}_A + \vec{a}_B = 0$

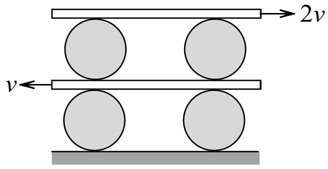
53. A particle of mass m moving with a velocity v makes an elastic one dimensional collision with a stationary particle of mass m establishing a contact with it for extremely small time T. Their force of contact increases from zero to F_0 linearly in time $T/4$, remains constant for a further time $T/2$ and decreases linearly from F_0 to zero in further time $T/4$ as shown in fig. The magnitude possessed by F_0 is



a) $\frac{mu}{T}$ b) $\frac{2mu}{T}$ c) $\frac{4mu}{3T}$ d) $\frac{3mu}{4T}$

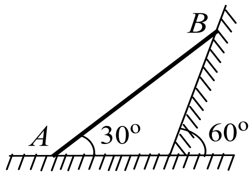
54. A system of identical cylinders and plates is shown in Figure. All the cylinders are identical and there is no slipping at any contact. The velocity of lower and upper plates are V and $2V$, respectively, as shown in

Figure. Then the ratio of angular speeds of the upper cylinders to lower cylinders is



a) $\frac{1}{3}$ b) 3 c) 1 d) None of these

55. In the figure shown, the instantaneous speed of end A of the rod is v to the left. The angular velocity of then rod of length L must be



a) $\frac{v}{2L}$ b) $\frac{v}{L}$ c) $\frac{v\sqrt{3}}{2L}$ d) None of these

56. A binary star consists of two stars A (mass 2.2 M_s) and B (mass 11 M_s), where M_s is the mass of the sun. They are separated by distance d and are rotating about their centre of mass, which is stationary. The ratio of the total angular momentum of the binary star to the angular momentum of star B about the centre of mass is

a) 7 b) 6 c) 9 d) 10

57. Imagine a hard surface along xz plane to be fixed. A particle moving along the line $4x + 3y - 12 = 0$, with a speed of 10 m/s, from the positive side of y-axis, approaches towards the plane and collides. If the coefficient of restitution be $e = 0.75$, then the speed of the particle after collision will be

a) 5 m/s b) 8 m/s c) $6\sqrt{2}$ m/s d) $5\sqrt{2}$ m/s

58. Two solid cylinders P and Q of same mass and same radius start rolling down a fixed inclined plane from the same height at the same time. Cylinder P has most of its mass concentrated near its surface, while Q has most of its mass concentrated near the axis. Which statement (s) is (are) correct

a) Both cylinders P and Q reach the ground at the same time

b) Cylinder P has larger linear acceleration than cylinder Q

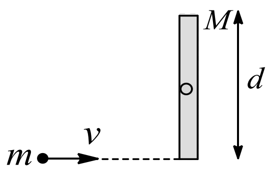
c) Both cylinder P and Q reaches the ground with same translational kinetic energy

d) Cylinder Q reaches the ground with larger angular speed

59. A smooth sphere is moving on a horizontal surface with velocity vector $2\hat{\imath} + 2\hat{\jmath}$ immediately before it hits a vertical wall. The wall is parallel to $\hat{\jmath}$ vector and the coefficient of restitution between the sphere and the wall is $e = 1/2$. The velocity vector of the sphere after it hits the wall is

a) $\hat{\imath} - \hat{\jmath}$ b) $-\hat{\imath} + 2\hat{\jmath}$ c) $-\hat{\imath} - \hat{\jmath}$ d) $2\hat{\imath} - \hat{\jmath}$

60. A mass m is moving at speed v perpendicular to a rod of length d and $M = 6$ m which pivots around a frictionless axle running through its centre. It strikes and sticks to the end of the rod. The moment of inertia of the rod about its centre is $Md^2/12$. Then the angular speed of the system just after collision is



a) $\frac{2v}{3d}$ b) $\frac{2v}{d}$ c) $\frac{v}{d}$ d) $\frac{3v}{2d}$

61. A particle falls freely near the surface near the surface of the earth. Consider a fixed point O (not vertically below the partically) on the ground. Then pick up the correct alternative or alternatives

a) Angular momentum of the particle about O is increasing

b) The moment of inertia of the particle about O is decreasing

c) The moment of inertia of the particle about O is decreasing

d) The angular velocity of the particle about O is increasing

62. The moment of inertia of a door of mass m, length $2l$ and width l about its longer side is

a) $\frac{11ml^2}{24}$ b) $\frac{5ml^2}{24}$ c) $\frac{ml^2}{3}$ d) None of these

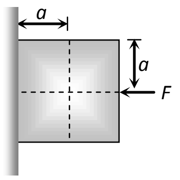
63. A cracker is thrown into air with a velocity of 10 m/s at an angle of 45° with the vertical. When it is at a height of 0.5 m from the ground, it explodes into a number of pieces which follow different parabolic paths. What is the velocity of centre of mass, when it is at a height of 1 m from the ground? (g =10 m/s^2)

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

64. A uniform disc of radius R lies in the $x-y$ plane, with its centre at origin. Its moment of linertia about z-axis is equal to its moment of inertia about line $y = x + c$. The value of c will be

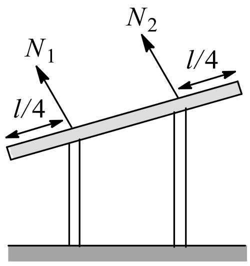
a) $-\frac{R}{2}$ b) $\pm\frac{R}{\sqrt{2}}$ c) $+\frac{R}{4}$ d) $-R$

65. A horizontal force F is applied such that the block remains stationary then which of the following statement is false



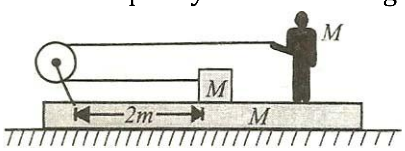
a) $f = mg$ [where f is the friction force] b) $F = N$ [where N is the normal force]
c) F will not produce torque d) N will not produce torque

66. A uniform rod of length l is placed symmetrically on two walls as shown in Figure. The rod is in equilibrium. If N_1 and N_2 are the normal forces exerted by the walls on the rod , then



a) $N_1 > N_2$ b) $N_1 < N_2$
c) $N_1 = N_2$ d) N_1 and N_2 would be in the vertical directions

67. A block of mass M is tied to one end of a massless rope. The other end of the rope is in the hands of a man of mass $2M$ as shown in fig. The block and the man are resting on a rough wedge of mass M. The whole system is resting on a smooth horizontal surface. The man starts walking towards right while holding the rope in his hands. Pulley is massless and frictionless. Find the displacement of the wedge when the block meets the pulley. Assume wedge is sufficiently long so that man does not fall down

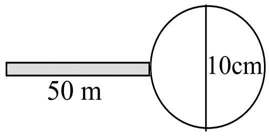


a) 1/2 m towards right b) 1/2 m towards left
c) The wedge does not move at all d) 1 m towards left

68. A ball of mass m moving with velocity v strikes the bob of a pendulum at rest. The mass of the bob is also m. If the collision is perfectly inelastic, the height to which the bob will rise is given by

a) $\frac{v^2}{8g}$ b) $\frac{v^2}{2g}$ c) $\frac{2v^2}{g}$ d) $\frac{v^2}{g}$

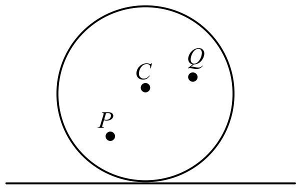
69. Figure shows a thin uniform rod 50 cm long and has a mass of 100 g. A hollow metal ball is filled with air and has a diameter 10 cm and total mass 50 g is fixed to one end of the rod. At what point along its length will the ball and rod balance horizontally?



a) 20 cm from the centre of the rod
b) 10 cm from the center of the rod
c) At the center of the rod
d) Where the ball is attached to the rod

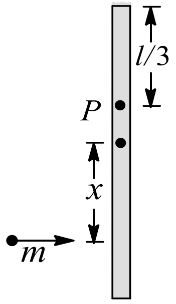
70. Two blocks of masses 5 kg and 2 kg are placed on a frictionless surface and connected by a spring. An external kick gives a velocity of 14 m/s to the heavier block in the direction of lighter one. The magnitudes of velocities of two block in the centre of mass frame after the kick are, respectively,
a) 4 m/s, 4 m/s
b) 10 m/s, 4 m/s
c) 4 m/s, 10 m/s
d) 10 m/s, 10 m/s

71. A disc is rolling (without slipping) on a horizontal surface C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of pints P, Q and C respectively, then



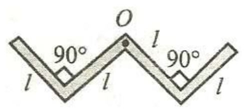
a) $v_Q > v_C > v_P$
b) $v_Q < v_C < v_P$
c) $v_Q = v_P, v_C = \frac{1}{2} v_P$
d) $v_Q < v_C > v_P$

72. A thin uniform rod of mass m and length l is kept on a smooth horizontal surface such that it can move freely. At what distance from centre of rod should a particle of mass m strike on the rod such the point P at a distance $l/3$ from the end of the rod is instantaneously at rest just after the elastic collision?



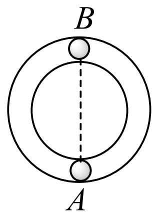
a) $\frac{1}{2}$
b) $\frac{1}{3}$
c) $\frac{1}{6}$
d) $\frac{1}{4}$

73. A thin rod of length $4l$ and mass $4m$ is bent at the points as shown in Figure. What is the moment of inertia of the rod about the axis passing through point O and perpendicular to the plane of the paper



a) $\frac{Ml^2}{3}$
b) $\frac{10Ml^2}{3}$
c) $\frac{Ml^2}{12}$
d) $\frac{Ml^2}{24}$

74. Two equal spheres A and B lie on a smooth horizontal circular groove at opposite ends of a diameter. At time $t = 0, A$ is projected along the groove and it first impinges on B at time $t = T_1$ and again at time $t = T_2$. If e is the coefficient of restitution, the ratio T_2/T_1 is



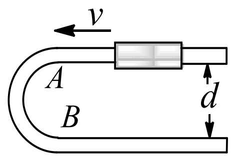
a) $\frac{2}{e}$
b) $\frac{(2+e)}{2}$
c) $\frac{2(e+1)}{e}$
d) $\frac{(2+e)}{e}$

75. A vessel at rest explodes breaking it into three pieces. Two pieces having equal mass fly off perpendicular to one another with the same speed of 30 m/s. The third piece has three times the mass of each of the other two pieces. What is the direction (w.r.t. the pieces having equal masses) and magnitude of its

velocity immediately after the explosion?

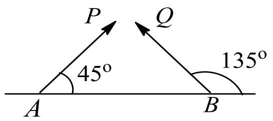
a) $10\sqrt{2}$, 135°   b) $10\sqrt{2}$,90°   c) $10\sqrt{2}$, 60°   d) $10\sqrt{2}$, 30°

76. A U-shaped wire has a semicircular bending between A and B as shown in fig. A bead of mass m moving with uniform speed v through a wire enters the semicircular bend at A and leaves at B with velocity $v/2$ after time T. The average force exerted by the bead on the part AB of the wire is



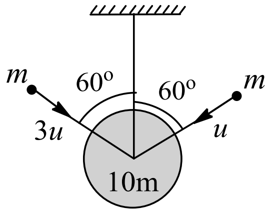
a) 0   b) $\frac{3mv}{2T}$ c) $\frac{3mv}{T}$ d) None of these

77. Particles P and Q of masses 20 g and 40 g, respectively, are projected from positions A and B on the ground. The initial velocities of P and Q make angles of 45° and 135°, respectively, with the horizontal as shown in the fig. Each particle has an initial speed of 49 m/s. The separation AB is 245 m. Both particles travel in the same vertical plane and undergo a collision. After the collision P retraces its path. The distance of Q from its initial position when it hits the ground is



a) 245 m   b) $\frac{245}{3}$ m   c) $\frac{245}{2}$ m   d) $\frac{245}{\sqrt{2}}$ m

78. A bob of mass 10 m is suspended through an inextensible string of length l. When the bob is at the rest in equilibrium position, two particles, each of mass m, strike it as shown in fig. The particles stick after collision. Choose the correct statement from the following:



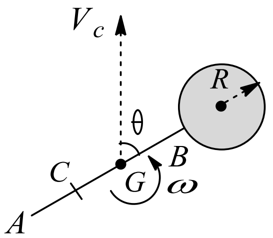
a) Impulse in the string due to tension is $2mu$

b) Velocity of the system just after collision is $v = \frac{u\sqrt{3}}{14}$

c) Loss of energy is $\frac{137}{28}\ mu^2$

d) Loss of energy is $\frac{137}{56}\ mu^2$

79. In Figure, the rod AB of mass $2m$ and length $4R$ is rigidly attached to a disc of mass m, and radius R in the same plane. The system has prescribed motion in its own plane defined by the velocity v of its centre of mass G and its angular velocity ω. If the end A of the rod is suddenly fixed by a pin, the new angular velocity ω' around point A is



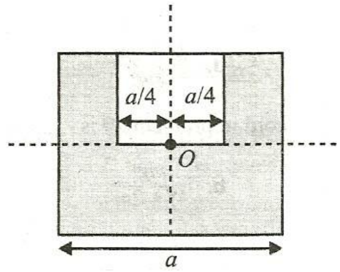
a) $\frac{18v_c \cos\theta + 55\ R\omega}{73R}$

b) $\frac{18v_c \sin\theta + 15\ R\omega}{73R}$

c) $\dfrac{54v_c \sin\theta + 55\,R\omega}{217R}$

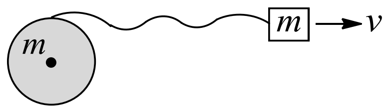
d) None of these

80. A square plate of edge $a/2$ is cut out from a uniform square plate of edge 'a' as shown in Figure. The mass of the remaining portion is M. The moment of inertia of the shaded portion about an axis passing through 'O'(centre of the square of side a) and perpendicular to the plane of plate is



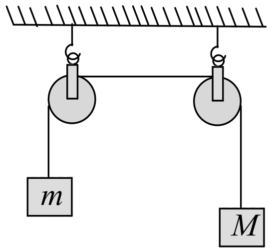
a) $\dfrac{9}{64}Ma^2$ b) $\dfrac{3}{16}Ma^2$ c) $\dfrac{5}{12}Ma^2$ d) $\dfrac{Ma^2}{6}$

81. A block of mass m is attached to a pulley disc of equal mass m and radius r by means of a slack string as shown. The pulley is hinged about its centre on a horizontal table and the block is projected with an initial velocity of 5 m/s. Its velocity when the string become taut will be



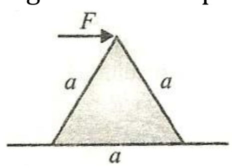
a) 3 m/s b) 2.5 m/s c) 5/3 m/s d) 10/3 m/s

82. Each pulley in Figure has radius r and moment of inertia l. The acceleration of the block is



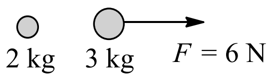
a) $\dfrac{(M-m)g}{\left(M+m+\frac{2I}{r^2}\right)}$ b) $\dfrac{(M-m)g}{\left(M+m-\frac{2I}{r^2}\right)}$ c) $\dfrac{(M-m)g}{\left(M+m+\frac{I}{r^2}\right)}$ d) $\dfrac{(M-m)g}{\left(M+m-\frac{I}{r^2}\right)}$

83. An equilateral prism of mass m rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the prism as shown in Figure. If the coefficient of friction is sufficiently high so that the prism does not slide before toppling, the minimum force required to topple the prism is



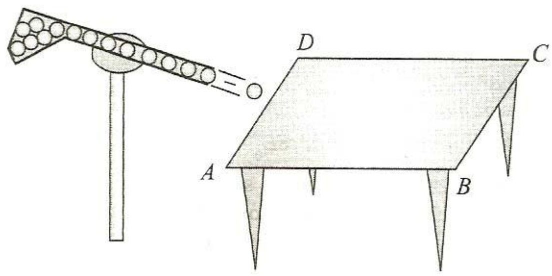
a) $\dfrac{mg}{\sqrt{3}}$ b) $\dfrac{mg}{4}$ c) $\dfrac{\mu mg}{\sqrt{3}}$ d) $\dfrac{\mu mg}{4}$

84. Two particles are shown in fig. At $t = 0$, a constant force $F = 6$ N starts acting on the 3 kg man. Find the velocity of the centre of mass of these particles at $t = 5$ s



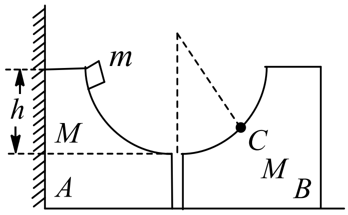
a) 5 m/s b) 4 m/s c) 6 m/s d) 3 m/s

85. A gun which fires small balls of mass 20 g is firing 20 balls per second on the smooth horizontal table surface $ABCD$. If the collision is perfectly elastic and balls are striking at the centre of table with a speed of 5m/s at an angle of 60° with the vertical just before collision, then force exerted by one of the legs on ground is (assume total weight of the table is 0.2 kg)



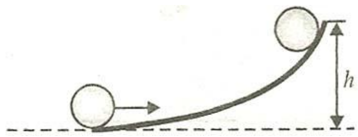
a) 0.5 N b) 1 N c) 0.25 N d) 0.75 N

86. Two identical blocks, having mass M each, are conjugated and place on a smooth floor as shown in fig. A small block of mass m is released from position as shown. Velocity of block B is maximum



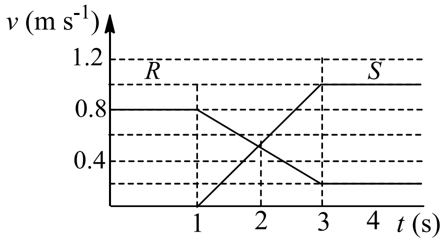
a) When m is at the highest position on B
b) When m is at the lowest position and moving left
c) When m is at C
d) When m is at lowest position and moving right

87. In the figure shown, a ball without sliding on a horizontal surface. It ascends a curved track up to height h and returns. The value of h is h_1 for sufficiently rough curved track to avoid sliding and is h_2 for smooth curved track, then



a) $h_1 = h_2$ b) $h_1 < h_2$ c) $h_1 > h_2$ d) $h_2 = 2h_1$

88. Figure shows the velocity- time graph for two masses R and S that collided elastically. Which of the following statements is true?



1. R and S moved in the same direction after the collision
2. The velocities of R and S were equal at the mid time of the collision

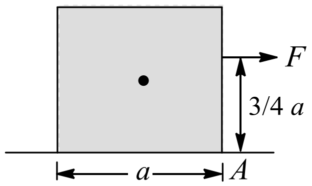
The mass of R was greater than mass of S

Which of the following is true?

a) i only b) ii only c) i and ii only d) i, ii and iii

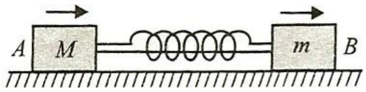
89. Two objects are at rest on a level frictionless surface. The objects are not connected. A force F is applied to one of the objects, which then moves with acceleration a. Mark the correct statement(s)
a) The concept of centre of mass cannot be applied because the external force does not act on both the objects
b) The centre of mass moves with acceleration that could be greater than a
c) The centre of mass moves with acceleration that must be equal to a
d) The centre of mass moves with acceleration that must be less than a

90. A cube of side a and mass m is to be tilted at point A by applying a force F as shown in Figure. The minimum force required is



a) mg b) $\frac{2}{3}mg$ c) $\frac{3}{2}mg$ d) $\frac{3}{4}mg$

91. Block A of mass M =2 kg is connected to another block B of mass $m = 1$ kg with a string and a spring of force constant $k = 600$ N/m as shown in fig. Initially, spring is compressed to 10 cm and whole system is moving on a smooth surface with a velocity v =1 m/s. At any time, thread is burnt, the velocity of block A, when B is having maximum velocity w.r.t. ground, is

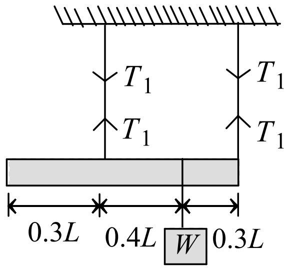


a) Zero b) 1 m/s c) 3 m/s d) None of these

92. A 3000 kg space probe is moving in a gravity free space at a constant velocity of 300 m/s. To change the direction of space probe, rockets have been fired in a direction perpendicular to the direction of initial motion of the space probe, the rocket firing exerts a thrust of 4000 N for 225 s. The space probe will turn by an angle of (neglect the mass of the rockets fired)

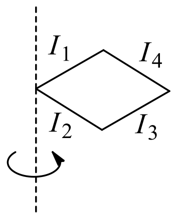
a) 30° b) 60° c) 45° d) 37°

93. In Figure, the bar is uniform and weighing 500 N. How large must W be if T_1 and T_2 are to be equal



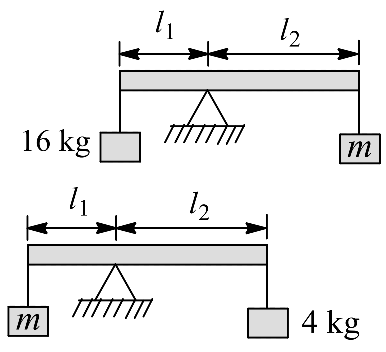
a) 500 N b) 300 N c) 750 N d) 1500 N

94. The moment of inertia of a system of four rods, each of length l and mass m, about the axis shown is



a) $\frac{2}{3}ml^2$ b) $2ml^2$ c) $3ml^2$ d) $\frac{8}{3}ml^2$

95. In an experiment with a beam balance, an unknown mass m is balanced by two known masses of 16 kg and 4 kg as shown in Figure

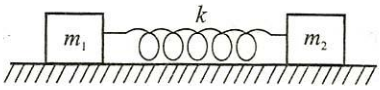


The value of the unknown mass m is

a) 10 kg b) 6 kg c) 8 kg d) 12 kg

96. Two blocks m_1 and m_2 are pulled on a smooth horizontal surface, and are joined together with a spring of

stiffness k as shown in fig. Suddenly, block m_2 receives a horizontal velocity v_0, then the maximum extension x_m in the spring is

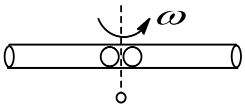


a) $v_0\sqrt{\frac{m_1 m_2}{m_1+m_2}}$ b) $v_0\sqrt{\frac{2m_1 m_2}{(m_1+m_2)k}}$ c) $v_0\sqrt{\frac{m_1 m_2}{2(m_1+m_2)k}}$ d) $v_0\sqrt{\frac{m_1 m_2}{(m_1+m_2)k}}$

97. Two painters are working from a wooden board 5 m long suspended from the top of a building by two ropes attached to the ends of the plank. Either rope can withstand a maximum tension of 1040 N. Painter A of mass 80 kg is working at a distance of 1 m from one end. Painter B of mass 60 kg is working at a distance of x m from the centre of mass of the board on the other side. Take mass of the board as 20 kg and $\mathrm{g}=10\ \mathrm{m/s^2}$. The range of x so that both the painter can work safely is

a) $\frac{1}{3}<x<\frac{11}{6}$ b) $0<x<\frac{11}{6}$ c) $0<x<2$ d) $\frac{1}{3}<x<2$

98. A smooth tube of certain mass is rotated in a gravity-free space and released. The two balls shown in Figure move towards the ends of the tube. For the whole system, which of the following quantities is not conserved

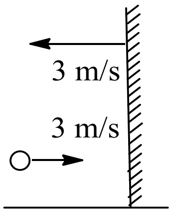


a) Angular momentum b) Linear momentum c) Kinetic energy d) Angular speed

99. An impulse $J=mv$ at one end of a stationery uniform frictionless rod of mass m and length l which is free to rotate in a gravity-free space. The impact is elastic. Instantaneous axis of rotation of the rod will pass through

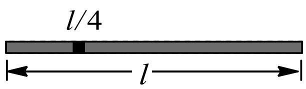
a) Its centre of mass
b) The centre of mass of the rod plus ball
c) The point of impact of the ball on the rod
d) The point which is at a distance 2/3 from the striking end

100. A highly elastic ball moving at a speed of 3 m/s approaches a wall moving towards it with a speed of 3 m/s. After the collision, the speed of the ball will be



a) 3 m/s b) 6 m/s c) 9 m/s d) Zero

101. A uniform thin rod of length l and mass m is hinged at a distance $l/4$ from one of the end released fron horizontal position as shown in Figure. The angular velocity of the rod as it passes the vertical position is



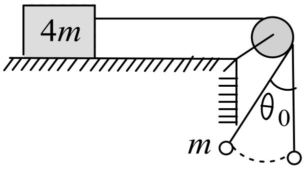
a) $2\sqrt{\frac{5\mathrm{g}}{7l}}$ b) $2\sqrt{\frac{6\mathrm{g}}{7l}}$ c) $\sqrt{\frac{3\mathrm{g}}{7l}}$ d) $2\sqrt{\frac{\mathrm{g}}{l}}$

102. A ring of radius R is first rotated with an angular velocity ω_0 and then carefully placed on a rough horizontal surface. The coefficient of friction between the surface and the ring is μ. Time after which its angular speed is reduced to half is

a) $\frac{\omega_0\mu R}{2\mathrm{g}}$ b) $\frac{\omega_0\mathrm{g}}{2\mu R}$ c) $\frac{2\omega_0 R}{\mu\mathrm{g}}$ d) $\frac{\omega_0 R}{2\mu\mathrm{g}}$

103. Two bodies of masses m and $4m$ are attached with a string as shown in fig. The body of mass m hanging from a string of length l is executing oscillations of angular amplitude θ_0 while the other body is at rest.

The minimum coeffcient of friction between the mass $4m$ and the horizontal surface should is

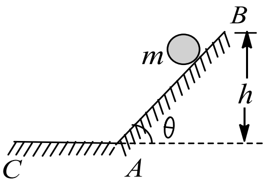


a) $\left(\frac{2-\cos\theta_0}{3}\right)$ b) $2\cos^2\left(\frac{\theta_0}{2}\right)$ c) $\left(\frac{1-\cos\theta_0}{2}\right)$ d) $\left(\frac{3-2\cos\theta_0}{4}\right)$

104. Two circular discs A and B are of equal masses and thicknesses but made of metal with densities d_A and $d_B (d_A > d_B)$. If their moments of inertia about an axis passing through their centres and perpendicular to circular faces are I_A and I_B, then

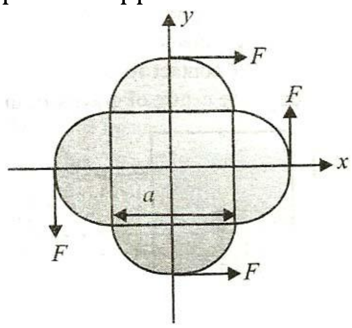
a) $I_A = I_B$ b) $I_A > I_B$ c) $I_A < I_B$ d) $I_A \geq I_B$

105. A particle of mass m comes down on a smooth inclined plane from point B at a height of h from rest. The magnitude of change in momentum of the particle between position A (just before arriving on horizontal surface) and C (assuming the angle of inclination of the plane as θ with respect to the horizontal) is



a) 0 b) $2m\sqrt{(2gh)}\sin\theta$ c) $2m\sqrt{(2gh)}\sin\left(\frac{\theta}{2}\right)$ d) $2m\sqrt{(2gh)}$

106. A planar object made up of a uniform square plate and four semicircular discs of the same thickness and material is being acted upon by four forces of equal magnitude as shown in Figure. The coordinates of point of application of forces is given by

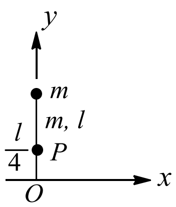


a) $(0, a)$ b) $(0, -a)$ c) $(a, 0)$ d) $(-a, 0)$

107. A radioactive nucleus initially at rest decays by emitting an electron and neutron at right angles to one another. The momentum of the electron is 3.2×10^{-23} kg m/s and that momentum of the neutron is 6.4×10^{-23} kg m/s. The direction of the recoiling nucleus with that of the electron motion is

a) $\pi - \tan^{-1}(2)$ b) $\tan^{-1}(2)$ c) $\tan^{-1}(0.5)$ d) $\frac{\pi}{2} + \tan^{-1}(2)$

108. A small ball of mass m is attached with upper end of a uniform straight rod of equal mass m and length l. The rod is held vertical over a smooth horizontal surface as shown in fig. When the system is released, the lower end slips freely and the systems falls down. Assuming the initial position of the lower end to be origin and initially rod to be along y-axis as shown in fig., the equation of trajectory of point P of the rod (P is at distance $l/4$ from the lower end) is



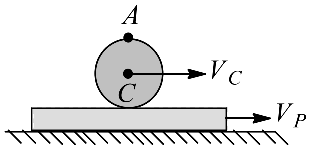
a) $4x^2 + 16y^2 = 4l^2$ b) $4x^2 + 16y^2 = l^2$ c) $x^2 + 4y^2 = l^2$ d) $x^2 + 4y^2 = 16l^2$

109. Three point masses m_1, m_2 and m_3 are located at the vertices of an equilateral triangle of side 'a'. What is

the moment of inertia of the system about an axis along the altitude of the tringle passing through m_1?

a) $(m_1 + m_2)\frac{a^2}{4}$ b) $(m_2 + m_3)\frac{a^2}{4}$ c) $(m_1 + m_3)\frac{a^2}{4}$ d) $(m_1 + m_2 + m_3)\frac{a^2}{4}$

110. In Figure the velocities are in ground frame and the cylinder is performing pure rolling on the plank, velocity of point $'A'$ would be

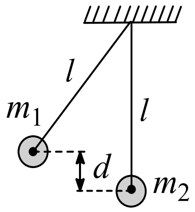


a) $2V_C$ b) $2V_C + V_P$ c) $2V_C - V_P$ d) $2(V_C - V_P)$

111. Two points of a rod move with velocities $3v$ and v perpendicular to the rod and in the same direction separated by a distance $'r'$. The angular velocity of the rod is

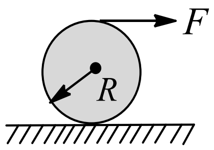
a) $\frac{3v}{r}$ b) $\frac{4v}{r}$ c) $\frac{5v}{r}$ d) $\frac{2v}{r}$

112. Two pendulums each of length l are initially situated as shown in fig. The first pendulum is released and strikes the second. Assume that the collision is completely inelastic and neglect the mass of the string and any frictional effects. How high does the centre of mass rise after the collision?



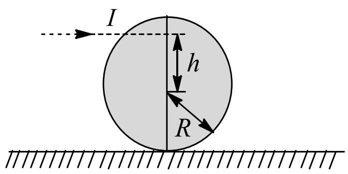
a) $d\left[\frac{m_1}{(m_1 + m_2)}\right]^2$ b) $d\left[\frac{m_1}{(m_1 + m_2)}\right]$ c) $d\left[\frac{(m_1 + m_2)}{m_2}\right]^2$ d) $d\left[\frac{m_2}{(m_1 + m_2)}\right]^2$

113. An object of mass M and radius R is performing pure rolling motion on a smooth horizontal surface under the action of a constant force F as shown in Figure. The object may be



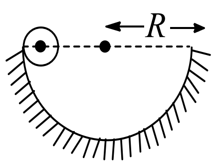
a) Disk b) Ring c) Solid cylinder d) Hollow sphere

114. A solid sphere rests on a horizontal surface. A horizontal impulse is applied at height h from centre. The sphere starts starts rolling just after the application of impulse. The ratio h/r will be



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

115. In the figure shown, a small ball of mass 'm' can move without sliding in a fixed semicircular track of radius R in a vertical plane. It is released from the top. The resultant force on the ball at the lowest point of the track is



a) $\frac{10mg}{7}$ b) $\frac{17mg}{7}$ c) $\frac{3mg}{7}$ d) Zero

116. A solid sphere of mass M, radius R and having moment of inertia about an axis passing through the centre of mass as I, is recast into a disc of thickness t, whose moment of inertia about an axis passing through its

edge and perpendicular to its plane remains I. Then, radius of the disc will be

a) $\frac{2R}{\sqrt{15}}$ b) $R\sqrt{\frac{2}{15}}$ c) $\frac{4R}{\sqrt{15}}$ d) $\frac{R}{4}$

117. An object initially at rest explodes into three fragments A, B and C. The momentum of A is $p\hat{i}$ and that of B is $\sqrt{3}\,p\hat{j}$ where p is a +ve number. The momentum of C will be

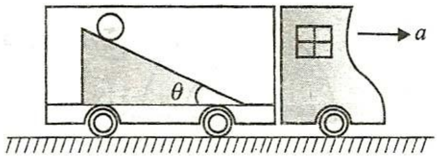
a) $(1+\sqrt{3})p$ in a direction making angle 120° with that of A

b) $(1+\sqrt{3})p$ in a direction making angle 150° with that of B

c) $2p$ in a direction making angle 150° with that of A

d) $2p$ in a direction making angle 150° with that of B

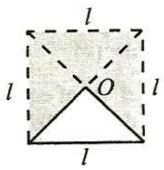
118. A smooth inclined plane is fixed in a car accelerating at $a = \text{g} \tan\theta$. If the sphere is set pure rolling on the incline, then



a) It will continue rolling b) It will slip down

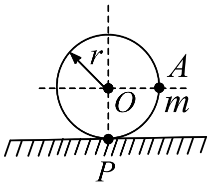
c) Its linear velocity will increase d) Its linear velocity will decrease

119. An isosceles triangular piece is cut from a square plate of side l.The piece is one-fourth of the square and mass of the remaining plate is M. The moment of inertia of the plate about an axis passing through O and perpendicular to its plane is



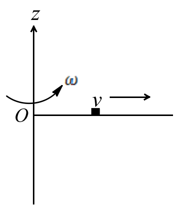
a) $\frac{Ml^2}{6}$ b) $\frac{Ml^2}{12}$ c) $\frac{Ml^2}{24}$ d) $\frac{Ml^2}{3}$

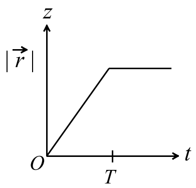
120. A particle of mass $'m'$ is rigidly attached at 'A' to a ring of mass $'3m'$ and radius 'r'. The system is released from rest and rolls without sliding. The angular acceleration of ring just after release is

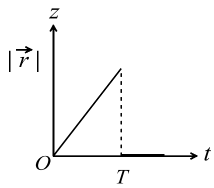


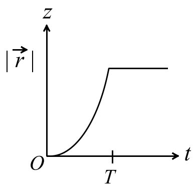
a) $\frac{\text{g}}{4r}$ b) $\frac{\text{g}}{6r}$ c) $\frac{\text{g}}{8r}$ d) $\frac{\text{g}}{2r}$

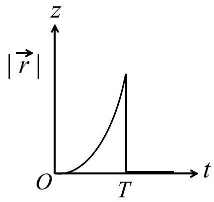
121. A thin uniform rod, pivoted at O, is rotating in the horizontal plane with constant angular speed ω, as shown in the figure. At time, $t = 0$, a small insect starts from O and moves with constant speed v with respect to the rod towards the other end. It reaches the end of the rod at $t = T$ and stops. The angular speed of the system remains ω throughout. The magnitude of the torque ($|\vec{\tau}|$ on the system about O, as a function of time is best represented by which plot



a) 

b) 

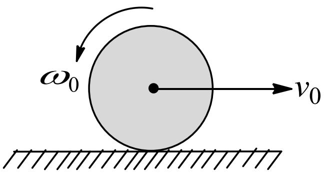
c) 

d) 

122. A balloon having mass $'m'$ is filled with gas and is held in hands of a boy. Then suddenly it gets released and gas starts coming out of it with a constant rate. The velocity of the ejected gas is also constant (2 m/s) with respect to the balloon. Find out the velocity of the balloon when the mass of gas is reduced to half

a) $\ln 2$ b) $2 \ln 4$ c) $2 \ln 2$ d) None of these

123. A uniform circular disc of radius r is placed on a rough horizontal surface and given a linear velocity v_0 and angular velocity ω_0 as shown. The disc comes to rest moving some distance to the right. It follows that



a) $3v_0 = 2\omega_0 r$ b) $2v_0 = \omega_0 r$ c) $v_0 = \omega_0 r$ d) $2v_0 = 3\omega_0 r$

124. A man stands at one end of a boat which is stationary in water. Neglect water resistance. The man now moves to the other end of the boat and again becomes stationary. The centre of mass of the 'man plus boat' system will remain stationary with respect to water

a) only when the man is stationary initially and finally
b) only if the man moves without acceleration on the boat
c) only if the man and the boat have equal masses
d) in all cases

125. A cannon of mass 1000 kg located at the base of an inclined plane fires a shell of mass 50 kg in horizontal direction with velocity 180 km/h. The angle of inclination of the inclined plane with the horizontal is 45°. The coefficient of friction between the cannon and inclined plane is 0.5. The maximum height, in metre, to which the cannon can ascend the inclined plane as a result of recoil is

a) $\frac{5}{6}$ b) $\frac{5}{24}$ c) $\frac{5}{12}$ d) None of these

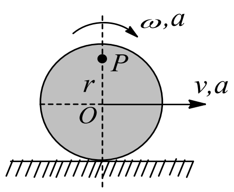
126. A cylinder having moment of inertia, which is free to rotate about its axis, receives an angular impulse of J kg m^2/s initially, followed by similar impulse after every 4 s. What is the angular speed of the cylinder 30 s after the initial impulse?

a) $\frac{7J}{I}$ b) $\frac{8J}{I}$ c) $\frac{J}{I}$ d) Zero

127. A bullet of mass 0.01 kg and travelling at a speed of 500 m/s strikes a block of 2 kg which is suspended by a string of length 5m. The centre of gravity of the block is found to rise a vertical distance of 0.1 m. What is the speed of the bullet after it emerges from the block?

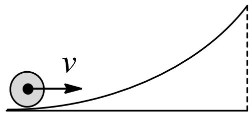
a) 200 m/s b) 220 m/s c) 204 m/s d) 284 m/s

128. A disc of radius R rolls on a horizontal ground with linear acceleration a and angular acceleration α as shown in Figure. The magnitude of acceleration of point P as shown in the figure at an instant when its linear velocity is v and angular velocity is ω will be



a) $\sqrt{(a + r\alpha^2) + (r\omega^2)^2}$ b) $\frac{ar}{R}$ c) $\sqrt{r^2\alpha^2 + r^2\omega^4}$ d) $r\alpha$

129. A small object of uniform density rolls up a curved surface with an initial velocity v. It reaches up to a maximum height of $3v^2/4$g w.r.t. the initial position. The object is



a) Ring b) Solid sphere c) Hollow sphere d) disc

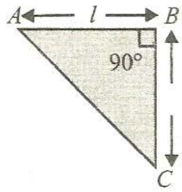
130. The moment of inertia of a solid sphere about an axis passing through the centre of gravity is $1/2\ MR^2$; then its radius of gyration about a parallel axis at a distance $2R$ from first axis is

a) $5R$ b) $\sqrt{\frac{22}{5}}R$ c) $\frac{5}{2}R$ d) $\sqrt{\frac{12}{5}}R$

131. A gun of mass M, fires a shell of mass m horizontally and the energy of explosion is such as would be sufficient to project the shell vertically to a height $'h'$. The recoil velocity of the gun is

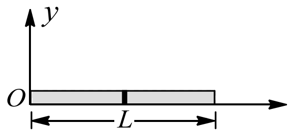
a) $\left(\frac{2m^2gh}{M(m+M)}\right)^{\frac{1}{2}}$ b) $\left(\frac{2m^2gh}{M(m-M)}\right)^{\frac{1}{2}}$ c) $\left(\frac{2m^2gh}{2M(m-M)}\right)^{\frac{1}{2}}$ d) $\left(\frac{2m^2gh}{2M(m+M)}\right)^{\frac{1}{2}}$

132. Figure shows a thin metallic triangular sheet ABC. The mass of the sheet is M. The moment of inertia of the sheet about side AC is



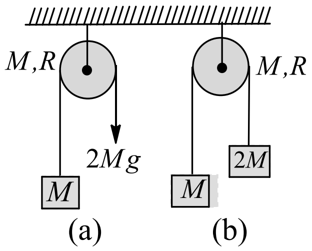
a) $\frac{Ml^2}{18}$ b) $\frac{Ml^2}{12}$ c) $\frac{Ml^2}{6}$ d) $\frac{Ml^2}{4}$

133. The figure shows a uniform rod lying along the x-axis. The locus of all the points lying on the $x - y$ plane, about which the moment of inertia of the rod is same as that O, is



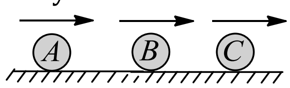
a) An ellipse b) A circle c) A parabola d) A straight line

134. A cord is wrapped on a pulley (disk) of mass M and radius R as shown in Figure. To one end of the cord, a block of mass M is connected as shown and to other end in (a) a force of 2 Mg and in (b) a block of mass $2M$. Let angular acceleration of the disk in A and B is α_A and α_B, respectively, then (cord is not slipping on the pulley)



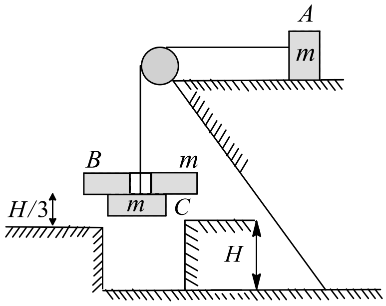
a) $\alpha_A = \alpha_B$ b) $\alpha_A > \alpha_B$ c) $\alpha_A < \alpha_B$ d) None of these

135. Three balls A, B and C of masses 2 kg, 4 kg and 8 kg, respectively, move along the same straight line and in the same direction, with velocities 4 m/s, 1 m/s and 3/4 m/s. If A collides with B and subsequently B collides with C, find the velocity of ball A and ball B after collision, taking the coefficient of restitution as unity



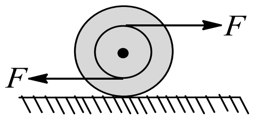
a) $V_A = 3, V_B = 9/4$
b) $V_A = 0, V_B = 3$
c) $V_A = 3, V_B = 0$
d) $V_A = 0, V_B = 0$

136. The system in fig. is released from rest from the position shown. After blocks have moved distance $H/3$, collar B is removed and block A and C continue to move. The speed of C just before it strikes the ground is



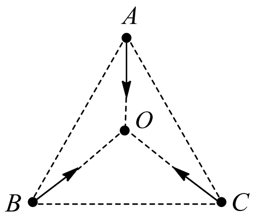
a) $\frac{4}{3}\sqrt{gH}$ b) $2\frac{\sqrt{gH}}{3}$ c) $\frac{\sqrt{13gH}}{3}$ d) $2\sqrt{2gH}$

137. A spool is pulled horizontally by two equal and opposite forces as shown in Figure. Which of the following statement are correct?



a) The centre of mass moves towards left
b) The centre of mass moves towards right
c) The centre of mass remains stationary
d) The net torque about the centre of mass of the spool is zero

138. Three particles A, B and C of equal masses move with equal speeds v along the medians of an equilateral triangle. They collide at the centroid O of the triangle. After collision A comes to rest while B retraces its path with speed v. The velocity of C is then



a) v, direction $\overrightarrow{OA}$ b) $2v$, direction $\overrightarrow{OA}$ c) $2v$, direction $\overrightarrow{OB}$ d) v, direction $\overrightarrow{BO}$

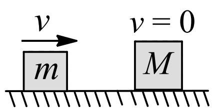
139. Two bodies with moments of inertia I_1 and $I_2 (I_1 > I_2)$ have equal angular momenta. If their kinetic energies of rotation are E_1 and E_2, respectively, then

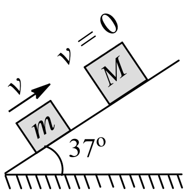
a) $E_1 = E_2$ b) $E_1 < E_2$ c) $E_1 > E_2$ d) $E_1 \geq E_2$

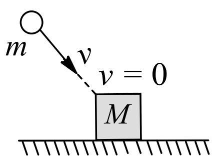
140. A bomb of mass 12 kg at rest explodes into two pieces of masses 4 kg and 8 kg. The velocity of 8 kg mass is 6 m/s. The kinetic energy of the other mass is

a) 48 J b) 32 J c) 24 J d) 288 J

141. In which of the following cases, the normal contact force between stationary block M and surface is impulsive?

a) 

b) 

c) 

d) None of these

142. When a bicycle is in motion, the force of friction exerted by the ground on the two wheels in such that it acts

a) In the backward direction on the front wheel and in the forward direction on the rear wheel
b) In the forward direction on the front wheel and in the background on the wheel
c) In the backward direction on both the front and the rear wheels
d) In the forward direction on both the front and the rear wheels

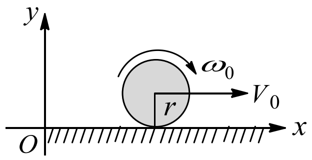
143. A pendulum consists of a wooden bob of mass m and of length l. A bullet of mass m_1 is fired towards the pendulum with a speed v_1. The bullet emerges out of the bob with a speed $v_1/3$ and the bob just completes motion along a vertical circle. Then v_1 is

a) $\left(\frac{m}{m_1}\right)\sqrt{5gl}$ b) $\frac{3}{2}\left(\frac{m}{m_1}\right)\sqrt{5gl}$ c) $\frac{2}{3}\left(\frac{m_1}{m}\right)\sqrt{5gl}$ d) $\left(\frac{m_1}{m}\right)\sqrt{gl}$

144. A ladder of length l and mass m is placed against a smooth vertical wall, but the dround is not smooth. Coefficient of friction between the ground and the ladder is μ. The angle θ at which the ladder will stay in equilibrium is

a) $\theta = \tan^{-1}(\mu)$ b) $\theta = \tan^{-1}(2\mu)$ c) $\theta = \tan^{-1}\left(\frac{\mu}{2}\right)$ d) None of these

145. A uniform sphere of mass m radius r and moment of inertia l about its centre moves along the x-axis as shown in Figure. Its centre of mass moves with velocity $= v_0$, and it rotates about its centre of mass with angular velocity $= \omega_0$. Let $\vec{L} = (I\omega_0 + mv_0r)(-k)$. The angular momentum of the body about the origin O is

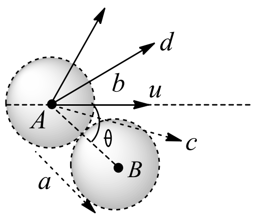


a) $\vec{L}$, only if $v_0 = \omega_0 r$
b) Greater than $\vec{L}$, if $v_0 > \omega_0 r$
c) Less than $\vec{L}$, if $v_0 > \omega_0 r$
d) $\vec{L}$, for all values of ω_0 and v_0

146. A force exerts an impulse I on a particle changing its speed from initial velocity u to final velocity $2u$. The applied force and the initial velocity are oppositely oriented along the same line. The work done by the force is

a) $\frac{3}{2}Iu$ b) $\frac{1}{2}Iu$ c) Iu d) $2Iu$

147. An elastic collision taken place between two smooth, rubber balls same radius as shown in fig. Initially, one ball is at rest and the other is moving with velocity u. At maximum compression



i. ratio of potential to initial KE of the system is $(\cos^2\theta)/2$
ii. ball B is moving along direction a
iii. ball A is moving along direction c or d
iv. value of e can not be used to finalise maximum compression velocities
Evaluate the above statements and choose the correct option from the following:
a) Statements i, ii are true and iii, iv are false
b) Statements i, ii are false and iii, iv are true
c) All statements are true
d) All statements are false

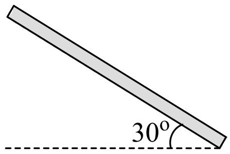
148. A ball of mass m moving with velocity v_0 makes an oblique elastic collision with a stationary ball of mass $2m$. The angle of divergence between the balls after collision in ground frame, if the ball of mass m turns by an angle of 30° in centre of mass frame is

a) $\frac{\pi}{2}$ b) $\frac{\pi}{3}$ c) $75° + \sin^{-1}\left(\frac{1}{1+\sqrt{3}}\right)$ d) $75° + \tan^{-1}\left(\frac{1}{1+\sqrt{3}}\right)$

149. A child is standing with folded hands at the centre of a platform rotating about its central axis. The kinetic energy of the system is K. The child stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is

a) $2K$ b) $\frac{K}{2}$ c) $\frac{K}{4}$ d) $4K$

150. A slender rod of mass m and length L is pivoted about a horizontal axis through one end and released from rest at an angle of 30° above the horizontal. The force exerted by the pivot on the rod are the instant when the rod passes through a horizontal position is



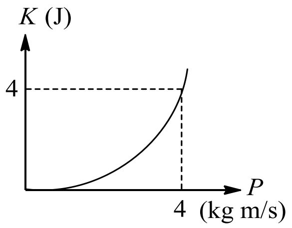
a) $\sqrt{\frac{10}{4}}mg$ along horizontal

b) mg along vertical

c) $\sqrt{\frac{10}{4}}mg$ along a line making an angle of $\tan^{-1}\left(\frac{1}{3}\right)$ with the horizontal

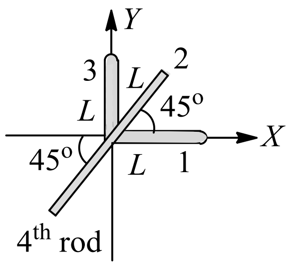
d) $\frac{\sqrt{10}}{4}mg$ along a line making an angle of $\tan^{-1}(3)$ with the horizontal

151. The graph between kinetic energy and momentum of a particle is plotted as shown in fig. The mass of the moving particle is



a) 1 kg b) 2 kg c) 3 kg d) 4 kg

152. Three identical uniform rods of the same mass M and length L are arranged in xy plane as shown in fig. A fourth uniform rod of mass $3M$ has been placed as shown in the xy plane. What should be the value of the length of the fourth rod such that the centre of mass of all the four rods lie at the origin?



a) $3L$ b) $2L$ c) $L(\sqrt{2}+1)/3$ d) $L(2\sqrt{2}+1)/3$

153. A particle of mass 2 kg moving with a velocity of 3 m/s is acted upon by a force which changes its direction of motion by an angle of 90° without changing its speed. What is the magnitude of impulse experienced by the particle?

a) 6 N s b) 2 N s c) $3\sqrt{2}$ N s d) $6\sqrt{2}$ N s

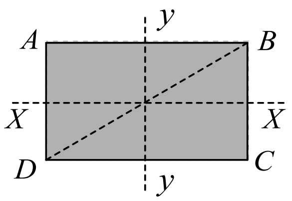
154. A sphere is rolling down an inclined plane without slipping. The ratio of rotational kinetic energy to total kinetic energy is

a) $\frac{5}{7}$ b) $\frac{2}{5}$ c) $\frac{2}{7}$ d) None of these

155. A particle of mass m moving with velocity 1 m/s collides perfectly elastically with another stationary particle of mass $2m$. If the incident particle is deflected by 90°, the heavy mass will make an angle θ with the initial direction of m equal to

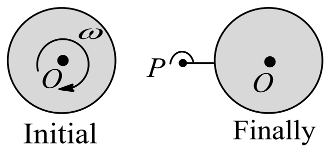
a) 60° b) 45° c) 15° d) 30°

156. In rectangle $ABCD$, $AB = 2l$ and $BC = l$. Axis xx and yy pass through the centre of the rectangle. The moment of inertia is least about



a) DB b) BC c) xx d) yy

157. A disc is freely rotating with an angular speed ω on a smooth horizontal plane. If it is hooked at a rigid page P and rotates without bouncing about a point on its circumference. Its angular speed after the impact will be equal to

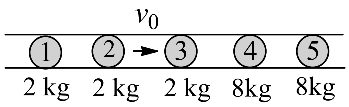


a) $\frac{2\omega}{3}$ b) $\frac{\omega}{3}$ c) $\frac{\omega}{2}$ d) None of these

158. A stationary body of mass 3 kg explodes into three equal pieces. Two of the pieces fly off at right angles to each other. One with a velocity of $2\hat{\imath}$ m/s and the other with a velocity of $3\hat{\jmath}$ m/s. If the explosion takes place in 10^{-5} s, the average force acting on the third piece in newtons is

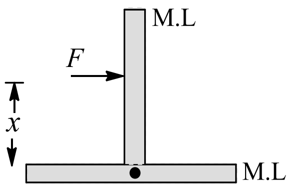
a) $(2\hat{\imath}+3\hat{\jmath})\times 10^{-5}$ b) $-(2\hat{\imath}+3\hat{\jmath})\times 10^{5}$ c) $(3\hat{\jmath}+2\hat{\imath})\times 10^{5}$ d) $(2\hat{\imath}+3\hat{\jmath})\times 10^{-5}$

159. Five balls are placed one after the other along a straight line as shown in the figure. Initially, all the balls are at rest. Then the second ball has been projected with speed v_0 towards the third ball. Mark the correct statements. (Assume all collisions to be head-on and elastic)



a) Total number of collisions in the process is 5
b) Velocity of separation between the first and fifth ball after the last possible collision is v_0
c) Finally, three balls remain stationary
d) All of the above

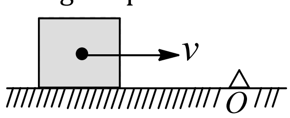
160. An inverted T-shaped object is placed on a smooth horizontal floor as shown in fig.



A force F is applied on the system as shown in fig. The value of x so that the system performs pure translational motion is

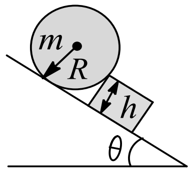
a) $\frac{L}{4}$ b) $\frac{3L}{4}$ c) $\frac{L}{2}$ d) $\frac{3L}{2}$

161. A cubical block of side a is moving with velocity v on a horizontal smooth plane as shown in Figure. It hits a ridge at point O. The angular speed of the block after it hits O is



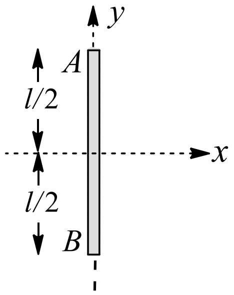
a) $\frac{3v}{4a}$ b) $\frac{3v}{2a}$ c) $\sqrt{\frac{3}{2}}a$ d) Zero

162. Find the minimum height of the obstacle so that the sphere can stay in equilibrium



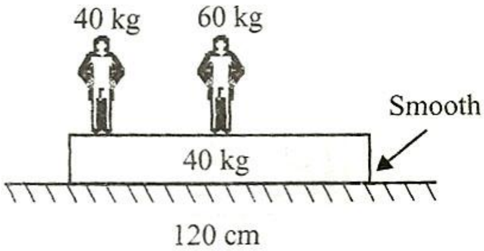
a) $\dfrac{R}{1+\cos\theta}$ b) $\dfrac{R}{1+\sin\theta}$ c) $R(1-\sin\theta)$ d) $R(1-\cos\theta)$

163. A uniform rod of mass m and length l is placed over a smooth horizontal surface along the y-axis and is at rest as shown in Figure. An impulsive force F is applied for a small time Δt along x-direction at point A. The x-coordinate of end A of the rod when the rod become parallel to x-axis for the first time is [initially, the coordinate of centre of mass of the rod is (0,0)]



a) $\dfrac{\pi l}{12}$ b) $\frac{l}{2}\left(1+\frac{\pi}{12}\right)$ c) $\frac{1}{2}\left(1-\frac{\pi}{6}\right)$ d) $\frac{l}{2}\left(1+\frac{\pi}{6}\right)$s

164. Two men 'A' and 'B' are standing on a plank. 'B' is at the middle of the plank and `$A'$ is at the left end of the plank. Lower surface of the plank is smooth. System is initially at rest and masses are as shown in fig. '$A$' and '$B$' start moving such that the position of `B' remains fixed with respect to ground, then 'A' meets 'B'. Then the point where A meets B is located at



a) The middle of the plank
b) 30 cm from the left end of the plank
c) The right end of the plank
d) None of these

165. Two particles of equal masses have velocities $\vec{v}_1 = 3\hat{\imath}$ m/s and $\vec{v}_2 = 2\hat{\jmath}$ m/s at any instant. The first particle has a constant acceleration $\vec{a}_1 = (3\hat{\imath} + 3\hat{\jmath})\text{m/s}^2$ while the acceleration of the other particle is zero. The centre of mass of the two particles moves in a

a) Circle b) Parabola c) Straight line d) Ellipse

166. A stationary body explodes into four identical fragments such that three of them fly off mutually perpendicular to each other, each with same KE, E_0. The energy of explosion will be

a) $6E_0$ b) $\dfrac{4E_0}{3}$ c) $4E_0$ d) $8E_0$

167. A ball falls under gravity from a height of 10 m with an initial downward velocity v_0. It collides with the ground, loses 50% of its energy in collision and then rises back to the same height. Find (i) the initial velocity v_0 and (ii) the height to which the ball would rise after collision if the initial velocity v_0 was directed upwards instead of downwards?

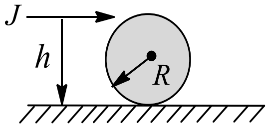
a) 14 m/s, 5m b) 14 m/s, 10m c) 7 m/s, 5m d) 7 m/s, 10m

168. A man stands at one end of the open truck which can run on frictionless horizontal rails. Initially, the man and the truck are at rest. Man now walks to the other end and stops. Then which of the following is true?

a) The truck moves opposite to direction of motion of the man even after the man ceases to walk
b) The centre of mass of the man and the truck remains at the same point throughout the man's walk
c) The kinetic energy of the man and the truck are exactly equal throughout the man's walk

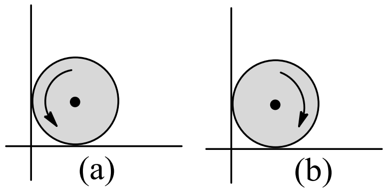
d) The truck does not move at all during the man's walk

169. A solid sphere of mass M and radius R is placed on a rough horizontal surface. It is struck by a horizontal cuestick at a height h above the surface. The value of h so that the sphere performs pure rolling motion immediately after it has been struck is



a) $\frac{2R}{5}$ b) $\frac{5R}{2}$ c) $\frac{7R}{5}$ d) $\frac{9R}{5}$

170. A sphere is placed rotating with its centre initially at rest in a corner as shown in figures (a) and (b). Coefficient of friction between all surfaces and the sphere is 1/3. Find the ratio of the friction forces f_a/f_b by ground in situation (a) and (b)

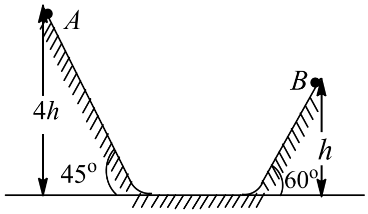


a) 1 b) $\frac{9}{10}$ c) $\frac{10}{9}$ d) None of these

171. A particle of mass m travelling with velocity v and kinetic energy E collides elastically to another particle of mass nm, at rest. What is the fraction of total energy retained by the particle of mass m?

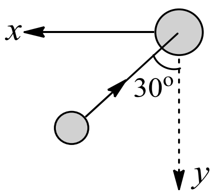
a) $\left(\frac{n+1}{n}\right)^2$ b) $\left(\frac{n+1}{n-1}\right)^2$ c) $\left(\frac{n-1}{n+1}\right)^2$ d) None of these

172. Two identical balls A and B are released from the position shown in fig. They collide elastically with each other on the horizontal portion. The ratio of heights attained by A and B after collision is (neglect friction)



a) 1:4 b) 2:1 c) 4:13 d) 2:5

173. A hockey player receives a corner shot at a speed of 15 m/s at angle 30° with y-axis and then shoots the ball along x-axis with the speed 30 m/s. If the mass of the ball is 150 g and it remains in contact with the hockey stick for 0.01 s, the force exerted on the ball along x-axis is



a) 281 N b) 187.5 N c) 562.5 N d) 375N

174. A body dropped from a tower explodes into two pieces of equal mass in mid-air. Which of the following is not possible?

a) Each part will follow parabolic path
b) Only one part will follow parabolic path
c) Both parts move along a vertical line
d) One part reaches the ground earlier than the other

175. A ball is dropped from a height of 45 m from the ground. The coefficient of restitution between the ball and the ground is 2/3. What is the distance travelled by the ball in 4th second of its motion. Assume negligible time is spent in rebounding. Let $g = 10 \text{ m s}^2$

a) 5 m b) 20 m c) 15 m d) 10 m

176. A particle of mass m is moving horizontally with a constant velocity v towards a rigid wall that is moving in opposite direction with a constant speed . Assuming elastic impact between the particle and wall, the work done by the wall in reflecting the particle is equal to

a) $(1/2)\ m(u+v)^2$

b) $(1/2)\ m(u+v)$

c) $(1/2)\ muv$

d) None of these

177. A particle of mass $4m$ is projected from the ground at some angle with horizontal. Its horizontal range is R. At the highest point of its path it breaks into two pieces of masses m and $3m$, respectively, such that the smaller mass comes to rest. The larger mass finally falls at a distance x from the point of projection, where x is equal to

a) $\frac{2R}{3}$ b) $\frac{7R}{6}$ c) $\frac{5R}{4}$ d) None of these

178. A body X with a momentum p collides with another identical statonary body Y one dimensionally. During the collision, Y gives an impulse J to body X. Then coefficient of restitution is

a) $\frac{2J}{p}-1$ b) $\frac{J}{p}+1$ c) $\frac{J}{p}-1$ d) $\frac{J}{2p}-1$

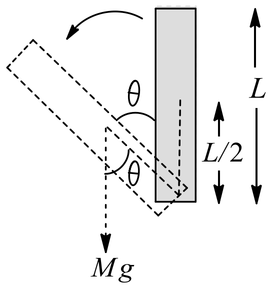
179. A shell is fired from a cannon with velocity v m/s at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon, then the speed in m/s of the other piece immediately after the explosion is

a) $3v\cos\theta$ b) $2v\cos\theta$ c) $\frac{3v}{2}\cos\theta$ d) $\frac{\sqrt{3}v\cos\theta}{2}$

180. In problem 5, the moment of inertia of the system about an axis passing through the point of intersection of diagonals and perpendicular to the plane of the square is

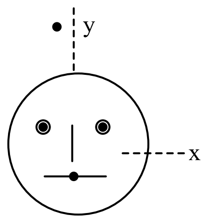
a) $\frac{4Ml^2}{3}$ b) $\frac{13Ml^2}{3}$ c) $\frac{Ml^2}{6}$ d) $\frac{13Ml^2}{6}$

181. A uniform rod of M and length L is pivoted at one end such that it can rotate in a vertical plane. There is negligible friction at the pivot. The free end of the rod is held vertically above the pivot and then released. The angular acceleration of the rod when it makes an angle θ with the vertical is



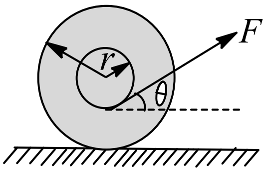
a) $g\sin\theta$ b) $\frac{g}{L}\sin\theta$ c) $\frac{3g}{2L}\sin\theta$ d) $6\ gL\sin\theta$

182. Look at the drawing given in the figure, which has been drawn with ink of uniform line-thickness. The mass of ink used to draw each of the two inner circles, and each of the two line segments is m. The mass of ink used to draw the outer circle is $6m$. The coordinates of the centres of the different parts are : outer circle (0, 0) left inner circle ($-a, a$), right inner circle (a, a) vertical line (0, 0) and horizontal line (0, $-a$). The y- coordinate of the centre of mass of the ink in the drawing is



a) $\frac{a}{10}$ b) $\frac{a}{8}$ c) $\frac{a}{12}$ d) $\frac{a}{3}$

183. The spool shown in the figure is placed on a rough horizontal surface and has inner radius r and outer radius R. The angle θ between the applied force and the horizontal can be varied. The critical angle (θ) for which the spool does not roll and remains stationary is given by



a) $\theta = \cos^{-1}\left(\frac{r}{R}\right)$ b) $\theta = \cos^{-1}\left(\frac{2r}{R}\right)$ c) $\theta = \cos^{-1}\sqrt{\frac{r}{R}}$ d) $\theta = \sin^{-1}\left(\frac{r}{R}\right)$

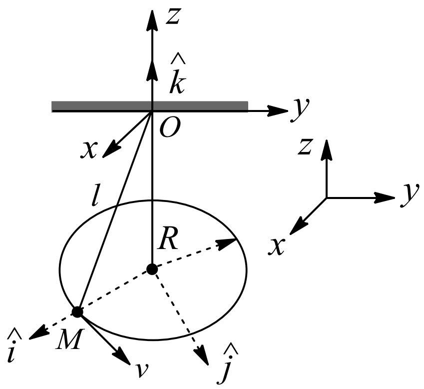
184. Angular momentum of a particle about a stationary point O varies with time as $\vec{L} = \vec{a} \times \vec{b}t^2$ where $\vec{a}$ and $\vec{b}$ are constant vectors with $\vec{a}$ perpendicular to $\vec{b}$. The torque $\vec{\tau}$ acting on the particle when angle between $\vec{\tau}$ and $\vec{L}$ is 45° is

a) $\sqrt{\frac{a}{b}} \times \vec{b}$ b) $2\sqrt{\frac{b}{a} \times \vec{b}}$ c) $\sqrt{\frac{a}{b}}$ d) None of these

185. A shell explodes and many pieces fly off in different directions. Which of the following is conserved?

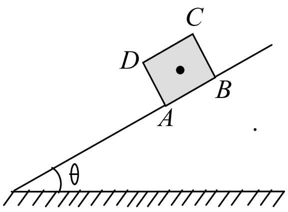
a) Kinetic energy b) Momentum
c) Neither momentum nor KE d) Momentum and KE

186. A conical pendulum consists of a mass M suspended from a strong sling of length l. The mass executes a circle of radius R in a horizontal plane with speed v. At time t, The mass is at position $R\hat{\imath}$ and has $v\hat{\jmath}$ velocity. At time t, the angular momemtum vector of mass M about the point from which the string passes on the ceiling is



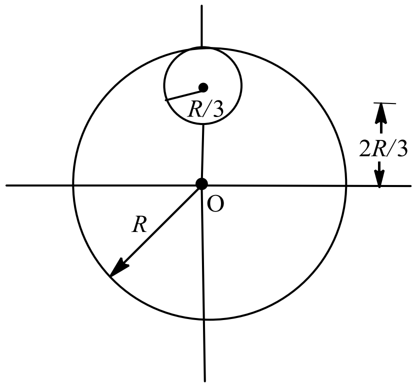
a) $Mv R\hat{k}$ b) $Mvl\hat{k}$
c) $Mvl\left[\sqrt{\frac{l^2 - R^2}{l}}\hat{\imath} + \frac{R}{l}\hat{k}\right]$ d) $-Mvl\left[\sqrt{\frac{l^2 - R^2}{l}}\hat{\imath} + \frac{R}{l}\hat{k}\right]$

187. A cube of side a is placed on an inclined plane of inclination θ. What is the maximum value of θ for which the cube will not topple?



a) 15° b) 30° c) 45° d) 60°

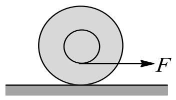
188. From a circular disc of radius R and mass 9 M, a small disc of radius $R/3$ is removed from the disc. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through O is



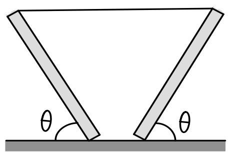
a) $4\ MR^2$ b) $\frac{40}{9}\ MR^2$ c) $10\ MR^2$ d) $\frac{37}{9}\ MR^2$

189. Two identical billiard balls undergo an oblique elastic collision. Initially, one of the balls is stationary. If the initially stationary ball after collision moves in a direction which makes an angle of 37° with direction of initial motion of the moving ball, then the angle through which initially moving ball will be deflected is
a) 37° b) 60° c) 53° d) $> 53°$

190. A yo-yo, arranged as shown, rests on a frictionless surface. When a forces F is applied to the string, the yo-yo
a) Moves to the left and rotates counterclockwise
b) Moves to the right and rotates counterclockwise
c) Moves to the left and rotates clockwise
d) Moves to the right and rotates clockwise



191. Two uniform boards, tied together with the help of a string, are balanced on a surface as shown in Fig

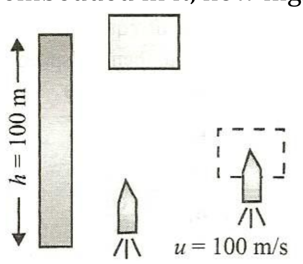


The coefficient of static friction between boards and surface is 0.5. The minimum value of θ, for which this type of arrangement is possible is
a) 30°
b) 45°
c) 37°
d) It is not possible to have this type of balanced arrangement

192. The tension in the cord in problem 29 is
a) $\frac{mg}{M+m}$ b) $\frac{mg}{M+2m}$ c) $\frac{2mg}{Mmg}$ d) None of these

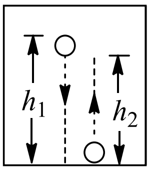
193. Two particle A and B, initially at rest, move towards each other under a mutual force of attraction. At the instant when the speed of A is V and the speed of B is $2V$, the speed of the centre of mass of the system is
a) $3V$ b) V c) $1.5V$ d) Zero

194. A wooden block of mass 10 g is dropped from the top of a tower 100 m high. Simultaneously, a bullet of mass 10 g is fired from the foot of the tower vertically upwards with a velocity of 100 m/s. If the bullet is embedded in it, how high will the block rise above the top of tower before it starts falling?($g = 10\ m/s^2$)



a) 75 m b) 85 m c) 80 m d) 10 m

195. A ball of mass m is released from rest relative to elevator at a height h_1 above the floor of the elevator. After making collision with the floor of the elevator it rebounces to height h_2. The coefficient of restitution for collision is e. For this situation, mark the correct statement(s)



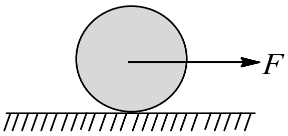
a) If elevator is moving down with constant velocity v_0, then $h_2 = e^2 h_1$

b) If elevator is moving down with constant velocity v_0, then $h_2 = e^2 h_1 - \frac{v_0^2}{2g}$

c) If elevator is moving down with constant velocity v_0, then impulse imparted by floor of the elevator to the ball is $m(\sqrt{2gh_2} + \sqrt{2gh_1} + 2v_0)$ in the upward direction

d) If elevator is moving with constant acceleration of g/4 in upward direction, then it is not possible to determine a relation between h_1 and h_2 from the given information

196. A solid sphere of mass m is lying at rest on a rough horizontal surface. The coefficient of friction between the ground and sphere is μ. The maximum value of F, so that the sphere will not slip, is equal to

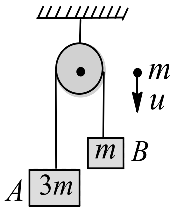


a) $\frac{7}{5}\mu mg$ b) $\frac{4}{7}\mu mg$ c) $\frac{5}{7}\mu mg$ d) $\frac{7}{2}\mu mg$

197. In problem 8, the ratio of the final velocity of the second ball to the initial velocity of the first ball is

a) $\frac{1-e}{1+e}$ b) $\frac{1+e}{1-e}$ c) $\frac{1+e}{2}$ d) $\frac{1-e}{2}$

198. A system of two blocks A and B are connected by an inextensible massless string as shown in fig. The pulley is massless and frictionless. Initially, the system is at rest. A bullet of mass `$m$' moving with a velocity `u' as shown hits block `B' and gets embedded into it. The impulse imparted by tension force to the block of mass $3m$ is

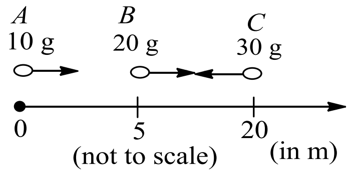


a) $\frac{5mu}{4}$ b) $\frac{4mu}{5}$ c) $\frac{2mu}{5}$ d) $\frac{3mu}{5}$

199. A body of mass 2 kg moving with a velocity of 6 m/s strikes in inelastically another body of same mass at rest. The amount of heat evolved during collision is

a) 36 J b) 18 J c) 9 J d) 3 J

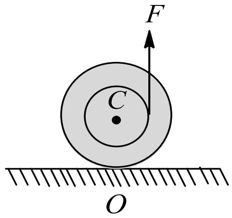
200. Figure shows three particles A, B and C on the x-axis. They are given velocities of $v_1 = 3$ m/s, $v_2 = 2$ m/s and $v_3 = 5$ m/s, respectively, in the directions shown. The position of centre of mass of A, B and C at time $t = 1$ s will be



a) $x = 11\frac{2}{3}$ m b) $x = 15\frac{1}{3}$ m c) $x = 10\frac{1}{3}$ m d) $x = 10\frac{2}{3}$ m

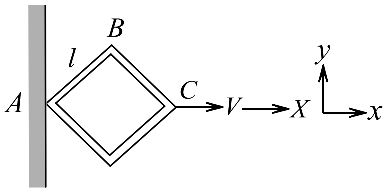
201. A yo-yo is placed on a rough horizontal surface and a constant force F, which is less than its weight, pulls it

vertically. Due to this



a) Friction force acts towards left, so it will move towards left
b) Friction force acts towards right, so it will move towards right
c) It will move towards left, so friction acts towards left
d) It will move towards right so friction force acts towards right

202. Four rods of side length l have been hinged to form a rhombus. Vertex A is fixed to a rigid support, vertex C is being moved aling the x-axis with constant velocity V as shown in Figure. The rate at which vertex B is nearing the x-axis at the moment the rhombus is in the form of a square is



a) $\frac{V}{4}$ b) $\frac{V}{\sqrt{2}}$ c) $\frac{V}{2}$ d) $\frac{V^2}{g}$

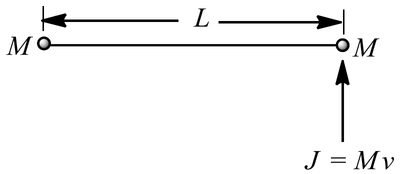
203. A small solid sphere of radius r rolls down an incline without slipping which ends into a vertical loop of radius R. Find the height above the base so that it just loops the loop

a) $\frac{5}{2}R$ b) $\frac{5}{2}(R-r)$ c) $\frac{25}{10}(R-r)$ d) $\frac{27}{10}R-\frac{17r}{10}$

204. Two blocks of masses 6 kg and 4 kg are attached to the two ends of a massless string passing over a smooth fixed pulley. If the system is released, the acceleration of the center of mass of the system will be

a) g, vertically downwards
b) g/5, vertically downwards
c) g/25, vertically downwards
d) Zero

205. Consider a body, shown in figure, consisting of two identical balls, each of mass M connected by a light rigid rod. If an impulse$J = Mv$ is impared to the body at one of its ends, what would be its angular velocity?



a) v/L b) $2v/L$ c) $v/3L$ d) $v/4L$

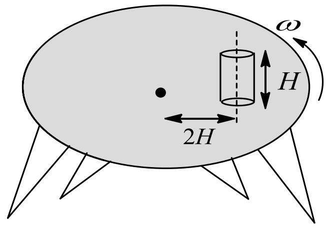
206. A solid cylinder of mass M and radius R is resting on a horizontal platform (which is parallel to the x-y plane) with its axis fixed along Y-axis and free to rotate about its axis. The platform is given a motion in the X-direction given by $= A\cos(\omega t)$. There is no slipping between the cylinder and the platform. The maximum torque acting on the cylinder during its motion is

a) $\frac{M\omega^2 AR}{3}$
b) $\frac{M\omega^2 AR}{2}$
c) $\frac{2}{3}\times M\omega^2 AR$
d) The situation is not possible

207. The first ball of mass m moving with a velocity u collides head on with the second ball of mass m at rest. If the coefficient of restitution is e, then the ratio of the velocities of the first and the second ball after the collision is

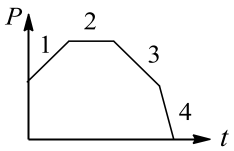
a) $\frac{1-e}{1+e}$ b) $\frac{1+e}{1-e}$ c) $\frac{1+e}{2}$ d) $\frac{1-e}{2}$

208. A cylinder of height H and diameter $H/4$ is kept on a frictional turntable as shown in Figure. The axis of the cylinder is perpendicular to the surface of the table and the distance of axis of the cylinder is $2H$ from the centre of the table. The angular speed of the turntable at which the cylinder will start toppling (assume that friction is sufficient to prevent slipping) is



a) $\sqrt{\frac{g}{2}\left(\frac{1}{2}-H\right)}$ b) $\sqrt{g\left(\frac{1}{2}-H\right)}$ c) $\sqrt{\frac{g}{4H}}$ d) $\sqrt{\frac{g}{8H}}$

209. A particle moves along the x-axis. The x-component of its mometum as a function of time is shown in fig. Rank the numbered regions according to the magnitude of the force acting on the particle from the least to the greatest

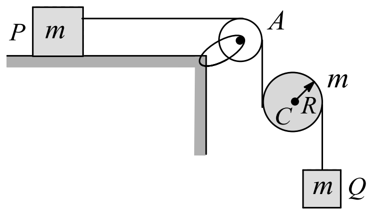


a) 1,2,3,4 b) 2,3,1,4 c) 2,3,4,1 d) 2,4,3,1

210. A uniform rod of mass m, length l rests on a smooth horizontal surface. Rod is given a sharp horizontal impulse p perpendicular to the rod at a distance $l/4$ from the centre. The angular velocity of the rod will be

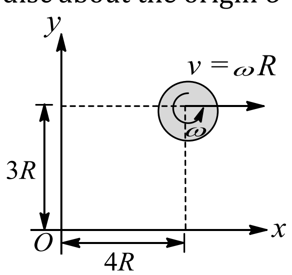
a) $\frac{3p}{ml}$ b) $\frac{p}{ml}$ c) $\frac{p}{2ml}$ d) $\frac{2p}{ml}$

211. Two blocks each of mass m and a cylinder C are connected as shown in Figure. Angular acceleration of the cylinder C of radius R is (all strings and pulley are ideal)



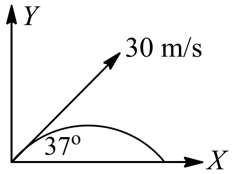
a) $\frac{2g}{3R}$ b) $\frac{2g}{5R}$ c) $\frac{2g}{R}$ d) $\frac{g}{2R}$

212. A disc of mass m and radius R moves in the $x-y$ plane as shown in Figure. The angular momentum of the disc about the origin O at the instant shown is



a) $-\frac{5}{2}mR^2\omega\hat{k}$ b) $\frac{7}{3}mR^2\omega\hat{k}$ c) $-\frac{9}{2}mR^2\omega\hat{k}$ d) $\frac{5}{2}mR^2\omega\hat{k}$

213. An object of mass 10 kg is launched from the ground at $t = 0$, at an angle of 37° above the horizontal with a speed of 30 m/s. At some time after its launch, an explosion splits the projectile into two pieces. One piece of mass 4 kg is observed at (105 m, 43 m) at $t = 2$ s. Find the location of second piece at $t = 2$ s?



a) (10, 2) b) (48, 16)
c) (10, −2) d) Information insufficient

214. A particle of mass m is made to move with uniform speed v_0 along the perimeter of a regular hexagon, inscribed in a circle of radius R. The magnitude of impulse applied at each corner of the hexagon is

a) $2\,mv_0\sin\frac{\pi}{6}$ b) $mv_0\sin\frac{\pi}{6}$ c) $mv_0\sin\frac{\pi}{3}$ d) $2mv_0\sin\frac{\pi}{3}$

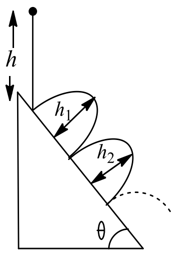
215. A ball collides elastically with another ball of the same mass. The collision is oblique and initially one of the balls was at rest. After the collision, the two balls move with same speed. What will be the angle between the velocities of the balls after the collision?

a) 60° b) 45° c) 60° d) 90°

216. In problem 35, work done on the cylinder for reaching an angular speed ω is

a) $\frac{MR^2\omega^2}{4}$ b) $\frac{MR^2\omega^2}{2}$ c) $\frac{MR^2\omega^2}{3}$ d) $\frac{2MR^2\omega^2}{3}$

217. A ball falls on an inclined plane as shown in Fig. The ball is dropped from height h. Coefficient of restitution for collision is e and the surface is frictionless. If $h_1, h_2, \dots, h_n$ are heights of n projectiles and $t_1, t_2, \dots, t_n$ are their corresponding time of flights, then



1. $t_1, t_2, \dots, t_n$ form a geometric progression of common ratio e
2. $h_1 > h_2 > h_3 \dots > h_n$
3. $t_1, t_2, \dots, t_n$ form a geometric progression of common ratio e
4. $h_1, h_2, \dots, h_n$ form a geometric progression of common ratio e

Evaluate the above statements and choose the correct option from the following

a) Statements i, ii are true and iii, iv are false

b) Statements i, ii, are false and iii, iv are true

c) All statements are true

d) All statements are false

218. After a totally inelastic collision, two object of the same mass and same initial speeds are found to move together at half of their initial speeds. The angle between the initial velocities of the object is

a) 120° b) 60° c) 150° d) 45°

219. If a spherical ball rolls on a table without slipping, the fraction of its total energy associated with rotation is

a) $\frac{3}{5}$ b) $\frac{2}{7}$ c) $\frac{2}{5}$ d) $\frac{3}{7}$

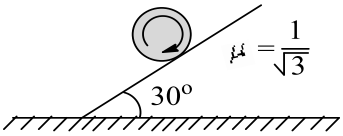
220. A sphere is released on a smooth inclined plane from the top. When it moves down, its angular momentum is

a) Conserved about every point
b) Conserved about the point of contact only

c) Conserved about the centre of the sphere only

d) Conserved about any point on a line parallel to the inclined plane and passing through the centre of the ball

221. A disc is rotated about its axis with a certain angular velocity and lowered gently on a rough inclined plane as shown in Figure, then



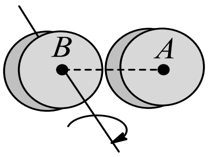
a) It will rotate at the position where it was placed and then will move downwards

b) It will go downwards just after it is lowered

c) It will go downwards first and then climb up

d) It will climb upwards and then move downwards

222. Two thin discs, each of mass M and radius r m, are attached as shown in Figure, to form a rigid body. The rotional inertia of this body about an axis perpendicular to the plane of disc B passing through its centre is

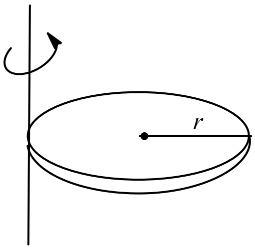


a) $2Mr^2$ b) $3Mr^2$ c) $4Mr^2$ d) $5Mr^2$

223. A train of mass M is moving on a circular tracke of radius 'R' with constant speed V. The length of the train is half of the perimeter of the track. The linear momentum of the train will be

a) 0 b) $\frac{2MV}{\pi}$ c) MVR d) MV

224. A solid sphere of radius R has moment of inertia I about its geometrical axis. If it is melted into a disc of radius r and thickness t. If its moment of inertia about the tangential axis (which is perpendicular to plane of the disc), is also equal to I, then the value of r is equal to



a) $\frac{2}{\sqrt{15}} R$ b) $\frac{2}{\sqrt{5}} R$ c) $\frac{3}{\sqrt{15}} R$ d) $\frac{\sqrt{3}}{\sqrt{15}} R$

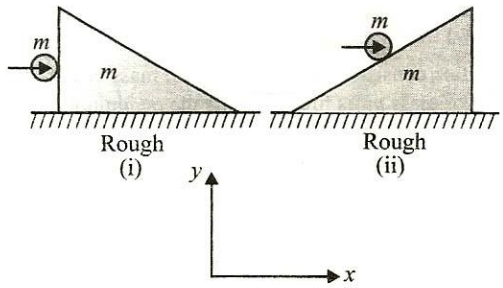
225. In problem 8, the ratio of the final and initial velocities of the first ball is

a) $\frac{1-e}{1+e}$ b) $\frac{1+e}{1-e}$ c) $\frac{1+e}{2}$ d) $\frac{1-e}{2}$

226. A strip of wood of mass M and length l is placed on a smooth horizontal surface. An insect of mass m starts at one end of the strip and walks to the other end in time t, moving with a constant speed. The speed of the insect as seen from the ground is

a) $\frac{l}{t}\left(\frac{M}{M+m}\right)$ b) $\frac{l}{t}\left(\frac{m}{M+m}\right)$ c) $\frac{l}{t}\left(\frac{M}{m}\right)$ d) $\frac{l}{t}\left(\frac{m}{M}\right)$

227. A ball of mass m collides horizontally with a stationary wedge on a rough horizontal surface, in the two orientations as shown. Neglect friction between the ball and the wedge. The student comment on the system of ball and wedge in these situations



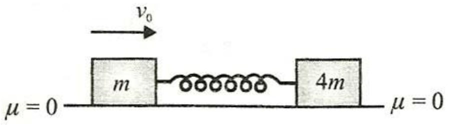
Saurav: Momentum of the system in x- direction will change by significant amount in both the cases
Rahul: There are no impulsive external forces in x- direction in both cases; hence the total momentum of the system in x- direction can be treated as conserved in both cases

a) Saurav is incorrect and Rahul is correct
b) Saurav is correct and Rahul is incorrect
c) Both are correct
d) Both are incorrect

228. A body of mass 3 kg moving with a velocity of 4 m/s towards left collides head on with a body of mass 4 kg moving in opposite direction with a velocity of 3 m/s. After collision the two bodies stick together and move with a common velocity which is

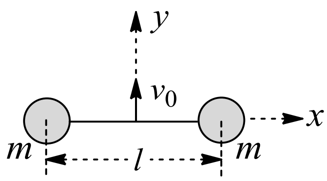
a) Zero
b) 12 m/s towards left
c) 12 m/s towards right
d) $\frac{12}{7}$ m/s towards left

229. Two blocks of masses m and $4m$ lie on a smooth horizontal surface connected with a spring in its natural length. Mass m is given velocity v_0 through an impulse as shown in fig. Which of the following is *not true* about subsequent motion?



a) Kinetic energy is maximum in ground frame and centre of mass (CM) frame simultaneously
b) Value of maximum and minimum kinetic energy is same in CM and ground frame
c) Minimum kinetic energy is zero in CM frame but non-zero in ground frame
d) Maximum and minimum kinetic energy of m in ground frame is, respectively, $\frac{1}{2}mv_0^2$ and zero

230. Two identical small balls, each of mass m, are connected by a massless and inextensible string of length l and placed on a smooth horizontal xy plane. An external agent starts pulling the string from its mid-point along y-axis with velocity v_0 as shown in Fig. When the separation between the two balls reduces to $l/2$, then the speed of each ball will be

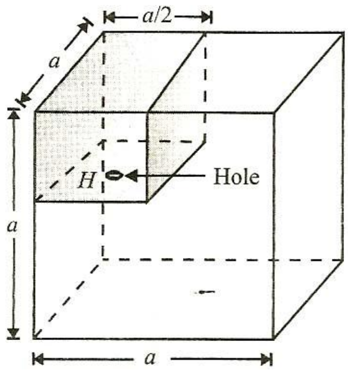


a) $2v_0$
b) v_0
c) $\frac{v_0}{2}$
d) None of the above

231. A ball falls vertically onto a floor with momentum p, and then bounces repeatedly. If the coefficient of restitution is e, then the total momentum imparted by the ball on the floor till the ball comes to rest is

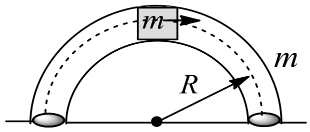
a) $p(1+e)$
b) $\frac{p}{1-e}$
c) $p\left(1+\frac{1}{e}\right)$
d) $p\left(\frac{1+e}{1-e}\right)$

232. Figure a hollow cube of side `a' and volume 'V'. There is a small chamber of volume $V/4$ in the cube as shown. The chamber is completely filled by m kg of water. Water leaks through a hole H and spreads in the whole cube. Then the work done by gravity in this process assuming that the complete water finally lies at the bottom of the cube is



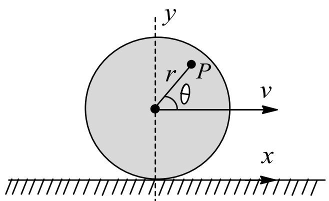
a) $\frac{1}{2}mg\,a$ b) $\frac{3}{8}mg\,a$ c) $\frac{5}{8}mg\,a$ d) $\frac{1}{8}mg\,a$

233. In a vertical plane inside a smooth hollow thin tube, a block of same mass as that of tube is released as shown in fig. When it is slightly disturbed it moves towards right. By the time the block reaches the right end of the tube, the displacement of the tube will be (where 'R' is the mean radius of the tube, assume that the tube remains in vertical plane)



a) $\frac{2R}{\pi}$ b) $\frac{4R}{\pi}$ c) $\frac{R}{2}$ d) R

234. A disc radius R rolls without slipping at speed v along positive x-axis. Velocity of point P at the instant shown in Figure is



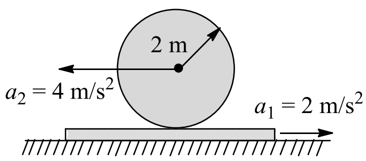
a) $\vec{V}_p = \left(v + \frac{vr\sin\theta}{R}\right)\hat{\imath} + \frac{vr\cos\theta}{R}\hat{\jmath}$

b) $\vec{V}_p = \left(v + \frac{vr\sin\theta}{R}\right)\hat{\imath} - \frac{vr\cos\theta}{R}\hat{\jmath}$

c) $\vec{V}_p = \frac{vr\sin\theta}{R}\hat{\imath} + \frac{vr\cos\theta}{R}\hat{\jmath}$

d) $\vec{V}_p = \frac{vr\sin\theta}{R}\hat{\imath} - \frac{vr\cos\theta}{R}\hat{\jmath}$

235. In Figure, a sphere of radius 2 m rolls on a plank. The acceleration of the sphere and the plank are indicated. The value of a is



a) 2 rad/s^2 b) 4 rad/s^2 c) 3 rad/s^2 d) 1 rad/s^2

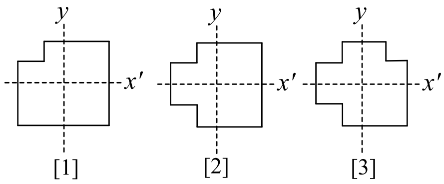
236. A plastic ball is dropped from a height of 1 m and rebounds several times from the floor. If 1.03 s elapse from the moment it is dropped to the second impact with the floor, what is the coefficient of restitution?

a) 0.03 b) 0.64 c) 0.02 d) 0.05

237. A continuous stream of particles, of mass m and velocity v, is emitted from a source at a rate of n per second. The particles travel along a straight line, collide with a body of mass M and get embedded in the body. If the mass M was originally at rest, its velocity when it has received N particles will be

a) $\frac{mvN}{Nm+n}$ b) $\frac{mvN}{Nm+M}$ c) $\frac{mv}{Nm+M}$ d) $\frac{Nm+M}{Nm}$

238. A machinist starts with three identical square plates but cuts one corner from one of them, two corners from the second and three corners from the third. Rank the three according to the x-coordinate of their centre of mass, from smallest to largest



a) 3,1,2　　b) 1,3,2　　c) 3,2,1　　d) 1 and 3 tie, then 2

239. A particle of mass $2m$ is projected at an angle of 45° with the horizontal with a velocity of $20\sqrt{2}$ m/s. After 1 s of explosion, the particle breaks into two equal pieces. As a result of this one part comes to rest. The maximum height from the ground attained by the other part is ($g = 10 \text{ m/s}^2$)

a) 50 m　　b) 25 m　　c) 40 m　　d) 35 m

240. A ball moving with a velocity of 6 m/s strikes an identical stationary ball. After collision each ball moves at an angle of 30° with the original line of motion. What are the speeds of the balls after the collision?

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

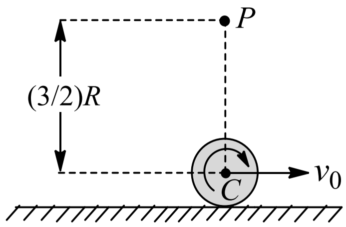
241. A ball of mass m is projected with a speed v into the barrel of a spring gun of mass M initially at rest lying on a frictionless surface. The mass sticks in the barrel at the point of maximum compression in the spring. The fraction of kinetic energy of the ball stored in the spring is

a) $\frac{m}{M}$　　b) $\frac{M}{m+M}$　　c) $\frac{m}{M+M}$　　d) None of the these

242. In an inelastic collision

a) momentum is conserved but kinetic energy is not conserved
b) momentum is not conserved but kinetic energy is conserved
c) neither momentum nor kinetic energy is conserved
d) both momentum and kinetic energy are conserved

243. A disc of mass M and radius R rolls without slipping on a horizontal surface. If the avelocity of its centre is v_0, then the total angular momentum of the disc about a fixed point P at a height $3/2\ R$ above the centre C

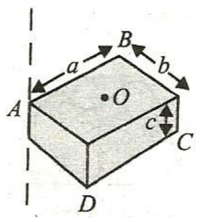


a) Increases continuously as the disc moves away
b) Decreases continuously as the moves away
c) Is equal to $2MR_{v_0}$
d) Is equal to MR_{v_0}

244. Seven identical eagles are flying south together at constant speed. A hunter shoots one of them, which immediately dies and falls on the ground. The other six continue flying south at the original speeds. After one eagle has hit the ground, the centre of mass of all the seven eagles

a) Continues south at the original speed, but is now located at some distance below the flying eagles
b) Continues south but at 6/7 of the original speed and is located at some distance below the flying eagles
c) Continues south but at 6/7 of the original speed and is located at some distance behind and below the flying eagles
d) Continues south but at 6/7 of the original speed and is located at the original location

245. Figure shows a uniform solid block of mass M and edge lengths a, b and c. Its M.I. about an axis through one edge and perpendicular (as shown) to the large face of the block is

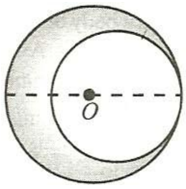


a) $\frac{M}{3}(a^2+b^2)$ b) $\frac{M}{4}(a^2+b^2)$ c) $\frac{7M}{12}(a^2+b^2)$ d) $\frac{M}{12}(a^2+b^2)$

246. A ring of radius R rolls without sliding with a constant velocity. The radius of curvature of the path followed by any particle of the ring at the highest point of its path will be
a) R b) $2R$ c) $4R$ d) None of these

247. A ring, cylinder and solid sphere are placed on the top of a rough incline on which the sphere can just roll without slipping. When all of them are released at the same instant from the same position, then
a) All of them reach the ground at the same instant
b) The sphere reaches first and the ring at the last
c) The sphere reaches first and the cylinder and ring reach together
d) None of the above

248. A circular plate of uniform thickness has a diameter of 28 cm. A circular portion of diameter 21 cm is removed from the plate as shown. O is the centre of mass of complete plate. The position of centre of mass of remaining portion will shift towards left from $'O'$ by

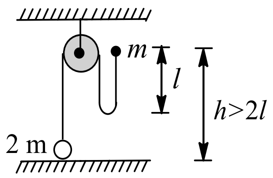


a) 5 cm b) 9 cm c) 4.5 cm d) 5.5 cm

249. A railway flat car has an artillery gun installed on it. The combined system has a mass M and moves with a velocity V. The barrel of the gun makes an angle α with the horizontal. A shell of mass m leaves the barrel at a speed v relative to the barrel. The speed of the flat car so that it may stop after the firing is
a) $\frac{mv}{M+m}$ b) $\left(\frac{Mv}{M+m}\right)\cos\alpha$ c) $\left(\frac{mv}{M+m}\right)\cos\alpha$ d) $(M+m)v\cos\alpha$

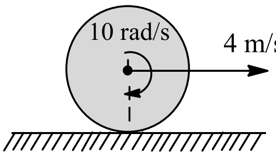
250. A slender rod of mass M and length L rests on a horizontal frictionless surface. The rod is pivoted about one of its ends. The impulse of the force exerted on the rod by the pivot when the rod is struck by a blow of impulse J perpendicular to the rod at other end is
a) J
b) $\frac{J}{2}$
c) $\frac{J}{3}$
d) Information is insufficient

251. In fig., a heavy ball of mass 2 m rests on the horizontal surface and the lighter ball of mass m is dropped from a height $h > 2l$. At the instant the string gets taut, the upward velocity of the heavy ball will be



a) $\frac{2}{3}\sqrt{gl}$ b) $\frac{4}{3}\sqrt{gl}$ c) $\frac{1}{3}\sqrt{gl}$ d) $\frac{1}{2}\sqrt{gl}$

252. A disc of radius 0.2 m is rolling with slipping on a flat horizontal surface, as shown in Fig. The instantaneous centre of rotation is (the lowest contact point is O and centre of disc is C)



a) Zero
b) 0.1 m above O on line OC
c) 0.2 m below O on line OC
d) 02 m above O on line OC

253. A stationary body explodes into two fragments of masses m_1 and m_2. If momentum of one fragments is p, the energy of explosion is

a) $\frac{p^2}{2(m_1+m_2)}$
b) $\frac{p^2}{2\sqrt{m_1 m_2}}$
c) $\frac{p^2(m_1+m_2)}{2m_1 m_2}$
d) $\frac{p^2}{2(m_1-m_2)}$

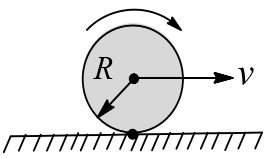
254. A mass of 2.9 kg is suspended from a string of length 50 cm and is at rest. Another body of mass 100 g which is moving horizontally with a velocity of 150 m/s strikes it. After striking the two bodies combine together. The tension in the string, when it makes an angle of 60° with the vertical is (Take g = 9.8 m/s^2)

a) 135.3 N
b) 165.7 N
c) 142 N
d) 90 N

255. A body is hanging from a rigid support by an inextensible string of length l. It is struck inelastically by an identical body of mass m moving with horizontal velocity $v = \sqrt{2gl}$, the tension in the string increases just after striking by

a) mg
b) $3mg$
c) $2mg$
d) None of these

256. A disc is performing pure rolling on a smooth stationery surface with constant angular velocity as shown in figure. At any instant, for the lower most point of the disc



a) Velocity is v, acceleration is zero
b) Velocity is zero, acceleration is zero
c) Velocity is v, acceleration is v^2/R
d) Velocity is zero, acceleration is v^2/R

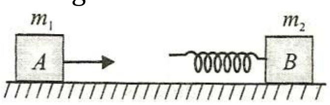
257. A solid cylinder is placed on the end of an inclined plane. It is found that the plane can be tipped at an angle θ before the cylinder starts to slide. When the cylinder turn on its sides and is allowed to roll, it is found that the steepest angle at which the ctlinder performs pure rolling is ϕ. The ratio tan ϕ/tan θ is

a) 3
b) $\frac{1}{3}$
c) 1
d) $\frac{1}{2}$

258. A particle of mass 200 g is dropped from a height of 50 m and another particle of mass100 g is simultaneously projected up from the ground along the same line with a speed of 100 m/s. The acceleration of the center of mass after 1 s is

a) 10 m/s^2
b) $\frac{10}{3}$ m/s^2
c) 0
d) None of these

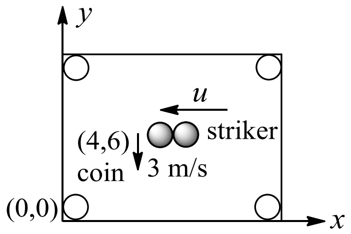
259. A block 'A' of mass m_1 hits horizontally the rear side of a spring (ideal) attached to a block B of mass m_2 resting on a smooth horizontal surface. After hitting, 'A' gets attached to the spring



Some statements are given at any moment of time:
I. If velocity of A is greater than B, then kinetic energy of the system will be decreasing
ii. If velocity of A is greater than B, then kinetic energy of the system will be increasing
iii. If velocity of A is greater than B, then momentum of the system will be decreasing
iv. If velocity of A is greater than B, then momentum of the system will be increasing
Now select correct alternative:

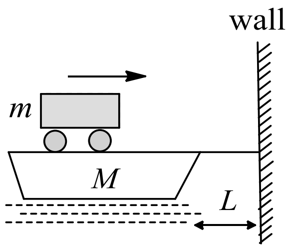
a) only iv b) only i c) ii. and iv d) i and iii

260. On a smooth carom board, a coin moving in negative y-direction with a speed of 3 m/s is being hit at the point (4, 6) by a striker moving along negative x-axis. The line joining the centres of the coin and the striker just before the collision is parallel to x-axis. After collision the coin goes into the hole located at the origin. Masses of the striker and the coin are equal. Considering the collision to be elastic, the initial and final speeds of the striker in m/s will be



a) (1, 0) b) (2, 0) c) (3, 0) d) None of these

261. A car of mass m is initially at rest on the boat of mass M tied to the wall of dock through a massless, inextensible string. The car accelerates from rest to velocity v_0 in times t_0. At $t = t_0$ the car applies brake and comes to rest relative to the boat in negligible time. Neglect friction between the boat and water; the time $'t'$ at which boat will strike the wall is



a) $\frac{L(M+m)}{mv_0}$

b) $t_0 + \frac{L(M+m)}{mv_0}$

c) $t_0 + \frac{L(M+m)}{Mv_0}$

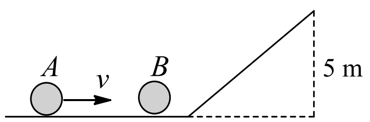
d) None of these

262. A bag of mass M hangs by a long massless rope. A bullet of mass m, moving horizontally with velocity u, is caught in the bag. Then for the combined (bag + bullet) system, just after collision

a) momentum is $muM/(M+m)$ b) kinetic energy is $mu^2/2$

c) momentum is $mu(M+m)/M$ d) kinetic energy is $m^2u^2/2(M+m)$

263. Two identical balls, of equal masses A and B, are lying on a smooth surface as shown in fig. Ball A hits ball B (which is at rest) with a velocity $v = 16$ m/s. What should be the minimum value of cofficient of restitution between A and B so that B just reaches the highest point of inclined plane?



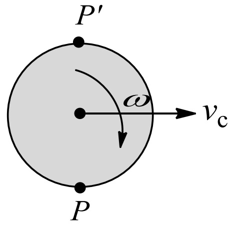
a) $\frac{2}{3}$ b) $\frac{1}{4}$ c) $\frac{1}{2}$ d) $\frac{1}{3}$

264. In the previous problem, the smallest kinetic energy at the bottom of the incline will be achieved by

a) The solid sphere b) The hollow sphere

c) The disc d) All will achieve the same kinetic energy

265. A sphere is moving towards +ve x-axis with a velocity v_c and rotates clockwise with angular speed ω as shown in Figure such that $v_c > \omega R$. The instantaneous axis of rotation will be

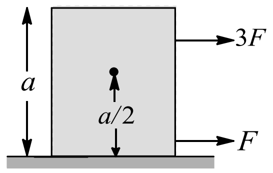


a) On point P b) On point P' c) Inside the sphere d) Outside the sphere

266. A ball impinges directly on another ball at rest. The first ball is brought to rest by the impact. If half of the kinetic energy is lost by the impact, the value of coefficient of restitution is

a) $\frac{1}{2}$ b) $\frac{1}{\sqrt{3}}$ c) $\frac{1}{\sqrt{2}}$ d) $\frac{\sqrt{3}}{2}$

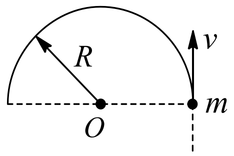
267. A rectangular block of mass M and height a is resting on a smooth level surface. A force F is applied to one corner as shown in Figure. At what point should a parallel force $3F$ be applied in order that the block shall undergo pure translational motion? Assume normal contact force between the block and surface passes through the centre of gravity of the block



a) $\frac{a}{3}$ vertically above centre of gravity b) $\frac{a}{6}$ vertically above centre of gravity

c) No such point exists d) It is not possible

268. A small bead of mass m moving with velocity v gets threaded on a stationary semicircular ring of mass m and radius R kept on a horizontal table. The ring can freely rotate about its centre. The bead comes to rest relative to the ring. What will be the final angular velocity of the system?

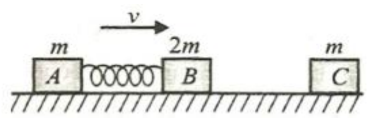


a) $\frac{v}{R}$ b) $\frac{2v}{R}$ c) $\frac{v}{2R}$ d) $\frac{3v}{R}$

269. In the above question, the ratio of the kinetic energies of the first ball to the second ball after collision is

a) $\frac{(1-n)^2}{2n}$ b) $\frac{(1-n)^2}{4n}$ c) $\frac{(1+n)^2}{2n}$ d) $\frac{(1+n)^2}{4n}$

270. Two blocks A and B of masses m and $2m$, respectively, are connected with the help of a spring having spring constant, k as shown in fig. Initially, both the blocks are moving with same velocity v on a smooth horizontal plane with the spring in its natural length. During their course of motion, block B makes an inelastic collision with block C of mass m which is initially at rest. The coefficient of restitution for the collision is 1/2. The maximum compression in the spring is



a) $\sqrt{\frac{2m}{k}}$ b) Will never be attained

c) $\sqrt{\frac{m}{12k}}\ v$ d) $\sqrt{\frac{m}{6k}}\ v$

271. A heavy chain of length 1 m and weight 20 kg hangs vertically with one end attached to a peg and carries a block of mass 10 kg at the other end. Find the work done in winding 50 cm of chain round the peg

a) 85 J b) 100 J c) 120 J d) 125 J

272. A mass M is moving with a constant velocity parallel to the x-axis. Its angular momentum with respect to

the origin

a) Is zero b) Remains constant c) Goes on increasing d) Goes on decreasing

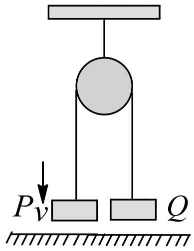
273. A trolley is moving horizontally with a velocity of v m/s w.r.t. earth. A man starts running in the direction of motion of trolley from one end of the trolley with a velocity 1.5 v m/s w.r.t. the trolley. After reaching the opposite end, the man turns back and continues running with a velocity of 1.5 v m/s w.r.t. trolley in the backward direction. If the length of the trolley is L, then the displacement of the man with respect to earth, measured as a function of time, will attain a maximum value of

a) $\frac{4}{3}L$ b) $\frac{2}{3}L$ c) $\frac{5L}{3}$ d) $1.5L$

274. A uniform ball of radius r rolls without slipping down from the top of a sphere of radius R. The angular velocity of the ball when it breaks from the sphere is

a) $\sqrt{\frac{5g(R+r)}{17r^2}}$ b) $\sqrt{\frac{10g(R+r)}{17r^2}}$ c) $\sqrt{\frac{5g(R-r)}{10r^2}}$ d) $\sqrt{\frac{10g(R+r)}{7r^2}}$

275. P and Q are two identical masses at rest suspended by an inextensible string passing over a smooth frictionless pulley. Mass P is given a downward push with a speed v as shown in fig. 1.191. It collides elastically with the floor and rebounds immediately. What happens immediately after collision?



a) P and Q both move upwards with equal speeds

b) P and Q both move upwards with different speeds

c) P moves upwards and Q moves downwards with equal speeds

d) Both P and Q are at rest

276. The momentum of a moving particle is vectorially gives as $\vec{p} = p_0(\cos t\,\hat{\imath} + \sin t\,\hat{\jmath})$, where t stands for time. Choose the correct option:

a) The applied force is constant

b) The momentum is constant

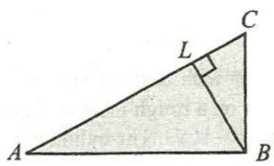
c) The applied force always remains perpendicular to the momentum

d) The applied force is always parallel to the momentum

277. A body is rotating with angular velocity 30 rads^{-1}. If its kinetic energy is 360 J, then its moment of inertia is

a) 0.8 kgm^2 b) 0.4 kgm^2 c) 1 kgm^2 d) 1.2 kgm^2

278. About which axis moment of inertia in the given triangular lamina is maximum?

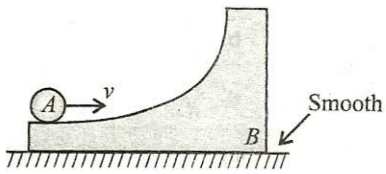


a) AB b) BC c) AC d) BL

279. In the above question, find the height by which the centre of mass of the system of 'chain + block' rises

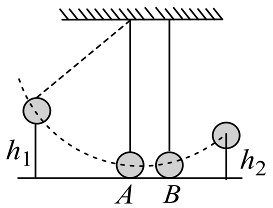
a) 0.417 m b) 0.437 m c) 0.365 m d) 0.405 m

280. In the figure shown, a ring A is initially rolling without sliding with a velocity v on the horizontal surface of the body B (of same mass as A). All surfaces are smooth. B has no initial velocity. What will be the maximum height reached by A on B?



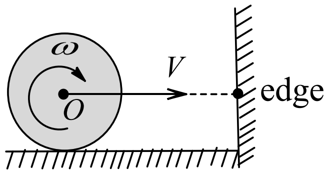
a) $\frac{3v^2}{4g}$ b) $\frac{v^2}{4g}$ c) $\frac{v^2}{2g}$ d) $\frac{v^2}{3g}$

281. Two identical metal spheres suspended by vertical cords, initially touch each other as shown in fig. Sphere A is pulled to the left to a height h_1 and released. After swinging down it collides elastically with sphere B. The height undergone by sphere B will be



a) h_1 b) Less than h_1 c) more than h_1 d) Zero

282. A uniform solid sphere of radius r is rolling on a smooth horizontal surface with velocity V and angular velocity $\omega = (V = \omega r)$. The sphere collides with a sharp edge on the wall as shown in Figure. The coefficient of friction between the sphere and the edge $\mu = 1/5$. Just after the collision the angular velocity of the sphere becomes equal to zero. The linear velocity of the sphere just after the collision is equal to

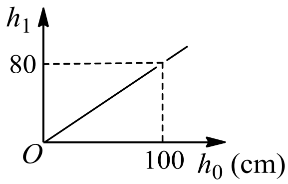


a) V b) $\frac{V}{5}$ c) $\frac{3V}{5}$ d) $\frac{V}{6}$

283. A cylinder rolls up an inclined plane, reaches some height, and then rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are
a) Up the incline while ascending and down the incline while descending
b) Up the incline while ascending as well as descending
c) Down the incline while ascending and up the incline while descending
d) Down the incline while ascending as well as descending

284. A canon shell moving along a straight line bursts into two parts. Just after the burst one part moves with momentum 20 N s making an angle 30° with the original line of motion. The minimum momentum of the other part of shell just after the burst is
a) 0 N s b) 5 N s c) 10 N s d) 17.32 N s

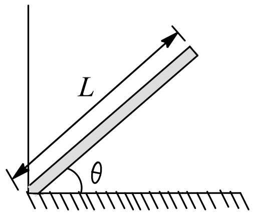
285. A ball released from a height h_0 above a horizontal surface rebounds to a height h_1 after one bounce. The graph that relates h_0 to h_1 is shown fig. If the ball (of the mass m) was dropped from an initial height h and made three bounces, the kinetic energy of the ball immediately after the third impact with the surface was



a) $(0.8)^3\ mgh$ b) $(0.8)^2\ mgh$ c) $0.8\ mg(h/3)$ d) $[1-(0.8)^3]mgh$

286. In perfectly inelastic collisions, the relative velocity of the bodies
a) Before impact is zero
b) Before impact is equal to that after impact
c) After impact is zero
d) Is characterized by none of the above

287. A uniform pole of length L and mass M is pivoted on the ground with a frictionless hinge. The pole makes an angle θ with the horizontal. The moment of inertia of the pole about one end is $(1/3)ML^2$. If the starts falling from the position shown in the accompanying figure, the linear acceleration of the free end of the pole immediately after release would be



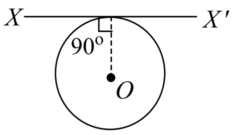
a) $\left(\frac{2}{3}\right) g \cos \theta$ b) $\left(\frac{2}{3}\right) g$ c) g d) $\left(\frac{3}{2}\right) g \cos \theta$

Multiple Correct Answers Type

288. A ball strikes a wall with a velocity $\vec{u}$ at an angle θ with the normal to the wall surface and rebounds from it at an angle β with the surface. Then
a) $(\theta + \beta) < 90°$, if the wall is smooth
b) If the wall is rough, coefficient of restitution $= \tan \beta / \cos \theta$
c) If the wall is rough, coefficient of restitution $< \tan \beta / \cot \theta$
d) None of the above

289. A particle of mass m is travelling with a constant velocity $\vec{\mathbf{v}} = v_0 \hat{\mathbf{i}}$ along the line $y = b, z = 0$. Let dA be the area swept out by the position vector from origin to the particle in time dt and L the magnitude of angular momentum of particle about origin at any time t. Then
a) $L =$ constant b) $L \neq$ constant c) $\frac{dA}{dt} = \frac{2L}{m}$ d) $\frac{dA}{dt} = \frac{L}{m}$

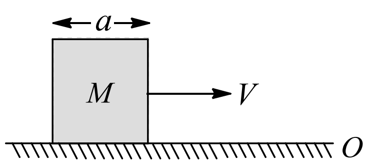
290. A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX' is



a) $\frac{\pi L^3}{8\pi^2}$ b) $\frac{\pi L^3}{16\pi^2}$ c) $\frac{5\pi L^3}{16\pi^2}$ d) $\frac{3\pi L^3}{8\pi^2}$

291. A ball of rolls down an inclined plane and acquires a velocity v_r when it reaches the bottom of the plane. If the same ball slides without friction and aquires rolling from the same height down an equally inclined smooth plane and aquires a velocity v_s (then which of the following statements are not correct?
a) $v_r < v_s$, because a work is done by the rolling ball against the frictional force
b) $v_r > v_s$, because the angular velocity acquired makes the rolling ball to travel faster
c) $v_r = v_s$, because kinetic energy of the two balls is same at the bottom of the planes
d) $v_r < v_s$, because the rolling balls acquires rotational as well as translational kinetic energy

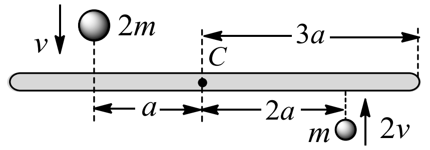
292. A cubical block of side a is moving with velocity V on a horizontal smooth plane as shown in Figure. It hits a ridge at point O. The angular speed of the block after it hits O is



a) $3V/(4a)$ b) $3V/(2a)$ c) $\sqrt{3V}/(\sqrt{2}a)$ d) Zero

293. A uniform bar of length $6a$ and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ moving in the same horizontal plane with speeds $2v$ and v, respectively, strike the bar (as shown in the figure) and stick to the bar after collision. Denoting angular velocity (about the centre of mass), total

energy and centre of mass velocity by ω, E and V_c respectively, we have after collision



a) $V_c = 0$
b) $\omega = \frac{3v}{5a}$
c) $\omega = \frac{v}{5a}$
d) $E = \frac{3mv^2}{5}$

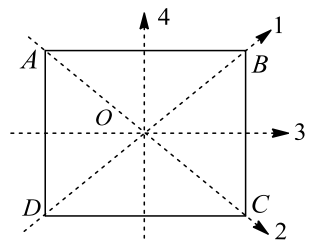
294. A horizontal disc rotates freely about a vertical axis through its centre. A ring, having the same mass and radius as the disc, is now gently placed on the disc. After some time, the two rotate with a common angular velocity, then
a) Some friction exists between the disc and the ring
b) The angular momentum of the "disc plus ring" is conserved
c) The final common angular velocity is (2/3)rd of the initial angular velocity of the disc
d) (2/4)rd of the initial kinetic energy changes to heat

295. A solid cylinder is rolling down a rough inclined plane of inclination θ. Then
a) The friction force is dissipative
b) The friction force is necessarily changing
c) The friction force will and rotation but hinder translation
d) The friction force is reduced if θ is reduced

296. A body of mass 2 kg moving with a speed of 3 ms^{-1} collides with a body of mass 1 kg moving with a speed of 4 ms^{-1}. If the collision is one dimensional and completely inelastic, the speed of composite mass after the collision may be
a) $\frac{3}{2}\text{ms}^{-1}$
b) $\frac{2}{3}\text{ms}^{-1}$
c) 4 ms^{-1}
d) $\frac{10}{3}\text{ms}^{-1}$

297. The radius of gyration of a body depends upon
a) Shape and size of body
b) Nature of mass distribution of body
c) Choice of axis of rotation
d) Mass of the body

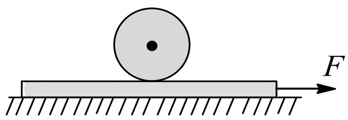
298. The moment of inertia of a thin square plate $ABCD$. Figure of uniform thickness about on axis passing through the centre O and perpendicular to the plane is



a) $I_1 + I_2$
b) $I_3 + I_4$
c) $I_1 + I_3$
d) $I_1 + I_2 + I_3 + I_4$

299. A man of mass m is standing at one end of a boat of mass M and length L. The body walks to the other end, the displacement of the
a) Centre of mass of the system is zero
b) Boat is $\frac{m}{M+m}L$
c) Man is $\frac{m}{M+m}L$
d) Boat is $\frac{m}{M}L$

300. A plank with a uniform sphere placed on it rests on a smooth horizontal plane. The plank is pulled to the right by a constant force F. If the sphere does not slip over the plank, then

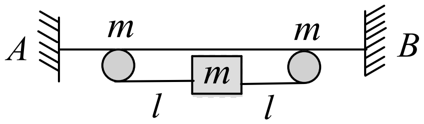


a) Both have the same acceleration
b) Acceleration of the centre of sphere is less than that of the plank
c) Work done by friction on the sphere is equal to its total kinetic energy
d) Total kinetic energy of the system is equal to work done by the force F

301. The moment of inertia of a body depends upon

a) The angular momentum
b) Mass of the body
c) Nature of mass distribution
d) Choice of the rotational axis

302. Two small rings, each of mass 'm', are connected to the block of same mass 'm' through an inextensible massless string of length 'l'. Rings are constrained to move over smooth rod AB. Initially, the the system is held at rest as shown in Fig. Let u ans v be the velocities of ring and block, respectively when string makes an angle 60° with the vertical



a) $u = \sqrt{\frac{gl}{5}}$
b) $u = \sqrt{\frac{8gl}{5}}$
c) $v = \sqrt{3gl}$
d) $v = \sqrt{\frac{3gl}{5}}$

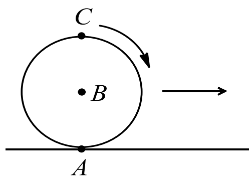
303. A particle of mass m is projected with a velocity v making an angle of 45° with the horizontal. The magnitude of the angular momentum of the projectile about the point of projection, when the particle is at its maximum height h, is

a) Zero
b) $\frac{mv^3}{4\sqrt{2g}}$
c) $\frac{mv^3}{\sqrt{2g}}$
d) $m\sqrt{2gh^3}$

304. When two particles collide and stick together:

a) ME is conserved
b) Energy is conserved
c) KE is conserved
d) Work is negative

305. A sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact, B is the centre of the sphere and C is its topmost point. Then,



a) $\vec{V}_C - \vec{V}_A = 2(\vec{V}_B - \vec{V}_C)$
b) $\vec{V}_C - \vec{V}_B = \vec{V}_B - \vec{V}_A$
c) $|\vec{V}_C - \vec{V}_A| = 2|\vec{V}_B - \vec{V}_C|$
d) $|\vec{V}_C - \vec{V}_A| = 4|\vec{V}_B|$

306. A ball strikes a smooth horizontal floor obliquely and rebounds inelastically

a) The kinetic energy of the ball just after hitting the floor is equal to the potential energy of the ball at its maximum height after rebound
b) Total energy of the ball is not conserved
c) The angle of rebound with the vertical is greater than the angle of incidence
d) None of the above

307. An isolated particle of mass m is moving in horizontal plane xy along the x–axis, at a certain height above the ground. It suddenly explodes into two fragment of masses $m/4$ and $3m/4$. An instant later, the smaller fragment is at $y = +15$ cm. The larger fragment at this instant is at

a) $y = -5$ cm
b) $y = +20$ cm
c) $y = +5$ cm
d) $y = -20$ cm

308. A man standing on the edge of the terrace of a high rise building throws a stone vertically up with a speed of 20 m/s. Two seconds later, an identical stone is thrown vertically downwards with the same speed of 20 m/s. Then

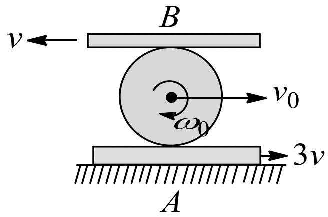
a) The relative velocity between the two stones remains constant till one hits the ground
b) Both will have the same kinetic energy, when they hit the ground
c) The time interval between their hitting the ground is 2 s
d) If the collision on the ground is perfectly elastic, both will rise to the same height above the ground

309. A thin uniform rod of mass m and length l is free to rotate about its upper end. When it is at rest, it receives an impulse J at its lowest point, normal to its length. Immediately after impact,

a) The angular momentum of the rod is Jl
b) The angular velocity of the rod is $3J/ml$
c) The kinetic energy of the rod is $3J^2/2m$
d) The linear velocity of the midpoint of the rod is $3J/2m$

310. In an elastic collision between two particles
a) The total kinetic energy of the system is always conserved
b) The kinetic energy of the system before collision is equal to the kinetic energy of the system after collision
c) The linear momentum of the system is conserved
d) The mechanical energy of the system before collision is equal to the mechanical energy of the system after collision

311. The disc of radius r is confined to roll without slipping at A and B. If the plates have the velocities shown, then

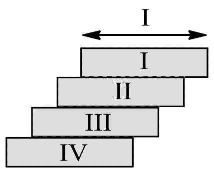


a) Angular velocity of the disc is $2V/r$
b) Linear velocity, $V_0 = V$
c) Angular velocity of the disc $3V/2r$
d) None of these

312. The velocity of the centre of mass of a two particle system is v and total mass of particles is M. The kinetic energy of the system
a) May be equal to $\frac{1}{2}Mv^2$
b) Must be equal to or less than Mv^2
c) May be equal to or greater than $\frac{1}{2}Mv^2$
d) Can not be exactly calculated as the information given is insufficient

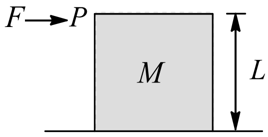
313. Two particles A and B, initially at rest, move towards each other by a mutual force of attraction. At the instant when the speed of A is v and the speed of B is $2v$, the speed of the centre of mass of the system is
a) $3v$
b) v
c) $1.5v$
d) Zero

314. Four bricks, each of length l, are put on the top of one another (fig) in such a way that part of each extends beyond the one beneath. For the largest equilibrium extensions,



a) The top brick overhanging the one below by $l/4$
b) The second brick from top over hanging the one below by $l/4$
c) The third brick from top overhanging the bottom one by $l/6$
d) The total overhanging length on the edge of the bottom brick is $(11/12)l$

315. A cubical block of side L rests on a rough horizontal surface with coefficient of friction sufficiently high so that the block does not slide before toppling; the minimum force required to topple the block is



a) Infinitesimal
b) $mg/4$
c) $mg/2$
d) $mg(1-\mu)$

316. A constant external torque τ acts for a very brief period Δt on a rotating system having moment of inertia l, then
a) The angular momentum of the system will change by $\tau\Delta t$
b) The angular velocity of the system will change by $\tau\Delta t/I$
c) If the system was initially at rest, it will acquire rotational kinetic energy $(\tau\Delta t)^2/2I$
d) The kinetic energy of the system will change by $(\tau\Delta t)^2/2I$

317. A solid sphere rolls without slipping on a rough horizontal floor, moving with a speed v. It makes an elastic

collision with a smooth vertical wall. After impact

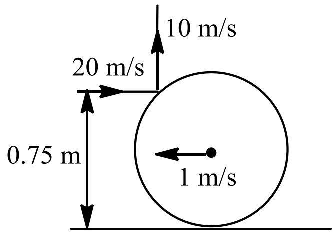
a) It will move with a speed v initially

b) Its motion will be rolling without slipping

c) Its motion will be rolling without slipping initially and its rotational motion will stop momentarily at some instant

d) Its motion will be rolling without slipping only after some time

318. A thin ring of mass 2kg and radius 0.5m is rolling without slipping on a horizontal plane with velocity 1m/s. A small ball of mass 0.1kg,moving with velocity 20m/s in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m/s. Immediately after the collision



a) The ring has pure rotation about its stationary

b) The ring comes to a complete stop

c) Friction between the ring the ground is to the left

d) There is no friction between the ring and the ground

319. When a man stands on a turn-table stretching with two equal loads in hand and rotates. Then he folds his arm. Which of the following statement is correct

a) Linear momentum is conserved
b) Kinetic energy increases
c) Angular momentum increases
d) Angular velocity increases

320. If the external forces acting on a system have zero resultant, the centre of mass

a) May not move
b) Must not accelerate
c) May move
d) May accelerate

321. A particle of mass m is projected with a velocity v making an angle of 45° with the horizontal. The magnitude of the angular momentum of the projectile about the point of projection, when particle is at its maximum height h, is

a) Zero
b) $mv^3/(4\sqrt{2})$g
c) $mv^3/(\sqrt{2})$g
d) $m\sqrt{2gh^3}$

322. A body moving towards a body of finite mass at rest collides with it. It is possible that

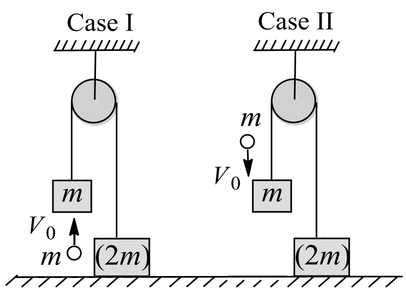
a) Both bodies come to rest

b) Both bodies move after collision

c) The moving body stops and the body at rest starts moving

d) The stationary body remains stationary and the moving body rebounds

323. Two masses $2m$ and m are connected by an inextensible light string. The string is passing over a light frictionless pulley. The mass $2m$ is resting on a surface and mass m is hanging in air is as shown in Fig. A particle of mass m strikes the mass m from below in case (I) with a velocity v_0 and in case (II) strikes mass m with a velocity v_0 from top and sticks to it



a) The conservation of linear momentum can be applied in both the cases just before and just after collision

b) The conservation of linear momentum can be applied in case I but cannot be applied in case II just before and just after collision

c) The ratio of velocities of mass m just after collision in first and second case is 1/2

d) The ratio of velocities of mass m just after collision in first and second case is 2

324. A 1 kg solid sphere rolls without slipping on a rough horizontal surface under the influence of a 7 N force. The force acts tangentially at the highest point of the sphere. Which of the following statements are correct? (7 N force acts towards right)

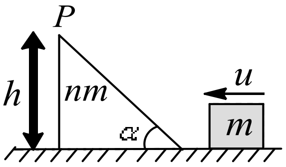
a) The frictional force on the sphere acts towards right

b) The value of the frictional force is 3 N

c) The acceleration of the centre of the sphere is 9.8 m/s^2

d) The acceleration of the centre of the sphere is 10 m/s^2

325. A block of mass m is pushed towards a movable wedge of mass nm and height h with a velocity u. All surfaces are smooth. Choose the correct statement from the following



a) Block will reach the top of the wedge if $u = \sqrt{2gh\left(1 - \frac{1}{n}\right)}$

b) Block will reach the top of the wedge if $u = \sqrt{2gh\left(1 + \frac{1}{n}\right)}$

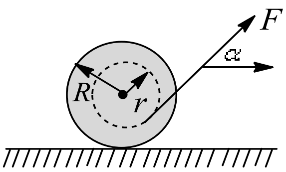
c) If the block overshoots P, the angle of projectile is

d) If the block overshoots P, the angle of projectile is less than

326. A particle of mass m is projected with a velocity V making an angle of 45° with the horizontal. The magnitude of angular momentum of the projectile about the point of projection when the particle at its maximum height h is

a) Zero b) $\frac{mv^3}{4\sqrt{2g}}$ c) $\frac{mV^3}{\sqrt{2g}}$ d) $\frac{mV}{\sqrt{2gh^3}}$

327. Inner and other radii of a spool are r and R I, respectively. A thread is wound over its inner surface and spool is placed over a rough horizontal surface. Thread is pulled by a force F as shown in Fig. In case of pure rolling, which of the following statements are false?



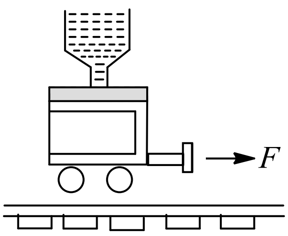
a) Thread unwinds, spool rotates anticlockwise and friction acts leftwards

b) Thread winds, spool rotates clockwise and friction acts leftwards

c) Thread winds, spool moves to the right and friction acts rightwards

d) Thread winds, spool moves to the right and friction does not come into existence

328. A flat cart of mass m_0 starts moving to the right due to a constant horizontal force F at $t = 0$. Sand spills on the flat cart from a stationary hopper. The velocity of loading is constant and is equal μ kg/s



a) Initial acceleration is equal to F/m_0

b) Acceleration at time t is $F/(m_0 + \mu t)$

c) Kinetic energy of loaded cart at an instant is equal to work done by force F up to that instant

d) Momentum of loaded cart at an instant is equal to impulse of force F up to that instant

329. A ring (R), a disc (D), a solid sphere (S) and a hollow sphere with thin walls (H), all having the same mass

but different radii, start together from rest at the top of an inclined plane and roll down without slipping. Then

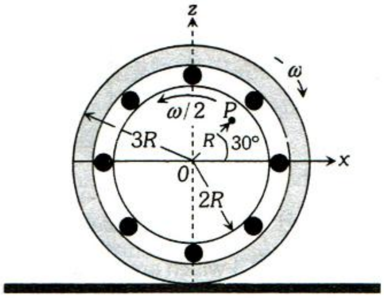
a) All of them will reach the bottom of the incline together

b) The body with the maximum radius will reach the bottom first

c) They will reach the bottom in the order S, D, H and R

d) All of them will have the same kinetic energy at the bottom of the incline

330. The figure shows a system consisting of (i) ring of outer radius $3R$ rolling clockwise without slipping on a horizontal surface with angular speed ω and (ii) an inner disc of radius $2R$ rotaing anti-clockwise with angular speed $\omega/2$. The ring and disc are separated by frictionless ball bearings. The system is in the $x - z$ plane. The point P on the inner disc is at a distance R from the origin, where OP makes an angle of 30° with the horizontal. Then with respect to the horizontal surface



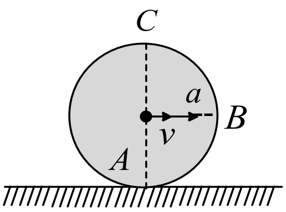
a) The point O has a linear velocity $3R\omega\hat{\imath}$

b) The point P has a linear velocity $\frac{11}{4}R\omega\hat{\imath} + \frac{\sqrt{3}}{4}R\omega\hat{k}$

c) The point P has a linear velocity $\frac{13}{4}R\omega\hat{\imath} - \frac{\sqrt{3}}{4}R\omega\hat{k}$

d) The point P has a linear velocity $\left(3 - \frac{\sqrt{3}}{4}\right)R\omega\hat{\imath} + \frac{1}{4}R\omega\hat{k}$

331. A wheel is rolling on a horizontal plane. At a certain instant, it has a velocity $'v'$ and acceleration a' of CM as shown in Figure. Acceleration of



a) A is vertically upwards

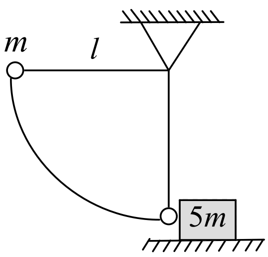
b) B may be vertically downwards

c) C cannot be horizontal

d) Some point on the rim may be horizontal leftwards

332. A pendulum bob of mass m connected to the end of an ideal string of length l is released from rest from horizontal position as shown in Fig.

At the lowest point, the bob makes an elastic collision with a stationary block of mass $5m$, which is kept on a frictionless surface. Mark out the correct statement(s) for the instant just after the impact



a) Tension in the string is $(17/9)\ mg$

b) Tension is the string is $3\ mg$

c) The velocity of the block is $\sqrt{2gl/3}$

d) The maximum height attained by the pendulum bob after impact is (measured from the lowest position) $4l/9$

333. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1$and $\vec{v}_2$, respectively, at time $t = 0$. They collide at time t_0. Their velocities become $\overrightarrow{v_1'}$ and $\overrightarrow{v_2'}$ at time $2t_0$ while still moving in air. The value of

$\left|\left(m_1\overrightarrow{v_1'} + m_2\overrightarrow{v_2'}\right)\right| - |(m_1\vec{v}_1 + m_2\vec{v}_2)|$ is

a) Zero b) $(m_1 + m_2)gt_0$ c) $\frac{1}{2}(m_1 + m_2)gt_0$ d) $2(m_1 + m_2)gt_0$

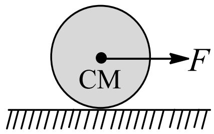
334. A sphere is rolled on a rough horizontal surface. It gradually slows down and stops. The force of friction tries to

a) Decrease the linear velocity
b) Increase the angular velocity
c) Increase the linear momentum
d) Decreases the angular momentum

335. The mathematical statement $\vec{v} = \vec{v}_c + \vec{v}'$, where $\vec{v}_c$ is the velocity of centre of mass, $\vec{v}'$ is the velocity of the point with respect to the centre of mass and $\vec{v}$ is the total velocity of the point with respect to the ground,

a) Is true for a rolling sphere
b) Is true for a block moving on a frictionless horizontal surface
c) Is true for a rolling cylinder
d) None of these

336. A solid sphere of mass M and radius R is pulled horizontally on a rough surface as shown in Fig. Choose the incorrect alternatives



a) The magnitude of the frictional force is $F/3$
b) The frictional force on the sphere acts forward
c) The acceleration of the centre of mass is $2F/3M$
d) The acceleration of the centre of mass is F/M

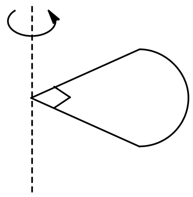
337. A uniform rod is resting freely over a smooth horizontal plane. A particle moving horizontally strikes at one end of the rod normally and get stuck. Then

a) The momentum of the particle is shared between the particle and the rod remains conserved
b) The angular momentum about the mid-point of the rod before and after the collision is equal
c) The angular momentum about the center of mass of the combination before and after the collision is equal
d) The center of mass of the rod particle system starts to move translationally with the original momentum of the particle

338. A ball moving with a velocity v hits a massive wall moving towards the ball with a velocity u. An elastic impact lasts for time Δt

a) The average elastic force acting on the ball is $[m(u + v)]/\Delta t$
b) The average elastic force acting on the ball is $[2m(u + v)]/\Delta t$
c) The kinetic energy of the ball increases by $2mu(u + v)$
d) The kinetic energy of the ball remains the same after the collision

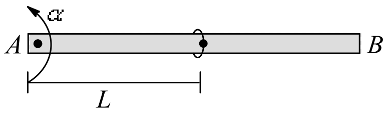
339. One quarter sector is cut from a uniform circular disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the centre of the original disc. Its moment of inertia about the axis of rotation is



a) $\frac{1}{2}MR^2$ b) $\frac{1}{4}MR^2$ c) $\frac{1}{8}MR^2$ d) $\sqrt{2}\,MR^2$

340. Two horizontal discs of different radii are free to rotate about their central vertical axes. One is given some angular velocity, the other is stationary. Their rims are now brought in contact. There is friction between the rims. Then
a) The force of friction between the rims will disappear when the discs rotate with equal angular speeds
b) The force of friction between the rims will disappear when they have equal linear velocities
c) The angular momentum of the system will be conserved
d) The rotational kinetic energy of the system will not be conserved

341. A long horizontal rod has a bead which can slide along its length and initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ, and gravity is neglected, then the time after which the bead starts slipping is



a) $\sqrt{\mu/\alpha}$ b) $\mu/\sqrt{\alpha}$ c) $\frac{1}{\sqrt{\mu\alpha}}$ d) Infinitesimal

342. A ball hits the floor and rebounds after an inelastic collision. In this case
a) The momentum of the ball just after collision is same as that just before the collision
b) The mechanical energy of the ball remains the same in collision
c) The total momentum of the ball and the earth is conserved
d) The total mechanical energy of the ball and the earth is conserved

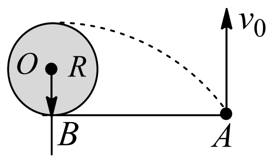
343. Velocity of a particle of mass 2 kg changes from $\vec{v}_1 = -2\hat{\imath} - 2\hat{\jmath}$ m/s to $\vec{v}_2 = (\hat{\imath} - \hat{\jmath})$ m/s after colliding with a plane surface
a) The angle made by the plane surface with the positive x-axis is $90° + \tan^{-1}\left(\frac{1}{3}\right)$
b) The angle made by the plane surface with the positive x-axis is $\tan^{-1}\left(\frac{1}{3}\right)$
c) The direction of change in momentum makes an angle $\tan^{-1}\left(\frac{1}{3}\right)$ with the positive x-axis
d) The direction of change in momentum makes an angle $90° + \tan^{-1}\left(\frac{1}{3}\right)$ with the plane surface

344. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A plamb bob is suspended from the roof of the car by a light rod length 1.00 m. The angle made by the rod with the track is
a) Zero b) 30° c) 45° d) 60°

345. A smooth sphere A is moving on a frictionless horizontal plane with angular speed ω_A and ω_B, respectively. Then
a) $\omega_A < \omega_B$ b) $\omega_A = \omega_B$ c) $\omega_A = \omega$ d) $\omega_B = \omega$

346. Which of the following is/are correct?
a) If centre of mass of three particles is at rest and it is known that two of them are moving along different lines, then the third particle must also be moving
b) If centre of mass remains at rest, then net work done by the forces acting on the system must be zero
c) If centre of mass remains at rest, then the net external force must be zero
d) If speed of centre of mass is changing, then there must be some net work being done on the system from outside

347. A horizontal plane supports a fixed vertical cylinder of radius R and a particle is attached to the cylinder by a horizontal thread AB as shown in Fig. The particle initially rest on a horizontal plane. A horizontal velocity v_0 is imparted to the particle, normal to the threading during subsequent motion. Point out the false statement

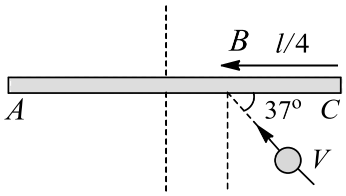


a) Angular momentum of particle about O remains constant
b) Angular momentum about B remains constant
c) Momentum and kinetic energy both remain constant
d) Kinetic energy remains constant

348. A uniform chain of length L and mass M is lying on a smooth table and one–third of its length is hanging vertically down over the edge of the table. If g is the acceleration due to gravity, the work required to pull the hanging part on to the table is
a) MgL b) $MgL/3$ c) $MgL/9$ d) $MgL/18$

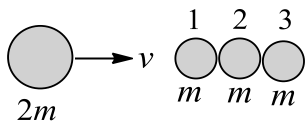
349. The torque τ on a body about a given point is found to be equal to $A \times L$ where A is a constant vector, and L is the angular momentum of the body about that point. From this it follows that
a) dL/dt is perpendicular to L at all instants of time
b) The component of L in the direction of A does not change with time
c) The magnitude of L does not change with time
d) L does not change with time

350. A rod AC of length l and mass m is kept on a horizontal smooth plane. It is free to rotate and move. A particle of same mass m moving on the plane with velocity v strikes the rod at point B making angle 37° with the rod. The collision is elastic. After collision,



a) The angular velocity of the rod will be $72/55\ v/l$
b) The center of the rod will travel a distance $\pi l/3$ in the time in which it makes half rotation
c) Impulse of the impact force is $24mV/55$
d) None of these

351. A steel ball o mass $2m$ suffers one-dimensional elastic collision with a row of three steel balls, each of mass m. If mass $2m$ has collided with velocity v and the three balls numbered 1, 2, 3 were initially at rest, then after the collision



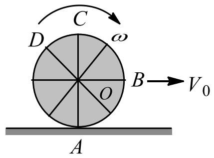
a) Balls 1, 2 and 3 would start moving to the right, each with velocity $v/3$
b) Balls 2 and 3 would start moving to the right, each with velocity $v/2$
c) Balls 2 and 3 would start moving to the right, each with velocity v
d) Ball 1 and ball of mass $2m$ would remain at rest

352. A disc of circumference s is at rest at a point A on a horizontal surface when a constant horizontal force begins to act on its centre. Between A and B there is sufficient friction to prevent slipping and the surface is smooth to the right of B, $AB = s$. The disc moves from A to B in time T. To the right of B,
a) The angular acceleration of the disc will disappear, linear acceleration will remain unchanged
b) Linear acceleration of the disc will increase
c) The disc will make one rotation in time $T/2$
d) The disc will cover a distance greater than s in further time T

353. Choose the correct statements from the following:
a) The general form of Newton's second law of motion is $\vec{F}_{ext} = \vec{m}a$
b) A bond can have energy and get no momentum

c) A body having momentum must necessarily have kinetic energy
d) The relative velocity of two bodies in a head-on elastic collision remains unchanged in magnitude and direction

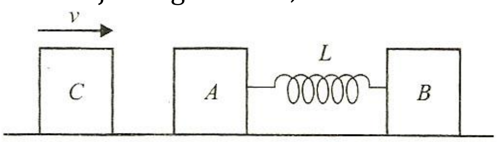
354. Consider a bicycle wheel rolling without slipping on a rough level road at a linear speed as shown in figure. Then



a) The speed of the particles A is zero
b) The speed of B, C and D are all equal to v_0
c) The speed of C is $2v_0$
d) The speed of B is greater than the speed of O

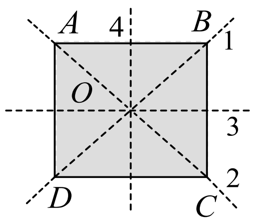
355. A handball falls on the ground and rebounds elastically along the same line of motion. Then
a) The linear momentum of the universe remains conserved
b) The linear momentum of the ball is not conserved
c) During the collision, the whole of the kinetic energy of the ball is converted into potential energy and then completely converted into kinetic energy of the ball
d) During the collision, the kinetic energy remains constant

356. Two blocks A and B, each of mass m, are connected by a massless spring of natural length L and spring constant K. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in Fig. A third identical block C, also of mass m, moves on the floor with a speed v along the line joining A and B, and collides elastically with A. Then



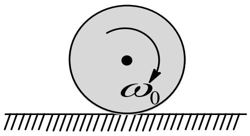
a) The kinetic energy of the $A-B$ system, at maximum compression of the spring, is zero
b) The kinetic energy of the $A-B$ system, at maximum compression of the spring, is $\frac{mv^2}{4}$
c) The maximum compression of the spring is $v\sqrt{\left(\frac{m}{K}\right)}$
d) The maximum compression of the spring is $v\sqrt{\left(\frac{m}{2K}\right)}$

357. The moments of inertia of a thin square plate $ABCD$ of uniform thickness about an axis passing through the centre O and perpendicular to the plate are



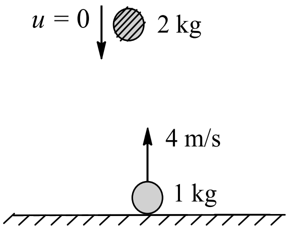
a) $I_1 + I_2$
b) $I_3 + I_4$
c) $I_1 + I_3$
$I_1 + I_2 + I_3 + I_4$
d) (where I_1, I_2, I_3 and I_4 are, respectively, the moments of inertia about axes 1, 2, 3 and 4, where axes are in the plane of the plate)

358. A disc is given an initial angular velocity ω_0 and placed on a rough horizontal surface as shown Fig. The quantities which will not depend on the coefficient of friction is/are



a) The time until rolling beings
b) The displacement of the disc until rolling begins
c) The velocity when rolling begins
d) The work done by the force of friction

359. A ball of mass 1 kg is thrown up with an initial speed of 4 m/s. A second ball of mass 2 kg is released from rest from some height as shown in fig. Choose the correct statement (s)



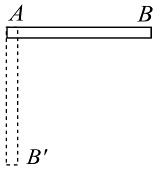
a) The centre of mass of the two balls comes down with acceleration g/3
b) The centre of mass first moves up and then comes down
c) The acceleration of the centre of mass is g downwards
d) The centre of mass of the two balls remains stationary

360. Which of the following statements are correct for instantaneous axis of rotation?
a) Acceleration of every point lying on the axis be equal to zero
b) Velocity of a point distance r from the axis is equal to $r\omega$
c) If moment of inertia of a body about the axis is I and angular velocity is ω, then kinetic energy of the body is equal to $I\omega^2/2$
d) Moment of inertia of a body is least about instantaneous axis of rotation among all the parallel axes

361. A sphere A moving with speed u and rotating with an angular velocity ω makes a head-on elastic collision with an identical stationery sphere B. There is no friction between the surface of A and B. Choose the correct alternative(s). Disregard gravity
a) A will stop moving but continue to rotate with an angular velocity ω
b) A will come to rest and stop rotating
c) B will move with speed u without rotating
d) B will move with speed u and rotate with an angular velocity ω

362. A particle strikes a horizontal smooth floor with velocity u making an angle θ with the floor and rebounds with velocity v making an angle $\emptyset$ with the floor. If the coefficient of restitution between the particle and the floor is e, then
a) The impulse delivered by the floor to the body is $mu(1+e)\sin\theta$
b) $\tan\emptyset = e\tan\theta$
c) $v = u\sqrt{1-(1-e)^2\sin^2\theta}$
d) The ratio of final kinetic energy to the initial kinetic energy is $(\cos^2\theta + e^2\sin^2\theta)$

363. Consider the rotation of a rod of mass m and length l from position AB to AB'. Which of the following statements are correct?
a) Weight of the rod is lowered by $l/2$
b) Loss of gravitational potential energy is $\frac{1}{2}mgl$
c) Angular velocity is $\sqrt{3g/l}$
d) Rotational kinetic energy is $\frac{ml^2\omega^2}{6}$



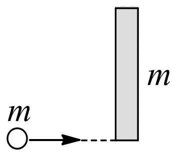
364. The uniform speed of a body is the same as seen from any point in the body. A light cord is wrapped around the rim of the disc and mass of 1 kg is tied to the free end. If it is released from rest,

a) The tension in the cord is 5 N
b) In the first 4 s the angular displacement of the disc is 40 rad
c) The work done by the torque on the disc in the first 4 s is 200 J
d) The increase in kinetic energy of the disc in the first 4 s is 200 J

365. Consider three uniform solid spheres, sphere (i) has radius 'r' and mass 'm', sphere (ii) has radius r and mass $3m$, sphere (iii) has radius $3r$ and mass 'm'. All the spheres can be placed at the same point on the same inclined plane where they will roll without slipping to the bottom. If allowed to roll down the incline then at the bottom of the incline

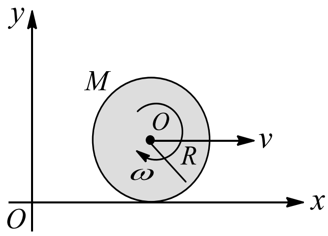
a) Sphere (i) will have the largest speed
b) Sphere(ii) will have the largest speed
c) Sphere (ii) will have the largest kinetic energy
d) All the sphere will have equal speed

366. A particle, moving horizontally, collides perpendicularly at one end of a rod having equal mass and placed on a smooth horizontal surface



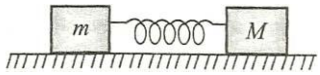
a) Particle cones to rest if collision is perfectly elastic and center of rod starts to move with the same velocity
b) Particle continues to move along the same direction, whatever is the value of e
c) Particle may get rebound back
d) Velocity of mid-point of the rod will be less than $v_0/2$ if the particle gets stuck

367. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown Figure. The magnitude of angular momentum of the disc about the origin O is



a) $(1/2)MR^2\omega$ b) $MR^2\omega$ c) $(3/2)MR^2\omega$ d) $2Mr^2\omega$

368. An ideal spring is permanently connected between two blocks of masses M and m. The blocks-spring system can move over a smooth horizontal table along a straight line along the length of the spring as shown in Fig. The blocks are brought nearer to compress the spring and then released. In the subsequent motion



a) Initially they move in opposite directions with velocities inversely proportional to their masses
b) The ratio of their velocities remains constant
c) Linear momentum and energy of the system remain conserved
d) The two blocks will oscillate about their centre of mass, which remains stationary

369. A solid sphere starts from rest at the top of an incline of height h and length l and moves down. The force of fraction between the sphere and athe inclinme is F. This is sufficient to prevent slipping. The kinetic

energy of the sphere at the bottom of the incline is W, then

a) The work done against the force of fraction is Fl

b) The heat produced is Fl

c) $W = mgh - Fl$

d) $W > (mgh - Fl)$

370. Two point masses of 0.3 kg and 0.7 kg are fixed at the ends of a rod of length 1.4 m and of negligible mass. The rod is set rotating about an axis perpendicular to its length with a uniform angular speed. The point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum is located at a distance of

a) 0.42 m from the mass of 0.3 kg
b) 0.70 m from the mass of 0.7 kg
c) 0.98 m from the mass of 0.3 kg
d) 0.98 m from the mass of 0.7 kg

371. Let I be the moment of inertia of a uniform plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to

a) I
b) $I \sin^2 \theta$
c) $I \cos^2 \theta$
d) $I \cos^2(\theta/2)$

372. In which of the following cases, the centre of mass of a rod is certainly not at its centre?

a) The density continuously increases from left to right

b) The density continuously decreases from left to right

c) The density decreases from left t right up to the centre and then increases

d) The density increases from left to right up to the centre and then decreases

373. Two identical sphere A and B are free to move and to rotate about their centres. They are given the same impulse J. The lines of action of the impulses pass through the centre of A and away from the centre of B, then

a) A and B will have the same speed

b) B will have greater kinetic energy than A

c) They will have the same kinetic energy, but the linear kinetic energy of B will be less than that of A

d) The kinetic energy of B will depends on the point of impact of the impulse on B

374. A rigid body is in pure rotation, that is, undergoing fixed axis rotation. Then which of the following statement(s) are true?

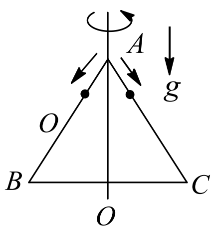
a) You can find two points in the body in a plane perpendicular to the axis of rotation having the same velocity

b) You can find two points in the body in a plane perpendicular to the axis of rotation having the same acceleration

c) Speed of all the particles lying on the curved surface of a cylinder whose axis coincides with the axis of rotation is the same

d) Angular speed of the body is the same as seen from any point in the body

375. An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at A. The triangle is set rotating about the vertical axis AO. Then the beads are released from rest simultaneously and allowed to slide down, one along AB and the other along AC as shown. Neglecting frictional effects, the quantities that are conserved as the beads slide down are



a) Angular velocity and total energy (kinetic and potential)

b) Total angular momentum and total energy

c) Angular velocity and moment of inertia about the axis of rotation

d) Total angular momentum and moment of inertia about the axis of rotation

376. If the external forces acting of a system have zero resultant, the centre of mass

a) Must not move b) Must not accelerate c) May move d) May accelerate

377. Two particles of masses m_1 and m_2 and velocities u_1 and αu_1 $(\alpha \neq 0)$ make an elastic head on collision. If the initial kinetic energies of the two particles are equal and m_1 comes to rest after collision, then

a) $\frac{u_1}{u_2} = \sqrt{2} + 1$ b) $\frac{u_1}{u_2} = \sqrt{2} - 1$ c) $\frac{m_2}{m_1} = 3 + 2\sqrt{2}$ d) $\frac{m_2}{m_1} = 3 - 2\sqrt{2}$

378. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Two objects, each of mass m, are attached gently to the opposite ends of the diameter of the ring. The wheel now rotates with an angular velocity

a) $\frac{\omega M}{(M + m)}$ b) $\frac{\omega(M - 2m)}{(M + 2m)}$ c) $\frac{\omega M}{(M + 2m)}$ d) $\frac{\omega(M + 2m)}{M}$

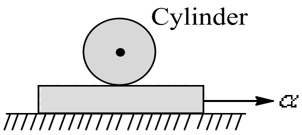
379. A mass m is moving with a constant velocity along a line parallel to the x-axis, away from the origin. Its angular momentum with respect to the origin

a) Is zero b) Remains constant c) Goes on increasing d) Goes on decreasing

380. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. The force exerted by the liquid at the other end is

a) $\frac{M\omega^2 L}{2}$ b) $M\omega^2 L$ c) $\frac{M\omega^2 L}{4}$ d) $\frac{M\omega^2 L^2}{4}$

381. A uniform cylinder of mass M and radius R is placed on a rough horizontal board, which in turn is placed on a smooth surface. The coefficient of friction between the board and the cylinder is μ. If the board starts accelerating with constant acceleration a, as shown in the figure, then



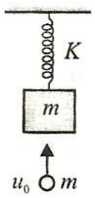
a) For pure rolling motion of the cylinder, direction of frictional force is forward and its magnitude is $Ma/3$

b) The maximum value of a, so that the cylinder performs pure rolling is $3\mu g$

c) The acceleration of the center of mass of the cylinder under pure rolling condition for the given a is $a/3$

d) None of these

382. A block of mass 'm' is hanging from massless spring of spring constant K. It is in equilibrium under the influence of gravitational force. Another particle of same mass 'm' moving upwards with velocity u_0 hits the block and sticks to it. For the subsequent motion, choose the *incorrect* statements:



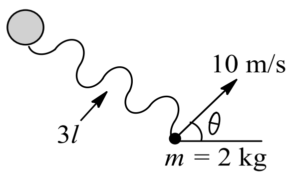
a) Velocity of the combined mass must be maximum at natural length of the spring

b) Velocity of the combined mass must be maximum at the new equilibrium position

c) Velocity of the combined mass must be maximum at the instant particle hits the block

d) Velocity of the combined mass must be maximum at a point lying between old equilibrium position and natural length

383. A string of length $3l$ is connected to a fixed cylinder whose top view is shown in Fig. The string is initially slack. The order end of the string (connected to a marble) is moving at a constant velocity of 10 m/s as shown. The string will get stretched at some instant and impulsive tension occurs in the string. If hinge is exerting a force of 40000 N for 0.25 ms on the cylinder to bear up the impact of impulsive tension, then mark the correct statements. (Take string to be light, breaking tension of the string is 2×10^5 N)



a) The angle made by the velocity of marble with the length of string when it is just stretched is 60°

b) The marble will move in a circular path of varying radius with constant speed of $5\sqrt{3}$ m/s, after the string is taut

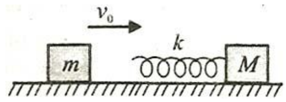
c) To answer above two options, the volume of θ must be given

d) The string will break if impulse duration is less than 0.05 min

384. A shell is fired from a cannon with a velocity v (m/s) at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed (in m/s) of the other piece immediately after the explosion is

a) $3v\cos\theta$ b) $2v\cos\theta$ c) $\frac{3}{2}v\cos\theta$ d) $\sqrt{\frac{3}{2}}v\cos\theta$

385. A block of mass m moving with a velocity v_0 collides with a stationary block of mass M to which a spring of stiffness k is attached, as shown in Fig. Choose the correct alternative(s)



a) The velocity of the centre of mass is v_0

b) The initial kinetic energy of the system in the centre of mass frame is $\frac{1}{4}\left(\frac{mM}{M+m}\right)v_0^2$

c) The maximum compression in the spring is $v_0\sqrt{\frac{mM}{m+M}\frac{1}{k}}$

d) When the spring is in the state of maximum compression, the kinetic energy in the centre of mass frame is zero

386. A ball hits the floor and rebounds after an inelastic collision. In this case choose the correct statement(s).

a) The momentum of the ball just after the collision is the same as that just before the collision

b) The mechanical energy of the ball remains the same in the collision

c) The total energy of the ball and earth is conserved

d) The total momentum of the ball and earth is conserved

387. A solid cylinder of mass m and radius r is rolling on a rough inclined plane of inclination θ. The coefficient of friction between the cylinder and incline is μ. Then

a) Frictional force is always $\mu mg\cos\theta$ b) Friction is dissipative force

c) By decreasing θ, frictional force decreases d) Friction opposes translation and supports rotation

388. A body of mass 2 kg moving with a velocity 3 m/s collides with a body of mass 1 kg moving with a velocity of 4 m/s in opposite direction. If the collision is head on and completely inelastic, then

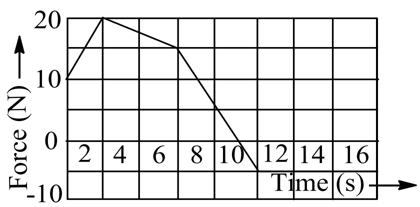
a) Both particles move together with velocity (2/3) m/s

b) The momentum of system is 2 kg m/s throughout

c) The momentum of system is 10 kg m/s

d) The loss of KE of system is (49/3) J

389. Figure gives force versus time graph. The force is acting on a particle of mass 2.0 kg at rest at $t = 0$ and particle is moving in one dimension. Which of the following are correct?



a) The impulse of the force in the time interval $t = 8$ s to $t = 12$ s is -10 N s

b) The velocity change in the interval $t = 8$ s to $t = 16$ s is -15 N s
c) The kinetic energy of the particle at $t = 6$ s is 2500 J
d) The kinetic energy of the particle at $t = 6$ s is 500 J

390. A bucket of water of mass 21 kg is suspended by a rope wrapped around a solid cylinder 0.2 m in diameter. The mass of the solid cylinder is 21 kg. The bucket is released from rest. Which of the following statements are correct
a) The tension in the rope is 70 N
b) The acceleration of the bucket is $(20/3)$ m/s^2
c) The acceleration of the bucket is independent of the mass of the bucket
d) All of these

391. A uniform cylinder of mass m rests on two rough horizontal planks. A thread is wound on the cylinder. The hanging end of the thread is pulled vertically down with a constant force F
a) Since horizontal acceleration is provided by the friction acting on the cylinder, its translation kinetic energy $(1/2mv^2)$ is equal to work done by this friction
b) Since moment about instantaneous axis of rotation is produced by force F, kinetic $(1/2\, I\omega^2)$ is equal to work done by F where l ismoment of inertia about the instantaneous axis of rotation and ω is the angular velocity
c) Since cylinder is moving, energy is lost against friction
d) Work done by $F+$ work done by friction on cylinder = total KE of the cylinder

Assertion - Reasoning Type

This section contain(s) 0 questions numbered 392 to 391. Each question contains STATEMENT 1(Assertion) and STATEMENT 2(Reason). Each question has the 4 choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

a) Statement 1 is True, Statement 2 is True; Statement 2 **is** correct explanation for Statement 1

b) Statement 1 is True, Statement 2 is True; Statement 2 **is not** correct explanation for Statement 1

c) Statement 1 is True, Statement 2 is False

d) Statement 1 is False, Statement 2 is True

392

Statement 1: When a body dropped from a height explodes in mid air, its centre of mass keeps moving in vertically downward direction

Statement 2: Explosion occur under internal forces only. External force is zero

393

Statement 1: The speed of whirlwind in a tornado is alarmingly high

Statement 2: If no external torque acts on a body, its angular velocity remains conserved

394

Statement 1: It is harder to open and shut the door if we apply force near the hinge

Statement 2: Torque is maximum at hinge of the door

395

Statement 1: A uniform thin rod of length L is hinged about one of its ends and is free to rotate about the hinge without friction. Neglect the effect of gravity. A force F is applied at a distance x from hinge on the rod such that the force is always perpendicular to the rod. As value of x is increased from zero to L, the component of reaction by the hinge on the rod perpendicular to the length of rod increases

Statement 2: Under the conditions given in Statement 1 as x is increased from zero to L, the angular acceleration of the rod increases

396

Statement 1: A particle is moving on a straight line with a uniform velocity, its angular momentum is always zero

Statement 2: The momentum is zero when particle moves with a uniform velocity

397

Statement 1: A sphere is performing pure rolling on a rough horizontal with constant angular velocity. Frictional force acting on the sphere is zero

Statement 2: Velocity of contact is zero

398

Statement 1: The total kinetic energy of a rolling solid sphere is the sum of translational and rotational kinetic energies

Statement 2: For all solid bodies total kinetic energy is always twice the translational kinetic energy

399

Statement 1: If there is no external torque on a body about its center of mass, then the velocity of the center of mass remains constant

Statement 2: The linear momentum of an isolated system remains constant

400

Statement 1: A disc is rolling on a rough horizontal surface. The instantaneous speed of the point of contact during perfect rolling is zero with respect to the ground

Statement 2: The force of friction can help in achieving pure rolling condition

401

Statement 1: A judo fighter in order to throw his opponent on to the mattries he initially bend his opponent and then rotate him around his hip

Statement 2: As the mass of the opponent is brought closer to the fighter's hip, the force required to throw the opponent is reduced

402

Statement 1: The mass of a body cannot be considered to be concentrated at the centre of mass of the body for the purpose of computing its moment of inertia

Statement 2: Then the moment of inertia of every body about an axis passing through its centre of mass would be zero

403

Statement 1: The velocity of a body at the bottom of an inclined plane of given height is more when it slides down the plane compared to when it rolls down the same plane

Statement 2: In rolling down, a body acquires both, KE of translation and KE of rotation

404

Statement 1: Many great rivers flow towards the equator. The sediments that they increases the time of rotation of the earth about its own axis

Statement 2: The angular momentum of the earth about its rotation axis is conserved

405

Statement 1: The centre of mass of a body will change with the change in shape and size of the body.

Statement 2: $\vec{r} = \frac{\sum_{i=1}^{i=n} m_i \vec{r}_i}{\sum_{i=1}^{i=n} m_i}$

406

Statement 1: If a ball projected up obliquely from the ground breaks up into several fragments in its path, the centre of the system of all fragments moves in the same parabolic path compared to initial one till all fragments are in air

Statement 2: In the situation of Statement 1, at the instant of breaking, the fragments may be thrown in different directions with different speeds

407

Statement 1: Moment of inertia of a particle is same, whatever be the axis of rotation

Statement 2: Moment of inertia depends on mass and distance of the particles

408

Statement 1: A body cannot have energy without having momentum but it can have momentum without having energy

Statement 2: Momentum and energy have different dimensions

409

Statement 1: In a two–body collision, the momenta of the particles are equal and opposite to one another, before as well as after the collision when measured in the centre of mass frame

Statement 2: The momentum of the system is zero from the centre of mass frame

410

Statement 1: A ladder is more likely to slip when a person is near the top than when he is near the bottom

Statement 2: The friction between the ladder and the floor decreases as he climbs up

411

Statement 1: A shell at rest, explodes. The centre of mass of fragments moves along a straight path

Statement 2: In explosion the linear momentum of the system remains always conserved

412

Statement 1: The centre of mass of a two particle system lies on the line joining the two particles, being closer to the heavier particle

Statement 2: This is because product of mass of one particle and its distance from centre of mass in numerically equal to product of mass of other particle and its distance from centre of mass

413

Statement 1: The centre of mass of a body may lie where there is no mass

Statement 2: Centre of mass of a body is a point, where the whole mass of the body is supposed to be concentrated

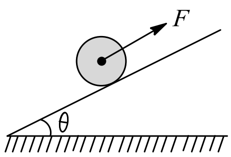
414

Statement 1: A block is kept at the top of a smooth wedge which is kept on a smooth horizontal surface. As the block slides down the wedge, centre of the mass of the system will be accelerated

Statement 2: When external force acting on the system is zero, centre of mass is in rest

415

Statement 1: A disc is allowed to roll purely on an inclined plane as shown in Figure. A force F parallel to the incline and passing through the centre of the disc acts which remains constant during the motion



It is possible that for certain values of F, the friction on the disc is acting along downward direction and for certain other values of F, the friction on the disc be acting along upward direction and there is no other possibility

Statement 2: The friction (if acting) will be static will be static and not kinetic in nature

416

Statement 1: When a diver dives, the rotational kinetic energy of the diver increases during several somersaults

Statement 2: When diver pulls his limbs, the moment of inertia decreases and on account of conservation of angular momentum his angular speed increases

417

Statement 1: A particle strikes head-on with another stationary particle such that the first particle comes to rest after collision. The collision should necessarily be elastic

Statement 2: In elastic collision, there is no loss of momentum of the system of the particles

418

Statement 1: Torque is equal to rate of change of angular momentum

Statement 2: Angular momentum depends on moment of inertia and angular velocity

419

Statement 1: If there is no external torque on a body about is center of mass, then the velocity of the center of mass remains constant.

Statement 2: The liner momentum of an isolated system remains constant.

420

Statement 1: The centre of mass of a proton and an electron, released from their respective positions remains at rest

Statement 2: The centre of mass remain at rest, if no external force is applied

421

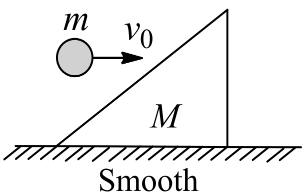
Statement 1: No external force acts on a system of two spheres which undergo a perfectly elastic head–on collision. The minimum kinetic energy of this system is zero if the net momentum of the system is zero

Statement 2: If any two bodies undergo a perfectly elastic head–on collision, at the instant of maximum deformation, the complete kinetic energy of the system is converted to deformation potential energy of the system

422

Statement 1: A particle of mass m strikes a smooth wedge of mass M as shown in Fig. Linear momentum of the particle along the surface of wedge is conserved during collision

Statement 2: Wedge exerts a force perpendicular to the inclined face of the wedge on particle during collision



423

Statement 1: Moment of inertia of circular ring about a given axis is more than moment of inertia of the circular disc of same mass and same size, about the same axis

Statement 2: The circular ring hollow so its moment of inertia is more than circular disc which is solid

424

Statement 1: A ladder is more apt to slip, when you are high up on it than when you just begin to climb

Statement 2: At the high up on a ladder, the torque is large and on climbing up the torque is small

425

Statement 1: When ice on polar caps of earth melts, duration of the day increases

Statement 2: $L = L\omega = I.\frac{2\pi}{T}$ = constant

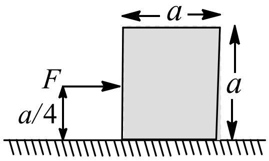
426

Statement 1: The angular momentum under a central force is constant.

Statement 2: Inverse square law of force is conservative.

427

Statement 1: A uniform cubical block (of side a) undergoes translational motion on a smooth horizontal surface under action of horizontal force F as shown in Fig. Under the given condition, the horizontal surface exerts normal reaction non-uniformly on the lower surface of the block



Statement 2: For the cubical block given in statement 1, the horizontal force F has a tendency to rotate the cube about its centre in clockwise sence. Hence, the lower right edge of the cube presses the horizontal surface harder in comparison to the force exerted by the lower left edge of the cube on horizontal surface

428

Statement 1: The centre of mass of a body may lie where there is no mass

Statement 2: The centre of mass has nothing to do with the mass

429

Statement 1: Inertia and moment of inertia are same quantities

Statement 2: Inertia represents the capacity of a body to oppose its state of motion or rest

430

Statement 1: The centre of mass of body may lie there is no mass.

Statement 2: Centre of mass of a body is a point, where the whole mass of the body is supposed to be con centrated

431

Statement 1: The centre of mass of an electron and proton, when released moves faster towards proton

Statement 2: This is because proton is heavier

432

Statement 1: At the centre of earth, a body has centre of mass, but no centre of gravity

Statement 2: Acceleration due to gravity is zero at the centre of earth

433

Statement 1: Torque due to force is maximum when angle between $\vec{r}$ and $\vec{F}$ is 90°

Statement 2: The unit of torque is newton-metre

434

Statement 1: The velocity of a body at the bottom of an inclined plane of a given height is more when it slides down the plane compared to when it is rolling down the same plane

Statement 2: In rolling down, a body acquires both kinetic energy of translation and rotation

435

Statement 1: The centre of mass of system of n particles is the weighted average of the position vector of the n particles making up the system

Statement 2: The position of the centre of mass of a system is independent of coordinate system

436

Statement 1: If no external force acts on a system of particles, then the centre of mass will not move in any direction

Statement 2: If net external force is zero, then the linear momentum of the system remains constant

437

Statement 1: A rigid disc rolls without slipping on a fixed rough horizontal surface with uniform angular velocity. Then the acceleration of lowest point on the disc is zero

Statement 2: For a rigid disc rolling without slipping on a fixed rough horizontal surface , the velocity of the lowest point on the disc is always zero

438

Statement 1: Torque is time rate of change of a parameter, called angular momentum

Statement 2: This is because in linear motion, force represents time rate of change of linear momentum

439

Statement 1: The position of centre of mass of a body does not depend upon shape and size of the body

Statement 2: Centre of mass of a body lies always at the centre of the body

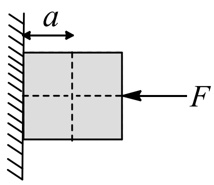
440

Statement 1: If a sphere of mass m moving with speed u undergoes a perfectly elastic head–on collision with another sphere of heavier mass M at rest $(M > m)$, then direction of velocity of sphere of mass m is reserved due to collision (no external force acts on system of two spheres)

Statement 2: During a collision of spheres of unequal masses, the heavier mass exerts more force on the lighter mass in comparison to the force which lighter mass exerts on the heavier one

441

Statement 1: A horizontal force F is applied such that the block remains stationary because N will produce torque



Statement 2: The torque produces by friction force is equal and opposite to the torque produced due to normal reaction (N)

442

Statement 1: A wheel moving down a perfectly frictionless inclined plane will undergo slipping (not rolling motion)

Statement 2: For perfect rolling motion, work done against friction is zero

443

Statement 1: Two Cylinders, one hollow (metal) and the other solid (wood) with the same mass and identical dimensions are simultaneously allowed to roll without slipping down an inclined plane from the same height. The hollow cylinder will reach the bottom of the inclined plane first

Statement 2: By the principle of conservation of energy, the total kinetic energies of both the cylinders are identical when they reach the bottom of the incline

444

Statement 1: The centre of mass of a two particle system lies on the line joining the two particles, being closer to the heavier particle

Statement 2: Product of mass of one particle and its distance from centre of mass is numerically equal to product of mass of other particle and its distance from centre of mass

445

Statement 1: If the earth shrinks (without change in mass) to half it's present size, length of the day would become 6 hr

Statement 2: As size of earth change, its moment of inertia changes

446

Statement 1: Radius of gyration of body is a constant quantity

Statement 2: The radius of gyration of a body about an axis of rotation may be defined as the root mean square distance of the particle from the axis of rotation

447

Statement 1: There are two propellers in a helicopter

Statement 2: Angular momentum is conserved

448

Statement 1: The centre of mass of an electron and proton, when released moves faster towards proton

Statement 2: Proton is heavier than electron

449

Statement 1: A solid sphere is rolling on a rough horizontal surface. Acceleration of contact point is zero

Statement 2: A solid sphere can roll on the smooth surface

450

Statement 1: A disc is rolling on an inclined plane without slipping. The velocity of centre of mass is V. The other points on the disc lie on a circular arc having same speed as that of the centre of mass

Statement 2: When a disc is rolling on an inclined plane, the magnitude of velocities of all points from the contact point is the same, having distance equal to radius r

451

Statement 1: In rolling, all points of a rigid body have the same linear speed

Statement 2: The rotational motion does not affect the linear velocity of rigid body

452

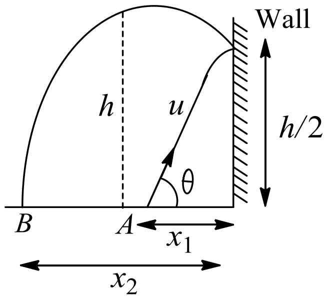
Statement 1: Centre of mass of an isolated system has a constant velocity

Statement 2: If the centre of mass of an isolated system is already at rest, it remains at rest

Matrix-Match Type

This section contain(s) 0 question(s). Each question contains Statements given in 2 columns which have to be matched. Statements (A, B, C, D) in **columns I** have to be matched with Statements (p, q, r, s) in **columns II.**

453. A particle is projected with a speed u at an angle θ with horizontal from point A. It strikes elastically with a vertical wall at height $h/2$. It rebounds and reaches maximum height h and falls back on the ground at point B as shown in Fig. Distances from A to wall and from wall to B are x_1 and x_2, respectively, and time to cover x_1 and x_2 are t_1 and t_2, respectively. Match the values in column I with the expressions in column II



Column-I	Column- II
(A) $\sqrt{2}$	(p) $\frac{x_2 - x_1}{x_2 + x_1}$ or $\frac{x_2 + x_1}{x_2 - x_1}$
(B) $\frac{1}{\sqrt{2}}$	(q) $\frac{t_2 - t_1}{t_2 + t_1}$ or $\frac{t_2 + t_1}{t_2 - t_1}$
(C) 1	(r) $\frac{u \sin\theta}{g(t_1 + t_2)}$
(D) $\frac{1}{2}$	(s) $\frac{u\cos\theta(t_1 + t_2)}{(x_1 + x_2)}$

CODES :

	A	B	C	D
a)	d	a,b	c	d
b)	a,b	d	a,b	c
c)	a,b	a,b	d	c
d)	a,b	c	a,b	d

454. Match the statements in Column I with those in Column II. One or more matching is possible

Column-I	Column- II
(A) Solid sphere rolling with slipping on a rough horizontal surface	(p) Total kinetic energy is conserved
(B) Solid sphere in pure rolling on a rough horizontal surface and no other force is acting	(q) Angular momentum about the CM is conserved
(C) Solid sphere in pure rolling on a smooth horizontal surface	(r) Angular momentum about a contact point on the contact surface is conserved
(D) Solid sphere in pure rolling on a rough incline	(s) Momentum is conserved

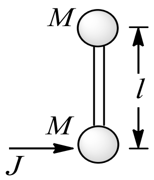
(t) Total mechanical energy is conserved

CODES :

	A	B	C	D
a)	C	a,b,c,d, e	a,b,c,d, e	e
b)	a,b,c	d,e	b,c,d	d,e
c)	b,c	d,e	a,b	c
d)	a	b	c	d

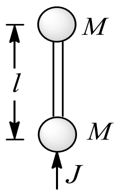
455.

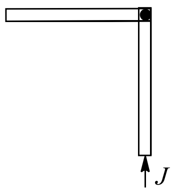
Column-I | **Column- II**

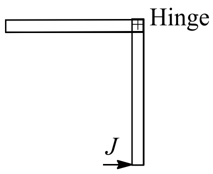
(A) 

(impulse)

Rod is massless, dumb-bell is placed on a smooth horizontal surface

(B) 

(C) 

(D) 

(p) Translation occurs

(q) Rotation occurs

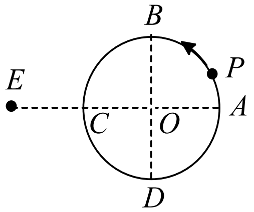
(r) Angular momentum increases

(s) Linear momentum increases

CODES :

	A	B	C	D
a)	A,b	b,a	d.c	a
b)	c	d,a	b,a	b
c)	b,a	c	a,d	b
d)	a,b,c,d	a,d	a,b,c,d	b,c,d

456. A particle P moves with constant speed on a circle in anticlockwise direction as shown in figure



Match column I and with Column II:

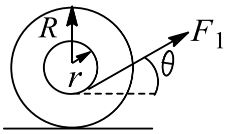
Column-I		Column- II	
(A)	Angular momentum of the particle about O	(p)	Is minimum when the particle is at A
(B)	Angular momentum of the particle about E	(q)	Is maximum when the particle is at A
(C)	Angular velocity of the particle about O	(r)	Does not remain constant
(D)	Angular velocity of the particle about E	(s)	Remains constant

CODES :

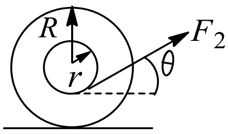
	A	**B**	**C**	**D**
a)	D	b,c	d	a,c
b)	b	c	d	a
c)	a	b	c	d
d)	b,a	c	d	a

457. A uniform yo-yo (longer radius R, small radius r) is resting on a perfectly rough horizontal table. This equation should be attempted after forces $F_1, F_2, F_3$and F_4 are applied separately as shown

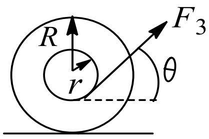
Column-I

(A) 

$\cos\theta = r/R$

(B) 

$\cos\theta < (r/R)$

(C) 

$\cos\theta = (r/R)$

Column- II

(p) Centre of mass of the yo-yo accelerates towards the left

(q) Centre of mass of the yo-yo accelerates towards the right

(r) Friction acts on the yo-yo towards the left

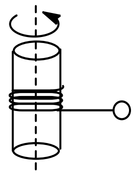
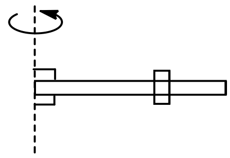
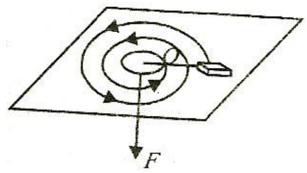
(s) Friction acts on the yo-yo towards the right

CODES :

	A	**B**	**C**	**D**
a)	B,c	a,c	c	
b)	d	b	a	

c)	c	d	a
d)	b,c	d,a	b

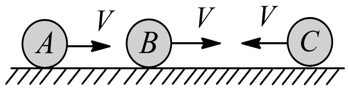
458.

	Column-I		Column- II
(A)	 A small particle of mass m is given an initial velocity in horizontal plane and winds its cord around the fixed vertical shaft of radius a	(p)	Conservation of angular momentum
(B)	 A smooth rod rotates with some angular velocity. A small sleeve starts sliding along the rod	(q)	Conservation of kinetic energy
(C)	Two ice-skaters approach each other at equal speeds along the parallel path separated by some distance. They link hands as they pass by and pull each other to reduce their separation	(r)	Conservation of total mechanical energy
(D)	 A small body tied to a non-stretchable thread of mass m is lying over a smooth horizontal plane. Other end of the thread is being drawn into a hole O	(s)	Work is done by internal forces

CODES :

	A	**B**	**C**	**D**
a)	D,a	b	c,a	a,c
b)	c	d,a	b,a	b
c)	b,a	c	a,d	b
d)	b,c	a,b,c	a,d	a,d

459. Two spheres A and B move on a smooth horizontal surface with same velocity V and have some separation between them. A third sphere C is moving in opposite direction on the same surface with the same speed. All the spheres are of equal mass. The collisions are elastic. V_{CM} represents the centre of mass velocity of all the three spheres. Column II represents the values after all the possible impacts have occurred



Column-I	Column- II
(A) If A and B are not connected to each other	(p) V_{CM} before collision $= V/3$
(B) If A and B are connected to each other by a massless rigid rod	(q) V_{CM} after all the collision $= \frac{V}{3}$
(C) If A and B are connected by an ideal string	(r) Momentum of system $(B + C)$ is not conserved
(D) If A and B are connected by an ideal spring which is initially unstretched	(s) Momentum of system $(B + C)$ is conserved

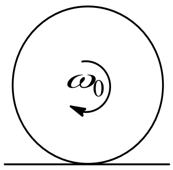
CODES :

	A	B	C	D
a)	a,b,c	a,b,c	a,b	a,b
b)	a,b,c	a,b	a,b,c	a
c)	a,b	a,b,c	a,b	a,b,
d)	b	a,b	b,c	a,b,c

460.

Column-I | **Column- II**

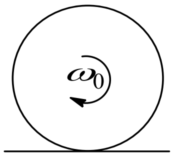
(A)



Ring

(p) Rotational work done by the friction is negative till pure rolling begins

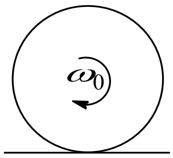
(B)



Cylinder

(q) Translational work done is positive till pure rolling starts

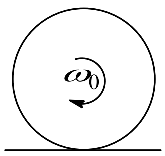
(C)



Solid sphere

(r) When pure rolling begins velocity of centre of mass is minimum

(D)



Hollow sphere

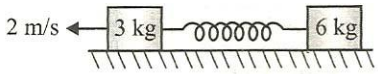
(s) Takes maximum time for pure rolling to begin

CODES :

	A	B	C	D
a)	A,b,d	a,b	a,b,c	a,b

b)	b,a	a,b,c	d,a	b
c)	c	c	a,b,c	a,b,c
d)	c,d	b,a	c,d	a

461. Two blocks of masses 3 kg and 6 kg are connected by an ideal spring and are placed on a frictionless horizontal surface. The 3 kg block is imparted a speed of 2 m/s towards left. (Consider left as positive direction)

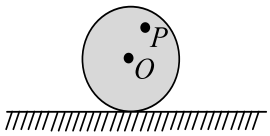


Column-I		Column- II	
(A)	When the velocity of the 3 kg block is $\frac{2}{3}$ m/s	(p)	The velocity of centre of mass is $\frac{2}{3}$ m/s
(B)	When the speed of the 3 kg block is $\frac{2}{3}$ m/s	(q)	Deformation of the spring is zero
(C)	When the speed of the 3 kg block is minimum	(r)	Deformation of the spring is maximum
(D)	When the velocity of the 6 kg block is maximum	(s)	Both the blocks are at rest with respect to each other

CODES :

	A	**B**	**C**	**D**
a)	a	b,c	a,b,c,d	a,c,d
b)	a,c,d	a,b,c,d	a	a,b
c)	a,b	a,c,d	a	a,b,c,d
d)	a	a,b,c,d	a,b	a,c,d

462. A uniform disc rolls without slipping on a rough horizontal surface with uniform angular velocity. Point O is the centre of disc and P is a point on disc as shown in Figure. In each situation oc column I a statement is given and the corresponding results are given in Column II. Match the statements in Column I with the results in Column II



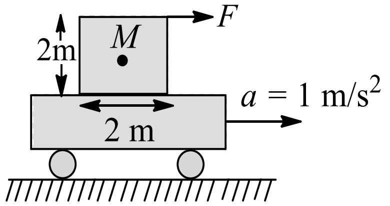
Column-I		Column- II	
(A)	The velocity of point P on the disc	(p)	Changes in magnitude with time
(B)	The acceleration of point P on the disc	(q)	Always directed from that point (the point on disc given in column I) towards the centre of disc
(C)	The tangential acceleration of point P on the disc	(r)	Is always zero
(D)	The acceleration of the point on the disc which is in constant with rough horizontal surface	(s)	Is non-zero and remains constant in magnitude

CODES :

	A	**B**	**C**	**D**

a)	C	a	b,d	a
b)	a	b,d	a	b,d
c)	c	a	b	d
d)	d	c	a	b

463. A cubical block having square cross section of side 2 m and of mass $M = 10$ kg is resting over a platform moving at constant acceleration $a = 1\ \text{m/s}^2$. Coefficient of friction between the block and the platform is $\mu = 0.1$. A force F acts at the top of the cube as shown in figure. Now match Column I with Column II



Column-I	Column- II
(A) $F = 0$	(p) Block neither topples nor slips over the platform
(B) $F = 45$ N	(q) Block topples but does not slip over the platform
(C) $F = 15$ N	(r) Block slips but does not topple over the platform
(D) $F = 25$ N	(s) Block slips as well as topples on the platform

CODES :

	A	**B**	**C**	**D**
a)	A	d	a	c
b)	c	b	a	d
c)	b	a	c	d
d)	d	c	b	a

464. In Column I, information about the force(s) acting on a body is mentioned, while in Column II information about the motion of a body is given. Match the entries in Column II with the entries in Column I

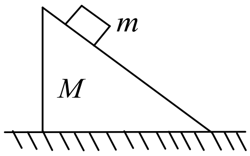
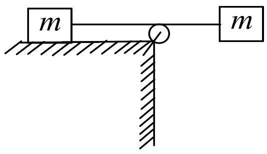
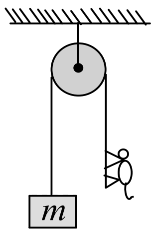
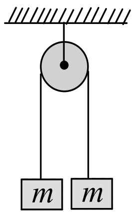
Column-I	Column- II
(A) A single force through centre of mass	(p) Rotational motion
(B) Equal and opposite forces separated by non-zero distance	(q) Translation motion
(C) Equal and opposite forces acting at the same point	(r) Na motion
(D) A single forces not through centre of mass	(s) Centre of mass performs curvilinear motion

CODES :

	A	**B**	**C**	**D**
a)	B	a	c	a,b,d

b)	c	d	b,a	d,e
c)	b,c	a,b	d,a	c
d)	c,a	d	b,c	e

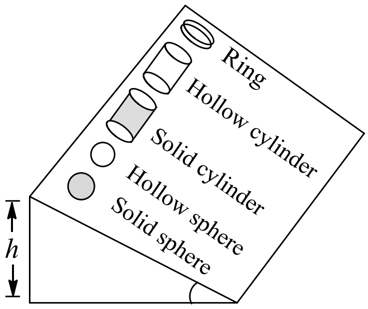
465. In each situation of column I, a system involving two bodies is given. All strings and pulleys are light and friction is absent everywhere. Initially, each body of every system is at rest. Consider the system in all situations of column I from rest till any collision occurs. Then match the statements in column I with the corresponding results in column II

Column-I	Column- II
(A) The block plus wedge system is placed over smooth horizontal surface. After the system is released from rest, the centre of mass of system 	(p) Shifts towards right
(B) The string connecting both the blocks of mass m is horizontal. The left block is placed over smooth horizontal table as shown. After the two blocks system is released from rest, the centre of mass of system 	(q) Shifts downwards
(C) The block and the monkey have the same mass. The monkey starts climbing up the rope. After the monkey starts climbing up, the centre of mass of monkey + block system 	(r) Shifts upwards
(D) Both blocks of mass m are initially at rest. The left block is given initial at rest. The left block is given initial velocity u downwards. Then, the centre of mass of two–block system afterwards 	(s) Does not shift

CODES :

	A	B	C	D
a)	d	a	c	b
b)	c	d	b	a
c)	b	a	c	d
d)	b	c	d	a

466. A solid sphere, a thin-walled hollow sphere, a solid cylinder, a thin-walled hollow cylinder and a ring, each of mass m and radius R, are simultaneously released at rest from the top of an inclined plane, as shown in Figure. The objects roll down the plane without slipping. Also we may consider the objects and the surface on which they roll to be perfectly rigid. Match Columns I and II

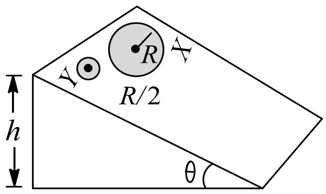


	Column-I		Column- II
(A)	Time taken to reach the bottom is maximum for	(p)	Solid sphere
(B)	Angular acceleration is maximum for	(q)	Hollow cylinder
(C)	Kinetic energy at the bottom is the same for	(r)	Hollow sphere
(D)	Rotational kinetic energy is maximum for	(s)	Ring

CODES :

	A	B	C	D
a)	B,d	a	a,b,c,d	b,d
b)	b	d	c	a
c)	c,d	b,a	d	a
d)	c,a	b,d	a,c	a,b,c

467. A solid sphere X of mass $'M'$ and radius R and another sphere Y of mass $'2M'$ and radius $'R/2'$ are simultaneously released at rest from the top of an inclined plane as shown in figure. The spheres roll without slipping. Also we may consider the spheres and the surface on which they roll to be perfectly rigid. Match Columns I and II



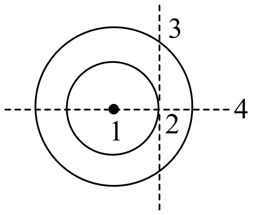
Column-I | **Column- II**

(A) More for sphere X	(p) Speeds of the two spheres at the bottom of the incline
(B) More for sphere Y	(q) Time taken by the spheres to reach the bottom
(C) Same for both spheres	(r) Angular acceleration
(D) Zero	(s) Kinetic energy at the bottom

CODES :

	A	**B**	**C**	**D**
a)	C	a	b	d
b)	b	d	a	c
c)	does not m	c	a,b	does notma
d)	d	b	c	a

468. From a uniform disc of mass M and radius R, a concentric disc of radius $R/2$ is cut out. For the remaining annular disc: I_1 is the moment of inertia about axis '1', I_2 about '2', I_3 about '3' and I_4 about '4'. Axis '1' and '2' are perpendicular to the disc and '3' and '4' are in the plane of the disc



Axis'2', '3' and '4' intersect at a common point
Match the following

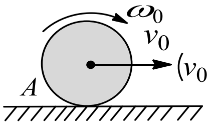
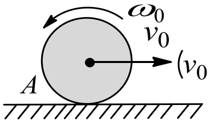
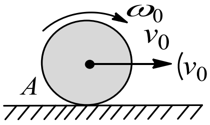
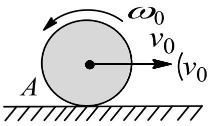
Column-I	**Column- II**
(A) I_1 is equal to	(p) $\frac{21}{32}MR^2$
(B) I_2 is equal to	(q) $I_1/2$
(C) $I_3 + I_4$ is equal to	(r) $\frac{15}{32}MR^2$
(D) $I_2 - I_3$ is equal to	(s) None of these

CODES :

	A	**B**	**C**	**D**
a)	D	c	b	a
b)	c	a	a	b
c)	b	a	c	d
d)	a	b	c	d

469. In each situation of Column I, uniform disc of mass m and radius R rolls on a rough fixed horizontal surface as shown. At $t = 0$ (initially) the angular velocity of the disc is ω_0 and velocity of the centre of mass of the disc is v_0 (in horizontal direction). The relation between v_0 and ω_0 for each situation and also initial sense

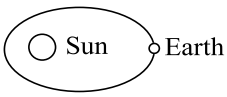
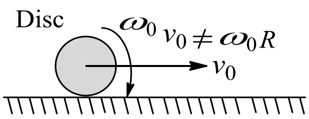
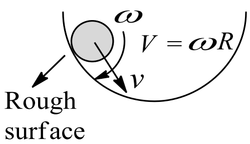
of rotation is given for each situation in column I. Then match the statements in Column I with the corresponding results in Column II

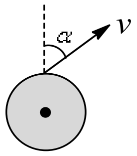
Column-I	Column- II
(A) 	(p) The angular momentum of the disc about point A (as shown in the figure) remain conserved
(B) 	(q) The kinetic energy of the disc after it starts rolling without slipping is less than its initial kinetic energy
(C) 	(r) In the duration disc rolls with slipping, the friction acts on the disc towards the left
(D) 	(s) In the duration disc rolls with slipping, the friction acts on the disc for some time to the right and for some time to the left

CODES :

	A	B	C	D
a)	C	d	b	a
b)	a,c	d,c	c,d	c,d
c)	b,a	b,c	d	a,c
d)	a,b,c	a,b,c	a,b	a,b,c

470. Choose the correct option

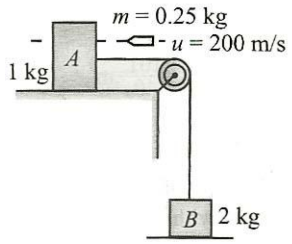
Column-I	Column- II
(A) Earth moving in an elliptical orbit (only earth is system) 	(p) Conservation of linear momentum along any direction
(B) A disc having translation and rotation motion both (both slipping on a rough surface (only disc in system) 	(q) Conservation of linear momentum along specific direction
(C) A sphere rolling without slipping on a curved surface (only the sphere in system) 	(r) Conversion of angular momentum about any point in the space
(D) Projection of a particle from the surface of earth (only particle in system)	(s) Conversion of angular momentum about a specific point in the space



CODES :

	A	B	C	D
a)	B	d	c	a
b)	c,d	b,a	d	a
c)	d	b	a	c
d)	c	d	does not m	d

471. A block A of mass $M_A = 1$ kg is kept on a smooth horizontal surface and attached by a light thread to another block B of mass $M_B = 2$ kg. Block B is resting on ground, and thread and pulley are massless and frictionless. A bullet of mass $m = 0.25$ kg moving horizontally with velocity of $u = 200$ m/s penetrates through block A and comes out with a velocity of 100 m/s



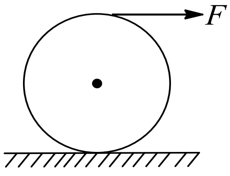
	Column-I		Column- II
(A)	Velocity of the 2 kg block just after the bullet comes out	(p)	50/3
(B)	Maximum displacements of 1 kg block in left direction	(q)	25
(C)	Impulse by the string on block B	(r)	25/3
(D)	Impulse by the particle on block A	(s)	5.2

CODES :

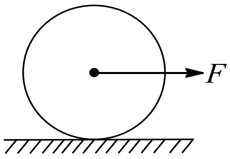
	A	B	C	D
a)	c	d	a	b
b)	a	b	d	c
c)	b	d	a	c
d)	b	a	c	d

472. Assume sufficient friction to prevent slipping

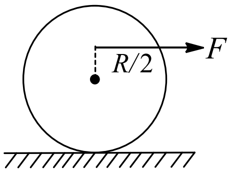
Column-I	Column- II

(A) 

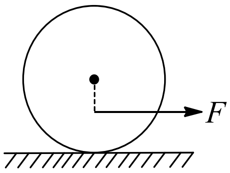
(p) Body accelerates forward

(B) 

(q) Rotation about the centre of mass is clockwise

(C) 

(r) Friction force acts backward

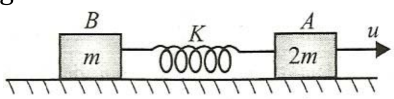
(D) 

(s) No friction acts

CODES :

	A	**B**	**C**	**D**
a)	B,a	b,c	d	a,c
b)	a,b,d	a,b,c	a,b,d	a,b,c
c)	c	d	b	a
d)	a,c	d,c	c,d	c,d

473. Two blocks A and B of masses m and $2m$, respectively, are connected by a massless spring of spring constant K. This system lies over a smooth horizontal surface. At $t = 0$, block A has velocity u towards right as shown, while the speed of block B is zero, and the length of the spring is equal to its natural length at that instant. In each situation of column I, certain statements are given and corresponding results are given in column II. Match the statements in column I with the corresponding results in column II



Column-I		**Column- II**	
(A)	The velocity of block A	(p)	Can never be zero
(B)	The velocity of block B	(q)	May be zero at certain instants of time
(C)	The kinetic energy of the system of two blocks	(r)	Is minimum at maximum compression of spring
(D)	The potential energy of spring	(s)	Is maximum at maximum extension of spring

CODES :

	A	B	C	D
a)	A,c	b,d	a	b
b)	a	b	a,c	b,d
c)	d	b,d	b	a,c
d)	a	a	b	b,d

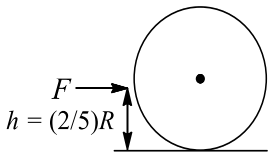
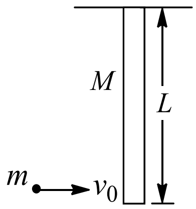
474. Centre of mass of a system is unique point which is very helpful in solving the problems related to the motions of rigid bodies. In columns I and II, some statements regarding centre of mass are given. Match the columns:

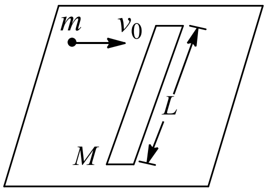
	Column-I		**Column- II**
(A)	In the absence of external forces, the internal forces	(p)	Inside the material of the body
(B)	Centre of mass of a body can be	(q)	May affect the motion of individuals
(C)	The kinetic energy of the system of two blocks	(r)	Do not affect the motion of centre of mass
(D)	Centre of mass of a solid cylinder is	(s)	Outside the material of the body

CODES :

	A	B	C	D
a)	B,c	a,d	c	a
b)	a,d	c	b,c	a
c)	b,c	a	a,d	c
d)	c	b,c	a,d	a

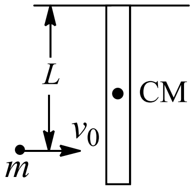
475. Match the entries in Column I with those in Column II

	Column-I		**Column- II**
(A)	 An impulsive force acts at a height $h = (2/5)R$ on a solid sphere, lying on a rough surface	(p)	Momentum is conserved
(B)	 A small particle of mass m moving horizontally collides with a vertical hinged rod inelastically; $e = 0$	(q)	Angular momentum is conserved

(C) 

A small particle of mass m strikes elastically at the end of a horizontal rod kept on a smooth surface

(r) Energy is conserved

(D) 

A small particle of mass m collides with a vertical rod elastically

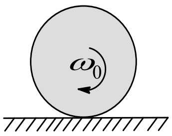
(s) Momentum increases

CODES :

	A	**B**	**C**	**D**
a)	D	b,d	a,b,c	b,c,d
b)	d	c	b	a
c)	b,a	c,d	c	a
d)	b,a	b,c	d	a,c

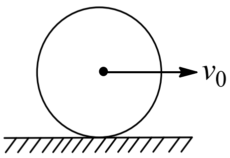
476.

Column-I	**Column- II**

(A) 

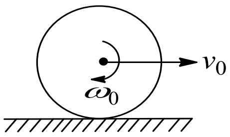
A spinning ball lowered on a rough surface

(p) Net work done by friction force is negative

(B) 

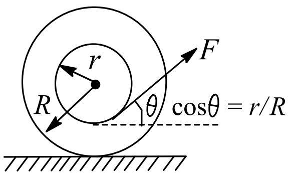
A ball is projected with velocity v_0 on a rough surface

(q) Angular momentum about the CM is conserved

(C) 

A ball projected with velocity $v_0 = R\omega_0$ projected on a smooth borizontal on a smooth borizontal surface

(r) Translation work done by friction is positive

(D) 

A spool pulled by a fore F, rolling without

(s) Net work done by friction is zero

slipping on a rough surface

CODES :

	A	B	C	D
a)	A,b,c	a	d	d
b)	c	d	b	a
c)	c	a	d	c,d
d)	b,a	b,c	d	a,c

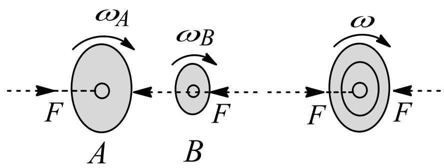
477. In column I, nature of collision between two bodies is given while in column II some physical quantity that may remain conserved during the collision is given. Match the entries of column I with the entries of column II

Column-I	Column- II
(A) Elastic collision	(p) Kinetic energy is conserved
(B) Inelastic collision	(q) Kinetic energy of the system may increase
(C) Perfectly inelastic collision	(r) Kinetic energy is not conserved
(D) Collision between two cars moving at high speeds	(s) Total energy is conserved

CODES :

	A	B	C	D
a)	A,d	c,d	c,d	c,d
b)	c,d	a,d	c,d	c,d
c)	c,d	c,d	a,d	c,d
d)	c,d	c,d	c,d	a,d

478. Figure (a) shows two disc A and B, rotating about a common axis with constant angular speeds ω_A and ω_B, respectively. Moment of inertia of disc A is l_A and that of disc B is l_B.The discs are then gently pushed towards each other by forces that act along the axis. Finally, the discs rub against each other and attain a common angular speed ω, as shown in figure (b). Match Colums I and II



(a) (b)

Column-I	Column- II
(A) As the discs stick together, the final angular speed, ω	(p) Will be zero
(B) Torque on each disc, due to the force F applied on the disc	(q) Will be decreasing
(C) When the discs are rubbing against each other, the kinetic energy of their system	(r) $\frac{l_A\omega_A + l_B\omega_B}{l_A + l_B}$

(D) Angular momentum of the system				(s) There will be loss of energy in doing work against the non-conservative internal forces

CODES :

	A	B	C	D
a)	B	c	a	
b)	c	a	b,d	does notma
c)	a	c	b	
d)	d	a	c	

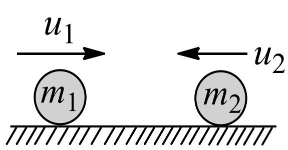
479. Each of the body in column I show the moment of inertia about its diameter in column II. Select the correct answer (matching list I with List II) as per code given below the lists.

Column-I	Column- II
(A) Ring	(1) $\frac{M}{4}(R_1^2 + R_2^2)$
(B) Disc	(2) $\frac{1}{4}MR^2$
(C) Annular Disc	(3) $\frac{1}{2}MR^2$

CODES :

	A	B	C	D
a)	2	3	1	
b)	3	2	1	
c)	3	1	2	
d)	1	2	3	

480. Two balls of masses m_1 and m_2 are moving towards each other with speeds u_1 and u_2, respectively. They collide head-on and their speeds are v_1 and v_2 after collision ($m_1 = 8$ kg, $m_2 = 2$ kg, $u_2 = 3$ m/s)



Column-I	Column- II
(A) The speed u_1 (in m/s) so that both balls move in same direction if co-efficient of restitution is $e = 0.5$	(p) $\frac{1}{14}$
(B) The speed u_1 (in m/s) so that the maximum fraction of energy is transformed to m_2 (assume elastic collision)	(q) $\frac{1}{8}$
(C) Co-efficient of restitution if m_2 stops after collision and $u_1 = 0.5$ m/s	(r) 2
(D) If collision is inelastic and $u_1 = 3$ m/s, the loss of kinetic energy (in J) after collision may be	(s) 4

CODES :

	A	B	C	D
a)	c	c,d	a,b,c,d	a
b)	c,d	c	a	a,b,c,d
c)	a	c,d	c	a,b,c,d
d)	c,d	a,b,c,d	c	a

481. Match the following:

Column-I	Column- II
(A) Inelastic collisions	(p) Kinetic energy of the system may decrease
(B) Elastic collisions	(q) Kinetic energy of the system may increase
(C) Total work done is zero	(r) Kinetic energy of the system may remains constant
(D) Non-conservative forces are not present	(s) Just before and after collision, momentum remains constant

CODES :

	A	B	C	D
a)	c	a,d	b,d	a,d
b)	c,d	c	a,d	a,b,c
c)	c	a,d	c,d	a,b,c
d)	a,d	c,d	c	a,b,c

482. Column I contains physical quantity/process while column II contains formula/ principle. Match columns I and II, such that the formula/principle is correct corresponding to the quantity in column I

Column-I	Column- II
(A) Momentum	(p) $m(v_2 - v_1)$
(B) Impulse	(q) Only momentum is conserved
(C) Elastic collision	(r) Momentum and kinetic energy both are conserved
(D) Inelastic collision	(s) mv

CODES :

	A	B	C	D
a)	a	b	c	d
b)	b	c	d	a
c)	a	c	b	d

d)	d	a	c	b

483. Column I gives the bodies which are released one by one from the top of an inclined plane. Assume each body rolls purely

Column-I		Column- II	
(A)	Wooden solid cylinder	(p)	KE_{rot} is maximum at the bottom
(B)	Iron solid cylinder	(q)	KE_{trans} is minimum at the bottom
(C)	Thin iron cylindrical shell	(r)	Takes minimum time to reach the bottom
(D)	Thin wooden cylindrical shell	(s)	Takes maximum time to reach the bottom

CODES :

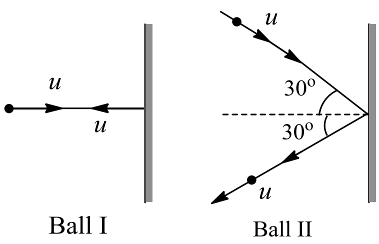
	A	B	C	D
a)	B,a	b,c	d	a,c
b)	c	c	a,b,c	a,b,c
c)	c,d	b,a	c,d	a
d)	a,d	b,a	d	a,c

Linked Comprehension Type

This section contain(s) 96 paragraph(s) and based upon each paragraph, multiple choice questions have to be answered. Each question has atleast 4 choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

Paragraph for Question Nos. 484 to -484

We sometimes encounter examples where a large force acts for very short duration of time producing an appreciable and finite change in linear momentum of the body. Such forces are know as impulsive forces. As an example consider two identical cricket balls of mass m and initial speed u approaching a rigid wall. One ball strikes the wall normally and rebounds with same speed. Another ball strikes the wall making and angle of 30° from normal and is elastically reflected back as shown in figure. Now answer the following questions



484. What is the magnitude of force on the wall due to ball number 1?

a) mu b) $\sqrt{2}mu$ c) $\frac{mu}{2}$ d) Data insufficient

Paragraph for Question Nos. 485 to - 485

A tennis ball is dropped from a height h_0 on a horizontal marble flooring. The ball rebounds to a height h_1, then again falls on the floor, again rebounds and so on.

485. The maximum height of rebound h_n after n rebounds will be

a) $ne.h_0$ b) $n^e.h_0$ c) $e^n.h_0$ d) $e^{2n}.h_0$

Paragraph for Question Nos. 486 to - 486

The three equations of rotational motion are $\omega = \omega_0 + \alpha t$; $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ and $\omega^2 - \omega_0^2 = 2\alpha\,\theta$, where the symbols have their usual meanings. Also, $v - r\,\omega$; $\omega = \frac{2\pi}{T} = 2\pi n$ are the known standard relations. Use them to answer the following questions :

486. The angular velocity of minutes hand of a watch is

a) $\frac{\pi}{30}$ rad s^{-1} b) $\frac{\pi}{60}$ rad s^{-1} c) $\frac{\pi}{1800}$ rad s^{-1} d) $\frac{\pi}{3600}$ rad s^{-1}

Paragraph for Question Nos. 487 to - 487

The centre of mass of a body is a point at which the whole mass of the body is supposed to be concentrated. If the body consists of two particles of masses m_1, m_2 with $\vec{\mathbf{r}}_1$ and $\vec{\mathbf{r}}_2$ as their position vectors, then the position vector of the centre of mass is

$$\vec{\mathbf{r}}_{CM} = \frac{m_1\vec{\mathbf{r}}_1 + m_2\vec{\mathbf{r}}_2}{m_1 + m_2}$$

Similarly, velocity of centre of mass of two particles moving with velocities $\vec{\mathbf{v}}_1$ and $\vec{\mathbf{v}}_2$ is

$\vec{\mathbf{v}}_{CM} = \frac{m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2}{m_1 + m_2}$, and

Acceleration of centre of mass of two particles having acceleration $\vec{\mathbf{a}}_1$and $\vec{\mathbf{a}}_2$is

$$\vec{\mathbf{a}}_{CM} = \frac{m_1\vec{\mathbf{a}}_1 + m_2\vec{\mathbf{a}}_2}{m_1 + m_2}$$

For an isolated system, where no external force acts, $\vec{\mathbf{a}}_{CM} = 0$ and $\vec{\mathbf{v}}_{CM} =$ constant.

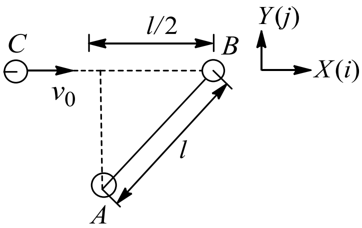
Read the above paragraph and answer the following questions:

487. Two bodies of masses 2 kg and 4 kg are moving towards each other with equal velocity 5 ms^{-1}. The velocity of centre of mass is

a) $-\frac{5}{3}$ms^{-1} b) $\frac{5}{3}$ms^{-1} c) $\frac{3}{5}$ms^{-1} d) $-\frac{3}{5}$ms^{-1}

Paragraph for Question Nos. 488 to - 488

Three spheres, each of mass m, can slide freely on a frictionless, horizontal surface. Spheres A and B are attached to an inextensible, inelastic cord of length 'l' and are at rest in the position shown where sphere B is struck by sphere C which is moving to the right with a velocity v_0. Knowing that the cord is taut where sphere B is struck by sphere C and assuming 'head on' inelastic impact between B and C, we cannot conserve kinetic energy of the entire system



488. The velocity of B immediately after collision is along unit vector

a) $\hat{\imath}$
b) $\frac{\hat{\imath}+\hat{\jmath}}{\sqrt{2}}$
c) $\frac{\sqrt{3}}{2}\hat{\imath}+\frac{1}{2}\hat{\jmath}$
d) None of these

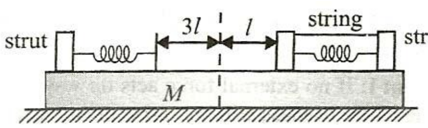
Paragraph for Question Nos. 489 to - 489

Collision is a physical process in which two or more objects, either particle masses or rigid bodies, experience very high force of interaction for a very small duration. It is not essential for the objects to physically touch each other for collision to occur. Irrespective of the nature of interactive force and the nature of colliding bodies, Newton's second law holds good on the system. Hence, momentum of the system before and after the collision remains conserved if no appreciable external force acts on the system during collision
The amount of energy loss during collision, if at all, is indeed dependent on the nature of colliding objects. The energy loss is observed to be maximum when objects stick together after collision. The terminology is to define collision as 'elastic' if no energy loss takes place and to define collision as 'plastic' for maximum energy loss. The behavior of system after collision depends on the position of cooling objects as well. A unidirectional motion of colliding objects before collision can turn into two dimensional after collision if the line joining the centre of mass of the two colliding objects is not parallel to the direction of velocity of each particle before collision. Such type of collision is referred to as oblique collision which may be either two or three dimensional

489. According to the definition of collision in paragraph 1, which of the following physical process is not a collision?
a) A projectile exploding into three fragments at its highest point
b) Two soap bubbles coalescing to form a bubble of larger radius
c) A vertically upward thrown particle changing direction at its highest point
d) A piece of magnet thrown on a metallic surface

Paragraph for Question Nos. 490 to - 490

According to the principle of conservation of linear momentum if the external force acting on the system is zero, the linear momentum of the system will remain conserved. It means if the centre of mass of a system is initially at rest, it will remain at rest in the absence of external force, that is, the displacement of centre of mass will be zero



A plank of mass M is placed on a smooth horizontal surface. Two light identical springs, each of stiffness K, are rigidly connected to struts at the end of the plank as shown in Fig. When the springs are in their unextended position, the distance between their free ends is $3l$. A block of mass m is placed o the plank and pressed against one of the springs so that it is compressed to l. To keep the block at rest it is connected to the strut by means of a light string. Initially, the system is at rest. Now the string is burnt

490. The maximum displacement of the plank is

a) $\frac{5ml}{M}$
b) $\frac{5ml}{M+m}$
c) $\frac{3ml}{M+m}$
d) $\frac{4ml}{M+m}$

Paragraph for Question Nos. 491 to - 491

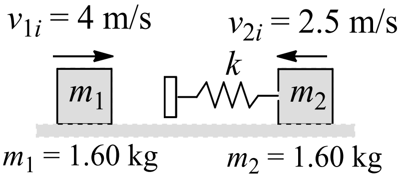
Two identical balls A and B, each of mass 2 kg and radius R, are suspended vertically from inextensible strings as shown in Fig. The third ball C of mass 1 kg and radius $r = (\sqrt{2}-1)R$ falls and hits A and B symmetrically with 10 m/s. Speed of both A and B just after the collision is 3 m/s

491. Speed of C just after collision is

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

Paragraph for Question Nos. 492 to - 492

An elastic collision takes place between two masses, m_1 and m_2, moving on a frictionless surface as shown in Fig. The spring constant is $k = 600$ N/m

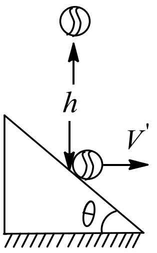


492. What is the velocity of block 2 at the instant when block 1 is moving to the right with a velocity 3.00 m/s?

a) 1.50 m/s
b) −2.62 m/s
c) 4.64 m/s
d) −1.74 m/s

Paragraph for Question Nos. 493 to - 493

A smooth ball is dropped from height h on a smooth incline as shown in Fig. After collision, the velocity of the ball is directed horizontally



493. Find the coefficient of restitution

a) $\cot^2\theta$
b) $\sin^2\theta$
c) $\tan^2\theta$
d) $\cos^2\theta$

Paragraph for Question Nos. 494 to - 494

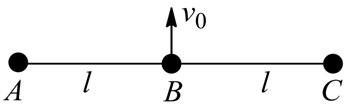
After falling from rest through a height h, a body of mass m begins to raise a body of mass $M (M > m)$ connected to it through a pulley

494. Determine the time it will take for the body of mass M to return to its original position

a) $\frac{2m}{M+m}\sqrt{\frac{2h}{g}}$
b) $\frac{2m}{M-m}\sqrt{\frac{2h}{g}}$
c) $\frac{2m}{M-m}\sqrt{\frac{h}{g}}$
d) $\frac{m}{M-m}\sqrt{\frac{2h}{g}}$

Paragraph for Question Nos. 495 to - 495

Three identical balls are connected by light inextensible strings with each other as shown and rest over a smooth horizontal table. Length of each string is l



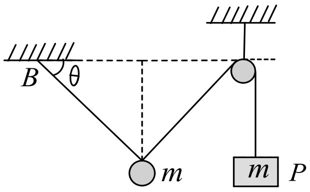
At moment $t = 0$, ball B is imparted a velocity v_0 perpendicular to the strings and then the system is left on its own

495. Calculate the velocity of B just before A collides with ball C

a) $\frac{v_0}{3}$ b) $\frac{2v_0}{3}$ c) $\frac{2v_0}{5}$ d) None of these

Paragraph for Question Nos. 496 to - 496

In Fig. a pulley is shown which is frictionless and a ring of mass m can slide on the string without any friction. One end of the string is attached to point B and to the other end, a block 'P' of mass m is attached. The whole system lies in vertical plane

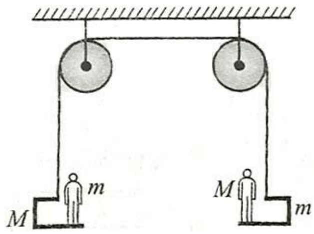


496. If the system is released from rest, it is found that the system remains at rest. What is the value of θ?

a) 30° b) 45° c) 60° d) 75°

Paragraph for Question Nos. 497 to - 497

A system of men and trolley is shown in Fig. To the left end of the string, a trolley of mass M is connected on which a man of mass m is standing. To the right end of the string another trolley of mass m is connected on which a man M is standing. Initially, the system is at rest. All of a sudden both the men leap upwards simultaneously with the same velocity u w.r. t. ground

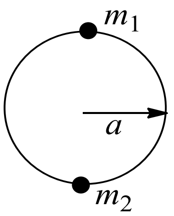


497. Find the relative velocity of left man with respect to his trolley just after he leaps upwards

a) $\frac{mu}{m+M}$ b) $\frac{Mu}{m+M}$ c) $\frac{2mu}{m+M}$ d) $\frac{2Mu}{m+M}$

Paragraph for Question Nos. 498 to - 498

Two beads A and B of masses m_1 and m_2, respectively, are threaded on a smooth circular wire of radius a fixed in a vertical plane. B is stationary at the lowest point when A is gently dislodged from rest at the highest point. A collided with B at the lowest point. The impulse given to B due to collision is just great enough to carry it to the level of the centre of the circle while A is immediately brought to rest by the impact

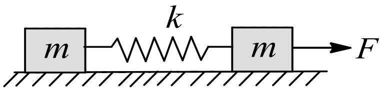


498. Find the ratio $m_1 : m_2$

a) 1 b) $\sqrt{2}$ c) $1\sqrt{2}$ d) 2

Paragraph for Question Nos. 499 to - 499

Two blocks of equal mass m are connected by an unstretched spring and the system is kept at rest on a frictionless horizontal surface. A constant force F is applied on the first block pulling away from the other as shown in Fig.



499. Then the displacement of the centre of mass m at time t is

a) $\frac{Ft^2}{2m}$ b) $\frac{Ft^2}{3m}$ c) $\frac{Ft^2}{4m}$ d) $\frac{Ft^2}{m}$

Paragraph for Question Nos. 500 to - 500

A ball of mass m makes head–on elastic collision with a ball of mass nm which is initially at rest

500. The fractional transfer of energy by the first ball to the second ball is

a) $\frac{4n}{(n-1)^2}$ b) $\frac{2n}{(n+1)^2}$ c) $\frac{2n}{(n-1)^2}$ d) $\frac{4n}{(n+1)^2}$

Paragraph for Question Nos. 501 to - 501

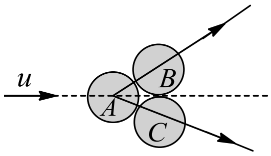
A ball falls on the ground from height h_1 and rebounds to a height of h_2

501. The fractional loss in the kinetic energy of ball during the collision with the ground is

a) $\frac{h_1 - h_2}{h_1}$ b) $\frac{h_1 - h_2}{h_2}$ c) $\frac{h_2}{h_1}$ d) $\sqrt{h_1 - h_2/h_1}$

Paragraph for Question Nos. 502 to - 502

Two equal spheres B and C, each of mass m, are in contact on a smooth horizontal table. A third sphere A of same size as that of B or C but mass $m/2$ impinges symmetrically on them with a velocity u and is itself brought to rest



502. The coefficient of restitution between the two spheres A and B (or between A and C) is

a) $\frac{1}{3}$ b) $\frac{1}{4}$ c) $\frac{2}{3}$ d) $\frac{3}{4}$

Paragraph for Question Nos. 503 to - 503

A pendulum consists of a wooden bob of mass M and length l. A bullet of mass m is fired towards the pendulum with a speed v. The bullet emerges immediately out of the bob from the other side with a speed of $v/2$ and the bob starts rising. Assume no loss of mass of bob takes place due to penetration

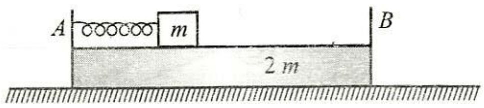
503. What is the momentum transferred to the bob by the bullet?

a) mv b) $\frac{mv}{2}$ c) $\frac{Mv}{2}$ d) Mv

Paragraph for Question Nos. 504 to - 504

According to the principle of conservation of linear momentum, if the external force acting on the system is zero, the linear momentum of the system will remain conserved. It means if the centre of mass of a system is initially at rest, it will remain at rest in the absence of external force, that is, the displacement of centre of mass will be zero

Two blocks of masses 'm' and '$2m$' are placed as shown in Fig. There is no friction anywhere. A spring of force constant 'k' is attached to the bigger block. Mass 'm' is kept in touch with the spring but not attached to it. 'A' and 'B' are two supports attached to '$2m$'. Now m is moved towards left so that spring is compressed by distance 'x' and then the system is released from rest



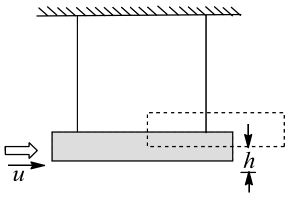
504. Find the relative velocity of the blocks after 'm' leaves contact with the spring

a) $\sqrt{\frac{2k}{3m}}$ b) $3x\sqrt{\frac{k}{2m}}$ c) $x\sqrt{\frac{3k}{2m}}$ d) None of these

Paragraph for Question Nos. 505 to - 505

A ballistic pendulum is a device that was used to measure the speeds of bullets before the development of electronic timing devices. The devise consists of a large block of wood of mass M, hanging from two long cords. A bullet of mass m is fired into the block, the bullet comes quickly into rest and the block + bullet rises to a vertical distance h before the pendulum comes momentarily to rest as the ends of the arc

In the process, the linear momentum is conserved. In such a collision, some kinetic energy is dissipated as heat; so mechanical energy is not conserved. When there is a loss in mechanical energy, the collision is said to be inelastic. Further when two bodies coalesce, the collision is said to be perfectly inelastic

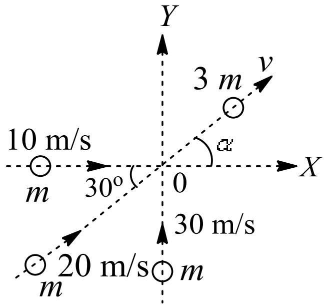


505. After collision what is the combined velocity of the bullet + block system?

a) $\frac{m}{M}u$ b) $\frac{m}{M+m}u$ c) $\frac{M}{M+m}u$ d) $\frac{M+m}{M}u$

Paragraph for Question Nos. 506 to - 506

Three particles of equal masses travelling with velocities of 10 m/s, 20 m/s and 30 m/s, respectively, along x-axis, at an angle of 30° to the direction of positive x-axis and y-axis (as shown in Fig.) collide simultaneously and get sticked to each other

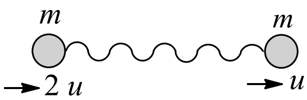


506. The combined particle will move with velocity

a) $\frac{10}{3}\sqrt{20+2\sqrt{3}}$ m/s b) $\frac{10}{3}\sqrt{20-2\sqrt{3}}$ m/s c) $\frac{10}{3}\sqrt{(5-\sqrt{3})}$m/s d) $\frac{10}{3}\sqrt{(5+\sqrt{3})}$m/s

Paragraph for Question Nos. 507 to - 507

Two identical balls, each of mass m, are tied with a string and kept on a frictionless surface. Initially, the string is slack. They are given velocities $2u$ and u in the same direction. Collision between the balls is perfectly elastic

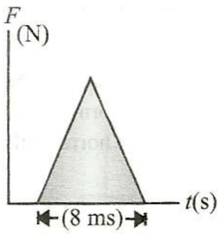


507. After the first collision, what is the total loss in kinetic energy of the balls?

a) $2mu^2$ b) mu^2 c) $3mu^2$ d) Zero

Paragraph for Question Nos. 508 to - 508

The following problems illustrate the effect of a time–dependent force of a large average magnitude which acts on a moving object only for a short duration. Such forces are called 'impulsive' forces. According to the impulse-momentum theorem, impulse delivered to a body is equal to the change of linear momentum of the body
A ball of mass 250 g is thrown with a speed of 30 m/s. The ball strikes a bat and it is hit straight back along the same line at a speed of 50 m/s. Variation of the interaction force, as long as the ball remains in contact with the bat, is as shown in Fig.

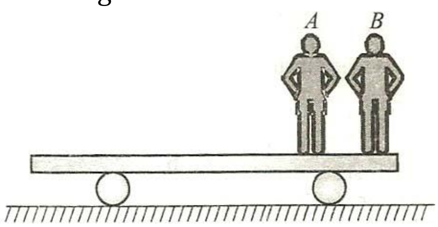


Answer these questions

508. Maximum force exerted by the bat on the ball is
a) 2500 N b) 5000 N c) 7500 N d) 1250 N

Paragraph for Question Nos. 509 to - 509

Two persons, A of mass 60 kg and B of mass 40 kg, are standing on a horizontal platform of mass 50 kg. The platform is supported on wheels on a horizontal frictionless surface and is initially at rest. Consider the following situations

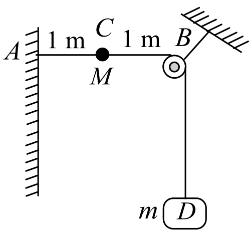


(i) Both A and B jump from the platform simultaneously and in the same horizontal direction
(ii) A jumps first in a horizontal direction and after a few seconds B also jumps in the same direction
In both the situations above, just after the jump, the person (A or B) moves away from the platform with a speed of 3 m/s relative to the platform and along the horizontal Answer these questions

509. In situation (i), just after both A and B jump from the platform, velocity of centre of mass of the system (A, B and the platform) is
a) 2 m/s b) 6 m/s c) 5 m/s d) None of these

Paragraph for Question Nos. 510 to - 510

A string with one end fixed on a rigid wall, passing over a fixed frictionless pulley at a distance of 2 m from the wall, has a point mass M of 2 kg attached to it at a distance of 1 m from the wall. A mass m of 0.5 kg is attached to the free end. The system is initially held at rest so that the string is horizontal between wall and pulley and vertical beyond the pulley as shown in Fig. The system is released from the rest from the position as shown



510. The ratio of velocity of M and m when M strikes the wall is
a) $\frac{\sqrt{5}}{2}$ b) $\frac{2}{\sqrt{5}}$ c) $\frac{3}{\sqrt{5}}$ d) $\frac{\sqrt{5}}{3}$

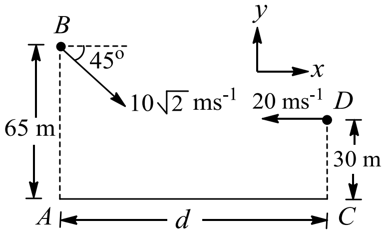
Paragraph for Question Nos. 511 to - 511

Two identical shells are fired from a point on the ground with same muzzle velocity at angle of elevation $\alpha = 45°$ and $\beta = \tan^{-1} 3$ towards top of a cliff, 20 m away from the point of firing. If both the shells reach the top simultaneously, then

511. Muzzle velocity is
 a) 10 m/s b) 5 m/s c) 15 m/s d) 20 m/s

Paragraph for Question Nos. 512 to - 512

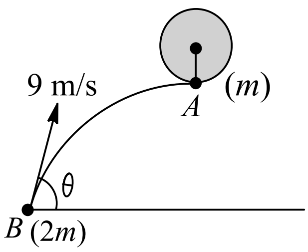
A ball of mass m is thrown at an angle of 45° to the horizontal from the top of a 65 m high tower AB as shown in Fig. at $t = 0$. Another identical ball is thrown with velocity 20 m/s horizontally towards AB from the top of a 30 m high tower CD 1 s after the projection of the first ball. Both the balls move in the same vertical plane. If they collide in mid–air,



512. The two balls will collide at time $t =$
 a) 2 s b) 5 s c) 10 s d) 3 s

Paragraph for Question Nos. 513 to - 513

A ball A of mass m is suspended by a thread of length $r = 1.2$ m. A another ball B of mass $2m$ is projected from the ground with velocity $u = 9$ m/s such that at the highest point of its trajectory it collides head–on elastically with ball A. It is observed that during subsequent motion, tension in the thread at the highest point is equal to mg



513. At highest point of B, the velocity of ball A is
 a) $6\sqrt{2}$ m/s b) $2\sqrt{6}$ m/s c) $3\sqrt{2}$ m/s d) $3\sqrt{6}$ m/s

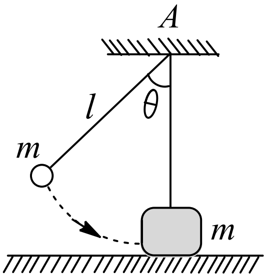
Paragraph for Question Nos. 514 to - 514

Two identical buggies each of mass 150 kg move one after the other without friction with same velocity 4 m/s. A man of mass m rides the rear buggy. At a certain moment, the man jumps into the front buggy with a velocity v relative to his buggy. As a result of this process, rear buggy stops. If the sum of kinetic energies of the man and the front buggy just after collision with the front buggy differs from that just before collision by 2700 J, then

514. The mass m of the man is
a) 60 kg b) 75 kg c) 50 kg d) 90 kg

Paragraph for Question Nos. 515 to - 515

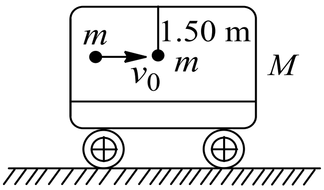
In the arrangement shown in Fig., the ball and the block have the same mass m 1 kg each, $\theta = 60°$ and length $l = 2.50$ m. Coefficient of friction between the block and the floor is 0.5. When the ball is released from the position shown in Fig., it collides with the block and the block stops after moving a distance 2.50 m



515. The velocity of block just after collision is
a) 10 m/s b) 5 m/s c) 2.5 m/s d) 3 m/s

Paragraph for Question Nos. 516 to - 516

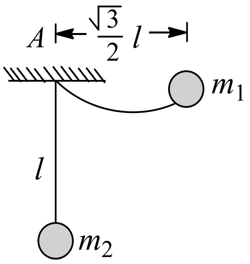
A ball of mass $m = 1$ kg is hung vertically by a thread of length $l = 1.50$ m. Upper end of the thread is attached to the ceiling of a trolley of mass $M = 4$ kg. Initially, the trolley is stationary and it is free to move along horizontal rails without friction. A shell of mass $m = 1$ kg, moving horizontally with velocity $v_0 = 6$ m/s, collides with the ball and gets stuck with it. As a result, the thread starts to deflect towards right



516. The velocity of the combined body just after collision is
a) 2 m/s b) 3 m/s c) 1 m/s d) 4 m/s

Paragraph for Question Nos. 517 to - 517

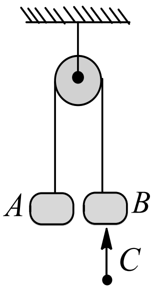
Two balls of masses $m_1 = 100$ g and $m_2 = 300$ g are suspended from point A by two equal inextensible threads, each of length $l = 32/35$ m. Ball of mass m_1 is drawn aside and held at the same level as A but at a distance $(\sqrt{3}/2)l$ from A, as shown in Fig. When ball m_1 is released, it collides elastically with the stationary ball of mass m_2



517. Velocity u_1 with which the ball of mass m_1 collides with the other ball is
    a) 1 m/s b) 2 m/s c) 3 m/s d) 4 m/s

Paragraph for Question Nos. 518 to - 518

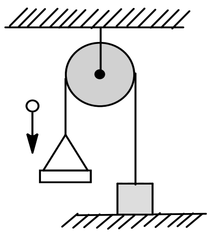
Two identical blocks A and B each of the mass 2 kg are hanging stationary by a light inextensible flexible string, passing over a light and frictionless pulley, as shown in Fig. A shell of C of mass 1 kg moving vertically upwards with velocity 9 m/s collides with block B and gets stuck to it



518. Calculate the time after which block B starts moving downwards
    a) 0.90 s b) 1s c) 0.60 s d) 0.30 s

Paragraph for Question Nos. 519 to - 519

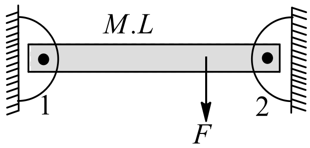
A pan of mass $m = 1.5$ kg and a block of mass $M = 3$ kg are connected to each other by a light inextensible string, passing over a light pulley as shown in Fig. Initially, the block is resting on a horizontal floor. A ball of mass $m_0 = 0.5$ kg collides with the pan at a speed $v_0 = 20$ m/s. Consider this instant of collision at $t = 0$. Assume collision to be perfectly inelastic. Now, answer the following questions based on the above information



519. Mark the correct statement(s) for this situation
    a) After the collision, the pan + ball system moves downwards with decreasing speed
    b) After the collision, the block is moving upwards with the same speed with which the ball + pan system is moving downwards
    c) The block will jerk for a number of times during its motion
    d) All of these

Paragraph for Question Nos. 520 to - 520

A uniform rod of mass $M = 2$ kg and length L is suspend by two smooth hinges 1 and 2 as shown in Fig. A force $F = 4$ N is applied downward at a distance $L/4$ from hinge 2. Due to the application of force F, hinge 2 breaks. At this instant, applied force F is also removed. The rod starts to ratate downward about hinge 1. (g = 10 m/s^2)

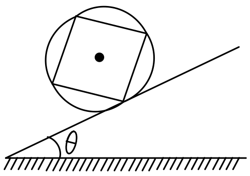


520. The reaction at hinge 1, before hinge 2 breaks, is

a) 24 N b) 12 N c) 11 N d) 10 N

Paragraph for Question Nos. 521 to - 521

Four identical rods of mass $M = 6$ kg each are welded at their ends to form a square and then welded to a massive ring having mass $m = 4$ kg and radius $R = 1$ m. If the system is allowed to roll down the incline of inclination $\theta = 30°$, determine the minimum value of the coefficient of static friction that will prevent slipping

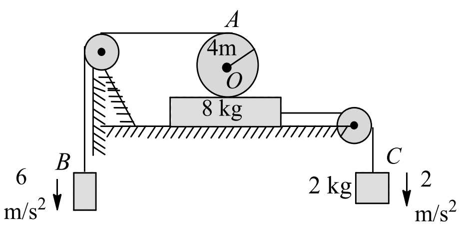


521. The moment of inertia of the system about the centre of ring will be

a) 20 kg m^2 b) 40 kg m^2 c) 10 kg m^2 d) 60 kg m^2

Paragraph for Question Nos. 522 to - 522

Figure shows a uniform smooth solid cylinder A of radius 4 m rolling without slipping on the 8 kg plank which, it turn, is supported by a fixed smooth surface. Block B is known to accelerate down with 6m/s^2 and block C moves down with acceleration 2m/s^2

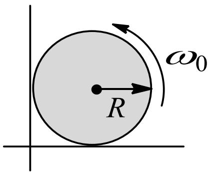


522. What is the angular acceleration of the cylinder?

a) $\frac{4}{5}$ rad s^{-2} b) $\frac{6}{5}$ rad s^{-2} c) 2 rad s^{-2} d) 1 rad s^{-2}

Paragraph for Question Nos. 523 to - 523

A uniform cylinder of radius R is spinned about its axis to the angular velocity ω_0 and then placed into a corner, see the figure. The coefficient of friction between the corner walls and the cylinder is μ_k



523. The normal reaction imparted by the wall on the cylinder is

a) $\frac{2\mu_k mg}{1+\mu_k^2}$ b) $\frac{\mu_k mg}{1+\mu_k^2}$ c) $\frac{\mu_k mg}{1+2\mu_k^2}$ d) $\frac{\mu_k mg}{1+\mu_k^2}$

Paragraph for Question Nos. 524 to - 524

A man of mass 100 kg stands at the rim of a turntable of radius 2 m and moment of inertia 4000 kg m^2 mounted on a vertical frictionless shaft at its centre. The whole system is initially at rest. The man now walks along the outer edge of the turntable (anticlockwise) with a velocity of 1 m/s relative to the earth

524. With what angular velocity and in what direction does the turntable rotate?

a) The table rotate anticlockwise (in the direction of the man motion) with angular velocity 0.05 rad/s
b) The table rotates clockwise (opposite to the man) with angular velocity 0.1 rad/s
c) The table rotate clockwise (opposite to the man) with angular velocity 0.05 rad/s
d) The table rotates anticlockwise (in the direction of the man motion) with angular velocity 0.1 rad/s

Paragraph for Question Nos. 525 to - 525

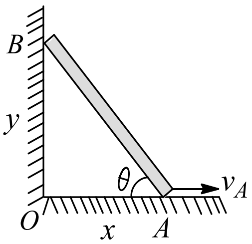
A small block of mass 4 kg is attached to a cord passing through a hole in a horizontal frictionless surface. The block is originally revolving in a circle of radius of 5 m about the hole, with a tangential velocity of 4 m/s. The cord is then pulled slowly from below, shortening the radius of the circle in which the block revolves. The breaking strength of the cord is 200 N

525. What will be the radius of the circle when the cord breaks?

a) 4.0 m b) 1.0 m c) 3.0 m d) 2.0 m

Paragraph for Question Nos. 526 to - 526

End A of a rod AB is being pulled on the floor with a constant velocity v_0 as shown. Taking the length of the rod as l, at an instant when the rod makes an angle 37° with the horizontal, calculate



526. The velocity of end B

a) $\frac{3}{5}v_0$ b) $\frac{4}{5}v_0$ c) $\frac{5}{3}v_0$ d) $\frac{5}{4}v_0$

Paragraph for Question Nos. 527 to - 527

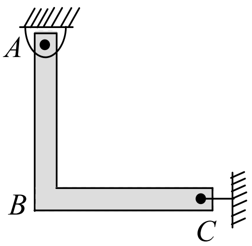
A uniform rod of length l and mass $2m$ rests on a smooth horizontal table. A point mass m moving horizontally at right angles to the rod with initial velocity v collides with one end of the rod and sticks to it

527. Determine the angular velocity of the system after the collision

a) $\frac{v}{l}$ b) $\frac{2v}{l}$ c) $\frac{5v}{3l}$ d) $\frac{3v}{2l}$

Paragraph for Question Nos. 528 to - 528

An L shaped uniform rod of mass $2M$ and length $2L(AB = BC = L)$ is held as shown in figure with a string fixed between C and wall so that AB is vertical and BC is horizontal. There is no friction between the hinge and the rod at A



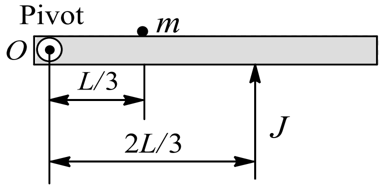
528. Find the tension in the string

a) $\frac{Mg}{3}$ b) $\frac{Mg}{4}$ c) Mg d) $\frac{Mg}{2}$

Paragraph for Question Nos. 529 to - 529

A uniform rod of length L and mass M is lying on a frictionless horizontal plane and is pivoted at one of its ends as shown in Figure. There is no friction at the pivot. An inelastic ball of mass m is fixed with the rod at a distance $L/3$ from O. A horizontal impulse J is given to the rod at a distance $2L/3$ from O in a direction perpendicular to the rod. Assume that the ball remains in contact with the rod after the collision and impulse J acts for a small time interval Δt

Now answer the following question

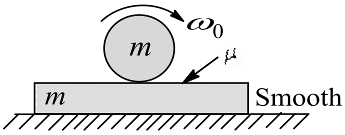


529. Find the resulting instantaneous angular velocity of the rod after the impulse

a) $\frac{3J}{(m+3M)L}$ b) $\frac{6J}{(m+3M)L}$ c) $\frac{3J}{(3m+M)L}$ d) $\frac{6J}{(3m+M)L}$

Paragraph for Question Nos. 530 to - 530

A long horizontal plank of mass $'m'$ is lying on a smooth horizontal surface. A sphere of same mass $'m'$ and radius 'r' is spinned about its own axis with angular velocity ω_0 and gently placed on the plank. The coefficient of friction between the plank and the sphere is μ. After some time the pure rolling of the sphere on the plank will start. Answer the following questions

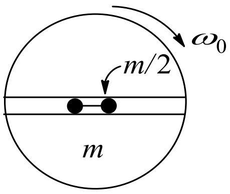


530. Find the time t at which the pure rolling starts

a) $\frac{\omega_0 r}{9\mu g}$ b) $\frac{2\omega_0 r}{9\mu g}$ c) $\frac{\omega_0 r}{3\mu g}$ d) $\frac{2\omega_0 r}{\mu g}$

Paragraph for Question Nos. 531 to - 531

A disc of mass $'m'$ and radius 'R' is free to rotate in a horizontal plane about a vertical smooth fixed axis passing through its centre. There is a smooth groove along the diameter of the disc and two small balls of mass $m/2$ each are placed in it on either side of the centre of the disc as shown in Figure. The disc is given an initial angular velocity ω_0 and released



531. The angular speed of the disc when the balls reach the end of the disc is

a) $\frac{\omega_0}{2}$ b) $\frac{\omega_0}{3}$ c) $\frac{2\omega_0}{3}$ d) $\frac{\omega_0}{4}$

Paragraph for Question Nos. 532 to - 532

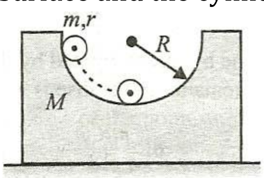
A uniform rod of length L lies on a smooth horizontal table. The rod has a mass M. A particle of mass m moving with speed v strikes the rod perpendicularly at one of the ends of the rod sticks to it after collision

532. Find the velocity of the centre of mass C of the system constituting "the rod plus the particle"

a) $\frac{2Mv}{M-m}$ b) $\frac{2mv}{M+m}$ c) $\frac{Mv}{M+m}$ d) $\frac{mv}{M+m}$

Paragraph for Question Nos. 533 to - 533

A uniform solid cylinder of mass 2 kg and radius 0.2 m is released from rest at the top of a semicircular track of radius 0.7 m cut in a block of mass $M = 3$ kg as shown in Figure. The block is resting on a smooth horizontal surface and the cylinder rolls down without slipping



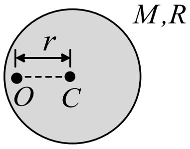
Based on the above information, answer the following questions:

533. The distance moved by the block when the cylinder reaches the bottom of the track is

a) 0.3 m　　b) 0.5 m　　c) 0.7 m　　d) 0.2 m

Paragraph for Question Nos. 534 to - 534

A disc of mass M and radius R can rotate freely in a vertical plane about a horizontal axis at O distance r from the centre of the disc as shown in Figure. The disc is released from rest in the shown position. Answer the following questions based on the above information

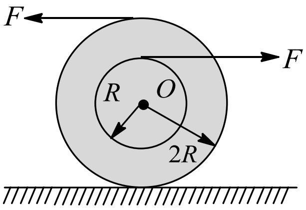


534. The angular acceleration of the disc when OC rotates by an angle of 37° is

a) $\frac{8rg}{5[R^2+2r^2]}$　　b) $\frac{5rg}{4[R^2+2r^2]}$　　c) $\frac{10rg}{3[R^2+2r^2]}$　　d) $\frac{8rg}{5R^2}$

Paragraph for Question Nos. 535 to - 535

In Figure, $F = 10$ N, $R = 1$ m, mass of the body is 2 kg and moment of the body about an axis passing through O and perpendicular to the plane of body is 4 kg-m^2. O is the centre of mass of the body

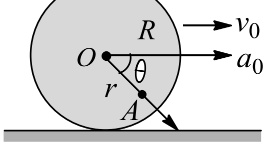


535. If the ground is smooth, what is the total kinetic energy of body at $t = 2$s. Initially, the body was at rest

a) 25 J　　b) 16.67 J　　c) 50 J　　d) 37.5 J

Paragraph for Question Nos. 536 to - 536

A wheel of radius R rolls without slipping and its centre O has an acceleration a_0. A point A on the wheel is at a distance r from O. For given value of a_0, R and r, determine the angle θ and velocity v_0 of the wheel for which A has no acceleration in this position

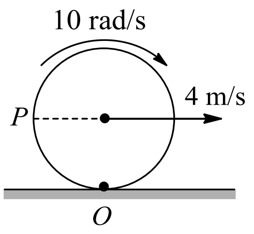


536. Angle θ is given by

a) 30°　　b) $\sin^{-1}\left(\frac{r}{R}\right)$　　c) 60°　　d) $\cos^{-1}\left(\frac{r}{R}\right)$

Paragraph for Question Nos. 537 to - 537

A disc of radius 20 CM is rolling with slipping on a flat horizontal surface. At a certain instant the velocity of its centre is 4 m/s and its angular velocity is 10 rad/s. The lowest contact point is O

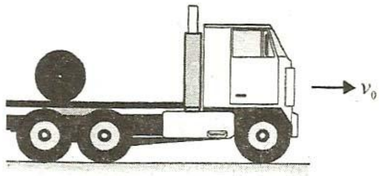


537. Velocity of point O is

a) 2 m/s b) 4 m/s c) 1 m/s d) 3 m/s

Paragraph for Question Nos. 538 to - 538

A solid sphere of mass M and redius R is initially at rest. Solid sphere is gradually lowered onto a truct moving with constant velocity v_0

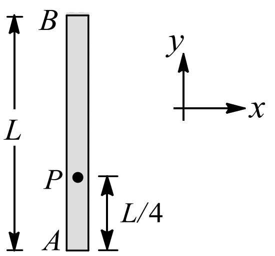


538. What is the final speed of the sphere's centre of mass in ground frame when eventually pure rolling sets in

a) $\frac{5}{7}v_0$ b) $\frac{2}{7}v_0$ c) $\frac{7}{5}v_0$ d) $\frac{7}{2}v_0$

Paragraph for Question Nos. 539 to - 539

A uniform rod AB hinged about a fixed point P is initially vertical. A rod is released from vertical position. When rod is in horizontal position



539. The acceleration of the centre of mass of the rod is

a) $-\frac{6g}{7}\hat{\imath}-\frac{12g}{7}\hat{\jmath}$ b) $-\frac{12g}{7}\hat{\imath}-\frac{6g}{7}\hat{\jmath}$ c) $-\frac{3g}{7}\hat{\imath}-\frac{9g}{7}\hat{\jmath}$ d) $-\frac{9g}{7}\hat{\imath}-\frac{3g}{7}\hat{\jmath}$

Paragraph for Question Nos. 540 to - 540

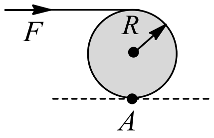
A uniform disc of mass m radius R rotates about a fixed vertical axis passing through its centre with angular velocity ω. A particle of same mass m and moving horizontally with velocity $2\omega R$ towards centre of the disc collides with the disc and sticks to its rim

540. The angular velocity of the disc after the particle sticks to it is

a) $\frac{\omega}{5}$ b) $\frac{\omega}{3}$ c) $\frac{\omega}{2}$ d) $\frac{\omega}{4}$

Paragraph for Question Nos. 541 to - 541

When a body is hinged at a point and a force is acting on the body in such a way that the line of action of force is at some distance from the hinged point, the body will start rotating about the hinged point. The angular acceleration of the body can be calculated by finding the torque of that force about the hinged point. A disc of mass m and radius R is hinged at point A at its bottom and is free to rotate in the vertical plane. A force of magnitude F is acting on the ring at the top most point

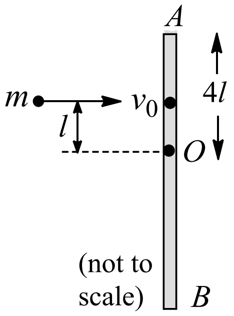


541. Tangential acceleration of the centre of mass is

a) $\frac{3F}{4m}$ b) $\frac{F}{m}$ c) $\frac{2F}{3m}$ d) $\frac{4F}{3m}$

Paragraph for Question Nos. 542 to - 542

A rod AB of mass M and length $8l$ lies on a smooth horizontal surface. A particle of mass $'m'$ and velocity v_0 strikes the rod perpendicular to its length, as shown Figure. As a result of the collision, the centre of mass of rod attains a speed of $v_0/8$ and the particle rebounds back with a speed of $v_0/4$. Find the following



542. The ratio $\frac{M}{m}$,

a) $\frac{M}{m} = 10$ b) $\frac{M}{m} = 4$ c) $\frac{M}{m} = 8$ d) $\frac{M}{m} = 5$

Paragraph for Question Nos. 543 to - 543

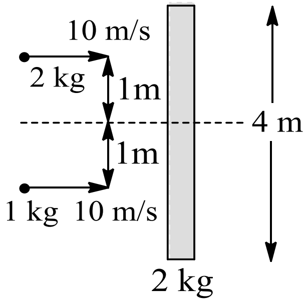
A block of mass m is kept on a horizontal rular. The friction coefficient between the ruler and the block is μ. The ruler is fixed at one end and the block is at a distance L from the fixed end. The ruler is rotated about the fixed end in the horizontal plane through the fixed end

543. What can the maximum angular speed be for which the block does not slip?

a) $\left(\frac{\mu g}{L}\right)^{1/4}$ b) $\left(\frac{\mu g}{2L}\right)^{1/2}$ c) $\left(\frac{2\mu g}{L}\right)^{1/2}$ d) $\left(\frac{\mu g}{L}\right)^{1/2}$

Paragraph for Question Nos. 544 to - 544

A long slender rod of mass 2 kg and length 4 m is placed on a smooth horizontal table. Two particles of masses 2 kg and 1 kg strike the rod simultaneously and stick to the rod after collision as shown in Fig

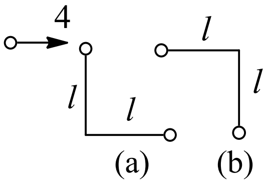


544. Velocity of the centre of mass of the rod after collision is

a) 12 m/s b) 9 m/s c) 6 m/s d) 3 m/s

Paragraph for Question Nos. 545 to - 545

A sphere ball of mass M moving with initial velocity v collides elastically with another ball of mass M, which is fixed at one end of L shaped rigid massless frame as shown in Fig (a). The L shaped frame contains another mass M connected at the other end



545. The speed of the striking mass after collision is

a) $\mu/2$ backwards b) 0 c) $\mu/3$ in same direction d) $\mu/7$ backwards

Paragraph for Question Nos. 546 to - 546

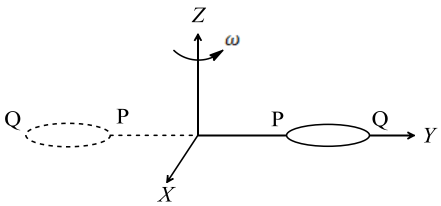
Two discs A and B are mounted coaxially on a vertical axle. The discs have moments of inertia I and $2I$ respectively about the common axis. Disc A is imparted an initial angular velocity 2ω using the entire potential energy of a spring compressed by a distance x_1. Disc B is imparted an angular velocity ω by a spring having the same spring constant and compressed by a distance x_2. Both the discs rotate in the clockwise direction

546. The loss of kinetic energy during the above process is

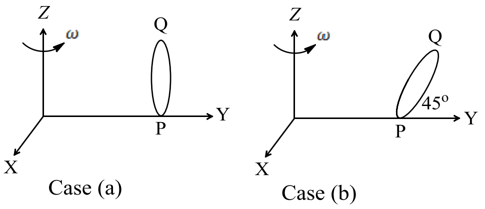
a) $\frac{I\omega^2}{2}$ b) $\frac{I\omega^2}{3}$ c) $\frac{I\omega^2}{4}$ d) $\frac{I\omega^2}{6}$

Paragraph for Question Nos. 547 to - 547

The general motion of a rigid body can be considered to be a combination of (i) a motion---centre of mass about an axis, and (ii) its motion about an instantaneous axis passing through centre of mass. These axes need not be stationary. Consider, for example, a thin uniform welded (rigidly fixed) horizontally at its rim to a massless stick, as shown in the figure. Where disc-stick system is rotated about the origin on a horizontal frictionless plane with angular speed ω, the motion at any instant can be taken as a combination of (i) a rotation of the centre of mass the disc about the z-axis, and (ii) a rotation of the disc through an instantaneous vertical axis pass through its centre of mass (as in seen from the changed orientation of points P and Q). Both the motions have the same angular speed ω in the case



Now consider two similar systems as shown in the figure: case (a) the disc with its face vertical and parallel to $x - z$ plane; Case (b) the disc with its face making an angle of 45° with $x - y$ plane its horizontal diameter parallel $x - axis$. In both the cases, the disc is welded at point P, and systems are rotated with constant angular speed ω about the $z - axis$

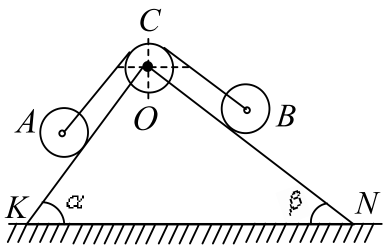


547. Which of the following statement regarding the angular speed about the instantaneous axis (passing through the centre of mass) is correct

a) It is $\sqrt{2}\omega$ for both the cases
b) It is ω for case (a); and $\frac{\omega}{\sqrt{2}}$ for case (b)
c) It is ω for case (a); and $\sqrt{2}\omega$ for case (b)
d) It is ω for both the cases

Integer Answer Type

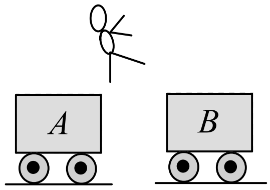
548. A wheel A is connected to a second wheel B by means of inextensible string passing over a pulley C, which rotates about a fixed horizontal axle O, as shown in the figure. The system is released from rest. The wheel A rolls down the inclined plane OK thus pulling up wheel B which rolls along the inclined plane ON



Determine the velocity (in m/s) of the axle of wheel A, when it has travelled a distance s $= 3.5$ m down the slope. Both wheels and the pulley are assumed to be homogeneous disks of identical weight and radius. Neglect the weight of the string. The string does not slip over C

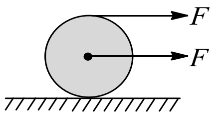
[Take $\alpha = 53°$ and $\beta = 37°$]

549. A child of mass 4 kg jumps from cart B to cart A and then immediately back to cart B. The mass of each cart is 20 kg and they are initially at rest. In both the cases the child jumps at 6 m/s relative to the cart. If the cart moves along the same line with negligible friction with the final velocities of V_B and V_A, respectively, find the ratio of $6v_B$ and $5v_A$

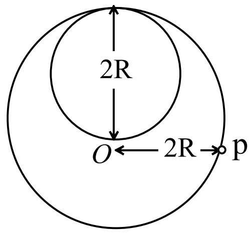


550. A stone of mass m, tied to the end of a string, is whirled around in a horizontal circle (neglect the force due to gravity). The length of the string is reduced gradually keeping the angular momentum of the stone about the centre of the circle constant. Then the tension in the string is given by $T = A/r^n$, where A is a constant, r is the instantaneous radius of the circle and n is

551. Two forces of magnitude F are acting on a uniform disc kept on a horizontal rough surface as shown in the figure. Friction force by the horizontal surface on the disc is nF. Find the value of n



552. A lamina is made by removing a small disc of diameter $2R$ from a bigger disc of uniform mass density and radius $2R$, as shown in the figure. The moment of inertia of this lamina about axes passing through O and P is I_O and I_P, respectively. Both these axes are perpendicular to the plane of the lamina. The ratio $\frac{I_P}{I_O}$ to the nearest integer is

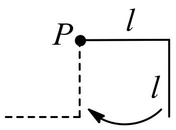


553. A light inextensible thread is wound round a solid cylindrical reel of mass $m = 1.5$ kg and radius 10 CM. The end of the string is held fixed and the reel is allowed to fall so that the thread unwinds. If the axis of the reel remains horizontal the tension in the thread will be $T = '*'$ N. What is the value of '*'

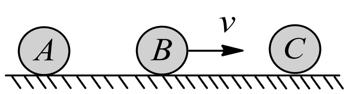
554. A binary star consists of two stars A(mass 2.2 Ms) and B (mass 11 Ms), where Ms is the mass of the sun. They are separated by distance d and are rotating about their centre of mass, which is stationary. The ratio of the total angular momentum of the binary star to the angular momentum of star B about the centre of mass is

555. A hollow sphere of radius 30 CM is released from rest on a rough inclined plane. The friction is enough to prevent any slipping. Find the angular velocity (in rad/s) of the sphere, when it descends through a vertical height of 3 CM

556. An L shaped thin uniform rod of total length $2l$ is free to rotate in a vertical plane about a horizontal axis at P as shown in Figure. The bar is released from rest. Neglect air and contact friction. Determine the angular velocity (in rad/s) at the instant when it has rotated through 90° and reached the dotted position as shown. (Take l =1/3 m)

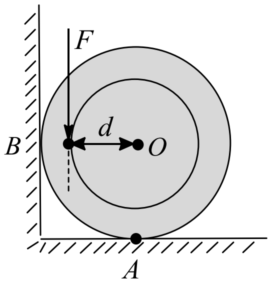


557. Three balls A, B and $C(m_A = m_C = 4m_B)$ are placed on a smooth horizontal surface. Ball B collides with ball C with an initial velocity v as shown in Fig. Find the total number of collisions between the balls (all collisions are elastic)

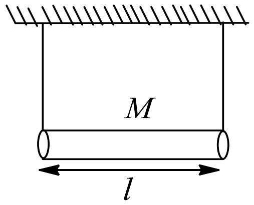


558. A small sphere of mall $m = 1$ kg is moving with a velocity $(4\hat{\imath} - \hat{\jmath})$m/s. It hits a fixed smooth wall and rebounds with velocity $(\hat{\imath} + 3\hat{\jmath})$m/s. The coefficient of restitution between the sphere and the wall is $n/16$. Find the value of n

559. A solid cylinder with $r = 0.1$ m and mass $M = 2$ kg is placed such that it is in contact with the vertical and a horizontal surface as shown in Figure. The coefficient of static friction is $\mu = (1/3)$ for both the surfaces. Find the distance d (in CM) from the centre of the cylinder at which a force $F = 40$ N should be applied vertically so that the cylinder just starts rotating in anticlockwise direction

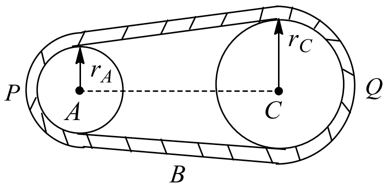


560. A uniform rod of length 1 m and mass 2 kg is suspended. Calculate tension T(in N) in the string at the instant when the right string snaps ($g = 10\ m/s^2$)



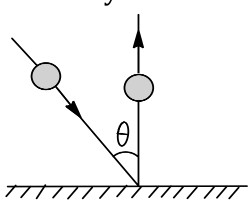
561. A bullet is fired on a fixed target. It penetrates inside the target through distance $d = 3.75$ cm and then stops, mass of the bullet is $m = 1$ kg and of the target is $M = 4$ kg. Now an identical bullet moving with the same velocity is fired on the identical target which is placed at rest on a frictionless horizontal surface. Then find the distance (in cm) to which the bullet will penetrate inside the target?

562. Two wheels A and C are connected by a belt B as shown in Figure. The radius of C is three times the radius of A. What would be the ratio of the rotational inertias (I_A/I_C) if both the wheels have the same rotational kinetic energy?

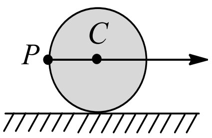


563. Four solid sphere each of diameter $\sqrt{5}$ CM and mass 0.5 kg are placed with their centres at the corners of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is $N \times 10^4$ kg m^2, then N is

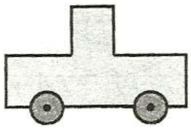
564. A ball of mass 1 kg moving with a velocity of 5 m/s collides elastically with rough ground at an angle θ with the vertical as shown in Fig. What can be the minimum coefficient of friction if ball rebounds vertically after collision? (giventan $\theta = 2$)



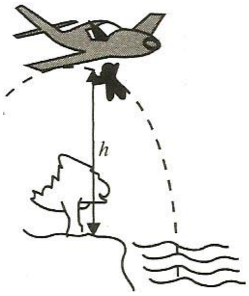
565. A disc of radius R is rolling purely on a flat horizontal surface, with a constant angular velocity. The angle between the velocity and acceleration vectors of point P is given by $\sin^{-1}(\sqrt{2}/n)$.What is the value of n?



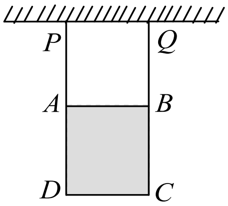
566. A uniform cylinder rests on a cart as shown. The coefficient of static friction between the cylinder and the cart is 0.5. If the cylinder is 4 CM in diameter and 10 CM in height, then what is the minimum acceleration (in m/s^2) of the cart needed to cause the cylinder to tip over?



567. A man of mass $M = 58$ kg jumps from an aeroplane as shown in Fig. He sees the hard ground below him and a lake at a distance $d = 1$ m from the point directly below him. He immediately puts off his jacket (mass $m = 2$ kg) and throws it in a direction directly away from the lake. If he just fails to strike the ground, find the distance (in 10^1 m) he should walk now to pick his jacket. (Neglect air resistance and take the velocity of man at the time of jump with respect to earth zero)



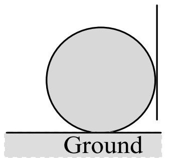
568. A square plate $ABCD$ of mass m and side l is suspended with the help to two ideal strings P and Q as shown. Determine the acceleration (in m/s^2) of corner A of the square just at the moment the string Q is cut. ($g = 10\ m/s^2$)



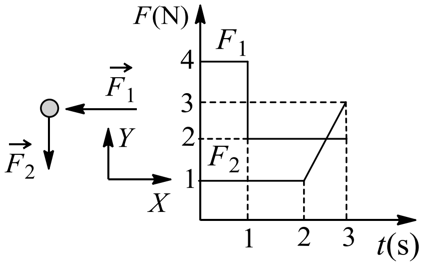
569. A ball of mass m makes head-on elastic collision with a ball of mass nm which is initially at rest. Show that the fractional transfer of energy by the first ball is $4n/(1+n)^2$. Deduce the value of n for which the transfer is maximum

570. A man standing on a trolley pushes another identical trolley (both trolleys are at rest on a rough surface), so that they are set in motion and stop after some time. If the ratio of mass of first trolley with man to mass of second trolley is 3, then find the ratio of the stopping distances of the second trolley to that of the first trolley. (Assume coefficient of friction to be the same for both the trolleys)

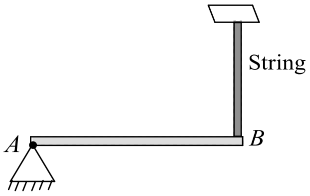
571. A boy is pushing a ring of mass 2 kg and radius 0.5 m with a stick as shown in the figure. The stick applies a force of 2 N on the ring and rolls it without slipping with an acceleration of $0.3\ m/s^2$. The coefficient of friction between the ground and the ring is large enough that rolling always occurs and the coefficient of friction between the stick and the ring is $(P/10)$. The value of P is



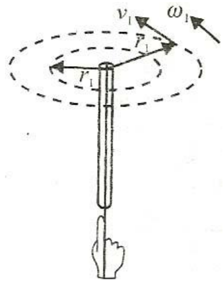
572. A particle with a mass of 1 kg is having a velocity of 10 m/s in +ve x-direction at $t = 0$. Forces $\vec{F}_1$ and $\vec{F}_2$ act on the particle whose magnitudes are changing with time according to the variation shown in Fig. The magnitude of the velocity of the particle at $t = 3$ s (neglect gravity effect) is found to be $n\sqrt{5}$ m/s. Find the value of n



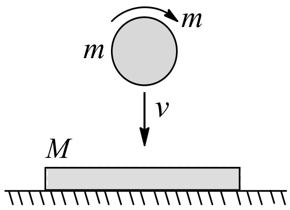
573. A uniform rod AB of mass 2 kg is hinged at one end A. The rod is kept in the horizontal position by a massless string tied to point B. Find the reaction of the hinge (in N) on end A of the rod at the instant when string is cut ($\mathrm{g} = 10\ \mathrm{m/s^2}$)



574. A point mass is tied to one end of a cord whose other end passes through a vertical hollow tube, caught in one hand. The point mass is being rotated in a horizontal circle of radius 2 m with a speed of 4 m/s. The cord is then pulled down so that the radius of the circle reduces to 1 m. Complete the ratio of kinetic energies under the final and initial states



575. A solid ball of mass m and radius r spinning with angular velocity ω falls on a horizontal slab of mass M with rough upper surface (coefficient of friction μ) and smooth lower surface. Immediately after collision the normal component of velocity of the ball remains half of its value just before collision and it stops spinning. Find the velocity of the sphere in horizontal direction immediately after the impact (given: $R\omega = 5$)



576. A frog sits on the end of a long board of length $L = 5$ m. The board rests on a frictionless horizontal table. The frog wants to jump to the opposite end of the board. What is the minimum take-off speed (in m/s), i.e., relative to ground 'v' that allows the frog to do the trick? The board and the frog have equal masses

: ANSWER KEY :

1)	a	2)	c	3)	c	4)	a	189)	c	190)	b	191)	b	192)	b
5)	c	6)	d	7)	b	8)	d	193)	d	194)	a	195)	a	196)	d
9)	b	10)	c	11)	c	12)	d	197)	c	198)	d	199)	b	200)	c
13)	a	14)	c	15)	b	16)	d	201)	a	202)	c	203)	d	204)	c
17)	d	18)	b	19)	b	20)	c	205)	a	206)	b	207)	a	208)	d
21)	c	22)	c	23)	d	24)	b	209)	b	210)	a	211)	b	212)	a
25)	b	26)	c	27)	a	28)	c	213)	d	214)	a	215)	d	216)	a
29)	b	30)	a	31)	a	32)	c	217)	a	218)	a	219)	b	220)	d
33)	d	34)	b	35)	d	36)	d	221)	a	222)	d	223)	b	224)	a
37)	c	38)	d	39)	b	40)	d	225)	d	226)	a	227)	d	228)	a
41)	b	42)	d	43)	d	44)	a	229)	b	230)	b	231)	d	232)	c
45)	d	46)	c	47)	b	48)	c	233)	c	234)	b	235)	c	236)	b
49)	b	50)	b	51)	c	52)	b	237)	b	238)	b	239)	d	240)	c
53)	c	54)	b	55)	b	56)	b	241)	b	242)	a	243)	d	244)	c
57)	c	58)	d	59)	b	60)	a	245)	a	246)	c	247)	a	248)	c
61)	b	62)	c	63)	a	64)	b	249)	c	250)	b	251)	a	252)	c
65)	d	66)	c	67)	b	68)	a	253)	c	254)	a	255)	c	256)	d
69)	b	70)	c	71)	a	72)	a	257)	a	258)	a	259)	b	260)	b
73)	b	74)	d	75)	a	76)	b	261)	b	262)	d	263)	b	264)	b
77)	c	78)	a	79)	c	80)	b	265)	d	266)	a	267)	b	268)	c
81)	d	82)	a	83)	a	84)	c	269)	b	270)	d	271)	d	272)	b
85)	b	86)	b	87)	c	88)	d	273)	c	274)	b	275)	a	276)	c
89)	d	90)	b	91)	c	92)	c	277)	a	278)	b	279)	a	280)	b
93)	d	94)	d	95)	c	96)	d	281)	a	282)	a	283)	b	284)	c
97)	c	98)	d	99)	d	100)	c	285)	a	286)	c	287)	d	1)	
101)	b	102)	d	103)	d	104)	c		a,c	2)	a,d	3)	d	4)	
105)	c	106)	b	107)	a	108)	b		a,b,c						
109)	b	110)	c	111)	d	112)	a	5)	a	6)	a,c,d	7)	a,b,d	8)	
113)	b	114)	b	115)	a	116)	a		c,d						
117)	d	118)	a	119)	a	120)	b	9)	b,d	10)	a,b,c	11)	a,b,c	12)	
121)	b	122)	c	123)	b	124)	d		a,b						
125)	b	126)	b	127)	b	128)	a	13)	b,c,d	14)	b,c,d	15)	a,d	16)	
129)	d	130)	b	131)	a	132)	b		b,d						
133)	b	134)	b	135)	d	136)	c	17)	b,d	18)	b,c	19)	b,c	20)	a
137)	b	138)	d	139)	b	140)	d	21)	a,b,c,d	22)	a,b,c,d	23)	b,c,d	24)	
141)	c	142)	c	143)	b	144)	d		a,b						
145)	d	146)	b	147)	c	148)	d	25)	a,c	26)	d	27)	a,b,c,d	28)	c
149)	b	150)	c	151)	b	152)	c	29)	a,b,c	30)	a,c,d	31)	a,c	32)	
153)	d	154)	c	155)	d	156)	c		b,d						
157)	b	158)	b	159)	d	160)	a	33)	a,b,c	34)	b,d	35)	b,c	36)	
161)	a	162)	d	163)	d	164)	c		b,d						
165)	b	166)	a	167)	b	168)	b	37)	a,b,d	38)	b,d	39)	b,d	40)	
169)	c	170)	b	171)	c	172)	c		a,c,d						
173)	c	174)	b	175)	c	176)	d	41)	a,d	42)	c,d	43)	a,b	44)	
177)	b	178)	a	179)	a	180)	a		a,b,c,d						
181)	c	182)	a	183)	a	184)	a	45)	a,d	46)	d	47)	a,b	48)	
185)	b	186)	c	187)	c	188)	a		a,b,c						

49)	a,b,c,d	50)	a,b,c,d	51)	b,c	52)	a
53)	b,d	54)	a	55)	c	56)	
	a,c						
57)	c	58)	c	59)	a,c	60)	
	a,b,c						
61)	d	62)	a,b,c	63)	a,b,c	64)	
	c,d						
65)	b,c,d	66)	b,c	67)	a,c	68)	
	a,b,c						
69)	b,d	70)	a,b,c	71)	c,d	72)	
	b,c						
73)	b,c	74)	a,c	75)	a,b,d	76)	
	a,b,c,d						
77)	a,b,c,d	78)	c,d	79)	b,d	80)	c
81)	a,b,c,d	82)	a,d	83)	c	84)	a
85)	a,b	86)	a,b,d	87)	c,d	88)	b
89)	b,c	90)	a,c	91)	c	92)	b
93)	a	94)	a,b,c	95)	a,c,d	96)	
	a,b,d						
97)	a	98)	c,d	99)	c,d	100)	
	c,d						
101)	a,b,d	102)	a,b,c	103)	a,b,c,d	104)	
	b,a						
1)	a	2)	c	3)	c	4)	d
5)	d	6)	b	7)	c	8)	d
9)	b	10)	a	11)	a	12)	b
13)	a	14)	a	15)	b	16)	e
17)	d	18)	a	19)	c	20)	e
21)	a	22)	a	23)	c	24)	d
25)	a	26)	d	27)	b	28)	d
29)	a	30)	c	31)	a	32)	b
33)	a	34)	a	35)	b	36)	c
37)	b	38)	e	39)	a	40)	d
41)	a	42)	b	43)	a	44)	b
45)	d	46)	d	47)	d	48)	d
49)	c	50)	a	51)	b	52)	d

53)	a	54)	a	55)	e	56)	b
57)	e	58)	d	59)	a	60)	d
61)	b	1)	c	2)	a	3)	d
	4)	a					
5)	a	6)	d	7)	a	8)	a
9)	b	10)	b	11)	a	12)	a
13)	c	14)	a	15)	c	16)	b
17)	d	18)	d	19)	a	20)	b
21)	b	22)	a	23)	a	24)	a
25)	a	26)	b	27)	b	28)	b
29)	d	30)	d	31)	b	1)	d
	2)	d	3)	c	4)	a	
5)	d	6)	c	7)	b	8)	a
9)	a	10)	c	11)	b	12)	a
13)	a	14)	c	15)	c	16)	c
17)	d	18)	a	19)	a	20)	b
21)	c	22)	b	23)	a	24)	d
25)	b	26)	d	27)	a	28)	d
29)	a	30)	a	31)	c	32)	b
33)	b	34)	d	35)	a	36)	d
37)	c	38)	a	39)	d	40)	b
41)	c	42)	d	43)	b	44)	a
45)	d	46)	b	47)	b	48)	b
49)	d	50)	d	51)	a	52)	c
53)	b	54)	a	55)	b	56)	a
57)	b	58)	d	59)	a	60)	d
61)	c	62)	d	63)	d	64)	d
1)	2	2)	1	3)	3	4)	0
5)	3	6)	5	7)	6	8)	2
9)	6	10)	2	11)	9	12)	6
13)	5	14)	3	15)	9	16)	9
17)	1	18)	2	19)	4	20)	3
21)	6	22)	1	23)	9	24)	4
25)	2	26)	5	27)	4	28)	2
29)	2						

: HINTS AND SOLUTIONS :

1 **(a)**

The moment of inertia about CM system $= \frac{4}{3}MI^2$

From perpendicular axis theorem,

$\frac{4}{3}MI^2 = Id_1 + Id_2 \quad (Id_1 = Id_2)$

$Id = \frac{2}{3}MI^2$ or $I = 4\frac{MI^2}{3}(\sin 45°)^2$

2 **(c)**

New momentum should be the resultant of individual moment. Therefore,

$(2mV)^2 = (mv)^2 + (mv)^2$

Or $V = \frac{v}{\sqrt{2}}$

3 **(c)**

Tangential acceleration

$a = r\alpha = R\left(\frac{2T}{MR}\right) = \frac{2T}{M}$

4 **(a)**

Velocity of upper block when lower block hits an obstacle,

$v = \sqrt{2al} = \sqrt{2\frac{F}{2M}l} = \sqrt{\frac{Fl}{M}}$

Now after collision retardation of upper block w.r.t. earth,

$a = \frac{\mu M g}{M} = \mu g$

$\therefore v^2 = u^2 + 2as$

$\therefore 0 = \frac{Fl}{M} - 2\mu g\ \frac{l}{2} \Rightarrow \mu = \frac{F}{Mg}$

5 **(c)**

Momentum of the system in x-direction is conserved because all the forces on the system in x -direction are balanced. But the force in y-direction is not balanced. So trajectory of motion of centre of the system is X constant

6 **(d)**

Mass of disc ∝ area, $M_A = 4M_B$ (as $R_A = 2R_B$)

$\frac{I_A}{I_B} = \frac{\frac{1}{2}M_A R_A^2}{\frac{1}{2}M_B R_B^2}$

7 **(b)**

As the normal force exerted by the horizontal surface passes through point B, the external torque on the ball is zero about point B. So the angular momentum of the ball is conserved about point B. $\left(\because \tau = \frac{dL}{dt}\right)$

8 **(d)**

Given $\alpha_A = 2\alpha = 5\ \text{m/s}^2 \Rightarrow \alpha = \frac{5}{2}\text{m/s}^2$

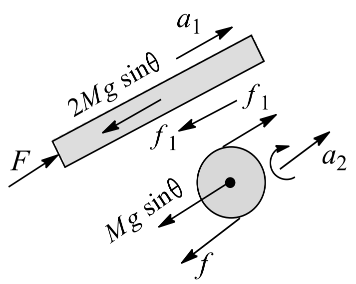
Hence, acceleration of B, $a_B = 1(a) = \frac{5}{2}\text{m/s}^2$

9 **(b)**

KE $= \frac{L^2}{2I}$, L remains constant. I doubles so KE becomes half

10 **(c)**

The free-body diagram of the plank and the cylinder is as shown in Fig



For plank, $F - f_1 - 2\,Mg\sin\theta = 2\,Mg_1$

For cylinder, $f_1 - f_2 - Mg\sin\theta = Ma_2$

$(f_1 + f_2)R = \frac{MR^2}{2}\alpha$

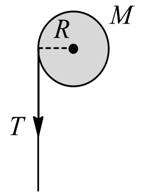
For no slipping between the plank and the cylinder, $a_2 + R\alpha = a_1$

For no slipping between the cylinder and the incline, $a_2 = R\alpha$

After solving the above equation, $f_1 = \frac{3F + 2Mg\sin\theta}{19}$

11 **(c)**

Torque exerted on the disc



Now $\tau = I\alpha$

$\alpha = \frac{\tau}{I} = \frac{TR}{\frac{1}{2}MR^2} = \frac{2TR}{MR^2} = \frac{2T}{MR}$

12 **(d)**

$\overset{m_1}{\underset{\rightarrow}{O}} V \quad \overset{m_2}{\underset{\leftarrow}{O}} V \quad \overset{m_1}{\underset{\rightarrow}{O}} V_1 \quad \overset{m_2}{\underset{\leftarrow}{O}} V_2$

$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$

$= -u_1 + 2u_2$ (neglecting m_1 in comparison to m_2)

$= -v + 2(-v) = -3v$

Hence, (a) is correct

Change in momentum of $m_1 = P_f - P_i = mv_1 -$

mv

$= -m3v - mv = -4\,mv$

Hence, (b) is correct

Change in KE of $m_1 = K_f - K_i = \frac{1}{2}mv_1^2 - \frac{1}{2}\,mv^2$

$= \frac{1}{2}\,m(3v)^2 - \frac{1}{2}\,mv^2 = 4\,mv^2$

Hence, (c) is correct

13 **(a)**

From conservation of angular momentum

$$\frac{ML^2}{12}\omega_0 = \left[\frac{ML^2}{12} + 2m\left(\frac{L}{2}\right)^2\right]\omega$$

$$\omega = \left(\frac{M}{M+6m}\right)\omega_0$$

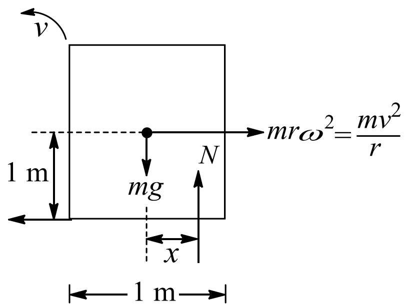
14 **(c)**

$H = I\omega$, here $I = \frac{M(2d)^2}{12} = \frac{Md^2}{3}$

$$\omega = \frac{H}{(Md^2/3)} = \frac{3H}{Md^2}$$

15 **(b)**

The free-body diagram of the box w.r.t. the truck is as shown in figure



For vertical equilibrium, $m\text{g} = N$

For horizontal equilibrium, $f = (mv^2)/r$

For rotational equilibrium, $f \times 1 = N \times x$

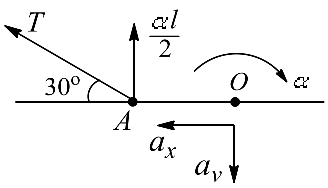
For no tipping to take place, $x < (1/2)$m

So, $m\text{g} \times x = \frac{mv^2}{r} \Rightarrow x = \frac{v^2}{r\text{g}} < \frac{1}{2} \Rightarrow v < \sqrt{\frac{r\text{g}}{2}} = 10$ m/s

16 **(d)**

Acceleration of point A along the string is zero. Therefore,

$$a_x \cos 30° - a_y \cos 60° + \frac{\alpha l}{2}\cos 60° = 0$$



17 **(d)**

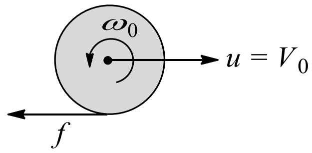
$\frac{1}{2}mv^2 = \frac{1}{2}I\left(\frac{v}{R}\right)^2 = m\text{g}\left(\frac{3v^2}{4\text{g}}\right)$

$\therefore\ \ I = \frac{1}{2}\,mR^2$

$\therefore$ Body is disc.

18 **(b)**

Here, $u = V_0, \omega_0 = -\frac{V_0}{2R}$



At pure rolling:

$V = V_0 - \left(\frac{f}{m}\right)t$

and $\frac{V}{R} = -\frac{V_0}{2R} + \left(\frac{f}{mR}\right)t$

(in pure rolling, $V = R\omega$)

$\left(\alpha = \frac{\tau}{I} = \frac{fR}{mR^2} = \frac{f}{mR}\right)$

$V_0 - V = V + \frac{V_0}{2}$

$2V = \frac{V_0}{2} \Rightarrow V = \frac{V_0}{4}$

19 **(b)**

Equation of motion is

$M\text{g} - T = Ma$ ...(i)

Taking torque about the axis passing through the centre of the spool and perpendicular to it,

$TR = I\alpha = \frac{1}{2}MR^2\left(\frac{a}{2}\right)$

$T = \frac{1}{2}Ma$ ...(ii)

From Eqs. (i) and (ii),

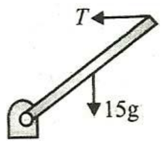
$Ma = M\text{g} - \frac{1}{2}Ma$

$a = \frac{2\text{g}}{3}$

$\therefore T = \frac{M\text{g}}{3}$

20 **(c)**

The free-body diagram of the rod is shown in the figure. (Force exerted by the hinge on the rod are not shown)



Take torque about the hinge

$T \times 3 - 15\text{g} \times 2 = 0 \Rightarrow T = 100$ N

21 **(c)**

The downward component of velocity of other part will be 30 m/s. Now applying conservation of momentum along horizontal direction,

$m \times 20 = \left(\frac{m}{2}\right)v_x$ or $v_x = 40$ m/s

So the net velocity of the other part =

$\sqrt{30^2 + 40^2} = 50$ m/s

22 **(c)**

Component of initial momentum along the wall is

$P_{iy} = mv_0 \sin 37° \hat{j}$

Component of final momentum along the wall is

$P_{fy} = \frac{mv_0}{2} \sin 53° \hat{j}$

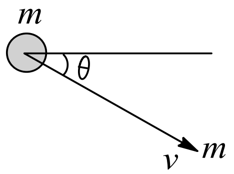
So, component of impulse along the wall is

$J_y = P_{fy} - P_{iy}$

$\frac{mv_0}{2} \times \frac{4}{5} - \frac{mv_0}{1} \times \frac{3}{5} \hat{j} = -\frac{mv_0}{5} \hat{j}$

23 **(d)**

The impact takes place along the line joining them. Since the particle at rest is constrained to move on the horizontal surface, we cannot conserve the momentum along the line joining them. Since no net force is acting on the system of particles parallel to the surface, conservation of linear momentum along that direction yields the following result



$mv \cos \theta = (m + m)v' \Rightarrow v' = \frac{v}{2} \cos 60° = \frac{v}{4}$

24 **(b)**

$\tau = I\alpha$ or $\alpha = \frac{\tau}{I}$

Here, as the force is applied at midpoint,

$\tau_A = \tau_B = F \times \frac{L}{2}$

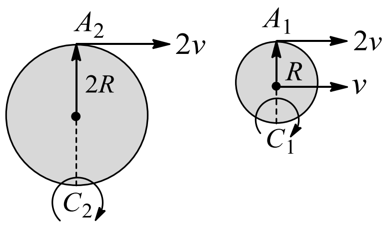
And as moment of inertia depends on the distribution of mass w.r.t. the axis of rotation, hence

$I_A > I_B$ or $\alpha_A > \alpha_B$

i.e., angular acceleration is more in case (b)

25 **(b)**

In figure, C_1 and C_2 are IC (instantaneous centre of rotation) of the two cylinders. The cylinder can be considered as rotating about C_1 and C_2. In the absence of slipping between the plank and the cylinders, points A_1 and A_2 have the same velocity. Angular velocity of the larger cylinder is $\frac{2v}{4R} = \frac{v}{2R}$



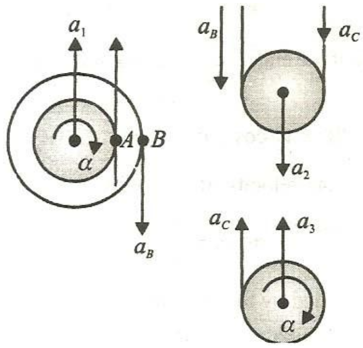
$v_{\text{CM}} = (2R)\left(\frac{v}{2R}\right) = v$

26 **(c)**

As the upper end of the string passing through A is connected with the roof (i.e., at rest). Hence, acceleration of A is zero

For A; $a_1 - \alpha r = 0$ ...(i)

Acceleration of point B; $a_B = 3\alpha r - a_1$ ...(ii)



From Eqs. (i) and (ii), $a_B = 2a_1$

For moving pulley,

$\frac{a_B + a_C}{2} = a_2$ ...(iii)

or $a_C = 2a_2 - a_B = 2a_2 - 2a_1$

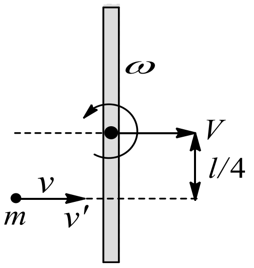
For disc,

$a_C = a_3 + 2r\alpha$ ...(iv)

From Eqs. (iii) and (iv), we get $2a_2 - a_3 = 4a_1$

27 **(a)**

Applying conservation of linear momentum,



$mv = mv' = mV \Rightarrow v = v' + V$ ...(i)

Applying conservation of angular momentum about point of collision

$0 = \left(\frac{m\ell^2}{12}\right)\omega - mV\left(\frac{\ell}{4}\right) \Rightarrow \ell\omega = 3V$ ...(ii)

Applying restituting eqution,

$(u_1 - u_2)_n = (v_2 - v_1) \Rightarrow (v - 0) = (V - v')$ ...(iii)

Solving Eqs (i), (ii), and (iii) we get $V = v$ and $\omega = \frac{3v}{\ell}$

Time taken the complete three revolutions ($\theta = 6\pi$)

$t = \frac{\theta}{\omega} = \frac{6\pi}{\omega} = \frac{6\pi\ell}{3v} = \frac{2\pi}{v}$

Hence, distance travelled by the centre of the rod is

$s = Vt = v\left(\frac{2\pi l}{v}\right) = 2\pi l$

28 **(c)**

$(m_1 + m_2)v = m_1u_1 + m_2u_2$

Or $v = \frac{2}{3}$ m/s

Here $u_2 = 0$

$\therefore$ Energy loss $= \frac{1}{2}(0.5) \times (2)^2 - \frac{1}{2}(1.5) \times \left(\frac{2}{3}\right)^2 = 0.67$ J

29 **(b)**

$$I = \frac{ML^2}{12} = \frac{6 \times 4 \times 4}{12} = 8 \text{ kg m}^2$$

From $\vec{\tau} = \vec{r} \times \vec{F} = [2\hat{\imath} \times (3\hat{\imath} + 2\hat{\jmath} + 6\hat{k})] = 4\hat{k} - 12\hat{\jmath}$

$$\tau_y = I\alpha \Rightarrow -12\,j = 8\alpha \Rightarrow a = -\frac{3}{2}j \text{ rad/s}^2$$

30 **(a)**

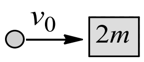
When the car is moving with the constant speed, the rod will be vertical. The centre of mass of the rod is moving with a velocity v_0 parallel to the plane. Conserving angular momentum about A, we get

$$mv_0\frac{l}{2}\cos\theta = \frac{ml^2}{3}\omega \Rightarrow \omega = \frac{3}{2}\frac{v_0}{l}\cos\theta$$

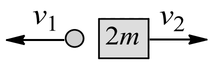
31 **(a)**

Velocity of the ball just before collision is

$v_0 = \sqrt{2gL}$



Before collision



After collision

Applying momentum conservation along horizontal direction (because momentum conserved in collision along the line of impact), we get

$mv_0 = -mv_1 + 2mv_2$

Applying coefficient of restitution equation, we get

$$e = \frac{2}{3} = \frac{v_1 + v_2}{v_0}$$

Solving the above two equations, we get

$$v_1 = \frac{v_0}{9} \text{ and } v_2 = \frac{5v_0}{9}$$

As the block moves a distance of $3L/2$ before coming to rest, so from work–energy theorem,

$$0 - \frac{1}{2}(2m)v_2^2 = -\mu \times 2\,mg\frac{3L}{2} \Rightarrow v_2^2 = 3\mu gL$$

$$\frac{25}{81} \times 2\,gL = 3\,\mu gL \Rightarrow \mu = \frac{50}{243}$$

For ball, KE is converted to gravitational potential energy after collision, so

$$0 - \frac{mv_1^2}{2} = -mg \times L(1 - \cos\theta)$$

$$\cos\theta = \frac{80}{81}$$

32 **(c)**

Because the planes of two rings are mutually perpendicular and centre are coincident, hence an axis, which is passing through the centre of one of the rings and to its plane, will be along the diameter of other ring. Hence, moment of inertia of the system

$$I_{\text{CM}} + I_{\text{diameter}} = mr^2 + \frac{mr^2}{2}$$

$$= \frac{3}{2}mr^2$$

33 **(d)**

In case of rolling in the inclined plane, friction is static and acts in the upward direction and is given by

$f = \frac{mg\sin\theta}{1+\frac{R^2}{k^2}}$ ...(i)

For sphere, $k^2 = \frac{2}{5}R^2$ ...(ii)

From Eqs.(i) and (ii), $f = \frac{2}{7}mg\sin\theta$(upwards)

34 **(b)**

Applying the law of conservation of momentum,

$400 \times 20 + 4000 \times 2.5 = -400 \times 5 + 4000v_2$

$\Rightarrow 8000 + 10000 + 2000 = 4000v_2$

$$\Rightarrow v_2 = 5 \text{ m}/s = 5 \times \frac{18}{5} \text{ km/h} = 18 \text{ km/h}$$

35 **(d)**

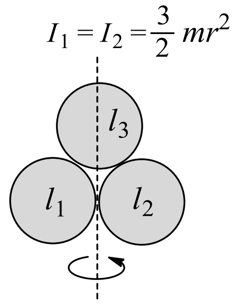
Since linear acceleration is same for all ($a = Mg\sin\theta - \mu\,Mg\cos\theta$) as they have same mass 'M' and same 'μ'

Hence, all will reach the bottom simultaneously

36 **(d)**

$I = I_1 + I_2 + I_3$

$$I_1 = I_2 = \frac{3}{2}mr^2$$



$$I_1 = I_2 = \frac{3}{2}mr^2$$

$$I = I_1 + I_2 + I_3 = \frac{7}{2}mr^2$$

37 **(c)**

$$\vec{a}_{\text{CM}} = \frac{\vec{F}}{m_1 + m_2} = \frac{16\hat{\imath} + 8\hat{\jmath}}{8 + 8} = \hat{\imath} + \frac{1}{2}\hat{\jmath}$$

$$|\vec{a}_{CM}| = \sqrt{1^2 + \left(\frac{1}{2}\right)^2} = \frac{\sqrt{5}}{2} \text{ m/s}^2$$

$$\tan\theta = \frac{a_y}{a_x} = \frac{\frac{1}{2}}{1} = \frac{1}{2} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{2}\right)$$

38 **(d)**

$$v_{CM-i} = \frac{200 \times 0 + 100 \times 100}{200 + 100} = \frac{100}{3} \text{ m/s}$$

$$v = v_{CM-i} + a_{CM} t = \frac{100}{3} - g \times 1 = \frac{70}{3} \text{m/s}$$

39 **(b)**

Apply conservation of momentum after piercing M_1: $mu = M_1 v + mu_1$ (i)

After it enters into M_2, finally bullet also moves with velocity v, so

$mu_1 = (M_2 + m)v$ (ii)

From (i) and (ii), we get

$mu = (M_1 + M_2 + m)v$ (iii)

Required percentage loss $= \frac{u-u_1}{u} \times 100 = \frac{m(u-u_1)}{mu} \times 100$

$$= \frac{M_1 v}{(M_1 + M_2 + m)v} \times 100$$

$$= \frac{1}{1 + 2.98 + 0.02} \times 100 = 25\%$$

40 **(d)**

Initially, both the blocks are under the gravity effect, so

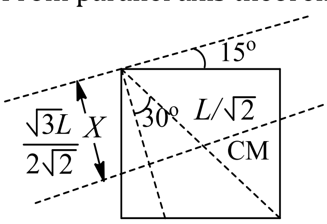
$$a_{CM} = \frac{4g + 2g}{4 + 2} = g$$

But once the jerk in the string occurs and string becomes taut, the 4 kg block moves down with acceleration g/3 and 2 kg block moves up with acceleration g/3. So,

$$a_{CM} = \frac{4 \times \frac{g}{3} - \frac{2g}{3}}{6} = \frac{g}{9}$$

41 **(b)**

From parallel axis theorem,



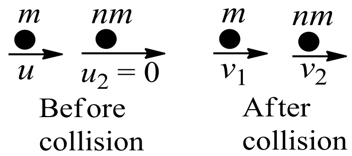
$$I_1 = \frac{ML^2}{12}, I_2 = I_1 + Mx^2 = \frac{ML^2}{12} + M\left(\frac{\sqrt{3}L}{2\sqrt{2}}\right)^2$$

$$= \frac{11ML^2}{24}$$

42 **(d)**

As the collision is elastic, we can find

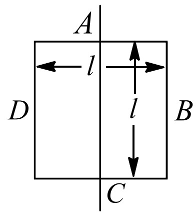
$$v_1 = \frac{1-n}{1+n}u, v_2 = \frac{2u}{1+n}$$



Hence, the required fraction is

$$\frac{\frac{1}{2}nmv_2^2}{\frac{1}{2}mu^2} = n\left(\frac{v_2}{u}\right)^2 = \frac{4n}{(1+n)^2}$$

43 **(d)**



$$I_{\text{median line}} = I_A + I_B + I_C + I_D$$

$$= 2 \times \frac{MI^2}{12} + 2M\left(\frac{l}{2}\right)^2 = \frac{MI^2}{6} + \frac{MI^2}{2} = \frac{2}{3}MI^2$$

44 **(a)**

In this problem, the velocity of the earth before and after the collision may be assumed zero. Hence, coefficient of restitution will be

$$e^n = \frac{v_1}{v_0} \times \frac{v_2}{v_1} \times \frac{v_3}{v_2} \times \cdots \times \frac{v_n}{v_n - 1}$$

Where v_n is the velocity after n^{th} rebounding and v_0 is the velocity with which the ball strikes the earth for the first time. Hence,

$$e^n = \frac{v_n}{v_0} = \frac{\sqrt{2gh_n}}{\sqrt{2gh_0}}$$

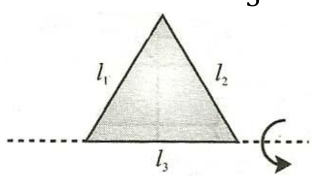
Where h_n is the height to which the ball rises after n^{th} rebounding.

Hence,

$$e^n = \frac{v_n}{v_0} = \frac{\sqrt{h_n}}{\sqrt{h_0}}$$

45 **(d)**

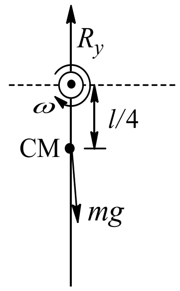
$$I = I_1 + I_2 + I_3 = \frac{ml^2}{3} + \frac{ml^2}{3} + 0 = \frac{2ml^2}{3}$$



46 **(c)**

KE of the rod is maximum when it is in the vertical position. From conservation of energy, we get

$$\frac{mgl}{4} = \frac{1}{2}\left[\frac{ml^2}{12} + \frac{ml^2}{16}\right]\omega^2$$



$\frac{\omega^2 l}{4} = \frac{6g}{7}$

and $R_y - mg = m(l/4)\omega^2$

$R_y = mg + m\left(\frac{6g}{7}\right)$

$= \frac{13mg}{7}$

47 **(b)**

If the collision is elastic, whole of the kinetic energy of the ball is transferred to the bob. Hence, $\frac{1}{2}mv^2 = mgh$ or $h = \frac{v^2}{2g}$

48 **(c)**

At the time of maximum compression, the speeds of blocks will be the same. Let that speed be v and maximum compression be x

Applying conservation of momentum,

$(m_1 + m_2)v = m_1v_1 + m_2v_2$

$\Rightarrow v = 4$ m/s

Applying conservation of mechanical energy

$\frac{1}{2}kx^2 + \frac{1}{2}(m_1 + m_2)v^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

Solving, we get $x = 0.02$ m

49 **(b)**

As no external force acts on the ball + box system, hence velocity of the system remains constant

50 **(b)**

Given that $I_Q = 4I_P$

Here I= mass × (radius)^2. If s is the linear mass density (mass/length) of the wire, then

$\sigma \times 2\pi(nr) \times n^2r^2 = 4(\sigma \times 2\pi r \times r^2)$

$\Rightarrow n^3 = 4 \Rightarrow n = (4)^{\frac{1}{3}}$

51 **(c)**

From the above problem, $T = \frac{Ma}{2}$

Now

$mg - T = ma$

or $mg - M\frac{a}{2} = ma$

or $mg = \left(m + \frac{M}{2}\right)a$

$a = \frac{2mg}{M + 2m}$

52 **(b)**

Since $\sum \vec{F}_{\text{ext}} = \vec{0}$

Therefore, momentum of the system will remain conserved and is equal to zero

53 **(c)**

Impulse= area of trapezium

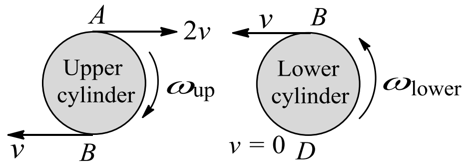
$= \frac{1}{2}\left(T + \frac{T}{2}\right)F_0 = \frac{3TF_0}{4}$

According to impulse-momentum theorem,

Impulse = Change in momentum

$\Rightarrow \frac{3TF_0}{4} = mu \Rightarrow F_0 = \frac{4mu}{3T}$

54 **(b)**



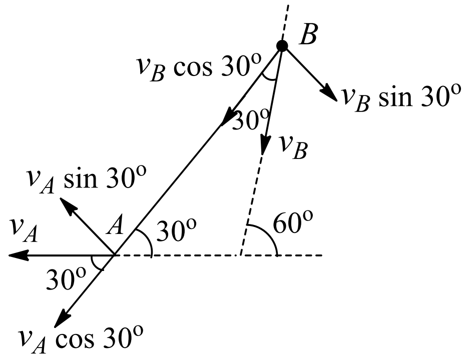
Angular velocity of the upper cylinder is

$\omega_{\text{up}} = \frac{2v-(-v)}{2R} = \frac{3v}{2R}$; for the lower cylinder

$\omega_{\text{lower}} = \frac{v - 0}{2R} = \frac{v}{2R}$

Hence , ratio, $\frac{\omega_{\text{up}}}{\omega_{\text{lower}}} = 3$

55 **(b)**



The velocities of the ends A and B along the length of rod should be the same

Hence, $v_A \cos 30° = v_B \cos 30° \Rightarrow v_A = v_B = v$

Hence, the angular velocity of the rod is

$\omega = \frac{(v_{AB})_\perp}{l} = \frac{2v \sin 30°}{l} \Rightarrow \omega = \frac{v}{\ell}$

56 **(b)**

$\frac{L_{\text{Total}}}{L_B} = \frac{(I_A + I_B)\omega}{I_B.\omega}$ (as ω will be same in both cases)

$= \frac{I_A}{I_B} + 1 = \frac{m_A r_A^2}{m_B r_B^2} + 1$

$= \frac{r_A}{r_B} + 1$ (as $m_A r_A = m_B r_B$)

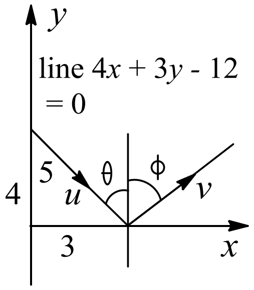
$= \frac{11}{2.2} + 1$ (as $r \propto \frac{1}{m}$)

$= 6$

∴ The correct answer is 6.

57 **(c)**

$v\sin\phi = u\ \sin\theta, v\cos\phi = eu\ \cos\theta$



$\Rightarrow v = u\sqrt{e^2\ \cos^2\theta + \sin^2\theta}$

$= 10\sqrt{(0.75)^2\left(\frac{4}{5}\right)^2 + \left(\frac{3}{5}\right)^2} = 6\sqrt{2}\text{ m/s}$

58 **(d)**

$I_P > I_Q$

$a_P = \frac{g\sin\theta}{I_P + mR^2}$

$a_Q = \frac{g\sin\theta}{I_Q + mR^2}$

$a_P > a_Q \Rightarrow V = u + at \Rightarrow t \propto \frac{1}{a}$

$t_P > t_Q$

$V^2 = u^2 + 2as \Rightarrow v \propto a \Rightarrow V_P < V_Q$

Translational $K.E. = \frac{1}{2}mV^2 \Rightarrow TR\ KE_P < TR\ KE_Q$

$V = \omega R \Rightarrow \omega \propto V \Rightarrow \omega_P < \omega_Q$

59 **(b)**

$\hat{j}$ Component, i.e., component of velocity parallel to wall remains unchanged while $\hat{\imath}$ component will become $(-1/2)\ (2\hat{\imath})$ or $-\hat{\imath}$. Therefore, velocity vector of the sphere after it hits the wall is

$-\hat{\imath} + 2\hat{j}$

60 **(a)**

By conservation of angular momentum about pivot

$L = I\omega$

$\frac{mvd}{2} = \left[\frac{Md^2}{12} + m\left(\frac{d}{2}\right)^2\right]\omega$

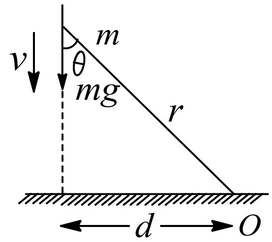
$= \left(\frac{md^2}{2} + \frac{md^2}{4}\right)\omega$

$= \frac{3}{4}md^2\omega \Rightarrow \frac{2}{3}\frac{v}{d} = \omega$

61 **(b)**

The magnitude of angular momentum of the particle about $O = mvd$

Since speed v of the particle increases, its angular momentum about O increases



Magnitude of inertia of the particle about $O = mr^2$

Hence, MI of the particle about O decreases

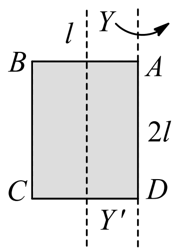
Angular velocity of the particle about $O = \frac{v\sin\theta}{r}$

Therefore, v and $\sin\theta$ increase and r decreases

Therefore, angular velocity of the particle about O increases

62 **(c)**

(About YY') $= \frac{ml^2}{12}$



Using parallel axis theorem,

$I(\text{about } AD) = \frac{ml^2}{12} + \frac{ml^2}{4} = \frac{ml^2}{3}$

63 **(a)**

Motion of centre of mass is exactly similar to the motion of a body had it not exploded

$u_x = u\ \cos\theta = \frac{10}{\sqrt{2}}\text{ m/s}, u_y = u\sin\theta = \frac{10}{\sqrt{2}}\text{ m/s}$

$v_x = u_x = \frac{10}{\sqrt{2}}\text{ m/s}$

(since there is no change in the horizontal velocity)

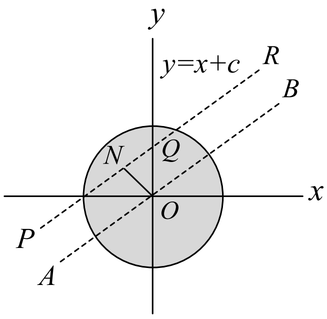
$v_y^2 - u_y^2 = 2(-g)(h)$

$\Rightarrow v_y^2 = \frac{100}{2} - 2 \times 10 \times 1 = 30$

Therefore, net velocity of CM$= \sqrt{v_x^2 + v_y^2}$

$= \sqrt{\frac{100}{2} + 30} = \sqrt{80} = 4\sqrt{5}\text{ m/s}$

64 **(b)**



$I_{PQR} = I_{AOB} + M(ON)^2$

$= \frac{1}{2}MR^2 + M\left(\frac{c}{\sqrt{2}}\right)^2$

But $= \frac{1}{4}MR^2 = I_2$

$c = \pm\frac{R}{\sqrt{2}}$

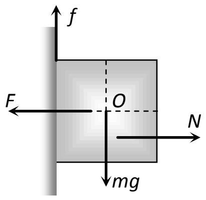
65 **(d)**

As the block remains stationary therefore

For translatory equilibrium

$\sum F_x = 0 \therefore F = N$

and $\sum F_y = 0 \therefore f = mg$



For rotational equilibrium $\sum \tau = 0$

By taking the torque of different forces about point 0

$\overrightarrow{\tau_F} + \overrightarrow{\tau_f} + \overrightarrow{\tau_N} + \overrightarrow{\tau_{mg}} = 0$

As F and mg passing through point O

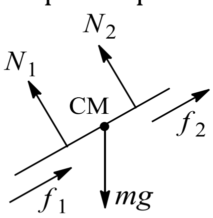
$\therefore \overrightarrow{\tau_1} + \overrightarrow{\tau_N} = 0$

As $\overrightarrow{\tau_f} \neq 0 \quad \therefore \overrightarrow{\tau_N} \neq 0$ and torque by friction and normal reaction will be in opposite direction

66 **(c)**

As rod is in equilibrium. The torque of all the forces about the CM is zero

$N_1\frac{l}{4} = N_2\frac{l}{4} \Rightarrow N_1 = N_2$

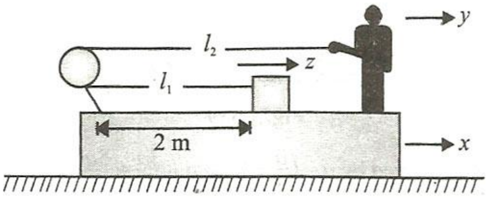


67 **(b)**

Let x be displacement of wedge w.r.t. ground, y be displacement of man w.r.t. ground and z be displacement of block w.r.t. ground. As the length of string will remain same, so

$(l_1 + z - x) + (l_2 + y - x) = l_1 + l_2$

$\Rightarrow z + y = 2x \quad$ (i)



Also, if the pulley and the block meet, then we can write

$x = z + 2 \quad$ (ii)

$\Delta x_{\text{cm}} = 0 \Rightarrow \frac{Mx + 2My + Mz}{4M} = 0$

$\Rightarrow x + 2y + z = 0 \quad$ (iii)

From Eqs. (i),(ii) and (iii),

$x = \frac{-1}{2}$ m, $y = \frac{3}{2}$ m, $z = \frac{-5}{2}$ m

68 **(a)**

Because the collision is perfectly inelastic, hence the two blocks stick together. By conservation of linear momentum,

$2mV = mv$ or $V = \frac{v}{2}$

By conservation of energy,

$2mgh = \frac{1}{2}2mV^2$ or $h = v^2/8\text{g}$

69 **(b)**

The rod will balance about centre of mass; so distance of centre of mass from the left end,

$x_{\text{CM}} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{100 \times 25 + 50 \times 55}{100 + 50}$

$= 35$ cm

Therefore, distance from centre of rod $= 35 - 25$ $=10$ cm to the right

70 **(c)**

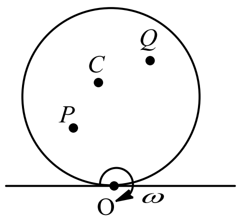
$v_{\text{CM}} = \frac{5 \times 14}{5 + 2} = 10$ m/s

Velocity of the 5 kg block w.r.t. CM $= 14 - 10 = 4$ m/s

Velocity of the 2 kg block w.r.t. CM $= 0 - 10 = -10$ m/s

71 **(a)**

In case of pure rolling bottommost point is the instantaneous centre of zero velocity.



Velocity of any point on the disc, $v = r\omega$, where r is distance of point from O.

$r_Q > r_C > r_P$

$\therefore \quad v_Q > v_C > v_P$

72 **(a)**

Let the impulse due to the particle be

$J, J = mv_{CM} \Rightarrow v_{CM} = \frac{J}{m}$

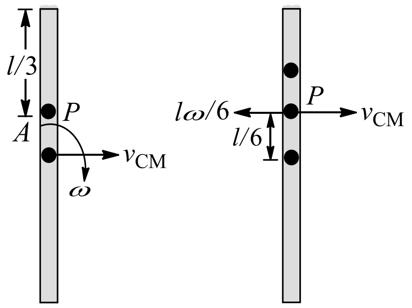
Angular impulse abut centre of mass is

$Jx = \frac{ml^2}{12}\omega \Rightarrow \omega = \frac{12Jx}{ml^2}$

For point A to be at rest instanteously,

$\vec{v}_{trans} + \vec{v}_{rot} = 0$

Or $v_{CM} = \frac{\omega \ell}{6}$



Thus $\frac{J}{m} = \frac{l}{6} \times \frac{12Jx}{ml^2}$

Which gives, $x = \frac{l}{2}$

73 **(b)**

Total MI$= I_1 + I_2 + I_3 + I_4$

$= 2I_1 + 2I_2$

$= 2(I_1 + I_2)[I_1 = I_3; I_1 = I_4]$

Now, $I_2 = I_3 = \frac{Ml^2}{3}$

Using parallel axis theorem, we have

$I = I_{CM} + Mx^2$ and $x = \sqrt{l^2 + \left(\frac{l}{2}\right)^2}$

$$I_1 = I_4 = \frac{Ml^2}{12} + M\left[\sqrt{l^2 + \left(\frac{l}{2}\right)^2}\right]^2$$

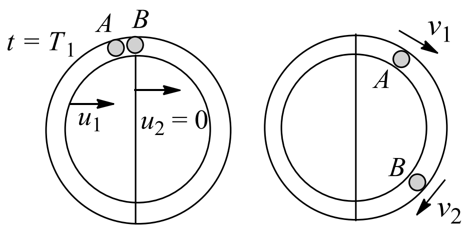
Putting all values, we get

$$I = \frac{10Ml^2}{3}$$

74 **(d)**

$T_1 = \frac{\pi R}{u_1}$ (i)

$\frac{v_2 - v_1}{u_1} = e \Rightarrow v_2 - v_1 = eu_1$



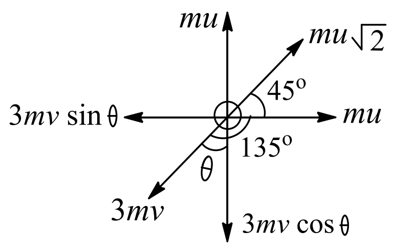
Time taken to collide A and B again is

$T_2 - T_1 = \frac{2\pi R}{v_2 - v_1} \Rightarrow T_2 - T_1 = \frac{2\pi R}{eu_1}$ (ii)

Dividing (ii) by (i), we get $\frac{T_2}{T_1} = \frac{2+e}{e}$

75 **(a)**

Suppose m is the mass of each piece flying off perpendicular to one another with same speed $u(= 30 \text{ m/s})$. Then $3m$ is the mass of the third piece. Let v be the velocity of the third piece



According to fig.,

$3\ mv \cos\theta = mu, 3\ mv \sin\theta = mu$

$\tan\theta = 1$ or $\theta = 45°$

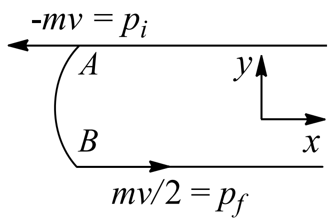
Hence, $3\ mv \cos 45° = mu$

Or $\frac{3v}{\sqrt{2}} = u = 30$ m/s or $v = 10\sqrt{2}$ m/s

(inclined at 135° w.r.t.direction of each one)

76 **(b)**

The momentum of the bead at A is $P_i = -mv\,\hat{\imath}$



The momentum of the bead at B is $\vec{P}_f = \left(\frac{mv}{2}\right)\hat{\imath}$

Therefore, the magnitude of the change in momentum between A and B is

$\Delta P = \left|\vec{P}_f - \vec{P}_i\right| = \left(\frac{3}{2}\right)mv$

Average force exerted by the bead on the wire is

$F_{av} = \frac{\Delta p}{\Delta t} = \frac{3mv}{2T}$

77 **(c)**

Both the particles will collide at the highest point of their path. Momentum of the particle p just before collision

$m_A V_A \cos 45° = 20 \times 10^{-3} \times 49 \times \frac{1}{\sqrt{2}}$

$= \frac{980}{\sqrt{2}} \times 10^{-3}$ kg m/s

Momentum of particle Q just before collision is

$m_B V_B \cos 135° = -40 \times 10^{-3} \times 49 \times \frac{1}{\sqrt{2}}$

$= \frac{1960}{\sqrt{2}} \times 10^{-3}$ kg m/s

After collision, let velocity of Q be V and velocity of P be 49 cos 45°. Therefore, momentum after collision is

$40 \times 10^{-3} V - \frac{49 \times 20 \times 10^{-3}}{\sqrt{2}}$

Applying law of conservation of momentum,

$\frac{980}{\sqrt{2}} \times 10^{-3} - 1960 \times \frac{10^{-3}}{\sqrt{2}}$

$$= 40 \times 10^{-3}\, V - \frac{980 \times 10^{-3}}{\sqrt{2}}$$

Or $V = 0$

Thus, particle Q will fall freely after collision. So the distance travelled by it will be 245/2 m, i.e.,122.5 m

78 **(a)**

Momentum in vertical direction

$mu \cos 60° + 3mu \cos 60° = 4\, mu \cos 60°$

$= 2mu$

This momentum becomes zero due to impulse in string

Hence, impulse in string $= 2mu$

Conservation of linear momentum in horizontal direction

$m(3u) \sin 60° - mu \sin 60° = 12\, mv$

$\Rightarrow v = \frac{\sqrt{3}u}{12}$

Loss of energy $= \frac{1}{2} m(9u^2) + \frac{1}{2} mu^2 - \frac{1}{2} \times 12\, m \times \left(\frac{\sqrt{3}u}{12}\right)^2$

$= \frac{39\, mu^2}{8}$

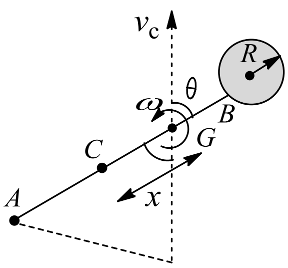
79 **(c)**

Let x be the position of CM of the system from CM of the rod

$2mx = m(R + 2R - x) \Rightarrow x = R$ ...(i)

$I_G = \frac{2m(4R)^2}{12} + 2mR^2 + \frac{mR^2}{2} + m(2R)^2$

$= \frac{55}{6} mR^2$ ...(ii)



Applying conservation of angular momentum,

$3mv_c \sin\theta\, 3R + I_G\omega = (I_G + 3m\, 9R^2)\omega'$

$\omega' = \frac{54mv_cR \sin\theta + 55mR^2\omega}{217mR^2}$

$= \frac{54v_c \sin\theta + 55R\omega}{217R}$

80 **(b)**

Let m_1 be the mass of the quare plate of side 'a'.

Then

$m_1 = \sigma\left(\frac{a}{2}\right)^2 ; m_2 = \sigma(a)^2;$

(σ being the real density)

And $m_2 - m_1 = M$

$I = \frac{m_2a^2}{6} - \left\{\frac{m_1\left(\frac{a}{2}\right)^2}{6} + m_1\left(\frac{a}{4}\right)^2\right\}$

$= \frac{\sigma a^4}{6} - \left\{\frac{\sigma\left(\frac{a}{2}\right)^4}{6} + \sigma\left(\frac{a}{4}\right)^2\left(\frac{a}{4}\right)^2\right\}$

Also, $M = \sigma\left(1 - \frac{1}{4}\right)a^2 \Rightarrow \sigma = \frac{4}{3}\frac{M}{a^2}$

After solving, we get $I = \left(\frac{4}{3}\frac{M}{a^2}\right)a^4\left\{\frac{27}{12\times16}\right\} \Rightarrow I = \frac{3Ma^2}{16}$

81 **(d)**

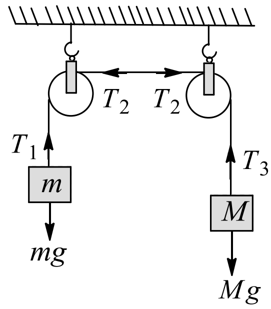
Apply conservation of angular momentum about the hinge, we get

$mvR = \frac{m}{2}R^2\omega + m(R\omega)R$

$R\omega = \frac{2v}{3} = \frac{2 \times 5}{3} = \frac{10}{3}$ m/s

82 **(a)**

$T_1 - mg = ma$ ...(i)



$Mg - T_3 = Ma$ ...(iii)

$r(T_3 - T_2) = I\alpha$ ...(iv)

and $a = R\alpha$

From Eqs. (ii) and (iv), we get

$T_3 - T_1 = \frac{2la}{R^2}$

From Eqs. (i) and (iii), we get

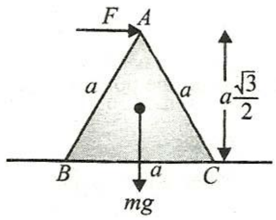
$(M - m)g = (M + m)a + T_3 - T_1$

$(M - m)g = (M - m)a + \frac{2la}{r^2}$

$\Rightarrow a = \frac{(M-m)g}{\left(M+m+\frac{2l}{r^2}\right)}$

83 **(a)**

The tendency of rotating will be about point C. For the minimum force, the torque of F about C has to be equal to the torque of mg about C



$$F\left(a\frac{\sqrt{3}}{2}\right) = mg\left(\frac{a}{2}\right) \Rightarrow F = \frac{mg}{\sqrt{3}}$$

84 **(c)**

Method -1: Acceleration of 3 kg:

$$a_2 = \frac{6}{3} = 2\ \text{m/s}^2$$

Velocity of 3 kg at $t = 5$ s: $v_2 = u_2 + a_2 t = 0 + 2 \times 5 = 10$ m/s

$$v_{\text{CM}(t=5\text{s})} = \frac{2 \times 0 + 3 \times 10}{2+3} = 6\ \text{m/s}$$

Method-2:

$$a_{\text{CM}} = \frac{F}{m_1 + m_2} = \frac{6}{2+3} = 1.2\ \text{m/s}^2$$

$$v_{\text{CM}} = u_{\text{CM}} + a_{\text{CM}}\, t = 0 + 1.2 \times 5 = 6\ \text{m/s}$$

85 **(b)**

Force on table due to collision of balls:

$$F_{\text{dynamic}} = \frac{dp}{dt} = 2 \times 20 \times 20 \times 10^{-3} \times 5 \times 0.5 = 2\ \text{N}$$

Net force on one leg $= \frac{1}{4}(2 + 0.2 \times 10) = 1$ N

86 **(b)**

Till then m remains on B , B will continue to accelerate due to contact force between m and B. Hence, velocity of B will be maximum when finally m leaves B

87 **(c)**

If the track in smooth (case A), only translation kinetic energy changes to gravitational potential energy

But, if the track id rough (case B), both translation and rotational kinetic energies change to potential energy

Therefore potential energy ($= mgh$) will be more in case B than in case A

Hence. $h_1 > h_2$

88 **(d)**

1. Since both have positive final velocities, hence, both moved in the same direction after collision

2. At $t = 2$ s, both had equal velocities

3. By conservation of linear momentum

$$m_1(0.8) = m_1(0.2) + m_2(1) \Rightarrow \frac{m_1}{m_2} = \frac{5}{3} \Rightarrow m_1 > m_2$$

89 **(d)**

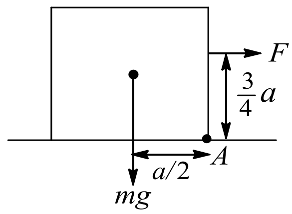
Let the masses be m_1 and m_2. Then

$$F = m_1 a \Rightarrow a = \frac{F}{m_1}$$

$$a_{\text{CM}} = \frac{m_1 a + m_2 \times 0}{m_1 + m_2} = \frac{F}{m_1 + m_2} < a$$

90 **(b)**

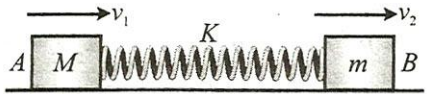
See the figure. For tilting about A the clockwise torque (due to F) should be greater than the anticlockwise torque about A



$$mg \times \frac{a}{2} = \frac{F3a}{4}; F = \frac{2mg}{3}$$

91 **(c)**

The velocity of B will be maximum when spring comes to its natural length. Let at that time their velocities are v_1 and v_2 as shown



Conservation of momentum:

$2v_1 + 1v_2 = (2+1) \times 1 \Rightarrow 2v_1 + v_2 = 3$ (i)

Conservation of energy:

$\frac{1}{2}2v_1^2 + \frac{1}{2}1v_2^2 = \frac{1}{2}600\left(\frac{10}{100}\right)^2 + \frac{1}{2}3(1)^2 \Rightarrow 2v_1^2 + v_2^2 = 9$ (ii)

From Eqs. (i) and (ii),

$v_1 = 2$m/s, $v_2 = -1$ m/s or $v_1 = 0$, $v_2 = 3$ m/s

The second solution is possible

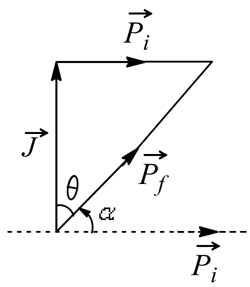
92 **(c)**

From impulse − momentum theorem,

$$\vec{J} = \vec{p}_f - \vec{p}_i \Rightarrow \vec{p}_f = \vec{J} + \vec{p}_i$$

Here $p_i = 3000 \times 300 = 9 \times 10^5$ kg m/s

$J = 4000 \times 225 = 9 \times 10^5$ kg m/s

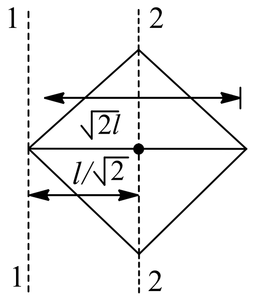


$$\tan\theta = \frac{p_i}{J} = 1 \Rightarrow \theta = 45°$$

So, the angle by which the space probe rotates is
$\alpha = \frac{\pi}{2} - \theta = 45°$

93 **(d)**
Taking torque about the attachment point for W, we get
$-T_1(0.4L) + T_2(0.3L) + 500(0.2L) = 0$
$T = 1000$ N, where $T_1 = T_2 = T$
$\Sigma F_y = 0 \Rightarrow 2T - W - 500 = 0$
$\Rightarrow W = 1500$ N

94 **(d)**
Moment of inertia about 2:
$$I_2 = 4\left(\frac{ml^2}{3}\sin^2 45°\right) = \frac{2ml^2}{3}$$
Apply perpendicular axis theorem,

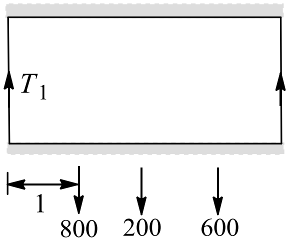


$$I_1 = I_2 + mh^2 = \frac{2ml^2}{3} + 4m\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{8}{3}ml^2$$

95 **(c)**
Balancing the torque:
For the first case: $16l_1 = ml_2$
For the second case: $ml_1 = 4l_2$
Divide them to get $m = 8$ kg

96 **(d)**
Using conservation of linear momentum, we have
$$m_2v_0 = (m_1 + m_2)v \Rightarrow v = \frac{m_2}{m_1 + m_2}v_0$$
From work–energy conservation,
$$\frac{1}{2}m_2v_0^2 - \frac{1}{2}(m_1 + m_2)\frac{m_2^2v_0^2}{(m_1 + m_2)^2} = \frac{1}{2}kx^2$$
$$x = v_0\sqrt{\frac{m_1m_2}{\text{k}(m_1 + m_2)}}$$

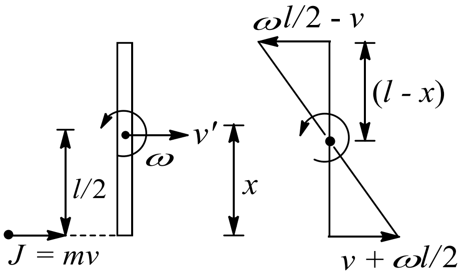
97 **(c)**
For vertical equilibrium, $T_1 + T_2 = 1600$ N



Take moment about O,
$T_1 \times 2.5 + 600x$
$T_2 \times 2.5 + 800 \times 1.5$
$T_1 = 1040 - 120x$
and $T_2 = 560 + 120x$
For safe working, $T_1 < 1040$ N and $T_2 < 1040$ N
$x > 0$ and $x < 2$, so the range is $0 < x < 2$

98 **(d)**
As $\Sigma\tau = 0$, angular momentum and linear momentum remain conserved. As the two balls will move radially out, I changes. In order to keep the angular momentum ($L = I\omega$) conserved, angular speed (ω) should change

99 **(d)**
$J = mv = mv'$
$\Rightarrow$ Velocity of the CM of rod $= v$
Applying impulse momentum equation about the CM of rod



(a) (b)

$$J\frac{l}{2} = I_{\text{CM}}\omega \Rightarrow \frac{mvl}{2} = \left(\frac{ml^2}{12}\right)\omega \Rightarrow \omega = \frac{6V}{\ell}$$
About instantaneous axis of rotation the rod is considered to have pure rotation
Let instantaneous axis of rotation be located at a distance x from the colliding end
$$\frac{\frac{\omega\ell}{2} - v}{\ell - x} = \frac{v + \frac{\omega\ell}{2}}{x} \quad \text{...(i)}$$
Substituting the value of $\omega = 6V/l$ in Eq.(i), we get $x = \frac{2}{3}\ell$

100 **(c)**
For elastic collision, $e = 1$. Let speed of the ball be v towards left after collision, then w.r.t. wall, incident velocity = reflected velocity. We get
$3 + 3 = v - 3 \Rightarrow v = 9$ m/s

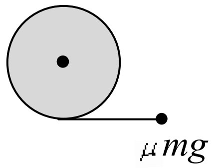
101 **(b)**

$$mg\left(\frac{l}{4}\right) = \frac{1}{2}\left[\frac{ml^2}{12} + m\left(\frac{1}{4}\right)^2\right]\omega^2$$

$$\omega = \sqrt{\frac{24g}{7l}} = 2\sqrt{\frac{6g}{7l}}$$

102 **(d)**

Taking τ about CM



$\mu mgR = MR^2\alpha$

$\mu g = R\alpha$

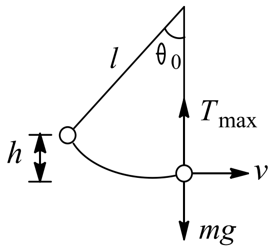
$\alpha = \frac{\mu g}{R}$

$\omega = \omega_0 - \frac{\mu g}{R}f = \frac{\omega_0}{2}$

$\frac{\omega_0}{2} = \frac{\mu g}{R}f \Rightarrow f = \frac{\omega_0 R}{2\mu g}$

103 **(d)**

Maximum tension in the string is in its lowest position. Speed of mass m in its lowest position is



$v^2 = 2gh = 2gl(1 - \cos\theta_0)$

$T_{max} - mg = \frac{mv^2}{l}$

$T_{max} = mg + 2\,mg(1 - \cos\theta_0)$

$= mg\,(3 - 2\cos\theta_0)$

Block of mass $4m$ dose not move. So, $\mu(4mg) \geq T_{max}$

Or $4\,\mu\,mg \geq mg\,(3 - 2\cos\theta_0)$

Or $\mu \geq \left(\frac{3 - 2\cos\theta_0}{4}\right)$

104 **(c)**

Let M be the mass of each disc. Let R_A and R_B be the radii of discs A and B, respectively. Then

$M = \pi R_A^2 t d_A = \pi R_B^2 t d_B$

As $d_A = d_B$, so $R_A^2 < R_B^2$. Now,

$I_A = \frac{1}{2}MR_A^2, I_B = \frac{1}{2}MR_B^2$

$\frac{I_A}{I_B} = \frac{R_A^2}{R_B^2} < 1$, i.e., $I_A < I_B$

105 **(c)**

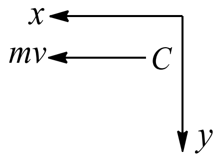
The velocity of the particle when it reaches point A from B is

$v = \sqrt{(2gh)}$ (directed along BA)

$(p_i)x = mv\ \cos\theta$ (i)

$(p_i)y = mv\ \sin\theta$ (ii)

When the particle reaches point C, the momentum is as shown in fig



$(p_f)_x = mv$ (iii)

$(p_f)_y = 0$ (iv)

Therefore, $(\Delta P)_x = (p_f)_x - (p_i)_x$

$= mv - mv\cos\theta$ (v)

$(\Delta p)_y = (p_f)y - (p_i)_y = -mv\ \sin\theta$

Magnitude of change in momentum is

$\sqrt{[mv(1 - \cos\theta)]^2 + (mv\ \sin\theta)^2}$

$$= 2m(\sqrt{2gh})\sin\left(\frac{\theta}{2}\right)$$

106 **(b)**

The two forces along the y- direction balance each other. Hence, the resultant force is $2F$ along the x-direction. Let the point of application of the force be at $(0, y)$

(By symmetry, x-coordinate will be zero)

For rotational equilibrium:

$F(a) + F(a) + F(a + y) - F(a - y) = 0$

$\Rightarrow y = -a$

Alternative method:

Torque will only be produced by the two forces acting along y-direction in anticlockwise direction. To balance this torque, we should apply a force $2F$ in order to produce a torque in the clockwise direction, which is only possible if we apply a force at a point below the x-axis

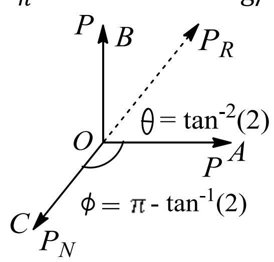
Then $\tau = F(a) + F(a) - 2F \times y = 0$

$\Rightarrow\ y = a$

107 **(a)**

$P_e = 3.2 \times 10^{-23}$ kg/s

$P_n = 6.4 \times 10^{-23}$ kg/s



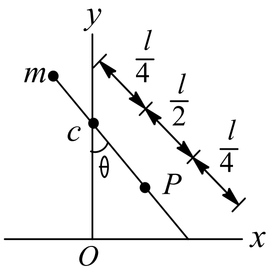
$\tan\theta = \frac{P_n}{P_e} = \frac{6.4 \times 10^{-23}}{3.2 \times 10^{-23}} = 2$

According to law of conservation of momentum, the residual nucleus must move in a direction just

opposite to that of $\vec{P}_R$, as shown in the figure.
Hence, direction of the recoiling nucleus with that of the electron motion $\emptyset = \pi - \theta = \pi - \tan^{-1}(2)$

108 **(b)**

Since the floor is smooth, therefore no horizontal force is acting on the system. Only three forces are acting on it, weight mg of the ball, weight mg of the rod and vertically upward reaction of the floor



Since the rod is released from rest and no horizontal force is acting on it, therefore centre of mass of the system will not displace horizontally; it means it will fall vertically downward
Since masses of the rod and ball are equal, therefore centre of mass 'c' is at mid-point of centre of the rod and the ball; it means at distance $l/4$ from the ball or 3/4 from the lower end
If at an instant the rod makes angle θ with the vertical, then point P and the system will be as shown in the figure
Co-ordinates of the point P are

$$x = \frac{l}{2}\sin\theta$$

$$y = \frac{l}{4}\cos\theta$$

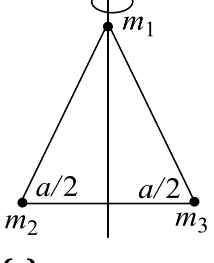
$$\therefore \sin\theta = \frac{2x}{l}$$

$$\cos\theta = \frac{4y}{l}$$

Using $\sin^2\theta + \cos^2\theta = 1$, we have
$4x^2 + 16y^2 = l^2$

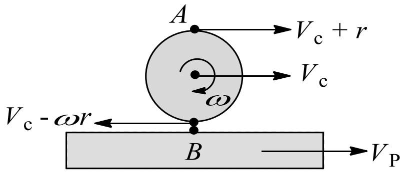
109 **(b)**

$$I = m_1\left(\frac{a}{2}\right)^2 + m_2\left(\frac{a}{2}\right)^2$$



110 **(c)**

For pure rolling velocity of the point of contact has to be equal to the velocity of the surface
Let us say cylinder rolls with angular velocity ω
At point B,
$V_C - \omega r = V_P \Rightarrow \omega r = V_C - V_p$
At point A,
$V_A = V_C + \omega r = 2V_C - V_P$



111 **(d)**

$$\omega_{\text{rod}} = \frac{(v_{\text{rel}})_\perp}{r}$$

$(V_{\text{rel}})_\perp$ is the velocity of one point w.r.t. other perpendicular to rod
$\omega_{\text{rod}} = \frac{3v - v}{r}$ and $'r'$ being the distance between the points

$$\omega_{\text{rod}} = \frac{2v}{r}$$

112 **(a)**

Applying the law of conservation of momentum,
$m_1 v_1 = (m_1 + m_2)V$ (i)
Where $v_1 = \sqrt{2gd}$ is the velocity with which m_1 collides with m_2
Therefore,

$$V = \frac{m_1}{(m_1 + m_2)}\sqrt{2gd}$$

Now, let the centre of mass rise through a height h after collision. In this case, the kinetic energy of $m_1 + m_2$ system is converted into potential energy at maximum height h

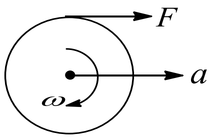
$$\Rightarrow \frac{1}{2}(m_1 + m_2)V^2 = (m_1 + m_2)gh$$

$$\Rightarrow \frac{1}{2}(m_1 + m_2)\left\{\frac{m_1}{m_1 + m_2}\right\}^2 2gd = (m_1 + m_2)gh$$

$$\Rightarrow h = d\left\{\frac{m_1}{m_1 + m_2}\right\}^2$$

113 **(b)**

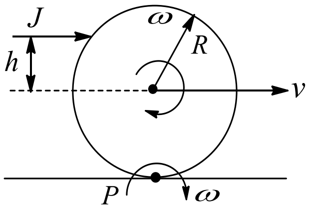
$F = Ma$
$FR - I\alpha$
For pure rolling, $a = R\alpha$



Solving the above equations, we get, $I = MR^2$
So the object may be a ring or a hollow cylinder

114 **(b)**

Rolling is rotation about point of contact.
Applying impulse momentum equation about P



$J(R+h)=I_P\omega$ ...(i)

and $J=mv$ ...(ii)

As sphere rolls $v=\omega R$, and $I=\frac{2}{5}mR^2+mR^2=\frac{7}{5}mR^2$

After solving, we get $\frac{h}{R}=\frac{2}{5}$

115 **(a)**

From conservation of energy, the kinetic energy of the ball at the lowest point is (v_c =speed of centre of ball)

$\frac{1}{2}mv_c^2+\frac{1}{2}\times\frac{2}{5}mv_c^2=mgR$

or $\frac{7}{10}mv_c^2=mgR$

Since the net tangential force on the sphere at the lowest point is zero, the net force on the sphere at the lowest position is

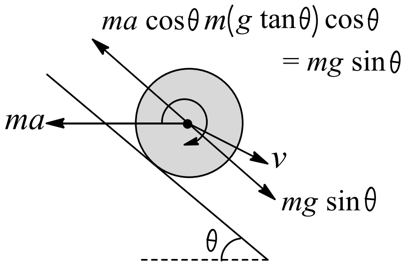
$=\frac{mv_c^2}{R}=\frac{10}{7}mg$ upwards

116 **(a)**

$\frac{2}{5}MR^2=\frac{3}{2}Mr^2\Rightarrow r=\frac{2R}{\sqrt{15}}$

118 **(a)**

The sphere will continue rolling because in the reference frame of incline (or car), the resultant force along the incline becomes zero



119 **(a)**

Mass of each of the four parts $=\frac{M}{3}$

Mass of the plate including the cut piece $=\frac{4M}{3}$

Moment of inertia of the whole plate (including the cut piece)

About the said axis $=\left(\frac{4M}{3}\right)\frac{l^2}{6}$

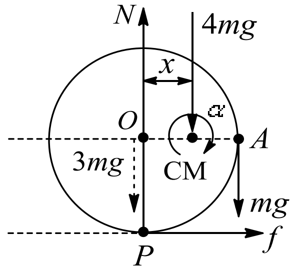
Now moment of inertia of the remaining portion should be 3/4 of the above $=Ml^2/6$

120 **(b)**

The distance of CM from the ring centre O

$$x=\frac{3m(0)+m(r)}{3m+m}=\frac{r}{4}$$

We can apply torque equation about point of contact as the ring is rolling



$\tau_P=I_P\alpha$

$4mg\left(\frac{r}{4}\right)=[(3mr^2+mr^2)+m(AP)^2]\alpha$

$\Rightarrow mgr=\left[4mr^2+m(\sqrt{2}r)^2\right]\alpha$

$\Rightarrow mgr=6mr^2\alpha\Rightarrow\alpha=\frac{g}{6r}$

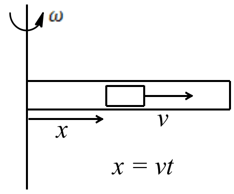
121 **(b)**

Angular momentum about rotational axis

$L_t=[I+m(vt)^2]\omega$

$\frac{dL_t}{dt}=2mv^2t\omega;$

Torque $\tau=(2mv^2\omega)t$



122 **(c)**

Neglecting gravity

$v=u\ln\left(\frac{m_0}{m_1}\right)$

$u=$ ejection velocity w.r.t. balloon

$m_0=$ initial mass

$m_t=$ mass at any time t

$v=2\ln\left(\frac{m_0}{m_0/2}\right)=2\ln 2$ m/s

123 **(b)**

Since the disc comes to rest, it stops rotating and translating simultaneously $v=0$ and $\omega=0$. That means, the angular momentum about the instantaneous point of contact just after the time of stopping is zero. We know that the angular momentum of the disc about P remains contant because frictional force f, N and mg pass through point P and thus produce no torque about this point

$\Rightarrow L_{\text{initial}}=L_{\text{final}}\Rightarrow mvr-l_0\omega_0=0$

$\Rightarrow mvr=\frac{1}{2}mr^2\omega_0\Rightarrow 2v_0=\omega_0 r$

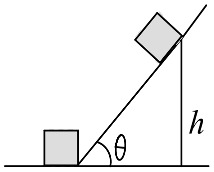
124 **(d)**

As long as no external force acts on the system of 'man + boat', its centre of mass will remain stationary

125 **(b)**

Velocity of shell = 180 km/h = 50 m/s

Let V be the velocity of the cannot after firing, then from the conservation of linear momentum,



$0 = 50 \times 50 - 1000\,V \Rightarrow V = 2.5$ m/s

Let the cannot go up by height h

Net work done by external forces = ΔKE

$$\Rightarrow -Mgh - \mu\, Mg\,\cos\theta \times \frac{h}{\sin\theta} = 0 - \frac{1}{2}MV$$

Where M is the mass of cannon,

Solving, we get $h = 5/24$ m

126 **(b)**

There can be a total of eight impulses given to the cylinder in 30 s. Using $\vec{J} = \vec{L}_f - \vec{L}_i$ for every impulse, we get

$$(8.J) = I \cdot \omega - 0 \Rightarrow \omega = \frac{8J}{I}$$

127 **(b)**

Suppose the velocity of the bullet of mass m is v and it strikes the block of mass M. After collision, the linear velocity of the block is V and that of the bullet is v'

Applying law of conservation of linear momentum, we get

$mv = MV + mv'$

Or $500 \times 0.01 = 2V + 0.01v'$

Or $5 = 2V + 0.01v'$ (i)

Now, the kinetic energy gained by the block $\frac{1}{2}MV^2$ raises it to a height h where it gains gravitational potential energy Mgh. By conservation of energy, we get

$$\frac{1}{2}MV^2 = Mgh$$

Or $V = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.1} = 1.4$ m/s

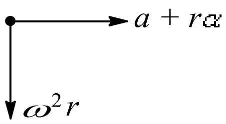
Putting the value of V in Eq. (i), we get

$5 = 2 \times 1.4 + 0.01v'$ or $v' = 220$ m/s

128 **(a)**

FBD of point P

In the earth frame, we have



So, resultant $= \sqrt{(a + r\alpha)^2 + (\omega^2 r)^2}$

129 **(d)**

$$\frac{mv^2}{2} + \frac{I\omega^2}{2} = mg \times \frac{3v^2}{4g} \Rightarrow I = \frac{mR^2}{2}$$

For pure rolling condition, $v = R\omega$

130 **(b)**

According to the theorem of parallel axis,

$I = I_{CG} + M(2R)^2$

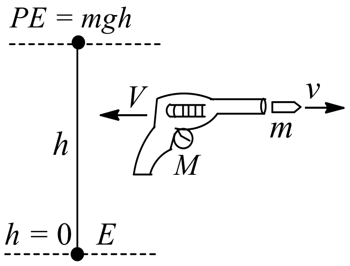
Where $I_{CG} = M.I.$ about an axis through the centre of gravity

$$I = \frac{2}{5}MR^2 + 4MR^2 = \frac{22}{5}MR^2$$

Or $MK^2 = \frac{22}{5}MR^2 \Rightarrow K = \sqrt{\frac{22}{5}}R$

131 **(a)**

L E is the energy of explosion, then since it is just sufficient to carry the bullet to a height h, so



We have $E = mgh$. Now, if v and V are the respective velocities of the bullet and the gun, respectively, then, from the law of conservation of linear momentum,

$mv + M(-V) = 0 \Rightarrow v = \frac{MV}{m}$ (i)

Also, $E = \frac{1}{2}mv^2 + \frac{1}{2}MV^2$

$\Rightarrow mgh = \frac{1}{2}m\left(\frac{MV}{m}\right)^2 + \frac{1}{2}MV^2$ [from Eq. (i)]

$$\Rightarrow 2mgh = \frac{M^2V^2}{m} + MV^2$$

$$\therefore \Rightarrow V = \left[\frac{2m^2gh}{M(M+m)}\right]^{1/2}$$

132 **(b)**

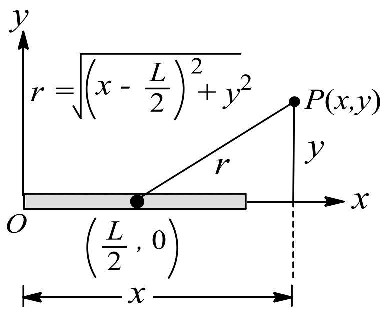
Moment of inertia of ABC about $AC = \frac{1}{2} \times$moment of inertia of square sheet $ABCD$ about

$AC = \frac{1}{2} \times [2M] \times \frac{l^2}{12} = \frac{Ml^2}{12}$

133 **(b)**

Let us take any point P on $x - y$ plane. The MI of the rod about O is

$I_P = I_{CM} + Mr^2$



Hence , $I_P = \frac{ML^2}{12} + M\left[\left(x - \frac{L}{2}\right)^2 + y^2\right]$

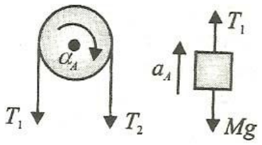
MI of the rod about $O, I_0 = \frac{ML^2}{3}$

Applying $I_P = I_0$, we get an equation of a circle

134 **(b)**

In Fig, $(T_2 - T_1)R = \frac{MR^2}{2}\alpha_A$

$T_1 - Mg = Ma_A$



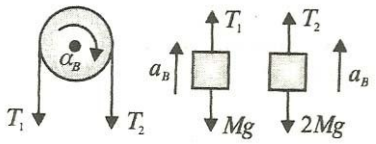
$T_2 = 2Mg$

$a_A = R\alpha_A$

$\alpha_A = \frac{2g}{3R}$

From Figure,

$(T_2 - T_1) \times R = \frac{MR^2}{2}\alpha_B$



$T_1 - \mathrm{Mg} = Ma_B$

$2\mathrm{Mg} - T_2 = 2Ma_B$

$a_B = R\alpha_B$

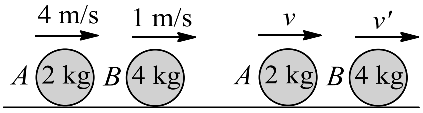
$\alpha_B = \frac{2\mathrm{g}}{7R}$

So, $\alpha_A > \alpha_B$

135 **(d)**

First consider the collision of balls A and B. Let the velocities of these two balls after their collision be v and v'

Momentum after impact = Momentum before impact



$\therefore 2v + 4v' = 2 \times 4 + 4 \times 1$

$\therefore\ 2v + 4v' = 12$

$\Rightarrow\ v + 2v' = 6$ (i)

Relative velocity after impact = $-e\ \times$ relative velocity before impact

$v - v' = -1(4 - 1)$

$v - v' = (-3)$ (ii)

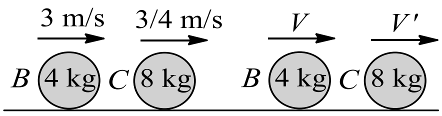
Subtracting Eq. (ii) from Eq. (i). we get

$3v' = 9$

$v' = 3$ m/s

Substituting in Eq. (ii), we get

$v - 3 = -3\ \ \Rightarrow v = 0$



Hence, after the collision ball A is brought to rest, while ball B will move with a velocity of 3 m/s.

Now consider the collision of balls B and C. Let the velocities of these balls after collision be V and V', respectively

Total momentum after impact = Total momentum before impact

$4V + 8V' = 4 \times 3 + 8 \times \frac{3}{4} = 18$

$V + 2V' = \frac{9}{2}$ (iii)

Relative velocity after impact =$-e\ \times$ relative velocity before impact

$V - V' = (-1)(3 - 3/4)$

$V - V' = -9/4$ (iv)

Subtracting Eq.(iv) from Eq.(iii), we get

$3V' = 27/4 \Rightarrow V' = 9/4$ m/s

$V = 0$

$V_A = 0, V_B = 0$

136 **(c)**

Initial acceleration of the system before the collar is removed:

$a_1 = \frac{2mg}{3m} = \frac{2\mathrm{g}}{3}$

Velocity at the time when the collar is removed:

$v_1 = \sqrt{2a_1\frac{H}{3}}$

Acceleration after the collar is removed

$a_2 = \frac{mg}{2m} = \frac{g}{2}$

Final velocity: $v_2^2 = v_1^2 + 2a_2H$

$= \frac{2a_1H}{3} + \frac{2g}{2}H = \frac{2}{3}\frac{2g}{3}H + gH$

$\Rightarrow v_2 = \frac{\sqrt{13gH}}{3}$

137 **(b)**

Friction force will act towards right

138 **(d)**

Initial momentum of the system is zero. So, final momentum should also be zero. Finally, A comes to rest after collision so to have final momentum zero, B and C should move in opposite directions

139 **(b)**

$E_1 = \frac{1}{2}I_1\omega_1^2 = \frac{1}{2}(I_1\omega_1)\omega_1 = \frac{1}{2}k\omega_1$

Now $I_1\omega_1 = I_2\omega_2 = k$(say)

$E_2 = \frac{1}{2}I_2\omega_2^2 = \frac{1}{2}(I_2\omega_2)\omega_2 = \frac{1}{2}k\omega_2$

$I_1 > I_2$ and $\omega_2 > \omega_1$

So, $E_2 > E_1$

140 **(d)**

By applying conservation of momentum, first find velocity of the second particle and then find its KE

141 **(c)**

Because here momentum changes abruptly in vertical direction

142 **(c)**

When the cycle is not pedaled but it is motion (due to previous effort) the wheels move in the direction such that the centre of mass of the wheel moves forward. Rolling friction will act in the opposite direction to the relative motion of the centre of mass of the body with respect to the ground. Therefore the rolling friction will act in the backward direction in both the wheels. The sliding friction will act in the forward direction of the rear wheel during pedaling

143 **(b)**

Applying the law of conservation of momentum,

$m_1v_1 = m_1\frac{v_1}{3} + mv$ or $v = \frac{2m_1v_1}{3m}$

To describe a vertical circle v should be $\sqrt{5gl}$. So,

$\frac{2m_1v_1}{3m} = \sqrt{5gl}$ or $v_1 = \left(\frac{m}{m_1}\right)\frac{3}{2}\sqrt{5gl}$

144 **(d)**

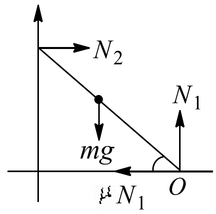
$mg = N_1$

$\mu N_1 = N_2$ or $N_2 = \mu mg$

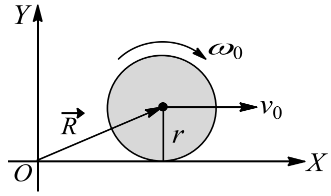
Taking moment about O, we get

$\mu mgl \sin\theta = mg\frac{1}{2}\cos\theta$

$\tan\theta = \frac{1}{2\mu}$ or $\theta = \tan^{-1}\left(\frac{1}{2\mu}\right)$



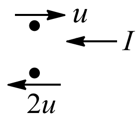
145 **(d)**



$\vec{L} = \vec{R} \times m\vec{v}_0 + I\vec{\omega}_0$

$= mv_0 + I\omega_0$(which is constant)

146 **(b)**



$I = m[2u - (-u)] = 3mu$

$W = \frac{1}{2}m[(2u)^2 - u^2] = \frac{3mu^2}{2} = \frac{Iu}{2}$

147 **(c)**

Initial KE $= \frac{1}{2}mu^2$

At the time of maximum compression,

$\text{KE} = \frac{1}{2}(2m)\left(\frac{u\cos\theta}{2}\right)^2 + \frac{1}{2}mu^2\sin^2\theta$

Change in KE $= \frac{mu^2}{4}\cos^2\theta$

Change in KE = PE

$\frac{\text{PE}}{\text{KE}} = \frac{1}{2}\cos^2\theta$

At the time of max. Compression, impulse on B is along direction a and that on A is in opposite direction. But the component of velocity of A in direction perpendicular to A is unchanged

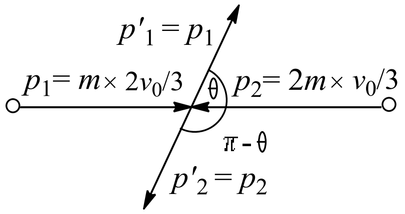
148 **(d)**

Let us solve this question in C frame. As the collision is elastic, the magnitude of momenta of all balls remains same after collision in this frame

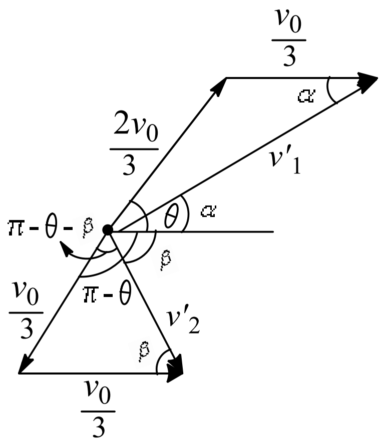
Velocity of C frame w.r.t. ground frame is

$v_C = \frac{mv_0}{3m} = \frac{v_0}{3}$

The momentum diagram in C frame is drawn as shown in fig.



Now, velocity of m after colision in C frame is $2v_0/3$ while that of $2m$ is $v_0/3$ along $\vec{p}_1{}'$ and $\vec{p}_2{}'$, respectively. Let $v_1{}'$ and $v_2{}'$ be the velocities of m and $2m$, respectively after collision in ground frame, then velocity vector diagrams can be drawn as shown



Using trigonometry, from upper triangle

$\sin\alpha = 2\sin(\theta - \alpha) \Rightarrow \alpha = \tan^{-1}\left[\frac{1}{1+\sqrt{3}}\right]$

From lower triangle:

$\pi - \theta - \beta = \beta \Rightarrow \beta = \frac{\pi - \theta}{2} = 75° \; [\because \theta = 30°]$

So, angle of divergence is $\alpha + \beta = 75° + \tan^{-1}\left(\frac{1}{1+\sqrt{3}}\right)$

Alternative method Write down conservation of momentum equations, coefficient of restitution equation, energy conservation and use the given conditions

149 **(b)**

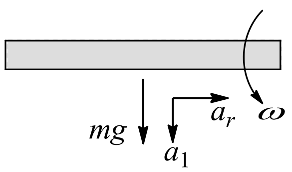
From conservation of angular momentum ($I\omega$= constant), angular velocity will remain half. As,

$K = \frac{1}{2}I\omega^2$

The rotational kinetic energy will become half.

150 **(c)**

The angular velocity of the rod about the pivot when it passes through the horizontal position is given by $mg \times \frac{L}{2}\sin 30° = \frac{mL^2}{3} \times \frac{\omega^2}{2}$



$\omega = \sqrt{\frac{3g}{2L}}$

Radial acceleration of the centre of mass (as centre of mass is moving in a circle of radius $L/2$) is given by $a_r = \omega^2\frac{L}{2} = \frac{3g}{4}$

Torque about pivot, in the horizontal position, is

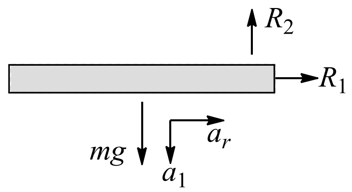
$\tau = mg\frac{L}{2} = I\alpha$

$\alpha = \frac{mgL/2}{mL^2/3} = \frac{3g}{2L}$

Tangential acceleration of the centre of mass,

$a_t = \frac{L}{2}\alpha = \frac{3g}{4}$

Draw the FBD of the rod at an instant when it passes through the horizontal position. Use Newton's second law of equation



$R_1 = ma_r = \frac{3mg}{4}$

$mg - R_2 = m \times a_t = \frac{3mg}{4}$

$R_2 = \frac{mg}{4}$

So, reaction force by the pivot on the rod,

$R = R_1^2 + R_2^2 = \sqrt{10}$

$mg/4$ at an angle of $\tan^{-1}(R_2/R_1)$ $[= \tan^{-1}(1/3)]$ with the horizontal

151 **(b)**

$K = \frac{P^2}{2m}$

From the graph, $4 = \frac{4^2}{2m} \Rightarrow m = 2$ kg

152 **(c)**

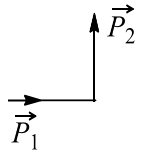
$$X_{CM} = \frac{3M\left(\frac{-x}{2\sqrt{2}}\right) + M \times \frac{L}{2} + M \times \frac{L}{2\sqrt{2}} + M \times 0}{6M} = 0$$

$$\Rightarrow x = \left(\frac{\sqrt{2}+1}{3}\right)L$$

153 **(d)**

$\vec{P}_1 = 2 \times 3\hat{\imath} = 6\hat{\imath}, \vec{P}_2 = 6\hat{\jmath}$

$\vec{I} = \vec{P}_2 - \vec{P}_1 = 6\hat{\jmath} - 6\hat{\imath}$



or $I = \sqrt{6^2 + 6^2} = 6\sqrt{2}$ N s

154 **(c)**

$$\frac{KE_{rot}}{KE_{tot}} = \frac{\frac{1}{2}I\omega^2}{\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2} = \frac{\frac{2}{5}mv^2}{\frac{7}{5}mv^2} = \frac{2}{7}$$

155 **(d)**

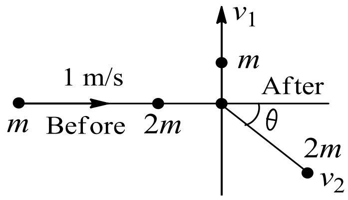
From conservation of momentum along incident direction

$m \times 1 = 2\,mv_2 \cos\theta$ (i)

From conservation of momentum along perpendicular direction,

$m \times 0 + 2m \times 0 = mv_1 - 2mv_2 \sin\theta$

$\Rightarrow v_1 = 2v_2 \sin\theta$ (ii)



From energy conservation,

$\frac{1}{2}m \times (1)^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}2\,mv_2^2$ (iii)

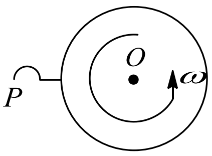
From Eqs. (i), (ii) and (iii), we get $\theta = 30°$

156 **(c)**

The distribution of mass is nearest to axis xx, hence moment of inertia is least about the xx-axis

157 **(b)**

During the impact, the forces pass through point P. Therefore, the torque produced by it about P is equal to zero



Consequently, the angular momentum of the disc about P, just before and after the impact, remains the same

$\Rightarrow L_2 = L_1$ ...(i)

Where L_1 = angular momentum of the disc about P just before the impact

$$I_0\omega = \frac{1}{2}mr^2\omega$$

L_2 = angular momentum of the disc about P just after the impact

$$I_0\omega = \left(\frac{1}{2}mr^2 + mr^2\right)\omega' = \frac{3}{2}mr^2\omega'$$

Just before the impact, the disc rotates about O. But just after the impact, the disc rotates about P

$$\Rightarrow \frac{1}{2}mr^2\omega = \frac{3}{2}mr^2\omega' \Rightarrow \omega' = \frac{1}{3}\omega$$

158 **(b)**

Since the body explodes into three equal parts, therefore

$$m_1 = m_2 = m_3 = \frac{m}{3} = 1\text{ kg}$$

Let the velocity of the third part be $\vec{v}$. According to the principle of conservation of linear momentum,

Momentum of system before explosion = Momentum of system after explosion

Or $mv = m_1v_1 + m_2v_2 + m_3v_3$

Or $3 \times 0 = 1 \times 2\hat{i} + 3\hat{j} + 1 \times \vec{v}$

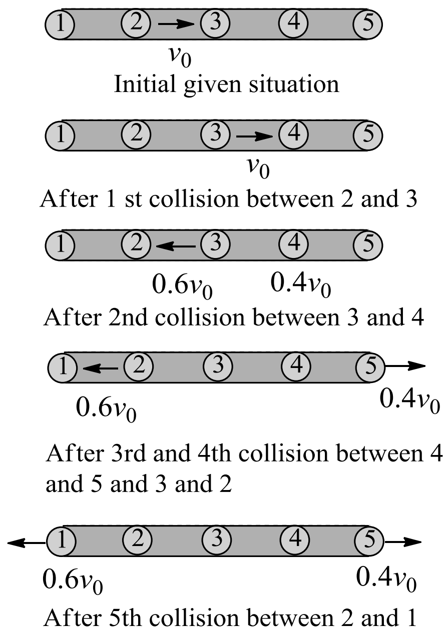
or $v = -(2\hat{i} + 3\hat{j})$ m/s

Average force acting on the third particle is

$$\vec{F} = \frac{m\vec{v}}{t} = \frac{-1 \times (2\hat{i} + 3\hat{j})}{10^{-5}} = -(2\hat{i} + 3\hat{j}) \times 10^5\text{ N}$$

159 **(d)**

The situation after various collisions is as shown in fig.



After first collision, the momentum of 1 and 2 will be exchanged (property of elastic collision) and hence second ball starts to move towards 3 with velocity v_0

160 **(a)**

The force has to be applied at the centre of mass of the system for pure translation motion

161 **(a)**

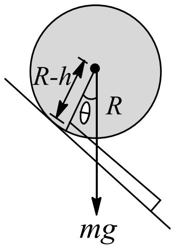
Conserving angular momentum about O (just before and just after) is

$$mv\frac{a}{2} = \left[\frac{ma^2}{6}\frac{ma^2}{2}\right]\omega \Rightarrow \omega = \frac{3v}{4a}$$

162 **(d)**

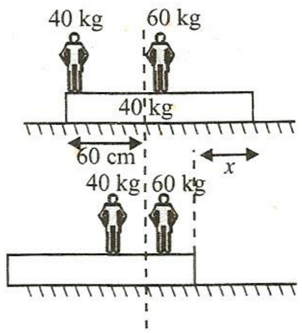
The sphere in on the verge of toppling when a line of action of weight passes through the edge

$$\cos\theta\frac{(R-h)}{R} \Rightarrow h = R - R\cos\theta$$



163 **(d)**
As torque =change in angular momentum
$F\Delta t = mv$(linear momentum) ...(i)
and $\left(F\frac{l}{2}\right)\Delta t = \frac{ml^2}{12}\omega$(angular momentum) ...(ii)
Dividing Eqs. (i) and (ii), we get
$2 = \frac{12v}{\omega l} \Rightarrow \omega = \frac{6v}{l}$
Using $S = ut$,
Displacement of CM is $\frac{\pi}{2} = \omega t = \left(\frac{6v}{l}\right)t$
and $x = vt$
Dividing, we get $\frac{2x}{\pi} = \frac{l}{6} \Rightarrow x = \frac{\pi l}{12}$
Coordination of A will be $\left[\frac{\pi l}{12} + \frac{l}{2}, 0\right]$

164 **(c)**
Taking the origin at the center of the plank,



$m_1\Delta x_1 + m_2\Delta x_2 + m_3\Delta x_3 = 0$ ($\because \Delta x_{CM} = 0$)
(Assuming the centres of the two men are exactly at the axis as shown in fig.)
$60 \times 0 + 40 \times 60 + 40(-x) = 0 \Rightarrow x = 60$ cm
Hence, A and B meet at the right end of the plank

165 **(b)**
v_{CM} and a_{CM} will not be in the same direction and acceleration is constant, hence path will be parabolic

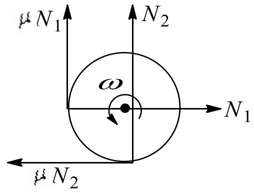
166 **(a)**
Let the three mutually perpendicular directions be along xy and z-axis, respectively.
$\vec{p}_1 = mv_0\hat{\imath}, \vec{p}_2 = mv_0\hat{\jmath}$
Where
$\frac{1}{2}mv_0^2 = E_0$
$\vec{p}_3 = mv_0\hat{k}$ and $\vec{p}_4 = m\vec{v}$
By linear momentum conservation,
$0 = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \vec{p}_4$
or $\vec{v} = -v_0(\hat{\imath} + \hat{\jmath} + \hat{k})$
or $v = v_0\sqrt{1^2 + 1^2 + 1^2} = v_0\sqrt{3}$
Total energy $= 3\left(\frac{1}{2}mv_0^2\right) + \frac{1}{2}mv^2 = 3E_0 + 3E_0 = 6E_0$

167 **(b)**
TE at initial point $= \frac{1}{2}mv_0^2 + mgh$
After collision, remaining energy
$= \frac{\frac{1}{2}mv_0^2 + mgh}{2}$
Hence, $\frac{\frac{1}{2}mv_0^2 + mgh}{2} = mgh$
(since after collision, it rebounds to same height h)
$\frac{1}{2}mv_0^2 + mgh = 2mgh$
$v_0 = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 10} = 14$ m/s
The ball would rise to the same height after collision if the initial velocity was directed upwards instead of downwards. Since while returning to the same point, the body would possess the same velocity in the downward direction, hence h =10 m

168 **(b)**
In the absence of external force, v_{CM} = constant
Here initially $v_{CM} = 0$; so $v_{CM} = 0$ throughout, i.e., position of centre of mass, remains unshifted

169 **(c)**
Let v be the velocity of the centre of mass of the sphere and ω be the angular velocity of the body about an axis passing through the centre of mass
$J = Mv$
$J(h - R) = \frac{2}{5}MR^2 \times \omega$
From the above two equations, $v(h - R) = \frac{2}{5}r^2\omega$
From the condition of pure rolling, $v = R\omega$
$h - R = \frac{2R}{5} \Rightarrow h = \frac{7R}{5}$

170 **(b)**
In figure, for translational equilibrium in vertical direction



In horizontal direction
$N_1 = \mu N_2$ ...(ii)
Solving. Eqs. (i) and (ii), $N_2 = \frac{mg}{1+\mu^2}$
The required friction is
$\mu N_2 = f_a = \frac{3}{10}mg$

In figure, the sphere has the tendency to move toward the right;

$N_1 = 0; N_2 = mg$

$f_b = \mu N_2 = \dfrac{mg}{3}$

Which gives $\frac{f_a}{f_b} = \frac{9}{10}$

171 **(c)**

$mv = mv_1 + nmv_2$

$v = v_1 + nv_2$

$= v_2\ v_1$

$$\Rightarrow v_2 = \frac{2v}{(n+1)}, v_1 = \left(\frac{1-n}{1+n}\right)v$$

$$\frac{\text{KE}_1}{\text{KE}_2} = \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv^2} = \left(\frac{n-1}{n+1}\right)^2$$

172 **(c)**

When the two balls collide with each other, as the mass of the two balls is equal, they exchange their velocities on colliding elastically. Let the speed of the ball B when it reaches back to the initial position be v. Then

$4mgh = \dfrac{1}{2}mv^2 + mgh \ \Rightarrow v = \sqrt{6gh}$

Height reaches by particle B (from highest point on the incline) is

$H_B = \frac{v^2 \sin^2 60°}{2g} = \frac{9h}{4}$; total height $= h + \frac{9h}{4} = \frac{13h}{4}$

After collision the particle A reaches the maximum height $= h$

Ratio $= \frac{H_A}{H_B} = \frac{4}{13}$

173 **(c)**

$$F_x = \frac{\Delta P_x}{\Delta t} = \frac{mv_{2x} - mv_{1x}}{\Delta t} = \frac{m(v_{2x} - v_{1x})}{\Delta t}$$

$$= \frac{(150 \times 10^{-3})[30 - (-15 \sin 30°)]}{0.01}$$

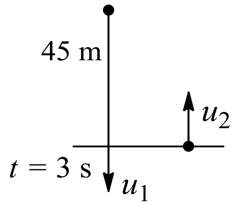
$$= \frac{(150 \times 10^{-3})(30 + 7.5)}{0.01} = 562.5 \text{ N}$$

174 **(b)**

If the velocities acquired due to explosions are in vertical direction, then options (c) and (d) are possible. If one of them follows parabolic path (or acquires velocity in horizontal direction), then other also has to follow parabolic path (or acquire velocity in horizontal direction to keep the momentum zero in horizontal direction). Hence, option (b) can never be possible

175 **(c)**

Time taken to fall through 45 m $= \sqrt{\frac{2 \times 45}{10}} = 3$ s



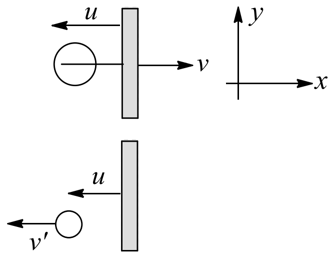
$u_1 = \sqrt{2gh} = \sqrt{2 \times 10 \times 45} = 30$ m/s

$u_2 = eu_1 = \dfrac{2}{3} \times 30 = 20$ m/s

Distance travelled in the fourth second = distance travelled in 1 s after rebounding $= 20 \times 1 - \frac{1}{2} \times 10(1)^2 = 15$ m

176 **(d)**

$$e = \frac{v_2 - v_1}{u_1 - u_2} \Rightarrow 1 = \frac{-u - (-v')}{v - (-u)}$$



$\Rightarrow\ v' = 2u + v$

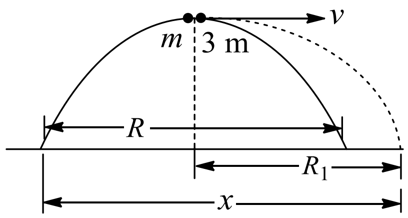
$\therefore W = \Delta\text{KE} = \dfrac{1}{2}mv'^2\ \dfrac{1}{2}mv^2$

$= \dfrac{1}{2}m[(2u+v)^2 v^2]\ 2 = mu(u+v)$

177 **(b)**

Apply conservation of momentum at highest point:

$4\ mu \cos\theta = 3\ mv \Rightarrow v = \frac{4}{3}\ u\ \cos\theta$ (i)



$R = (u\ \cos\theta)\ T$

$R_1 = v\dfrac{T}{2} = \dfrac{4}{3}\dfrac{u\cos\theta\ T}{2}$

$= \dfrac{2R}{3} \Rightarrow x = \dfrac{R}{2} + R_1 = \dfrac{R}{2} + \dfrac{2R}{3} = \dfrac{7R}{6}$

178 **(a)**

$u_1 = \dfrac{P}{m}, u_2 = 0, v_1 = \dfrac{(p - J)}{m}, v_2 = \dfrac{J}{m}$

Now apply $e = \frac{v_2 - v_1}{u_1 - u_2}$

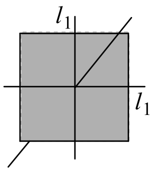
179 **(a)**

In case of projectile motion as at the highest point $(v)_{\text{vertical}} = 0$ and $(v)_{\text{horizontal}} = v\cos\theta$

The initial linear momentum of the system will be $mv\cos\theta$

Now as force of blasting is internal and force of gravity is vertical, so linear momentum of the system along horizontal is conserved, i.e.,
$P_1 + P_2 = mv\cos\theta$ or $m_1v_1 + m_2v_2 = mv\cos\theta$
But it is given that $m_1 = m_2 = m/2$ and as one part retraces its path,
$v_1 = -v\cos\theta$
$\frac{1}{2}m(-v\cos\theta) + \frac{1}{2}mv_2 = mv\cos\theta$
Solving, we get $v_2 = 3v\cos\theta$

180 **(a)**

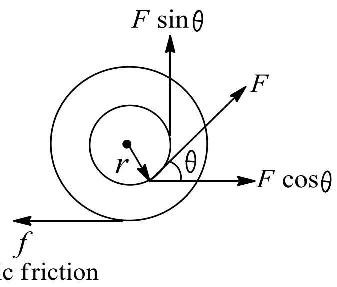


$I = I_1 + I_1 = 2\times\frac{2}{3}MI^2 = \frac{4}{3}MI^2$

181 **(c)**
The moment of inertia of the uniform rod about an axis through one end and perpendicular to length is
$I = \frac{ML^2}{3}$
Torque $(t = la)$ acting on the centre of gravity of the rod is given by
$\tau = Mg\left[\frac{L}{2}\sin\theta\right]$
or $\frac{ML^2}{3}\alpha = Mg\frac{L}{2}\sin\theta$
$\alpha = \frac{3g}{2L}\sin\theta$

182 **(a)**
$y_{CM} = \frac{m_1y_1+m_2y_2+m_3y_3+m_4y_4+m_5y_5}{m_1+m_2+m_3+m_4+m_5}$
$= \frac{(6m)(0)+m(a)+m(a)+m(0)+m(-a)}{6m+m+m+m+m} = \frac{a}{10}$

183 **(a)**
If the spool is not to translate,
$F\cos\theta = f$ ...(i)
If the spool is not to rotate,
$Fr = Ffr$ ...(ii)



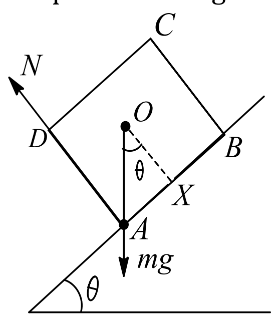
or $\frac{fR}{r}\cos\theta = f$
or $\cos\theta = \frac{r}{R} \Rightarrow \theta = \cos^{-1}\left(\frac{r}{R}\right)$
Also the line of action of F should pass through the bottom most point

184 **(a)**
$\vec{b} = \vec{a} + \vec{b}\,t^2$
$\frac{dL}{dt} = \vec{\tau} + 2\vec{b}t$
Let the angle between $\vec{L}$ and $\vec{\tau}$ be 45° at $t = t_0$, then
$\tan 45° = \frac{|\vec{b}|t_0^2}{|\vec{a}|}$
$t_0 = \sqrt{\frac{|\vec{a}|}{|\vec{b}|}}$, so $\vec{\tau}$ (at $t = t_0$) $= \sqrt{\frac{a}{b}}\times\vec{b}$

185 **(b)**
Because during explosion of a shell, $F_{ext} = 0$; hence according to law of conservation of momentum $\vec{P}_{system} =$ constant

186 **(c)**
From the figure in question, position vector of mass
$\vec{r} = R\hat{\imath} - \sqrt{l^2 - R^2\hat{k}}$
Linear moment $\hat{p} = Mv\hat{\jmath}$
$\vec{L} = \vec{r}\times\vec{p}$
Substituting the values, we get result (c)

187 **(c)**
The cube will not topple until the line of action of CM passes through the cube



That is, $\tan\theta = \frac{AX}{OX} = \frac{a/2}{a/2}$ or $\theta = 45°$

188 **(a)**
$I_{remaining} = I_{whole} - I_{removed}$
or $I = \frac{1}{2}(9M)(R^2) - \left[\frac{1}{2}m\left(\frac{R}{3}\right)^2 + \frac{1}{2}m\left(\frac{2R}{3}\right)^2\right]$ ...(i)
Here, $m = \frac{9M}{\pi R^2}\times\pi\left(\frac{R}{3}\right)^2 = M$
Substituting in Eq. (i), we have
$I = 4MR^2$

189 **(c)**
When two identical balls undergo elastic oblique collisions with one of them stationary, then after collision they will move at right angles to each other
Alternative method I: Just like in previous

question, you can proceed using centre of mass frame of reference

Alternative method II: Using basic equations of conservation of momentum, conservation of energy and coefficient of restitution, you can have the desired result

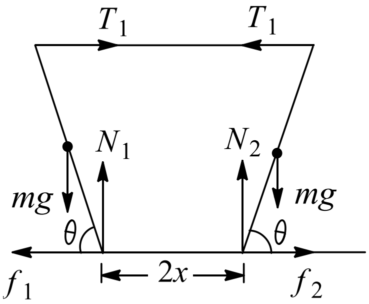
190 **(b)**

As there is no friction, net force is F which is towards right. Torque due to this force will be in anticlockwise direction

191 **(b)**

For the equilibrium of the entire structure,

$N_1 + N_2 = 2Mg$



$$Mg\left(\frac{l}{2}\cos\theta\right) + N_2 \times 2x - Mg\left(\frac{l}{2}\cos\theta + 2x\right) = 0$$

Given $N_2 = Mg, N_1 = Mg$

For individual boards, $T_1 = f_1, N_1 = Mg$

and $T_1 \times l\sin\theta = Mg\frac{l}{2}\cos\theta$

$$f_1 = T_1 = \frac{Mg}{2\tan\theta}$$

For safe equilibrium, $f_1 < f_L = \mu_s Mg$

$$\frac{Mg}{2\tan\theta} = \mu_s\, Mg \Rightarrow \tan\theta > \frac{1}{2\mu_s} \Rightarrow \theta = 45°$$

So the minimum value of θ for this type of arrangement is 45°

192 **(b)**

According to problems 30 and 31,

$$T = \frac{Ma}{2} = \frac{Mmg}{M + 2m}$$

193 **(d)**

We know that $F_{\text{ext}} = Ma_{\text{CM}}$ (i)

$F_{ext} = Ma_{CM}$

We consider the two particles in a system. Mutual force of attraction is an internal force. There are no external forces acting on the system. From Eq.(i), we get

$a_{\text{CM}} = 0$

Since initial $v_{\text{CM}} = 0$, therefore, final $v_{\text{CM}} = 0$

194 **(a)**

The bullet and block will meet after time

$$t = \frac{h}{u_{\text{rel}}} = \frac{100}{100} = 1$$

During this time, distance travelled by the block,

$$s_1 = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times 1^2 = 5 \text{ m}$$

Distance travelled by the bullet,

$s_2 = 100 - s_1 = 95$ m

Velocity of the bullet before collision,

$u_2 = u - gt = 100 - 10 \times 1 = 90$ m/s

Velocity of the block before collision,

$u_1 = gt = 10$ m/s

Let V be the combined velocity after collision

According to the law of conservation of momentum,

$m_1u_1 + m_2u_2 = (m_1 + m_2)V$

or $0.01 \times (-10) + 0.01 \times 90 = 0.02\,V$

(Velocity in upward direction is considered positive)

Solving, we get $V = 40$ m/s

Maximum height risen by the block $= \frac{V^2}{2g} = 80$ m

Height reached above the top of the tower is

$80 - s_1 = 80 - 5 = 75$ m

195 **(a)**

As coefficient of restitution equation is valid in all frames of reference, so in the frame of lift

$$e = \frac{\text{Velocity of separation}}{\text{Velocity of approach}} = \frac{v_f}{v_i} = \frac{\sqrt{2gh_2}}{\sqrt{2gh_1}} \quad \text{(i)}$$

$h_2 = e^2h_1$

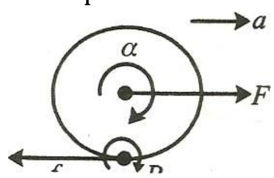
Impulse delivered by the elevator to ball is

$J = m\vec{v}_f - m\vec{v}_i = (m\sqrt{2gh_2} + \sqrt{2gh_1})$

If the elevator is accelerating, then replacing g with g +g/4 we get $h_2 = e^2h_1$

196 **(d)**

As sphere is rolling we can apply torque equation about point of contact (about P)



$$FR = I_P\alpha \Rightarrow FR = \left(\frac{7}{5}MR^2\right)\alpha$$

$\Rightarrow R\alpha = \frac{5F}{7M} = a$ (acceleration of cm)

Equation of translatory motion

$F - f = Ma \Rightarrow f = \frac{2}{7}F$ ...(i)

For no sliding, $f \leq \mu\, mg \Rightarrow F = \frac{7}{2}\mu mg$

197 **(c)**

As the collision is head-on,

$mu + 0 = mv_1 + mv_2$ or $u = v_1 + v_2$ (i)

Further, coefficient of restitution is

$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{v_2 - v_1}{u} \quad (\because\ u_2 = 0)$$

Or $eu = v_2 - v_1$ (ii)

Adding Eqs. (i) and (ii), we get

$v_1 = \frac{u(1-e)}{2}, v_2 = \frac{u(e+1)}{2}$ (iii)

Now $\frac{v_1}{v_2} = \frac{1-e}{1+e}$ (iv)

$\frac{v_1}{u} = \frac{1-e}{2}$ (v)

$\frac{v_2}{u} = \frac{1+e}{2}$ (vi)

198 **(d)**

By conservation of linear momentum along the string

$mu = (m + m + 3m)v$ or $v = \frac{u}{5}$

and impulse on block $A = 3\,m\,(v - 0)\frac{3\,mu}{5}$

199 **(b)**

$m_1u_1 + m_2u_2 = (m_1 + m_2)V$

$2 \times 6 + 2 \times 0 = (2+2)V$ or $V = 3$ m/s

Heat evolved = loss in KE $= \frac{1}{2} \times 2(6)^2 - \frac{1}{2}(2+2)(3)^2 = 18$ J

200 **(c)**

$$v_{CM} = \frac{10 \times 3 + 20 \times 2 - 30 \times 5}{10 + 20 + 30} = -\frac{4}{3} \text{ m/s}$$

$$x_{CM} = \frac{10 \times 0 + 20 \times 5 + 30 \times 20}{10 + 20 + 30} = \frac{35}{3} \text{ m/s}$$

$$x = x_{CM} + v_{CM}t$$

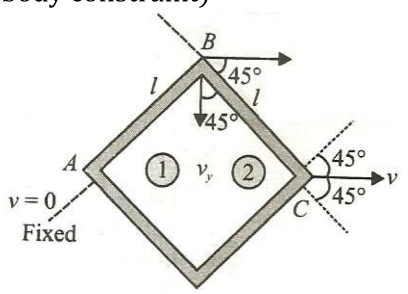
$$x = \frac{35}{3} + \left(-\frac{4}{3}\right) \times 1 = \frac{31}{3} = 10\frac{1}{3}\text{m}$$

201 **(a)**

F will provide anticlockwise torque about the centre due to which the bottommost point will tend to move towards right, so friction will act towards left. So it will move towards left

202 **(c)**

Let the velocity compounds of point B alongh x and y directions are v_x and v_y. As length of the rod is constant, along the length of the rod, velocity of each point must be the same (rigid body constraint)



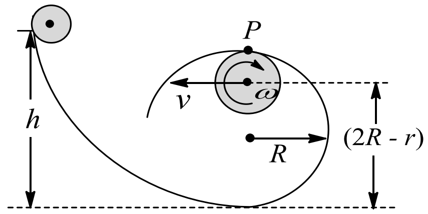
Along rod AC, $\frac{v_x}{\sqrt{2}} + \frac{v_y}{\sqrt{2}} = \frac{V}{\sqrt{2}}$

Along rod AB, $\frac{v_x}{\sqrt{2}} - \frac{v_y}{\sqrt{2}} = 0$

$$v_x = v_y = \frac{V}{2}$$

203 **(d)**

The minimum velocity at P, top of the loop, should be $v = \sqrt{g(R-r)}$, if the sphere keeps on rolling at top $v = \omega R$



$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mg(2R - r)$$

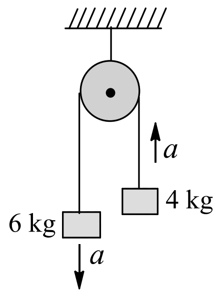
$$= \frac{1}{2}mg(R-r) + \frac{1}{2}\left(\frac{2}{5}\right)mR^2 2\omega^2 + mg(2R - r)$$

$$= \frac{7}{10}mg(R-r) + mg(2R - r)\left[\omega R = v = \sqrt{g(R-r)}\right]$$

$= \frac{mg}{10}(27R - 17r)$ or $h = \frac{1}{10}(27R - 17r)$

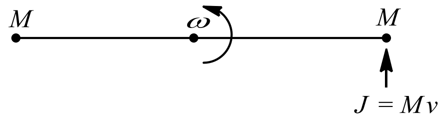
204 **(c)**

$$a = \frac{6-4}{6+4}g = \frac{g}{5}, a_{CM} = \frac{-6 \times a + 4a}{6+4} = -\frac{a}{5} = -\frac{g}{25}$$



205 **(a)**

Let ω be the angular velocity of the rod. Applying , Angular impulse = change in angular momentum about centre of mass of the system



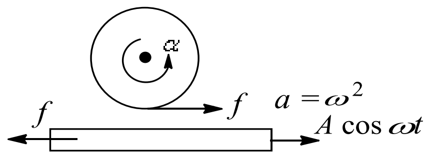
$J.\frac{L}{2} = I_c\omega$

$\therefore \quad (Mv)\left(\frac{L}{2}\right) = (2)\left(\frac{ML^2}{4}\right).\omega$

$\therefore \quad \omega = \frac{v}{L}$

206 **(b)**

The cylinder is having a fixed axis, so it can perform rotational motion only



$$fR = \frac{MR^2}{2}\alpha \Rightarrow f = \frac{MR}{2}\alpha$$

For no slipping,

$R\alpha =$ acceleration of the platform

$$\frac{2f}{M} = \omega^2 A \cos\omega t$$

For the maximum torque, f would be maximum and $f_{\max} = M\omega^2 A/2$

So the maximum torque,

$$\tau_{\max} = f_{\max} \times R = \frac{M^2\omega^2 AR}{2}$$

207 **(a)**

As the collision is head-on,

$mu + 0 = mv_1 + mv_2$ or $u = v_1 + v_2$ (i)

Further, coefficient of restitution is

$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{v_2 - v_1}{u} \quad (\because\ u_2 = 0)$$

Or $eu = v_2 - v_1$ (ii)

Adding Eqs. (i) and (ii), we get

$v_1 = \frac{u(1-e)}{2}, v_2 = \frac{u(e+1)}{2}$ (iii)

Now $\frac{v_1}{v_2} = \frac{1-e}{1+e}$ (iv)

$\frac{v_1}{u} = \frac{1-e}{2}$ (v)

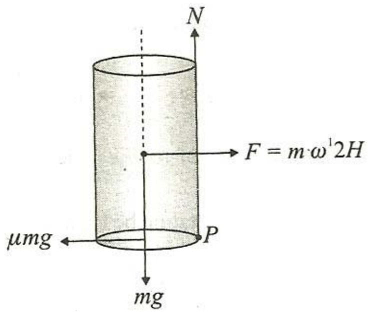
$\frac{v_2}{u} = \frac{1+e}{2}$ (vi)

208 **(d)**

$N = mg$ ...(i)

Net moment of all the forces about point P is zero

$$F\frac{H}{2} = mg\frac{H}{8}, \omega = \sqrt{\frac{g}{8H}}$$



209 **(b)**

$\vec{F} = \frac{d\vec{p}}{dt}$, find slope and then proceed

210 **(a)**

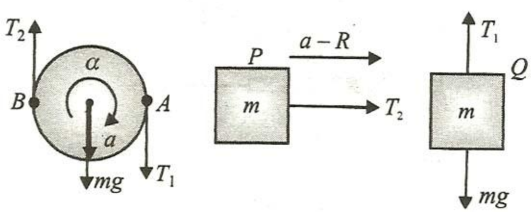
$$P\frac{l}{4} = \frac{ml^2}{12}\omega$$

211 **(b)**

Let a be the acceleration of the cylinder, then acceleration of point A on the cylinder

$\vec{a}_A = \vec{a}_{\text{trans}} + \vec{a}_{\text{rot}}$

$\vec{a}_A = \vec{a}_{\text{trans}} + \vec{a}_{\text{rot}}$



$|\vec{a}_A| = a + R\alpha = a_Q$

Similarly, the acceleration of point B on the cylinder is

$|\vec{a}_B| = a - R\alpha = a_P$

$mg - T_1 = m(a + R\alpha) = a_P$ ...(i)

$T_1 + mg - T_2 = ma$ ...(ii)

$T_2 = m(a - R\alpha)$ ...(iii)

$T_1R + T_2R = \frac{mR^2}{2}\alpha$ ...(iv)

On solving these equations, we get

$$a = \frac{2g}{3}, \alpha = \frac{2g}{5R}$$

212 **(a)**

$$\overrightarrow{L_0} = I_{\text{CM}}\vec{\omega} + m(\vec{r} \times \vec{v})$$

$$= \frac{1}{2}mR^2\omega\hat{k} + m(4R\hat{\imath} + 3R\hat{\jmath}) \times (\omega R\hat{\imath})$$

$$= \frac{1}{2}mR^2\omega\hat{k} - 3mR^2\omega\hat{k}$$

$$= -\frac{5}{2}mR^2\omega\hat{k}$$

213 **(d)**

As only the gravity force is acting on the system, the centre of mass of the system follows a parabolic path

At $t = 2$ s,

$x_{\text{CM}} = 30 \cos 37° \times 2 = 48$ m

$y_{\text{CM}} = 30 \sin 37° \times 2 - \frac{1}{2} \times 10 \times 2^2 = 16$ m

Let coordinates of the second piece, i.e., 6 kg piece be (x, y)

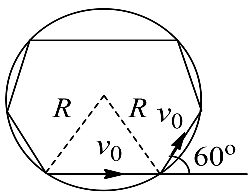
Then

$$x_{\text{CM}} = 48 = \frac{6x + 4 \times 105}{10} \Rightarrow x = 10 \text{ m}$$

$$y_{\text{CM}} = 16 = \frac{6y + 4 \times 43}{10} \Rightarrow y = -2 \text{ m}$$

Negative value of y shows that the second piece collides the ground before $t = 2$ s

214 **(a)**

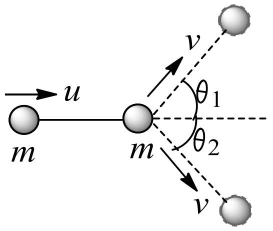


$I =$ change in momentum

$$= \sqrt{(mv_0)^2 + (mv_0)^2 - 2(mv_0)^2 \cos 60°}$$

$$= mv_0\sqrt{2 - 2\cos(\pi/3)} = 2mv_0 \sin\frac{\pi}{6}$$

215 **(d)**



Applying law of conservation of momentum, we get $mv\sin\theta_1 - mv\sin\theta_2 = 0$

$\Rightarrow \theta_1 = \theta_2$ (i)

$mu = mv(\cos\theta_1 + \cos\theta_2)$

$= 2mv\cos\theta\ [\theta_1 = \theta_2 = \theta(\text{say})]$

$\cos\theta = \frac{u}{2v}$ (ii)

According to law of conservation of KE,

$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$u^2 = 2v^2$ or $u = \sqrt{2}\text{v}$ (iii)

From Eqs. (ii) and (iii), we have $\cos\theta = \frac{\sqrt{2}v}{2v}$

Or $\cos\theta = \frac{1}{\sqrt{2}}$ or $\theta = 45°$

$\therefore \theta_1 + \theta_2 = 90°$

216 **(a)**

Work done = increasing in KE of the rotation

$W = \frac{1}{2}I\omega^2 = \frac{1}{2}\times\frac{1}{2}MR^2\omega^2 = \frac{1}{4}MR^2\omega^2$

217 **(a)**

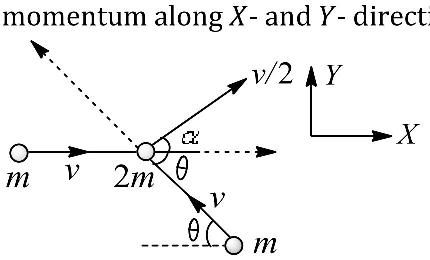
After the first collision, velocity perpendicular to the inclined plane becomes $ev\cos\theta$. Time of flight,

$t_1 = \frac{2eV}{\text{g}} t_2 = \frac{2e^2V}{\text{g}}, t_3 = \frac{2e^3V}{\text{g}}$

$h_1 = \frac{e^2v^2\cos\theta}{2\text{g}}, h_2 = \frac{e^4v^2\cos\theta}{2\text{g}}$

218 **(a)**

Let angle between initial velocities be $\pi - \theta$ and the situation is as shown in fig. Conserve the momentum along X- and Y- directions



$mv - mv\cos\theta = 2m\frac{v}{2}\cos\alpha$, for X-axis

$mv\sin\theta = 2m\frac{v}{2}\sin\alpha$, for Y-axis

Solving above equations, $\theta = 60°$

Required angle $= \pi - 60° = 120°$

219 **(b)**

$f_r = \frac{\frac{1}{2}I\omega^2}{\frac{1}{2}mv^2+\frac{1}{2}I\omega^2}$, where $I = \frac{2}{5}mr^2$,

$\omega = \frac{v}{r}$

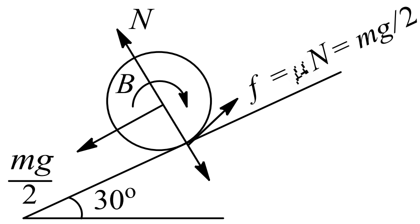
Solve to get $f_r = \frac{2}{7}$

220 **(d)**

As the inclined plane is smooth, the sphere can never roll, rather it will just slip down. Hence, the angular momentum remains conserved about any point on a line parallel to the inclined plane and passes through the centre of the ball

221 **(a)**

Here kinetic friction force will balance the force of gravity. So it will rotate at its initial position and will not move up or down. As its angular velocity becomes zero (friction also becomes zero), it will move downwards



222 **(d)**

Moment of inertia of discs A and B about the axis through their centre of mass and perpendicular to the plane will be

$I_{AA} = I_{BB} = \frac{1}{2}Mr^2$

Now, moment of inertia of disc A about an axis through B, by theorem of parallel axis will be

$I_{AA} = I_{BB} + M(2r)^2 = \frac{1}{2}Mr^2 + 4Mr^2 = \frac{9}{2}Mr^2$

So $I = I_{BB} + I_{AB} = \frac{1}{2}Mr^2 + \frac{9}{2}Mr^2 = 5Mr^2$

223 **(b)**

If we treat the train as a ring of mass $'M'$, then its CM will be at a distance $2R/\pi$ from the center of the circle. Velocity of the center of mass is

$V_{\text{CM}} = R_{\text{CM}}\omega = \frac{2R}{\pi}\frac{V}{R}\ \left(\because \omega = \frac{V}{R}\right)$

$= \frac{2V}{\pi} \Rightarrow MV_{\text{CM}} = \frac{2MV}{\pi}$

As the linear momentum of any system is MV_{CM}, the linear momentum of the train is $2MV/\pi$

224 **(a)**

$\frac{2}{5}MR^2 = \frac{1}{2}Mr^2 + Mr^2$

or $\frac{2}{5}MR^2 = \frac{3}{2}Mr^2$

$\therefore\quad r = \frac{2}{\sqrt{15}}R$

225 **(d)**

As the collision is head-on,

$mu + 0 = mv_1 + mv_2$ or $u = v_1 + v_2$ (i)

Further, coefficient of restitution is

$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{v_2 - v_1}{u} \quad (\because\ u_2 = 0)$$

Or $eu = v_2 - v_1$ (ii)

Adding Eqs. (i) and (ii), we get

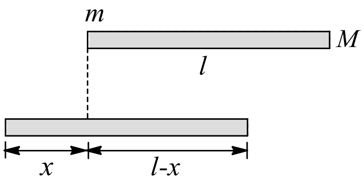
$v_1 = \frac{u(1-e)}{2}, v_2 = \frac{u(e+1)}{2}$ (iii)

Now $\frac{v_1}{v_2} = \frac{1-e}{1+e}$ (iv)

$\frac{v_1}{u} = \frac{1-e}{2}$ (v)

$\frac{v_2}{u} = \frac{1+e}{2}$ (vi)

226 **(a)**



$$m(l-x) = Mx \Rightarrow x = \frac{ml}{m+M}$$

Distance moved by insect w.r.t. ground is

$$l - x = l - \frac{ml}{m+M} = \frac{Ml}{m+M}$$

Speed $= \frac{\text{distance}}{\text{time}} = \frac{Ml}{t(M+m)}$

227 **(d)**

In case I there is no horizontal external impulse on ball and mass system while in case II friction is impulsive as normal with ground is impulsive. Hence, both statements are incorrect

228 **(a)**

Initial momentum: $3 \times 4 + 4 \times (-3) = 0$

Final momentum will also be zero. But both stick together, hence both come at rest

229 **(b)**

In both CM and ground frame, $K_{\max}$ is there, when x is zero in spring, which occurs simultaneously

$$v_{CM} = \frac{m(v_0) + 0}{5m} = \frac{v_0}{5}$$

$$K_{\max\,CM} = \frac{1}{2}m\left(\frac{4v_0}{5}\right)^2 + \frac{1}{2}(4m)\left(\frac{v_0}{5}\right)^2 = \frac{2}{5}mv_0^2$$

$K_{\max}$ ground $= \frac{1}{2}mv_0^2$

$K_{\text{mim CM}} = 0$

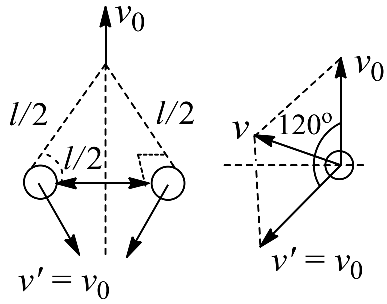
$K_{\min}$ ground$= \frac{1}{2}(m + 4m)v_{CM}^2 = \frac{mv_0^2}{10}$

$K_{\max m} = \frac{1}{2}mv_0^2$ (ground frame)

$K_{\min m} = 0$ (ground frame when energy is shared by spring and $4m$ only and m will reverse direction of motion)

230 **(b)**

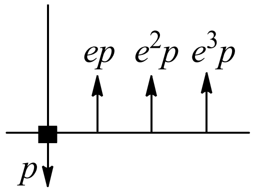
Using conservation of angular momentum about the midpoint, we can find the velocity of each ball relative to the midpoint. i.e., $v' = v_0$



Resultant velocity of ball= velocity of midpoint + velocity of ball w.r.t. midpoint

or $v = \sqrt{v_0^2 + v_0^2 + 2v_0^2 \cos 120°} = v_0$

231 **(d)**



$$\Delta p = (p + ep) + (ep + e^2p) + (e^2p + e^3p) + \cdots$$

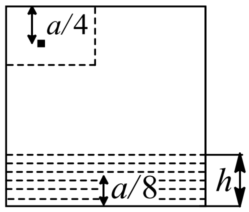
$$= p(1+e)[1 + e + e^2 + \cdots] = \frac{p(1+e)}{1-e}$$

232 **(c)**

Let h be the height of water surface. Then,

$$a^2h = a \times \frac{a}{2} \times \frac{a}{2}$$

$$h = \frac{a}{4}$$



CM gets lowered by $a - \left(\frac{a}{4} + \frac{a}{8}\right) = a - \frac{3a}{8} = \frac{5a}{8}$

Work done by gravity $= mg\frac{5a}{8}$

233 **(c)**

Let the tube be displaced by x towards left. Then

$$mx = m(R - x) \Rightarrow x = \frac{R}{2}$$

234 **(b)**

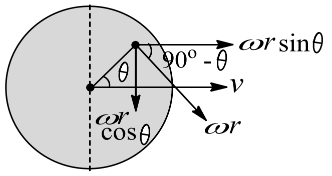
Here, $\omega = \frac{v}{R}$

$$V_{P_x} = \left(v + \frac{v}{R}r\sin\theta\right)\hat{\imath}$$

$$V_{P_y} = -\left(\frac{v}{R}r\cos\theta\right)\hat{\jmath}$$

$$\vec{V}_P = \left(v + \frac{vr\sin\theta}{R}\right)\hat{\imath} - \frac{vr\cos\theta}{R}\hat{\jmath}$$

$$= \left(v + \frac{vr\sin\theta}{R}\right)\hat{\imath} - \frac{vr\cos\theta}{R}\hat{\jmath}$$



235 **(c)**

As sphere rolls, the lowest point of the sphere should have the same acceleration as the plank

Hence, $a_1 = \alpha R - a_2$

$2 = 2\alpha - 4 \Rightarrow \alpha = 3 \text{ rad/s}^2$

236 **(b)**

The time elapsed from the moment it is dropped to the second impact with the floor is

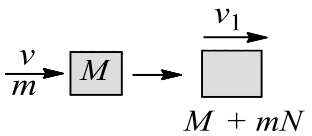
$$t = \sqrt{\frac{2h}{g}}\ (1 + 2e)$$

Align where h is the initial height of the body from the ground

$$1.03 = \sqrt{\frac{2}{9.8}}(1 + 2e)$$

Solving, we get $e = 0.64$

237 **(b)**

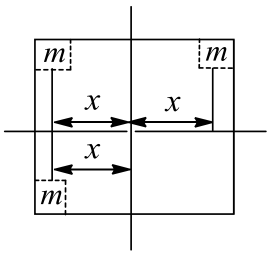


Momentum of all particles colliding = final momentum

$\Rightarrow mNv = (M + mN)v_1$

$v_1 = \dfrac{mvN}{M + mN}$

238 **(b)**



$x_1 = \left(\dfrac{mx}{M - m}\right) \Big| x_2 = \left(\dfrac{2mx}{M - 2m}\right) \Big| \; x_3 = \left(\dfrac{mx}{M - 3m}\right)$

$x_1 < x_3 < x_2$

239 **(d)**

$u_x = 20\sqrt{2}\cos 45° = 20$ m/s

$u_y = 20\sqrt{2}\ \sin 45° = 20$ m/s

After 1 s, horizontal component remains unchanged while vertical component becomes

$v_y = u_y - gt = 20 - 10 = 10$ m/s

Due to explosion, one part comes to rest. Hence, from conservation of linear momentum, vertical component of second part will become $v_{y1} = 20$ m/s. Therefore, maximum height attained by the second part will be

$H = h_1 + h_2$

Here, h_1 = height attained in 1 s

$= (20)(1) - \dfrac{1}{2} \times 10 \times 1^2 = 15$ m

and h_2 = height attained after 1 s

$\dfrac{v_{y1}^2}{2g} = \dfrac{(20)^2}{2 \times 10} = 20$ m

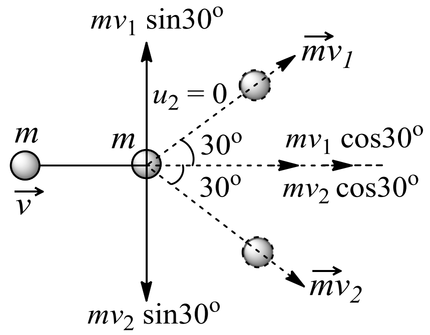
$\therefore H = 15 + 20 = 35$ m

240 **(c)**

Applying the law of conservation of momentum in perpendicular to the initial line of motion,

$0 = mv_1 \sin 30 - mv_2 \sin 30°$ or $v_1 = v_2$

Hence, speed of both will be same after collision



Now along the line of motion,

$mv = mv_1 \cos 30° + mv_2 \cos 30°$ (ii)

Putting Eq. (i) in Eq. (ii), $mv = 2mv_1 \cos 30°$

Or $v_1 = \frac{v}{\sqrt{3}} = \frac{6}{\sqrt{3}} = 2\sqrt{3}$ m/s

241 **(b)**

At maximum compression when m sticks to M,

$mv = (M + m)V$

$V = \dfrac{mv}{M + m}$

$\dfrac{\text{Fraction of KE}}{\text{Stored in spring}} \quad f = \dfrac{K_i - K_f}{K_i}$

$\therefore f = 1 - \dfrac{\frac{1}{2}(M + m)V^2}{\frac{1}{2}mv^2} \Rightarrow f = 1 - \left(\dfrac{m}{M + m}\right)$

$= \dfrac{M}{M + m}$

242 **(a)**

From theory

243 **(d)**

$\vec{L} = I_{CM}\vec{\omega} + m\vec{r} \times \vec{v}_{CM}$

$= \dfrac{MR^2}{2}\omega(-\hat{k}) + M\dfrac{3}{2}R(-\hat{j}) \times v_0\hat{i}$

$= MRv_0\hat{k}$

244 **(c)**

$$\vec{v}_{CM} = \frac{m_1 v_1 + m_2 v_2 + \cdots}{m_1 + m_2 + \cdots} = \frac{6mv}{7m} = \frac{6v}{7}$$

245 **(a)**

$$(\text{MI})_{CG} = M\left(\frac{a^2 + b^2}{12}\right)$$

According to the theorem of parallel axis,

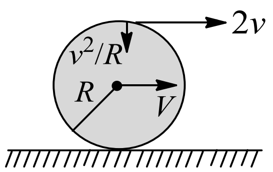
$$(\text{MI})_{\text{required axis}} = (\text{MI})^{CG} + M(OA)^2$$

$$= M\left(\frac{a^2+b^2}{12}\right) + M\left(\frac{a^2+b^2}{4}\right)$$

$$= M\left(\frac{a^2+b^2}{3}\right)$$

246 **(c)**

Radius of curvature $= \frac{(\text{Velocity})^2}{\text{Normal accelertion}}$



Radius of curvature $= \frac{(2v)^2}{v^2/R} = 4R$

247 **(a)**

For a body to roll without slipping on an incline of angle θ:

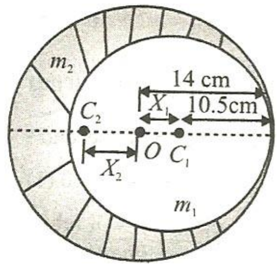
$$\mu \geq \frac{\tan\theta}{1 + \frac{mR^2}{I}}$$

I is minimum for the sphere, hence μ required is least for the sphere. Here it is given that μ is just sufficient to roll the sphere purely. It means the ring and the cylinder will not roll puarly, so kinetic friction will act on them. Ultimately, friction acting on each of the three will be $\mu mg\cos\theta$ and each of them will have the same acceleration. Hence, all of them reach at the same time

248 **(c)**

C_1 is the centre of mass of cut portion and C_2 that of remaining portion. We have to find x_2

$x_1 = 14 - 10.5 = 3.5$ cm



Mass will be proportional to area. So mass of the whole disc is

$M = k\pi(14)^2$

Mass of cut portion $m_1 = k\pi(10.5)^2$

Mass of the remaining portion $m_2 = M - m_1 =$

$k\pi(14^2 - 10.5^2)$

$= k\pi(24.5) \times (3.5)$

Now, $m_1 x_1 = m_2 x_2$

$$\Rightarrow x_2 = \frac{m_1 x_1}{m_2} = \frac{k\pi(10.5)^2 \times 3.5}{k\pi(24.5) \times 3.5} = 4.5\text{cm}$$

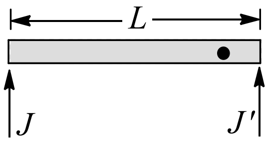
249 **(c)**

As the car stops, so velocity of bullet after firing is same w.r.t. ground and w.r.t. car. Conserving momentum in horizontal direction

$$(M + m)v = mv\cos\alpha \Rightarrow V = \frac{mv\cos\alpha}{M + m}$$

250 **(b)**

Let J' be the impulse exerted by the pivot on the rod. Then from impulse momentum theorem, $J + J' = mv_0$, where v_0 is the velocity acquired by the centre of mass



Now apply, angular impulse = change in angular momentum about the pivot

$$J \times L = \frac{ML^2}{3}\omega$$

$J \times \frac{ML}{3}\omega$, where ω is the angular velocity of the rod

$$v_0 = \frac{\omega L}{2} \Rightarrow Mv_0 = \frac{M\omega L}{2}$$

$$J + J' = \frac{3J}{2} \Rightarrow J' = \frac{J}{2}$$

251 **(a)**

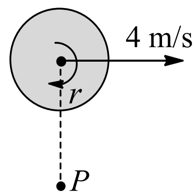
Velocity of m when string gets tight, $v_1 = \sqrt{2g\,2l} = 2\sqrt{gl}$

Combined velocity, $v_2 = \frac{mv_1}{3m}$

$$= \frac{v_1}{3} = \frac{2}{3}\sqrt{gl}$$

252 **(c)**

If instantaneous centre of rotation is P at a distance r from the centric line OC, then from the definition of instanteous centre of rotation, the velocity of point P should be zero



$v_p = 4 - 10r = 0$

$$r = \frac{2}{5}\text{m} = 0.4\text{ m}$$

So, instantaneous centre of rotation is at distance 0.2 m from O(below O) on line OC

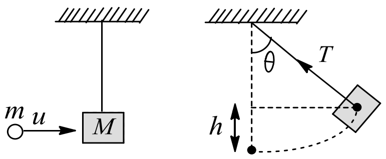
253 **(c)**

$u_1 = \frac{p}{m_1}, u_2 = \frac{p}{m_2}$

$E = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_0^2$

$= \frac{1}{2}\left[m_1\frac{p^2}{m_1^2} + m_2\frac{p^2}{m_2^2}\right] = \frac{p^2(m_1+m_2)}{2m_1m_2}$

254 **(a)**



Applying the law of conservation of linear momentum,

$mu = (M+m)V$

Or $V = \frac{mu}{(M+m)} = \frac{0.1\times150}{(0.1+2.9)} = 5$ m/s

If V_1 is the speed of the combined mass at the instant when the string makes an angle 60° with the vertical, then

$T = (M+m)g\cos60° + \frac{(M+m)V_1^2}{l}$

$= 3\times9.8\times\frac{1}{2} + \left(\frac{3V_1^2}{0.5}\right) = 14.7 + 6V_1^2$ (i)

Applying the law of conservation of mechanical energy, we have

$(\text{KE})_{\text{lowest point}} = (\text{KE}+\text{PE})_{\text{at any other point}}$

Or $\frac{1}{2}(m+M)V^2 = \frac{1}{2}(m+M)V_1^2 + (m+M)gh$

Or $\frac{1}{2}(m+M)V^2 = \frac{1}{2}(m+M)V_1^2 + (m+M)gl(1-\cos\theta)$

$\frac{1}{2}\times3\times25 = \frac{3}{2}V_1^2 + 3\times9.8\times0.5\left(1-\frac{1}{2}\right)$ (ii)

Solving for V_1^2, we get $V_1^2 = 20.1(\text{m/s})^2$

Putting this value in Eq. (i),we get

$T = 14.7 + 6\times20.1 = 135.3$ N

255 **(c)**

$mv = (m+m)v_1$ or $v_1 = \frac{v}{2}$

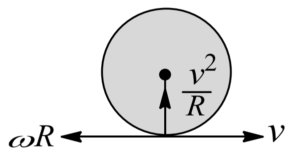
$T = \frac{2mv_1^2}{l} + 2\,mg = \frac{2mv^2}{4l} + 2\,mg$

$= \frac{m(2gl)}{2l} + 2\,mg = 3mg$

Initial tension $= mg$, increase in tension $= 2mg$

256 **(d)**

As the disc is in combined rotation and translation, each point has a tangential velocity and a linear velocity in the forward direction



From the figure,

V_{net}(for the lowest point)$= v - R\omega = v - v = 0$

and acceleration $\frac{v^2}{R} + 0 = \frac{v^2}{R}$

(Since the linear speed is constant)

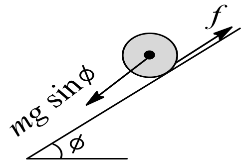
257 **(a)**

$f = Mg\sin\theta$

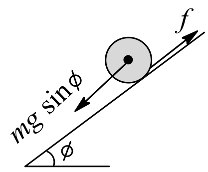
For no sliding $f < f_L$

$mg\sin\theta < \mu_s mg\cos\theta$

$\tan\theta = \mu_s$



For rolling friction, force $f = \frac{mg\sin\theta}{1+\frac{R^2}{k^2}}$



$\Rightarrow f = \frac{mg\sin\phi}{3}$

For pure rolling, $\frac{mg\sin\phi}{3} < \mu_s mg\cos\phi$

$\tan\phi < 3\mu_s$, so $\frac{\tan\phi}{\tan\theta} = 3$

258 **(a)**

As acceleration in both will be g =10 m/s^2, hence acceleration of centre of mass will also be g

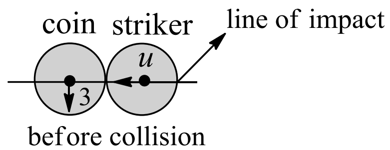
259 **(b)**

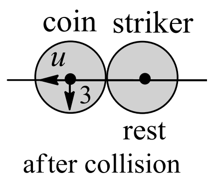
Statement (i) is correct because in this case, spring would be compressing. So PE in the spring will be increasing. It means KE of the system will be decreasing as the total mechanical energy of the system is constant

Further, momentum of the system will always be conserved. It will neither be increasing nor be decreasing

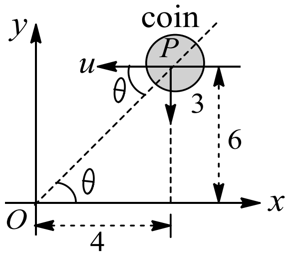
260 **(b)**

The line of impact for duration of collision is parallel to the x-axis. The situation of striker and coin just before the collision is given as





Because masses of coin and striker are same, their components of velocities along the line of impact shall exchange. Hence, the striker comes to rest and the x-and y-components of velocities of coin are u and 3 m/s, respectively, as shown in fig.



For coin to enter hole, its velocity must be along PO

$\tan\theta = \frac{6}{4} = \frac{3}{u}$ or $u = 2$ m/s

261 **(b)**

Till time t_0, friction on car will be in forward direction and on boat in backward direction. So the boat will not move till t_0. Let v be the velocity of car +boat system just after applying the brakes. From conservation of momentum,

$(m+M)v = mv_0 \Rightarrow v = \dfrac{mv_0}{m+M}$

Time taken is $t_0 + L/v = t_0 + \frac{L(m+M)}{mv_0}$

262 **(d)**

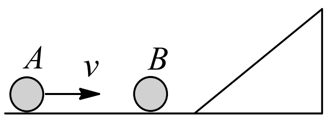
Let combined velocity of the system be v

$(m+M)v = mu \Rightarrow v = \dfrac{mu}{m+M}$

$\text{KE} = \dfrac{1}{2}(m+M)v^2 = \dfrac{m^2u^2}{2(M+m)}$

263 **(b)**

$v = 16$ m/s



Let velocity of B after collision be v_2 and that of A be v_1.Then

$v_2 = \sqrt{2gs} = \sqrt{2\times 10\times 5} = 10$ m/s

$mv_1 + mv_2 = mv$

$v_1 + 10 = 16 \Rightarrow v_1 = 6$ m/s

$e = \dfrac{v_2 - v_1}{v} = \dfrac{10-6}{16} = \dfrac{1}{4}$

264 **(b)**

For all the bodies, torque is the same

Now , $\text{KE} = \frac{1}{2}mv^2 + \frac{L^2}{2I}$

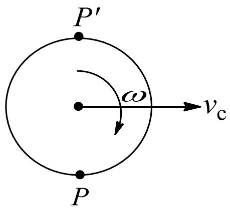
Linear velocity 'v' is the same for all as the same force acts on them

Therefore, the more value of moment of inertia implies the lesser kinetic energy

Among all, the hollow sphere has the maximum moment of inertia, $I = \left(\frac{2}{3}MR^2\right)$

265 **(d)**

The instantaneous axis of rotation will fall on the outside of the sphere. Since incase of pure rotation, the instantaneous axis of rotation will be on the centre. In case of pure rolling, the instantaneous axis of rotation will be on P



But if $v_C > \omega R$, then the instantaneous axis of rotation will fall out of the sphere

266 **(a)**

$m_1u_1 = m_2v_2$

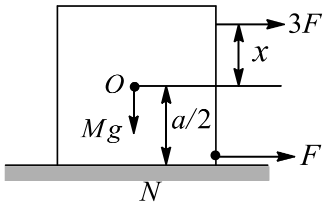
$\dfrac{1}{2}\, m_2v_2^2 = \dfrac{1}{2}\left[\dfrac{1}{2}m_1u_1^2\right]$

$\Rightarrow (m_2v_2)v_2 = \dfrac{1}{2}(m_1u_1)u_1 \Rightarrow\ v_2 = \dfrac{u_1}{2}$

$e = \dfrac{v_2 - v_1}{u_1 - u_2} = \dfrac{v_2 - 0}{u_1 - 0} = \dfrac{v_2}{u_1}\ \Rightarrow\ e = \dfrac{1}{2}$

267 **(b)**

The free-body diagram of the block can be drawn a shown as the body has to move in pure translation motion, the torque about the centre of gravity must be zero



$3F\times x = F\times\dfrac{a}{2} \Rightarrow x = \dfrac{a}{6}$

268 **(c)**

Using conversation of angular momentum about O, we get

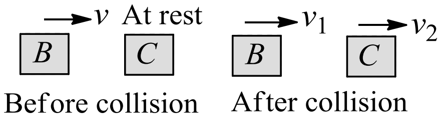
$mvR = (mR^2 + mR^2)\omega; \omega = \dfrac{v}{2R}$

269 **(b)**

$\dfrac{\frac{1}{2}mv_1^2}{\frac{1}{2}nmv_2^2} = \dfrac{v_1^2}{nv_2^2} = \dfrac{(1-n)^2}{4n}$

270 **(d)**

For collision of B and C



$2mv = 2mv_1 + mv_2$

$\frac{1}{2} = \frac{v_2 - v_1}{v} \Rightarrow 2v_2 - 2v_1 = v$

Solving above equations, $v_1 = \frac{v}{2}$ and $v_2 = v$

Now for blocks A and B plus spring system, using reduced mass concept, and applying work-energy theorem, let maximum compression in spring be x_0 and at the time of maximum compression relative velocity of blocks be zero. Reduced mass is given by

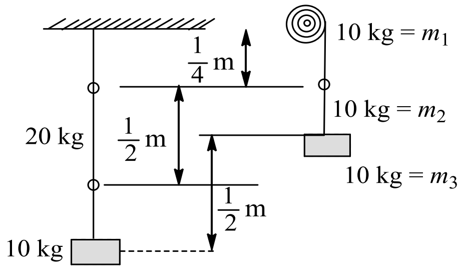
$$\mu = \frac{m \times 2m}{3m} = \frac{2m}{3}$$

$$0 - \frac{\mu \times (v - v/2)^2}{2} = -\frac{kx_0^2}{2} \Rightarrow x_0 = \left(\sqrt{\frac{m}{6k}}\right)v$$

271 **(d)**

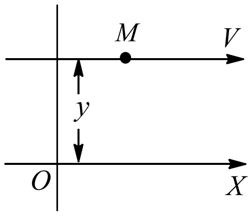
Work done,

$$W = 10 \times g \times \frac{1}{4} + 10 \times g \times \frac{1}{2} + 10 \times g \times \frac{1}{2}$$
$$= 125 \text{ J}$$



272 **(b)**

Angular momentum



$\vec{L} = \vec{r} \times \vec{P}$

$L =$ Monmentum $\times$perpendicular distance of line of action of momentum w.r.t. point of rotation

$L = MV \times y$

The quantities on the right side of the equation are not changing. Thus, magnitude is constant

273 **(c)**

Since velocity of man w.r.t. trolly is greater than velocity of trolly w.r.t. earth, after the man turns back displacement of the man will decrease, so maximum displacement will be at the moment when man turns back

$$\therefore\ t = \frac{L}{1.5\ V}$$

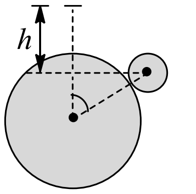
Displacement $= (v + 1.5\ v)t$

$$= 2.5\ v \frac{L}{1.5v} = \frac{5}{3}L$$

274 **(b)**

$$\frac{mv^2}{(R + r)} = mg\cos\theta,$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$



$$mg(R + r)(1 - \cos\theta) = \frac{1}{2}mv^2 + \frac{1}{5}mv^2$$
$$= \frac{7}{10}mv^2$$

$$\frac{10}{7}mg(R + r)(1 - \cos\theta) = mg\cos\theta$$

$$mv^2 = \frac{10}{7}mg\ (R + r)(1 - \cos\theta)$$

$$\frac{10}{7} = \frac{17}{7}\cos\theta \text{ or } \cos\theta = \frac{10}{17}$$

$$v = \sqrt{g(R + r)\cos\theta} = \sqrt{\frac{10}{7}g(R + r)}$$

and $\omega = \frac{v}{r} = \sqrt{\frac{10g(R+r)}{17r^2}}$

275 **(a)**

Since collision is elastic, P will rebound with same velocity as it strikes with. And at the time of collision, velocities of P and Q will be same in magnitude

276 **(c)**

$p = p_0(\cos t\ \hat{\imath} + \sin t\ \hat{\jmath})$

$$\vec{F} = \frac{d\vec{p}}{dt} p_0[-\sin t\ \hat{\imath} + \cos t\ \hat{\jmath}]$$

Both $\vec{p}$ and $\vec{F}$ are functions of time. So none of them is constant

We see that $\vec{F} \cdot \vec{p} = 0$, So $\vec{F} \perp^r \vec{p}$

277 **(a)**

Rotational kinetic energy $K_R = \frac{1}{2}I\omega^2$

$\therefore$ Its moment of inertia $= \frac{2K_R}{\omega^2}$

$$= 2 \times \frac{360}{(30)^2}$$
$$= 0.8 \text{ kg} - \text{m}^2$$

278 **(b)**

MOI is $\sum m_i r_i^2$. About BC masses are spread far away than about any other axis

279 **(a)**

$$\Delta y_{CM} = \frac{m_1\Delta y_1 + m_2\Delta y_2 + m_3\Delta y_3}{m_1 + m_2 + m_3}$$

$$= \frac{10 \times \frac{1}{4} + 10 \times \frac{1}{2} + 10 \times \frac{1}{2}}{10 + 10 + 10} = 0.417\text{m}$$

280 **(b)**

When the ring is at the maximum height, the wedge and the ring have the same horizontal component of velocity. As all the surface are smooth, in the absence of friction between the ring and the wedge surface, angular velocity of the ring remains constant

For conservation of mechanical energy, we get

$\frac{1}{2}mv^2+\frac{1}{2}I\omega^2=\frac{1}{2}mv'^2+\frac{1}{2}I\omega^2+\frac{1}{2}mv'^2+mgh$

Where v' is final common velocity;

$v'=\frac{v}{2}$ (from conservation of momentum) and

$h=\frac{v^2}{4g}$

281 **(a)**

The whole of the energy of A will be transferred to B. So B will rise to the same height

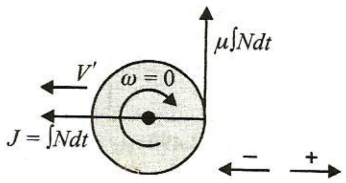
282 **(a)**

Impulse provided by the edge in the horizontal direction:

$-\int Ndt=-mV'-(mV)$ ...(i)

Friction impulse in the vertical direction

$\mu R\int Ndt=\frac{2}{5}mR^2\left(\frac{V}{R}\right)$ ...(ii)

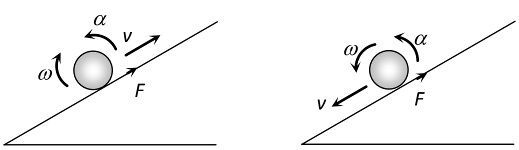


From Eqs. (i) and (ii), we get

$\int Ndt=2mV$ and $V'=V$

283 **(b)**

When the cylinder rolls up the incline, its angular velocity ω is clockwise and decreasing



This require an anticlockwise angular acceleration α, which is provided by the force of friction (F) acting up the incline

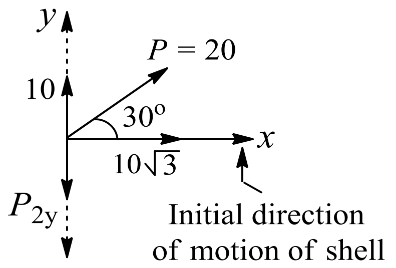
When the cylinder rolls down the incline, its angular velocity ω is anticlockwise and increasing. This requires an anticlockwise angular acceleration α, which is provided by the force of friction (F) acting up the incline

284 **(c)**

As shown in the figure, the components of momentum of one shell along initial direction and perpendicular to initial direction are

$P_{1x}=10\sqrt{3}$ N s and $P_{1y}=10$ N s

For momentum of the system to be zero in y-direction, P_{2y} must be 10 N s. The second part of the shell may or may not have momentum in x-direction $P_{2\min}=10$N s



285 **(a)**

$\frac{h_1}{h_0}=e^2\Rightarrow\frac{80}{100}=e^2\Rightarrow e=\sqrt{0.8}$

Velocity before the first impact $u=\sqrt{2gh}$

Velocity after the third impact $v_3=e^3\sqrt{2gh}$

$\text{KE}=\frac{1}{2}mv_3^2=e^6\,mgh=(0.8)^3\,mgh$

286 **(c)**

As in a perfectly inelastic collision, two bodies stick together after the collision and move with same velocity, so their relative velocity after the impact is zero

287 **(d)**

$\frac{MgL}{2}\cos\theta=\frac{ML^2}{3}\alpha$

$\alpha=\frac{3}{2}\frac{g\cos\theta}{L}$

$a=\alpha L=\frac{3}{2}g\cos\theta$

288 **(a,c)**

If wall is smooth $v\cos\alpha=eu\cos\theta$

$v\sin\alpha=u\sin\theta$

$\cot\alpha=eu\cot\theta$

$\alpha>\theta$

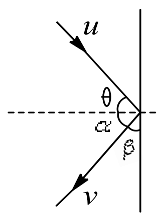
$\alpha+\beta>\theta+\beta$

$90°>\theta+\beta$

If wall is rough, then $v\cos\beta<u\sin\theta$

$v\sin\beta=eu\cos\theta$

From (i) and (ii), $e<\tan\beta/\cot\theta$



289 **(a,d)**

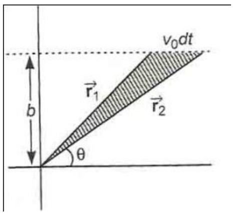
$L=mv_0r\sin\theta$

$L=mv_0b=$constant

$|\vec{\mathbf{r}}_1|+|\vec{\mathbf{r}}_2|=r$

Now, $dA=\frac{1}{2}(v_0dt)r\sin\theta$

or $\frac{dA}{dt} = \frac{mv_0 r \sin\theta}{2m} = \frac{L}{2M}$



290 **(d)**

The moment of inertia of the loop about XX' axis is

$$I_{XX} = \frac{mR^2}{2} + mR^2 + \frac{3}{2}mR^2$$

Where m =mass of the loop and R= radius of the loop

Here $m = Lp$ and $R = \frac{L}{2\pi}$; therefore

$$I_{XX'} = \frac{3}{2}(L\rho)\left(\frac{L}{2\pi}\right)^2 = \frac{3L^3\rho}{8\pi^2}$$

291 **(a,b,c)**

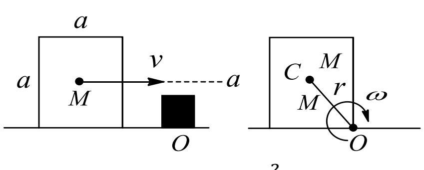
When the ball move along a smooth plane, the accelerating force on it is $mg\sin\theta$. Hence, its acceleration is equal to $g\sin\theta$

When the ball rolls down the rough inclined plane, then $mg\sin\theta$ acts down the plane but a friction comes into existence which acts up the plane. That friction produces angules acceleration on the ball and the net accelerating force on the ball becomes equal to ($mg\sin\theta$ −friction). Therefore, it has a smaller acceleration.

Therefore, its velocity at the bottom of the plane is less than that of the ball moving down a smooth plane or $v_s > v_r$

In fact, at the bottom of the planes both the balls have the same KE because loss of potential energy of both the balls is the same. But the ball rolling down a rough plane has translation as well as rotational kinetic energy at the bottom of the plane while ball sliding down a smooth plane has translational KE only. Therefore, translational KE of the rolling ball will be less than the translational KE of the ball sliding down the smooth plane. Hence, option (d) is correct

292 **(a)**



$r = \sqrt{2}\frac{a}{2}$ or $r^2 = \sqrt{2}\frac{a^2}{2}$

Net torque about O is zero

Therefore, angular momentum (L) about O will be conserved, or $L_1 = L_f$

$$MV\left(\frac{a}{2}\right) = I_0\omega = (I_{CM} + Mr^2)\omega$$

$$= \left\{\frac{Ma^2}{6} + M\frac{a^2}{2}\right\}\omega$$

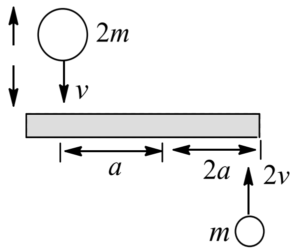
$$\omega = \frac{3V}{4a}$$

293 **(a,c,d)**

Applying conservation of linear momentum

$2m(-v) + m(2v) + 8m \times 0 = (2m + m + 8m)V_c$

$\Rightarrow V_c = 0$



Applying conservation of angular momentum about centre of mass, we get

$2mv \times a + m(2v) \times 2a = I\omega$

Where

$$I = \frac{1}{12}(8m)(6a)^2 + 2m \times a^2 + m \times 4a^2$$

$$= 30\, ma^2$$

$$6\, mva = 30\, ma^2 \times \omega \Rightarrow \frac{v}{5a} = \omega$$

Energy after collision,

$$E = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 30\, ma^2 \times \frac{v^2}{25a^2} = \frac{3mv^2}{5}$$

294 **(a,b,d)**

Let ω_1 = the initial angular velocity of the disc

ω_2 = the final common angular velocity of the disc and the ring

For the disc, $I_1 = \frac{1}{2}mr^2$

For the ring,

$I_2 = mr^2$

By conservation of angular momentum

$L = I_1\omega_1 = (I_1 + I_2)\omega_2$

$$\omega_2 = \frac{I_1\omega_1}{I_1 + I_2} = \frac{\omega_1}{3}$$

Initial kinetic energy = $E_1 = \frac{1}{2}I_1\omega_1^2$

Final kinetic energy = $E_2 = \frac{1}{2}(I_1 + I_2)\omega_2^2$

Heat produced = loss in KE

Ratio of heat produced to initial kinetic energy

$= (E_1 - E_1)/E_1 = 2/3$

295 **(c,d)**

While rolling down the incline, the frictional force acts up along the incline

The frictional force opposes the translational motion but supports the rotation about centre.

Thus, (c) is correct

The translational equation is

$mg\sin\theta - f = ma_C$ ...(i)

Rotational equation

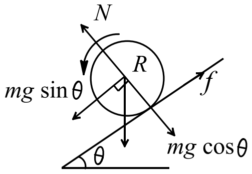
$f.R = I_{CM}.\alpha$ ...(ii)

Also for pure rolling $a_C = R\alpha$

Thus, $a_C = \left(\frac{g\sin\theta}{1+I_C/mR^2}\right)$

Thus, $a_C = \frac{2}{3}g\sin\theta \quad \left(\because I_C = \frac{mR^2}{2}\right)$

$\therefore f = mg\sin\theta - \frac{2}{3}mg\sin\theta$



$f = \frac{mg\sin\theta}{3}$

Obviously, if θ reduces, f also reduces

Thus, option (c) and (d) are correct

296 **(b,d)**

If v_1 and v_2 are in same direction then

$v_{\text{comp}} = \frac{m_1v_1 + m_2v_2}{m_1+m_2} = \frac{2\times3+1\times4}{2+1} = \frac{10}{3}\,\text{ms}^{-1}$

However, if v_1 and v_2 are in mutually opposite directions.

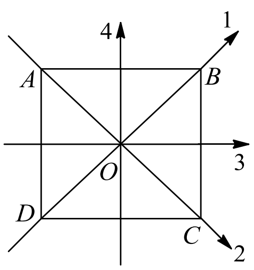
Then $v_{\text{comp}} = \frac{2\times3+1\times-4}{2+1} = \frac{2}{3}\text{ms}^{-1}$

297 **(a,b,c)**

The radius of gyration does not depend on the total mass of a body but depends upon the shape and size of body, distribution of mass within the body and choice of rotational axis

298 **(a,b,c)**

To find the moment of inertia of $ABCD$ about an axis passing through centre O and perpendicular to the plane of the plate, we use perpendicular axis theorem. If we consider $ABCD$ to be in the $X-Y$ plane, then we know that



$I_{zz'} = I_{xx'} + I_{yy'}$

$I_{zz'} = I_1 + I_2$ (i)

Also $I_{zz'} = I_3 + I_4$ (ii)

Adding Eqs. (i) and (ii), we get

$2I_{zz'} = I_1 + I_2 + I_3 + I_4$

But $I_1 + I_2$ and $I_3 = I_4$ (by symmetry)

$\therefore 2I_{zz'} = I_1 + I_1 + I_2 + I_3$

$= 2I_1 + 2I_3$

299 **(a,b)**

As there is no external force on the system hence displacement of the centre of mass of the system is zero. Hence (a) is correct.

300 **(b,c,d)**

Due to force F, the plank has a tendency to slide to the right below the sphere. Hence, friction acts on the plank to the left and that on the sphere acts to the right. The friction not only acts on accelerating force on the sphere but also produces an anticlockwise moment. Therefore, the here experiences a rightward translation acceleration and an anticlockwise angular acceleration simultaneously

If the angular acceleration of the sphere is a, then its centre of mass has a backward acceleration ra relative to the plank. Hence, its net acceleration becomes less than that of the plank. Hence, option (b) is correct. Obviously, option (a) is incorrect.

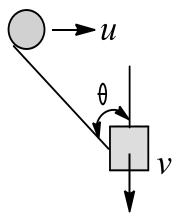
Since there is no sliding between the surface of the sphere and the plank, therefore, no energy is lost against friction

Since friction, acting on the sphere, is the only force which provides motion to it, therefore KE of the sphere at any instant is equal to work done by the friction acting on it. Hence, option (c) is correct

Since no energy is lost against friction. Therefore KE of the whole system is equal to work done by force F. Hence, option (d) is also correct

302 **(a,d)**

$v\cos\theta = u\sin\theta$



From conservation of energy,

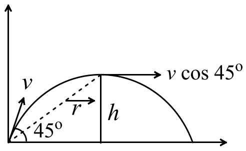
$mgl\cos\theta = 2\left(\frac{1}{2}mu^2\right) + \frac{1}{2}mv^2$

$u = \sqrt{\frac{2gl\cos\theta}{2+\tan^2\theta}} = \sqrt{\frac{gl}{5}}$, using $\theta = 60°$

$v = \sqrt{\frac{3gl}{5}}$

303 **(b,d)**

$\vec{L} = \vec{r}\times\vec{P}$



$\vec{L} = (mv\cos 45°)(h) = \frac{mvh}{\sqrt{2}}$ ...(i)

Now, $h = \frac{v^2 \sin^2 45°}{2g} = \frac{v^2}{4g}$ ...(ii)

Thus, $L = \frac{mv^3}{4\sqrt{2}g}$ ...(iii)

Also $v = (4gh)^{1/2}$ [from eq. (ii)]

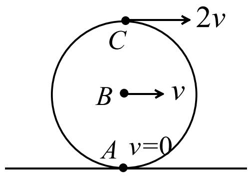
Hence, $L = \frac{m(4gh)^{3/2}}{4\sqrt{2}g}$

Thus, (b) and (d) are correct options

304 **(b,d)**

When two particles collide and stick together, energy is conserved and work done is negative because KE decreases. So, options (b) and (d) are correct

305 **(b,c)**



$\vec{V}_A = 0, \vec{V}_B = \vec{V}, \vec{V}_C = 2\vec{V}$

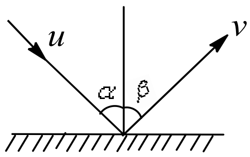
$\vec{V}_C - \vec{V}_B = \vec{V}_B - \vec{V}_A - \vec{V}$

$|\vec{V}_C - \vec{V}_A| = 2|\vec{V}_B - \vec{V}_C| = 2\vec{V}$

Option (b) and (c) both are correct

306 **(b,c)**

Let the ball strike the floor at angle α with the vertical and velocity at the instant of striking the floor be u and let the ball rebound with velocity v at angle β with the vertical as shown in Fig.



Since the floor is smooth, therefore horizontal component of velocity remains unchanged. Hence $v\sin\beta = u\sin\alpha$ (i)

Since, the floor is inelastic, therefore normal component of velocity just after the collision is less than that just before the collision. Hence, $v\cos\beta < u\cos\alpha$ (ii)

Dividing Eq. (i) by Eq. (ii), $\tan\beta > \tan\alpha$ or $\beta > \alpha$

Hence, option (c) is correct

Since the ball has a horizontal component of velocity, therefore, at highest point, its kinetic energy is not equal to zero

It means, at highest point, potential energy of the ball is less than the kinetic energy just after rebound. Hence, option (a) is incorrect

Since the floor is inelastic, therefore there is some loss of energy during the collision. Hence, the total energy of the ball does not remain conserved. So option (b) is also correct

307 **(a)**

Before explosion, particle was moving along x-axis, i.e., it has no y-component of velocity. Therefore, the centre of mass will not move in y-direction or we can say $y_{CM} = 0$

Now, $y_{CM} = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$

Therefore, $0 = \frac{(m/4)(+15) + (3m/4)(y)}{(m/4 + 3m/4)}$

or $y = -5$ cm

308 **(a,b,c,d)**

a. $v_1 = 20 - gt$

$v_2 = -20 - g(t-2)$

$v_1 - v_2 = [20 - gt] + 20 + g[t-2] = 20$ m/s

Clearly, it is time independent, i.e., relative velocity between the two stones remains constant

b. In both the cases, the total energy remains the same

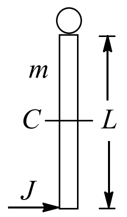
c. and d. These are simple constant

309 **(a,b,c,d)**

Angular momentum = linear momentum × perpendicular distance from the point of rotation

Or $L = JI$

Also, $I = \frac{ml^2}{3}$



$\omega = \frac{L}{I} = \frac{JI}{ml^2/3} = \frac{3J}{ml}$

Kinetic energy $= \frac{L^2}{2l}$

$= \frac{J^2 l^2}{2\frac{ml^2}{3}} = \frac{3J^2}{2m}$

$v_c = \omega\frac{l}{2} = \frac{3J}{2m}$

310 **(b,c,d)**

In an elastic collision, linear momentum of the system is always conserved i.e., in all the three stages of collision. But the kinetic energy of the system is not always conserved. It is conserved only before and after the collision. During collision it gets converted into potential energy

311 **(a,b)**

$v_0 - r\omega_0 = 3v$ ...(i)

$v_0 + r\omega_0 = -v$ ...(ii)

From Eqs. (i) and (ii), we get

$2v_0 = 2v \Rightarrow v_0 = v$

$v_0 + v_0 = -r\omega_0 \Rightarrow \omega_0 = \frac{2v}{r}$

312 **(a,c)**

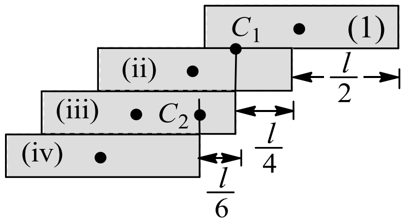
As total mass is M and velocity of centre of mass is v_1 hence KE of the system may have any value equal to or greater then $\frac{1}{2}Mv^2$. However exact value of KE can be calculated only when values of m_1, m_2, v_1 and v_2 are known to us.

313 **(d)**

Net external force on system is zero. Therefore, centre of mass always remains at rest

314 **(a,b,c,d)**

Let the weight of each brick be W and length l. As bricks are homogeneous, the centre of gravity of each brick must be at the midpoint. Therefore, the topmost brick will be in equilibrium if its centre of gravity lies at the edge of brick below it, i.e., II brick. Thus the topmost brick can have maximum equilibrium extension of $l/2$



C_1 is the centre of mass of the top two bricks which lies on the edge of the third brick

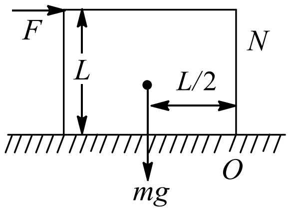
C_2 is the centre of mass of the top three bricks which lies on the edge of the fourth brick

Thus, the maximum overhanging length to top from the edge of bottom brick is

$\frac{l}{2} + \frac{l}{4} + \frac{l}{6} = \frac{11}{12}l$

315 **(c)**

The applied force shifts the normal reaction to one corner as shown in figure. At this situation, the cubical block starts topping about O. Taking torque about O, we get



$F \times L = mg \times \frac{L}{2}$

$\Rightarrow F = \frac{mg}{2}$

316 **(a,b,c)**

Let L angular momentum

$\tau = \frac{dL}{dt}$ or $dL = \tau dt$

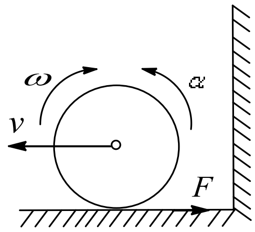
For constant torque, $\Delta L = \tau \Delta t = I\Delta\omega$

Or $I\omega$(if $\omega_I = 0$)

Rotational kinetic energy $= I\omega^2/2 = (\Delta L)^2/2l$

317 **(a,c,d)**

After impact, the force of friction will act in a direction opposite to that of the motion. The body will retain its initial angular motion (clockwise). The force of friction will cause linear retardation, reducing v. It will also cause an anticlockwise angular acceleration, which will reduce ω to zero and then introduce anticlockwise ω till rolling without slipping begins. F will then disappear



318 **(a,c)**

The data is incomplete. Let us assume that friction from ground on ring is not impulsive during impact.

From linear momentum conservation in horizontal direction,

we have

$(-2 \times 1) + (0.1 \times 20)$

$= (0.1 \times 0) + (2 \times v)$

Here, v is the velocity of CM of ring after impact.

Solving the above equation, we have

$v = 0$

Thus CM becomes stationary.

∴ Correct answer is (a).

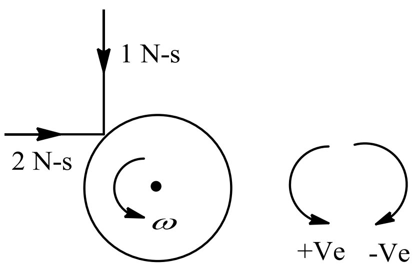
Linear impulse during impact

(i)In horizontal direction

$J_1 = \Delta p = 0.1 \times 20 = 2\ \text{N} - \text{s}$

(ii)In vertical direction

$J_2 = \Delta p = 0.1 \times 10 = 1\ \text{N} - \text{s}$



Writing the equation (about CM)

Angular impulse = Change in angular momentum

We have

$$1 \times \left(\frac{\sqrt{3}}{2} \times \frac{1}{2}\right) - 2 \times 0.5 \times \frac{1}{2}$$
$$= 2 \times (0.5)^2 \left[\omega - \frac{1}{0.5}\right]$$
Solving this equation ω becomes out ot be positive or ω anti-clockwise. So just after collision rightwards slipping is taking place. Hence, friction is leftwards. Therefore, option (c) is also correct.
∴ Correct options are (a) and (c).

319 **(b,d)**
M.I. decreases and angular velocity increases

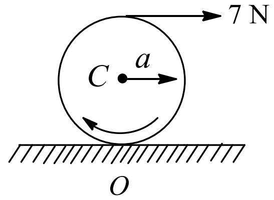
320 **(a,b,c)**
In the absence of external forces: $a_{CM} = 0$
$\left(\because \sum F_{ext} = Ma_{CM}\right)$
So CM will not accelerate. But if the system was moving initially, it will continue to move with same velocity

321 **(b,d)**
As $h = \frac{(v \sin 45°)}{2g} = \frac{v^2}{4g}$
and $L = mv\, r \sin\theta = (m \cos 45°)h$
$= \frac{mv}{\sqrt{2}} \cdot \left(\frac{v^2}{4g}\right) = \frac{mv^3}{4\sqrt{2}},$
Also, $L = mv\, r \sin\theta = (mv \cos 45°)h$
$= \frac{mv}{\sqrt{2}} . h$ and $v = \sqrt{4\,gh}$
$\therefore\ L = \frac{m}{\sqrt{2}} h . \sqrt{4gh} = m\sqrt{2gh^3}$

322 **(b,c)**
When the second body is at rest, velocities after the elastic collision are given by
$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1$ and $v_2 = \left(\frac{2m_1}{m_1 + m_2}\right) u_1$
It is obvious that both bodies move after the collision. If $m_1 = m_2$, then $v_1 = 0$ and $v_2 = u_1$.
Further, v_2 cannot be zero. So, options (b) and (c) are correct

323 **(b,d)**
In the first case : $(m + m)v_1 = mv_0 \Rightarrow v_1 = \frac{v_0}{2}$
In the second case:
$-\int T\, dt = (m + m)v - mv_0$ (i)
$\int T dt = 2\, mv$ (ii)
From Eqs. (i) and (ii),
$4\, mv = mv_0 \Rightarrow v = \frac{v_0}{4}$ and required ratio = 2

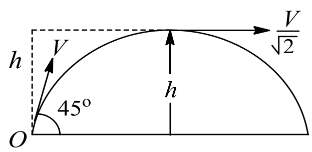
324 **(a,b,d)**
The point of contact between the sphere and the surface slips to the left. So, the frictional force f acts towards the right



If a is the linear acceleration of the centre of mass, then considering translational motion, we get
$7 + f = 1 \times a$ or $7 + f = a$ (i)
Considering rotational motion about centre C, we get
Net torque $= 7R - fR = I\alpha$
$R[7 - f] = \left[\frac{2}{3} \times 1 \times R^2\right] \frac{a}{R}$
$7 - f = \frac{2}{5} a$ (ii)
Adding Eqs.(i) and (ii), we get
$14 = \frac{7a}{5}$ or $a = 10\ \text{m/s}^2$
From Eq. (i), $7 + f = 10$ or $f = 3$ N

325 **(b,d)**
When the particle just reaches the top of the wedge
$mu = (m + nm)v$ (i)
Apply conservation of energy
$\frac{1}{2} mu^2 = \frac{1}{2}(M + m)v^2 + mgh$
Solve to get $u = \sqrt{2gh\left(1 + \frac{1}{n}\right)}$
Angle of projection w.r.t. wedge. But angle of projection as observed by the ground will be less than α because horizontal component velocity will be more in this case
$\vec{v}_{\text{block/ground}} = \vec{v}_{\text{block/wedge}} + \vec{v}_{\text{wedge/ground}}$

326 **(b,d)**
Angular momentum=
(momentum)×(perpendicular distance of the line of action of momentum from the axis of rotation)



Angular momentum about $O, L = \frac{mv}{\sqrt{2}} \times h$ (i)
Now, $h = \frac{V^2 \sin^2\theta}{2g} = \frac{V^2}{4g}$
$[\because \theta = 45°]$
From Eqs. (i) and (ii) , we get
$L = \frac{mv}{\sqrt{2}}(2\sqrt{gh})h = m\sqrt{2gh^3}$
Also from Eqs. (i) and (ii), we get
$L = \frac{mV}{\sqrt{2}} \times \frac{V^2}{4g} = \frac{mV^3}{4\sqrt{2}g}$

327 **(a,c,d)**

Since, the spool rolls over the horizontal surface, instantaneous axis of rotation passes through the point of contact of spool with the horizontal surface

About the instantaneous axis of rotation, moment produced by F is clockwise. Therefore, the spool rotates clockwise. In that case, acceleration will be rightward and thread will wind

If rotation motion of the spool is considered about its own, then the resultant moment on it must be clockwise. But moment produced by the force is anticlockwise and its magnitude is equal to F_1/r. Hence, moment produced by the friction (about its own axis) must be clockwise and its magnitude must be greater than Fr. It is possible only when friction acts leftwards. Therefore, option (b) is correct

328 **(a,d)**

Let at an instant 't', velocity of cart be v. Due to the sand falling on the cart, it experiences a retarding force, which is equal to μv. It means net accelerating force on the cart is equal to $(F - \mu v)$. But at this instant, mass of the loaded cart is equal to $(m_0 + \mu t)$

Therefore, acceleration at time t will be equal to $\frac{(F-\mu v)}{(m_0+\mu t)}$. It means option (b) is incorrect.

If in the above equation, t is substituted as zero, then initial acceleration of the cart is

$$a_0 = \frac{(F - \mu v)}{m_0}$$

But an initial moment, speed of flat cart is equal to zero. Hence, the initial acceleration becomes F/m_0. It means, option (a) is correct

If we consider a system of flat cart and falling sand particles, then sand particles exert a retarding force on the cart which is equal to μv and the cart exerts an accelerating force on sand particles which is also equal to μv. It means the only external force or the only resultant force acting on the system is equal to F

It means the momentum of the system at any instant t will be equal to impulse of the force F. Hence, option (d) is correct

The collision of the sand particles with the cart is perfectly inelastic because just after falling on the cart, sand particles start to move horizontally rightward with the cart while just before coming onto the cart, these sand particles have zero horizontal velocity. It means there is a loss of energy during the collision. Hence, kinetic energy of the loaded cart at an instant will be less than the work done by the force F up to that instant. Hence, option (c) is incorrect

329 **(c,d)**

In rolling without slipping, no work is done against friction. Hence, loss in gravitational potential energy of a body is equal to its total kinetic energy, i.e., linear plus rotational kinetic energies

Also, $v = \omega r$

Total kinetic energy $=\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

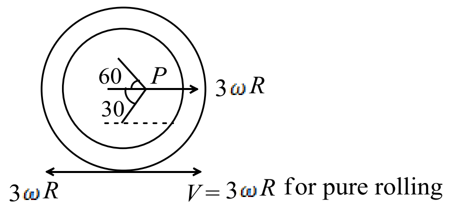
$$= \frac{1}{2}mv^2 + \frac{1}{2}(mK^2)\left(\frac{v^2}{r^2}\right)$$

$$= \frac{1}{2}mv^2\left[1 + \frac{K^2}{r^2}\right]$$

Where K = radius of gyration

As all the bodies have the sane final total kinetic energy, their final velocities will depend upon the ratio K/r. Bodies with the smaller value of K/r will have the greater v and hence will reach the bottom earlier

330 **(a,b)**



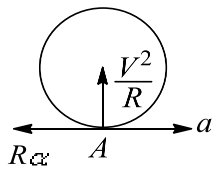
$V_0 = 3\omega R\hat{\imath}$

$$V_P = \left(3\omega R - \frac{\omega R}{2}\cos 60°\right)\hat{\imath} + \frac{\omega R}{2}\sin 60\hat{\jmath}$$

$$= \frac{11\omega R}{4}\hat{\imath} + \frac{\sqrt{3}\omega R}{4}\hat{\imath}$$

331 **(a,b,c,d)**

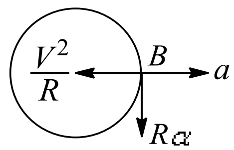
At A:



For a rolling wheel, $a = R\alpha$

Therefore, option (a) is correct

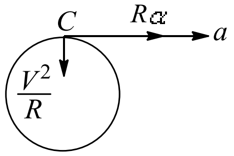
At B:



If $V^2/R = a$, then $a_B$may be vertically downwards

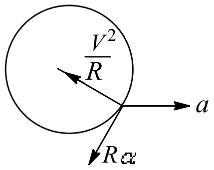
Therefore, option (b) is correct

At C:



Therefore, option (c) is correct

Consider this diagram:

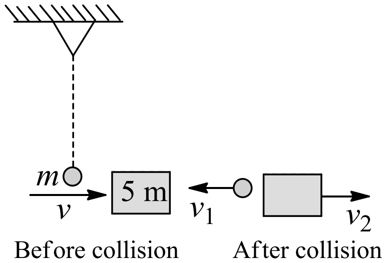


Therefore, option (d) is correct

332 **(a,d)**

The velocity of bob just before the impact is

$v = \sqrt{2gl}$ along the horizontal direction



From momentum conservation,

$mv = -mv_1 + 5\,mv_2$

From coefficient of restitution equation,

$1 = \frac{v_1 + v_2}{v} \Rightarrow v_1 + v_2 = v$

Solving above equations, we get $v_1 = \frac{2v}{3}$

$v_2 = \frac{v}{3}$

For tension in string, $T = mg = \frac{mv_1^2}{l}$

$\Rightarrow\ T = \frac{17}{9}mg$

Let the maximum height attained by the bob be h, then $\frac{mv_1^2}{2} = mgh$

$\Rightarrow\ h = \frac{4l}{9}$

333 **(d)**

$|(m_1\vec{v}_1 + m_2\vec{v}_2)| - |(m_1\vec{v}_1 + m_2\vec{v}_2)|$

= |change in momentum of the two particles|

=|external force on the system|× time interval

$= (m_1 + m_2)g(2t_0) = 2(m_1 + m_2)gt_0$

334 **(a,b)**

In rolling motion force of friction opposes translatory motion but helps in rotational motion. Thus, it wants to decrease the linear velocity but tends to increase the angular velocity

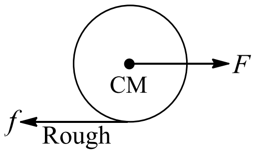
335 **(a,b,c)**

This relation is applicable to a body undergoing any kind of motion

336 **(a,b,c,d)**

Acceleration of centre of mass,

$$a_c = \frac{F}{M}\frac{1}{1 + \frac{K^2}{R^2}} = \frac{5F}{7M}\left(\because K = \sqrt{\frac{2}{5}}R\right)$$



Frictional force, $f = F\left[\frac{1}{1+\frac{R^2}{K^2}}\right] = \frac{2F}{7}$

Since $f = +$ve, friction is directed backward

Option (a), (b), (c) and (d) are incorrect. So option (a), (b), (c) and (d) are the correct options

337 **(a,b,c,d)**

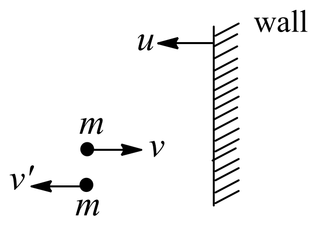
When the particle strikes at one end of the rod then an impulse is exerted by the particle on the rod along the direction of its original motion. An equal but opposite impulsive reaction is exerted by the rod on the particle. If system of rod and the particle is considered, then there is no external impulse on the system, hence momentum of the system remains conserved. Hence, option (a) is correct

Since, both the impulsive reactions act at the same point, one acts on the rod and other on the particle, hence no angular impulse is produced by these impulsive reaction about any point. It means, angular momentum of the system remains conserved about every point. Hence, option (b) and (c) are correct

338 **(b,c)**

In an elastic collision: $v_{\text{sep}} = v_{\text{app}}$

Or $v' - u = v + u$ or $v' = v + 2u$



Change in momentum of ball is

$|p_f - p_t| = |m(-v') - mv| = m(v' + v)$

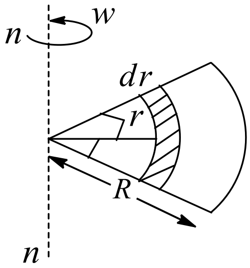
$= 2\,mu(u + v)$

Average force is $\frac{\Delta P}{\Delta t} = \frac{2m(u+v)}{\Delta t}$

Change in KE, $K_f - K_i = \frac{1}{2}mv'^2 - \frac{1}{2}mv^2 = 2m\,u(u + v)$

339 **(a)**

We cannot consider the quadrant as a single mass as the distance of different particles is different from the axis of rotation. So we take the help of calculus. Let us consider a segment as shown in Figure. All masses lying in this segment are at a distance r from the axis and hence considerd as a small differential mass dm. Let the thickness of the segment be dr



The mass per unit area of the quadrant
$=\frac{M}{\pi R^2/4}=\frac{4M}{\pi R^2}$

Area of the segment $=\frac{1}{4}[\pi(r+dr)^2-\pi r^2]=\frac{1}{4}\times 2\pi dr=\frac{\pi r dr}{2}$

Mass of the segment $dm=\frac{\pi r dr}{2}\times\frac{4M}{\pi R^2}=\frac{2M}{R^2}r^2dr$

MI of this segment about $nn'=\frac{2M}{R^2}rdr\times r^2\frac{2M}{R^2}r^2dr$

MI of the quadrant about $nn'=\int_0^R\frac{2M}{R^2}r^2d$

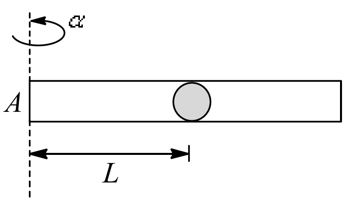
$=\frac{2M}{R^2}\times\frac{R^4}{4}\times\frac{MR^2}{2}$

340 **(b,d)**

The force of friction between the two surfaces in contact disappears when there is no relative (linear) motion between them. Angular momentum will not be conserved as the discs will have the final angular velocities in the opposite directions

341 **(a)**

When we are giving an angular acceleration to the rod, the bead is also having an instantaneous acceleration $a=L\alpha$. This will happen when a force is exerted on the bead by the rod. The bead has a tendency to move away from the centre. But due to friction between the bead and rod, this does not happen to the extent to which frictional force is capable of holding the bead. The frictional force here provides the necessary centripetal force. If the instantaneous angular velocity is ω, then



$mL\omega^2=\mu(ma)=\mu mL\alpha$

$\Rightarrow \omega^2=\mu\alpha$

By applying $\omega=\omega_0+\alpha t$, we get $\omega=\alpha t$

$\therefore \alpha^2t^2=\mu\alpha\Rightarrow t=\sqrt{\frac{\mu}{\alpha}}$

342 **(c)**

In an inelastic collision, only momentum of the system may remain conserved. Some energy can be lost in the form of heat, sound, etc

343 **(a,c)**

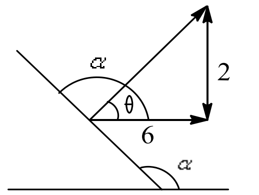
Impulse is change in momentum. Hence, impulse $=2(\vec{v}_2-\vec{v}_1)=2(3\hat{\imath}+\hat{\jmath})$

As impulse is in the normal direction of colliding surface

$\tan\theta=\frac{1}{3}$

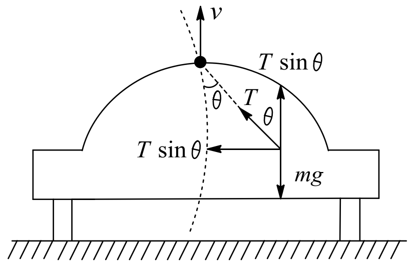
$\theta=\tan^{-1}\left(\frac{1}{3}\right)$

$\alpha=90°+\tan^{-1}\left(\frac{1}{3}\right)$



344 **(c)**

When the car is moving in a circular horizontal track of radius 10 m with a constant speed, then the bob is also undergoing a circular motion. The bob is under the influence of two forces



i. T (tension in the rod)

ii. mg(weight of the bob)

Resolving tension, we get

$T\cos\theta=mg$ (i)

and $T\sin\theta=\frac{mv^2}{r}$ (ii)

(Here $T\sin\theta$ is producing the necessary centripetal force for the circular motion)

Dividing Eqs. (i) and (ii), we get

$\tan\theta=\frac{v^2}{rg}=\frac{10\times10}{10\times10}=1\Rightarrow\theta=45°$

345 **(c)**

As the spheres are smooth, there will be no transfer of angular momentum. Thus, A, after collision, will remain with its initial angular momentum

346 **(a,c)**

a. As $\sum \vec{P} = 0$ and $\vec{P}_1 + \vec{P}_2 \neq 0, \vec{P}_3$ cannot be zero

b. For any system of two or more than two particles, KE can change due to work done by internal forces while the centre of mass remains at rest

c. $\vec{a}_{CM} = 0 \Rightarrow E\vec{F}_{ext} = 0$

d. It is possible to have changing speed of CM without any work done by ext. forces on the system. When a person accelerates himself on a rough horizontal surface without any flipping between his shoes and ground, work done by friction, normal reaction and weight all are zero but speed of centre of mass changes

347 **(a,b,c)**

Weight of the particle is balanced by normal reaction of the floor. Hence, the resultant force acting on the particle is provided by the tension in the thread

The line of acting of this tension passes through $'B'$. Hence, the tension produces a moment about B. It means, angular momentum about B does not remain conserved. The tension always produces a moment about O. Magnitude of this moment is equal to TR in an anticlockwise direction. Hence, options (a), (b) and (c) are incorrect. Since neither external work is done on the particle nor energy is lost against friction, therefore KE of the ball remains constant. Hence, option (d) is correct

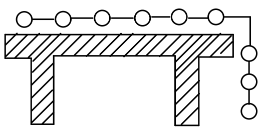
348 **(d)**

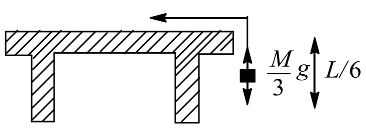
Method I:

The hanging part of the chain which is to be pulled can be considered as a point mass situated at the centre of the hanging part. The equivalent diagram is drawn The work done in bringing the mass up will be equal to the change in potential energy of the mass

$W =$ Change in potential energy

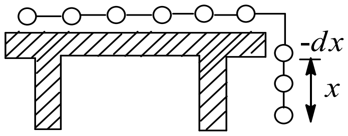
$= \frac{M}{3} \times g \times \frac{L}{6} = \frac{MgL}{18}$





Method II:

The mass per unit of the chain$= M/L$. Let us consider a finitesimally small length of the chain dx at a distance x from the bottom. To move dx to the top, a force equal to the weight of chain x will have to be applied upwards



Weight of chain of length $x = \left(\frac{M}{L}x\right)g$

Small amount of work done in moving dx to the top

$dW = \vec{F} \cdot \overrightarrow{dx} = F\,dx = \left(\frac{M}{L}x\right)g\,dx$

The total amount of work done in moving the one-third length of the hanging chain on the table will be

$W = \int_0^{L/3} \frac{M}{L} xg dx = \frac{M}{L} g$

$\int_0^{L/3} x\,dx = \frac{M}{L} g \left[\frac{x^2}{2}\right]_0^{L/3} = \frac{MgL}{18}$

349 **(a,b,c)**

$\vec{\tau} = \frac{d\vec{L}}{dt}$

Given that $\vec{\tau} = \vec{A} \times \vec{L}$

$\Rightarrow \frac{d\vec{L}}{dt} = \vec{A} \times \vec{L}$

From the cross-product rule, $\frac{d\vec{L}}{dt}$ is always perpendicular to the plane containing $\vec{A}$ and $\vec{L}$. By the dot product definition, $\vec{L} \cdot \vec{L} = \vec{L}$

Differentiating with respect to time, we get

$\vec{L}\frac{d\vec{L}}{dt} + \vec{L}\frac{d\vec{L}}{dt} = 2L\frac{\overrightarrow{dL}}{dt}$

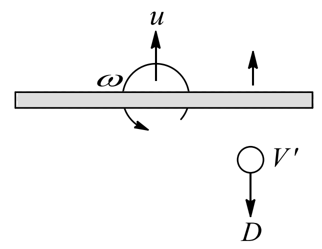
$2\vec{L}\frac{\overrightarrow{dL}}{dt} = 2L\frac{dL}{dt}$

Since $d\vec{L}/dt$ is perpendicular to $\vec{L}$

$\Rightarrow \frac{dL}{dt} = 0 \Rightarrow L =$ constant

350 **(a,b,c)**

The ball has V' component of its velocity perpendicular to the length of the rod immediately after collision. u is the velocity of CM of the rod and ω is angular velocity of the rod just after collision. The ball strikes the rod with a speed of $v \cos 53°$ in the perpendicular direction and its component along the length of the after the collision is unchanged



Using for the point of collision

Velocity of separation= Velocity of approach

$\frac{3V}{5} = \left(\frac{\omega l}{4} + u\right) + V'$ ...(i)

Conserving linear momentum (of rod+ particle) in the direction perpendicular to the rod

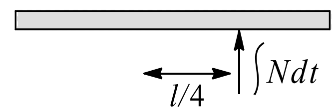
$mV\frac{3}{5} = mu - mV'$ ...(ii)

Conserving angular momentum about point $'D'$ as shown in the figure

$$0 = 0 + \left[mu\frac{l}{4} - \frac{ml^2}{12}\omega\right] \Rightarrow u = \frac{\omega l}{3}$$

$$\Rightarrow u = \frac{24V}{22}, W = \frac{75V}{55l}$$

Time taken rotate by π angle, $t = \frac{\pi}{\omega}$



In the same time, distance travelled $= u_2 t = \frac{\pi l}{3}$

Using angular impulse- angular momentum equation

$$\int Ndt\frac{l}{4} = \frac{ml^2}{4}.\frac{72V}{55l}\omega$$

$$\left\{\because \int Ndt\frac{l}{4} = \frac{24mV}{55}\right\}$$

[Using impulse-momentum equation on the rod $\int Ndt = mu = \frac{24mv}{55}$]

351 **(c,d)**

In option (a), neither momentum nor kinetic energy is conserved so collision is not elastic. Hence, option (a), is not correct

b. Same difficulty lies with option (b). So, only options (c) and (d) are correct

352 **(b,c,d)**

Let P = external force, F = force of friction between A and B, a_1=acceleration between A and B, a_2= acceleration beyond B

$P - F = ma_1$

$P = ma_2$

$a_2 > a_1$

Let α = angular acceleration between A and B

For one rotation, $\theta = 2\pi = \frac{1}{2}\alpha T^2$

$T = \sqrt{\frac{4\pi}{\alpha}}$ = time of travel from A to B

Angular velocity at $B = \omega_B = \alpha T$

For one rotation to the right of B,

$\theta = 2\pi = \omega_B t$

$$t = \frac{2\pi}{\alpha T} = \frac{\frac{1}{2}\alpha T^2}{\alpha T} = \frac{T}{2}$$

353 **(b,c)**

The general form of Newton's second law is

$$\vec{F}_{\text{ext}} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}$$

The form $\vec{F}_{\text{ext}} = m\vec{a}$ is valid only if $\frac{dm}{dt} = 0$, i.e., mass does not change with time. Hence, option (a) is incorrect.

Option (b) is correct because a body at rest may have potential energy yet no momentum. Option (c) is also correct. A body has momentum if it has mass and velocity and a body having mass and velocity must have kinetic energy. Option (d) is incorrect because the relative velocity remains unchanged in magnitude and gets reversed in direction

$v_2 - v_1 = -(u_2 - u_1)$

Hence, the correct options are (b) and (c)

354 **(a,c)**

From theory of rolling motion without slipping speed of particle at point of contact A is zero and at the top point C speed is $2v_0$. Moreover, speed of point O is $\vec{v}_0$ but that of B is $v_0\sqrt{2}$

355 **(a,b,c)**

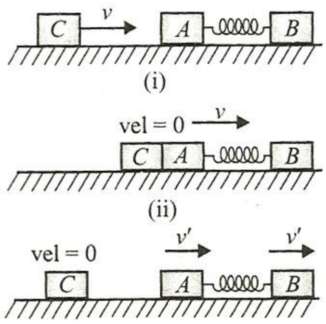
When the ball collides with the ground elastically, then a force is exerted by the ground on the ball along the vertical upward direction. An equal but opposite reaction is offered by the ball on the ground. Therefore, there is no resultant force on the system of ball and ground. Hence, the momentum of universe remains constant. Hence, option (a) is correct.

Since during collision, a force is exerted by the ground on the ball, therefore due to this impulsive reaction, momentum of the ball gets changed

If the ball collides with the ground with velocity v, then change in momentum of the ball is equal to 2 mv and this change takes place along vertically upward direction. Hence momentum of the ball does not remain conserved. Therefore, option (b) is correct During the collision, at an instant, centre of mass of the ball comes to rest. At that instant the ball has the maximum deformation. Due to that deformation, the ball tries to regain its original shape. Hence, it gets rebound. Hence, at an instant, during the collision, the whole of KE gets converted into its deformation energy which ultimately converts into KE. Therefore, option (c) is correct

356 **(b,d)**

In situation (i), mass C is moving towards right with velocity v. A and B are at rest. In situation (ii), which is just after the collision of C with A, C stops and A acquires a velocity v. When A starts moving towards right, the spring suffers a compression due to which B also starts moving towards right. The compression of the spring continues till there is a relative velocity between A and B. Once this relative velocity becomes zero, both A and B move with the same velocity v' and the spring is in a state of maximum compression



Applying momentum conservation in situations (ii) and (iii),

$$mv = mv' + mv' \Rightarrow v' = \frac{v}{2}$$

Therefore, KE of the system in situation (iii) is

$$\frac{1}{2}mv'^2 + \frac{1}{2}mv'^2 = mv'^2 = \frac{mv^2}{4}$$

Applying energy conservation, we get

$$\frac{1}{2}mv^2 = \frac{1}{2}mv'^2 + \frac{1}{2}mv'^2 + \frac{1}{2}Kx^2$$

Solve to get $x = v\sqrt{\frac{m}{2K}}$

357 **(a,b,c)**

According to the theorem of perpendicular axis: Moment of inertia of the plate about an axis passing through centre O and perpendicular to the plate is $I_0 = I_1 + I_2 = I_3 + I_4$. (Because diagonals 1 and 2 as well as 3 and 4 are mutually perpendicular)

Now, according to symmetry,

$I_1 = I_2 = I$(say)

and $I_3 = I_4 = I'$(say)

For a square plate

$$I_0 = \frac{M(L^2 + L^2)}{12} = \frac{ML^2}{6}$$

Hence, $I = I' = \frac{ML^2}{12}$

i.e., $I_1 = I_2 = I_3 = I_4 = \frac{ML^2}{12}$

Hence, $I_0 = I_1 + I_2 = I_3 + I_4 = I_1 + I_3$

i.e., options (a), (b), and (c) are correct

358 **(c,d)**

The velocity of the disc when rolling beings can be obtained using the conservation of angular momentum principle about the point through which the friction force acts. So, the coefficient of friction has no bearing on the final velocity. The work done by the force of friction will simply be changed to kinetic energy

359 **(b,c)**

The initial velocity of CM is upward. The acceleration of the CM is 'g' downward

360 **(b,c)**

In case of a wheel rolling on a horizontal plane, instantaneous axis of rotation of the wheel passes through A(point of contact of wheel with plane). But at A, acceleration is vertically upwards. It means, acceleration at A has non-zero value. Hence, option (a) is incorrect

If the point is at a distance r from the instantaneous axis of rotation, then its velocity (relative to the axis) will be equal to $r\omega$. But by definition, every point lying on the instantaneous axis of rotation is at rest at that instant. Therefore, the resultant velocity of the particle becomes equal to that relative velocity $r\omega$. Hence, option (b) is correct

If distance of centre of mass of a body from the instantaneous axis of rotation is equal to r and if its moment of inertia parallel to instantaneous axis of rotation but passing through centre of mass is equal to I_0, then $I = (I_0 = mr^2)$

Rotational KE of the body will be equal to $I_0\omega^2/2$ and translation KE of the body will be $mv^2/2$, where $v = r\omega$. Therefore, translation KE becomes equal to $mr^2\omega^2/2$. Hence, the total KE becomes equal to $(I_0\omega^2/2) + (mr^2\omega^2/2) = I\omega^2/2$

Hence, option (c) is correct

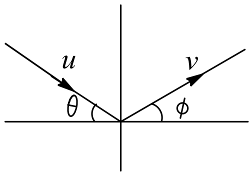
In case of a wheel rotating on a plane, instantaneous axis of rotation of the wheel passes through A which the centre of mass is at distance R from A. In that case, the moment of inertia about instantaneous axis of rotation is equal to $I = (I_0 + mR^2)$, where I_0 is moment of inertia about the centroidal axis. Hence, moment of inertia of the wheel about the instantaneous axis of rotation is greater than the minimum possible value. Hence, option (d) is incorrect

361 **(a,c)**

There will be exchange of linear velocities only. However, the two spheres cannot exert torque on each others, as their surfaces are frictionless and the angular velocities of the spheres do not change

362 **(a,b,d)**

$v \sin \varphi = eu \sin \theta, v \cos \varphi = u \cos \theta$



$v = u\sqrt{\cos^2 \theta + e^2 \sin^2 \theta}$

$= u\sqrt{1 - \sin^2 \theta + e^2 \sin^2 \theta}$

$= u\sqrt{1 - (1 - e^2) \sin^2 \theta}$

$I = m(v \sin \phi + u \sin \theta) = mu \sin \theta (1 + e)$

Ratio of KE $= \frac{\frac{1}{2}mv^2}{\frac{1}{2}mu^2} = \cos^2 \theta + e^2 \sin^2 \theta$

363 **(a,b,c,d)**

Equating loss of gravitational potential energy with the gain of rotational kinetic energy, we get

$\frac{1}{2}I\omega^2 = \frac{1}{2}mgl$

$\frac{1}{2} \times \frac{ml^2}{3} \times \omega^2 = \frac{1}{2}mgl$

$\omega = \sqrt{\frac{3g}{l}}$

Rotational kinetic energy $= \frac{1}{2}\frac{ml^2}{3}\omega^2 = \frac{ml^2\omega^2}{6}$

364 **(a,b,c,d)**

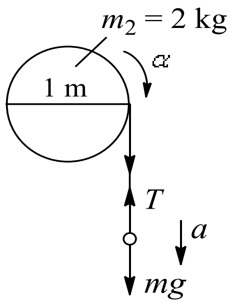
By FBD of particle,

$mg - T = ma$ ...(i)

By FFD of the disc,

$TR = I\alpha = I\frac{a}{R} \Rightarrow T = \frac{mR^2}{2}\frac{a}{R^2}$

$T = \frac{ma}{2} = a$



By Eqs. (i) and (ii), we get the following results

1. 5 m/s^2 and □ = 5 N

   and $\alpha = \frac{a}{R} = 5$ rad/s^2

2. For angular displacement of disc:

   $\theta = \omega t + \frac{1}{2}\alpha t^2$

   $= \frac{1}{2} \times 5 \times 4^2 = 40$ rad

3. Work done by torque is

   $f\tau d\theta = \tau \int d\theta = 5 \times 40 = 200$ J

4. ΔKE = Δ□ = 200 J

   $k_2 - k_1 = 200$ J

365 **(c,d)**

$mgh = 1/2mv^2[1 + (k^2/R^2)], k$ =radius of gyration. For all solid sphere, $k/R = 2v^2/5$= independent of m and R

366 **(b,d)**

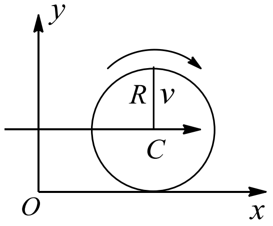
Whenever two particles having equal mass collide head on elastically, their velocities get interchanged. Therefore, if the particle collides at midpoint of the rod, then velocities would get interchanged. In that case option (a) would be correct. But now the particle strikes at an end of the rod, hence particle head-on collision does not take place. Therefore, option (a) is incorrect

It the particle gets rebound back to its original path, then its final momentum will become negative. Since mass of the particle and rod is equal, therefore law of conservation of momentum will be satisfied only when velocity of centre of mass of the rod is greater than original velocity of the particle. Hence, kinetic energy of the system (just after collision) will become greater than that (just before the collision), which is impossible. Hence, the particle cannot rebound back or it will continue but option (c) is incorrect.

If the particle gets stick to the rod, centre of mass of the system will lie a distance $l/4$ from the end at which the particle sticks. According to the law of conservation of momentum, centre of mass will start to move with velocity $v/2$. But the particle will simultaneously start to rotate about the centre of mass in an anticlockwise direction. Angular velocity ω of that rotational motion can be calculated by applying law of conservation of angular momentum. Hence, the resultant velocity of the midpoint of the rod will be equal to $[(v_0/2 - (l\omega/4)]$, which is obviously $v_0/2$. Therefore option (d) is correct

367 **(c)**

The disc has two types of motion, namely, translational and rotational. Therefore, there are two types of angular momentum and the total angular momentum is the sum of these two



$L = L_T + L_R, L_T$ =angular momentum due to translational motion

L_R =angular momentum due to rotational motion about CM $L = MV \times R + I_{\text{CM}}\omega I_{\text{CM}}$

$= MI$ about centre of mass C

$= M(R\omega)R + \frac{1}{2}MR^2\omega(V = R\omega$ in case of rolling motion and surface at rest)

$= \frac{3}{2}MR^2\omega$

368 **(a,b,c,d)**

Since the system of two blocks and a spring is placed on a smooth horizontal floor, therefore no external horizontal force acts on the system. Since the system is initially at rest, therefore centre of mass of the system will remain stationary and the block will oscillate with the same frequency. It means option (d) is correct. Since the system, is initially at rest and centre of mass stationary, therefore centre of mass cannot move or the momentum of the system remains equal to zero. It means, momenta of two blocks are numerically equal but they are in opposite directions. Therefore, ratio of magnitude of velocity of the two blocks will be in inverse ratio of their masses. Hence, option (a) is correct. Since ratio of mass is constant, therefore the ratio of their velocity will remain constant. It means that option (b) is also correct

Since the system is on smooth horizontal floor, therefore no energy loss takes place. Hence, linear momentum and energy of the system remain conserved. Therefore, option (c) is also correct

369 **(a,d)**

In rolling with slipping, the force of friction produces a torque which gives an angular acceleration to the body. Hence, part of the work done against friction is converted into rotational kinetic energy, which adds to the total kinetic energy. Only the remaining part of the work done against friction is converted into heat

370 **(c)**

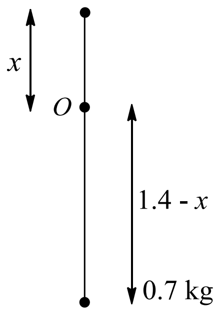
The moment o inertia of the system about axis of rotation O is

$I = I_1 + I_2$

$= 0.3x^2 + 0.7(1.4 - x)^2$

$= 0.3x^2 + 0.7\ (1.96 + x^2\ - 2.8\pi)$

$= x^2 + 1.372 - 1.96x$



The work done in rotating the rod is converted into its rotational kinetic energy

$\therefore W = \frac{1}{2}I\omega^2 = \frac{1}{2}[x^2 + 1.372 - 1.96x]\omega^2$

For work done to be minimum

$\frac{d\omega}{dx} = 0$

$\Rightarrow 2x - 1.96 = 0$

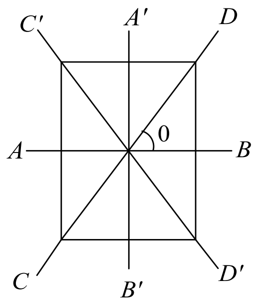
$\Rightarrow x = \frac{1.96}{2} = 0.98$ m

371 **(a)**

$A'B' \perp AB$ and $C'D \perp CD$

From symmetry, $I_{AB} = I_{A'B'}$ and $I_{CD} = I_{CD'}$

From theorem of perpendicular axis,



$I_{zz} = I_{AB}I_{A'B'} = I_{CD} + I_{CD'}$

$\Rightarrow 2I_{AB} = 2I_{CD}$

$\therefore I_{AB} = I_{CD}$

Alternative method:

The relation between I_{AB} and I_{CD} should be true for all values of θ

At $\theta = 0, I_{CD}\ = I_{AB}$

Similarly, at $\theta = \frac{\pi}{2}$

$I_{CD} = I_{AB}$(By symmetry)

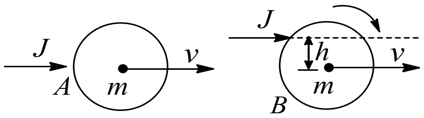
Keeping these things in mind. Only option (a) is correct

372 **(a,b)**

Distribution is uniformly uneven. Heavier part will have the CM closer than the lighter part

373 **(a,b,d)**

$J = mv$ for both. Sphere A has no angular motion. For sphere B, angular momentum imparted by $J = L = Jh$



374 **(c,d)**

All point in the body, in plane perpendicular to the axis of rotation, revolve in concentric circles. All points lying on the circle of same radius have same speed (and also same magnitude of acceleration) but different directions of velocity Hence there cannot be two points in the given plane with same velocity or with same acceleration. As mentioned above, points lying on circle of same radius have same speed

Angular speed of body at any instant w.r.t. any point on the body is same by definition

375 **(b)**

The MI about the axis of rotation is not constant as the perpendicular distance of the bead with the axis of rotation increases

Also since no external torque is acting, therefore

$\tau_{\text{ext}} = \dfrac{dL}{dt}$

$\Rightarrow L =$constt

$I\omega =$comstt

Since l increases, ω decreases

376 **(b,c)**

If $\vec{F}_{\text{ext}} = 0$, then acceleration of centre of mass of the system must be zero, but its speed may be either zero or may have a constant value in a given direction

377 **(a,c)**

Since both masses have equal kinetic energy, so

$\dfrac{1}{2}m_1u_1^2 = \dfrac{1}{2}m_2(\alpha u_1)^2$

$\Rightarrow\ m_2 = \frac{m_1}{\alpha^2}$ (i)

By law of conservation of momentum

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1u_1 + \dfrac{m_1}{\alpha^2}(\alpha u_1) = 0 + \left(\dfrac{m_1}{\alpha^2}\right)v_2$

$v_2 = \alpha u_1(1+\alpha)$ (ii)

Further by law of conservation of energy we have

$\dfrac{1}{2}m_1u_1^2 + \dfrac{1}{2}\left(\dfrac{m_1}{\alpha^2}\right)(\alpha u_1)^2 = 0 + \dfrac{1}{2}\left(\dfrac{m_1}{\alpha^2}\right)v_2^2$

$m_1u_1^2 = \dfrac{1}{2}\left(\dfrac{m_1}{\alpha^2}\right)v_2^2$

$v_2 = \sqrt{2}(\alpha u_1)$ (iii)

From Eqs. (ii) and (iii), we get

$\dfrac{v_2}{\alpha u_1} = \sqrt{2} = 1 + \alpha \Rightarrow \alpha = \sqrt{2} - 1$

$\dfrac{u_2}{u_1} = \sqrt{2} - 1$

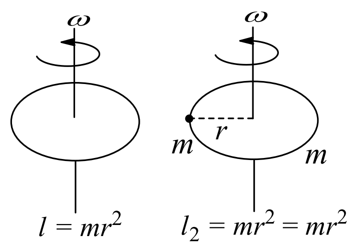
$\dfrac{u_1}{u_2} = \sqrt{2} + 1$ [on rationalising]

$\dfrac{m_2}{m_1} = \dfrac{1}{\alpha^2} = \left(\dfrac{1}{\sqrt{2}-1}\right)^2 = \left(\sqrt{2}+1\right)^2$

$\dfrac{m_2}{m_1} = 3 + 2\sqrt{2}$

378 **(c)**

Since the objects are placed gently, therefore no external torque is acting on the system. Therefore, angular momentum is constant



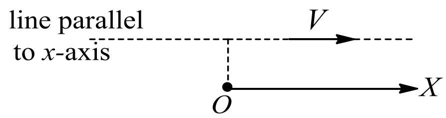
i.e., $I_1\omega_1 = I_2\omega_2$

$Mr^2 \times \omega_1 = (Mr^2 + 2mr^2)\omega_2$

$\therefore\ \omega_2 = \dfrac{M\omega}{M + 2m}$

379 **(b)**

Angular momentum of mass m moving with a constant velocity about origin is



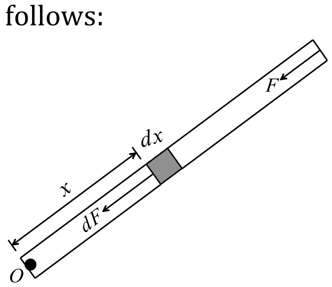
$L =$momentum $\times$ perpendicular distance of line of action of momentum from origin, $L = mv \times y$

In the given condition, mvy is a constant.

Therefore, angular momentum is constant

380 **(a)**

The force acting on the mass of liquid of length dx at a distance x from the axis of rotation O is as follows:



$dF = (dm) \times \omega^2$

$$dF = \frac{M}{L}dx \times x\omega^2$$

Therefore, the fore acting at the other end is for the whole liquid in tube

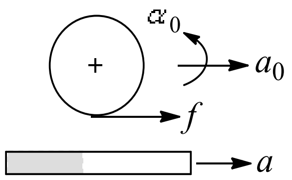
$$F = \int_0^L \frac{M}{L}\omega^2 x dx = \frac{M}{L}\omega^2 \int_0^L x dx$$

$$= \frac{M}{L}\omega^2 \left[\frac{x^2}{2}\right]^L = \frac{M}{L}\omega^2 \left[\frac{L^2}{2} - 0\right]$$

$$= \frac{ML\omega^2}{2}$$

381 **(a,b,c)**

Let the frictional force be in the forward direction, then



$f = ma_0$

and $fR = \frac{MR^2}{2}\alpha_0$

$a_0 = \frac{f}{M}$ and $\alpha_0 = \frac{2f}{MR}$

For pure rolling, $a_0 + R\alpha_0 = a$

$$\frac{f}{M} + \frac{2f}{M} = a \Rightarrow f = \frac{Ma}{3}$$

For pure rolling, $f < f_L = \mu M g$

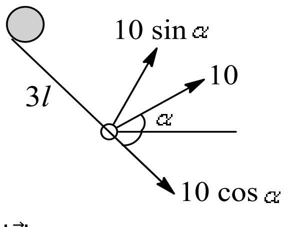
$$\frac{Ma}{3} < \mu M g \Rightarrow a < 3\mu g$$

382 **(a,c,d)**

In an SHM, the maximum velocity is at the equilibrium position

383 **(a,b,d)**

The impulse exerted by the string on the cylinder is equal and opposite to the impulse exerted by the cylinder on the string



$|\vec{J}| = 40000 \times 0.25 \times 10^{-3} = 10$ N s along the string

For marble, $J = 0 - (-2 \times 10 \cos\alpha)$

As final velocity of marble along the string is zero

Putting, J = 10 Ns we get $\alpha = 60°$

The string wraps up around the cylinder and marble moves in a circular path of varying radius with speed $10 \sin\alpha = 5\sqrt{3}$ m/s. The speed remains constant as only the tension force is present which is perpendicular to the velocity of the marble

For string to break, the impulsive tension has to be

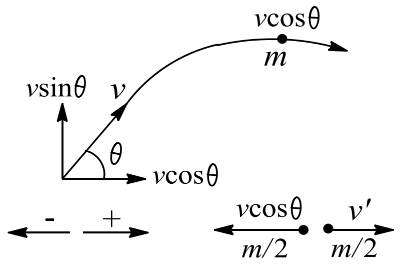
$\geq 2 \times 10^5$ N

$\therefore 40000 \times 0.25 \times 10^{-3} \geq 2 \times 10^5 \times \Delta t$

$\Rightarrow \Delta t \leq 0.05$ ms

384 **(a)**

Applying conservation of linear momentum at the highest point



(At highest point)

$$m(v\cos\theta) = \frac{m}{2} \times v' - \frac{m}{2} v\cos\theta$$

$$3v\cos\theta = v'$$

385 **(c,d)**

Using conservation of linear momentum,

$$mv_0 = (M+m)v$$

$$v = \frac{mv_0}{M+m}$$

KE in centre of mass frame:

$$\text{KE}_c = \frac{1}{2}m(v_0 - v)^2 + \frac{1}{2}Mv^2 = \frac{1}{2}\left(\frac{Mm}{M+m}\right)v_0^2$$

From energy conservation,

$$\frac{1}{2}mv_0^2 - \frac{1}{2}(m+M)v^2 = \frac{1}{2}Kx^2$$

$$\Rightarrow x = v_0\sqrt{\frac{mM}{k(M+m)}}$$

386 **(c,d)**

In an inelastic collision neither momentum of ball nor mechanical energy of ball will remain same. However, total energy and total momentum of earth- ball system will remain constant.

388 **(a,b,d)**

In completely inelastic collision, bodies coalesce

$$m_1u_1 - m_2u_2 = (m_1 + m_2)V$$

$$2 \times 3 - 1 \times 4 = (2+1)V; V = \frac{2}{3}\text{m/s}$$

Net momentum of system $P = m_1u_1 - m_2u_2$

$2 \times 3 - 1 \times 4 = 2$ kg m/s

$$\text{Loss in KE} = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \frac{1}{2}(m_1+m_2)V^2$$

$$= \frac{1}{2} \times 2 \times (3)^2 + \frac{1}{2} \times (1) \times (4)^2 - \frac{1}{2} \times (2+1) \times \left(\frac{2}{3}\right)^2$$

$= 9 + 8 - \frac{2}{3} = 17 - \frac{2}{3} = \frac{49}{3}$J

389 **(a,b,c)**

Each square has a value 2 s × 5 N = 10 N s

a. Area under the curve between 8 s and 12 s $=$ -1 square

b. Area for $t = 8$ s to $t = 16$ s

$= -3$ square$= -30$ N s

As mass $= 2$ kg

Hence, velocity change is given by

$\frac{-30 \text{ N s}}{2 \text{ kg}} = -15$ m/s

c. Area of $t = 0$ to $t = 6$ s is

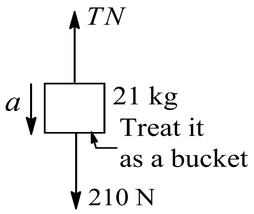
10 square $= 100$N s

Kinetic energy$= \frac{p^2}{2m} = \frac{100\times100}{2\times2} = 2500$ J

390 **(a,b,c,d)**

$210 - T = 32a$ (i)

Again, $\tau = R = I\alpha$



$TR = \frac{Ia}{R}$

$T = \frac{Ia}{R^2} = \frac{\frac{1}{2} \times 2I \times R^2 \times a}{R^2} = \frac{1}{2} \times 2Ia$

$2la = 2T$

From Eq (i), $10 - T = 2T$

or $3T = 210$

or $T = 0$ N

Again from Eq. (i) $210 - 70 = 21\ a$

$a = \frac{140}{21}\text{ms}^{-2} = \frac{20}{3}\text{ms}^{-2}$

391 **(b,a)**

When force F acts vertically downwards on the thread, the thread unwinds and the cylinder rotates clockwise. Hence, its surface tries to slip over the planks in a backward direction. Hence, a friction comes into existence and acts on the cylinder in a forward direction (rightward direction). It is the only horizontal force acting on the cylinder. Due to the friction, cylinder experiences a rightward translational acceleration. But the point at which the friction acts remains always at rest, therefore no energy is lost against the friction

Since the work is done by F and no energy is lost against the friction, therefore total kinetic energy of the cylinder at any instant is equal to work done by F. Hence, options (a) and (c) are incorrect and option (d) is correct

If I is the moment of inertia of a body about its instantaneous axis of rotation, then the total KE of the rotating body is equal to $I\omega^2/2$. Hence, option (b) is correct

392 **(a)**

Explosion is due to internal forces. As no external force is involved, the vertical downward motion of centre of mass is not affected

393 **(c)**

In a whirlwind in a tornado, the air from nearby regions gets concentrated in a small space thereby decreasing the value of its moment of inertia considerably. Since, $I\omega =$ constant, so due to decrease in moment of inertia of the air, its angular speed increases to a high value

If no external torque acts, then

$\tau = 0 \Rightarrow \frac{dL}{dt} = 0$ or $L =$ constant $\Rightarrow I\omega =$ constant

As in the rotational motion, the moment of inertia of the body can change due to the change in position of the axis of rotation, the angular speed may not remain conserved

394 **(c)**

Torque = Force × perpendicular distance of line of action of force from the axis of rotation (d)

Hence for a given applied force, torque or true tendency of rotation will be high for large value of d. If distance d is smaller, then greater force is required to cause the same torque, hence it is harder to open or shut down the door by applying a force near the hinge

395 **(d)**

As x increases, the required component of reaction decreases to zero and then increases (with direction reversed). Hence, statement I is false

396 **(d)**

When particle moves with constant velocity $\vec{v}$ then its linear momentum has some finite value $(\vec{P} = m\vec{v})$

Angular momentum $(L) =$ Linear momentum $(P) \times$ Perpendicular distance of line of action of linear momentum form the point of rotation (d)

So if $d \neq 0$ then $L \neq 0$, but if $d = 0$ then L may be zero. So we can conclude that angular momentum of a particle moving with constant velocity is not always zero

397 **(b)**
If angular velocity is constant, then frictional force acting on the sphere is zero. In case of pure rolling, velocity of contact point is zero

398 **(c)**
$K_N = K_R + K_T$

This equation is correct for any body which is rolling without slipping

For the ring and hollow cylinder only $K_R = K_T$

$i.e. K_N = 2K_T$

399 **(d)**
Velocity of center of mass of a body is constant when no external force acts on the body. If there is no external torque, it does not mean that no external force acts on it

400 **(b)**
Velocity of point of contact $V = (V_{\text{CM}} - \omega R)$

When pure rolling occurs, $V_{\text{CM}} = \omega R$

Hence, $V = 0$

Also frictional force can provide torque which further helps in achieving the pure rolling condition

401 **(a)**
Through bending weight of opponent is made to pass through the hip of judo fighter to make its torque zero

402 **(a)**
Moment of inertia is then sum of $m\, r^2$ terms. We cannot change all the r's, keep m's the same and expect $\Sigma m_i r_i^2$ to remain unchanged

403 **(b)**
In sliding down, the entire PE is converted only into linear KE. In rolling down, a part of same PE is converted into KE of rotation. Therefore, velocity acquired is less. Both the statements are true, but statement-2 is not a correct explanation of statement

404 **(a)**
Sediment deposited at the equator (away from the axis of rotation) increases the moment of inertia (not mass) of the Earth. Since $I\omega$=constant, ω dedcdreases and thus $I = 2\pi/\omega$ increases

405 **(a)**
Position vector of centre of mass depends on masses of particles and their location. Therefore, change in shape/size of body do change the centre of mass

406 **(b)**
The centre of mass of the fragments will continue its parabolic path. After the breakage, fragments may move in different directions. Both statements are correct but Statement II is not the explanation of Statement I

407 **(e)**
The moment of inertia of a particle about an axis of rotation is given by the product of the mass of the particle and the square of the perpendicular distance of the particle from the axis of rotation. For different axis, distance would be different, therefore moment of inertia of a particle changes with the change in axis of rotation

408 **(d)**
A body may not have momentum but may have potential energy by virtue of its position. But if the body has no energy, then its kinetic energy is zero and therefore its momentum is zero

Dimension of momentum= $[MLT^{-1}]$

Dimension of energy= $[ML^2T^2]$

409 **(a)**
The momentum of a system of particles from any frame is given by

$\vec{P} = m\, \vec{v}_{\text{CM}}$

From the centre of mass frame,

$\vec{v}_{\text{CM}} = \vec{O}$

$\Rightarrow\ \vec{P} = 0$

So individual bodies should have momenta in opposite directions to make net momentum zero

410 **(c)**
As the person climbs up, normal reaction and friction between the ladder and the wall both increases. This decreases normal reaction from the floor, decreasing limiting value of friction there. This increases the possibility of the ladder to ship

411 **(e)**
As the shell is initially at rest and after explosion, according to law of conservation of linear momentum, the centre of mass remains at rest. While parts of shell move in all direction, such that total momentum of all parts is equal to zero

412 **(a)**
The assertion is true and reason is correct explanation of the assertion.

413 **(a)**
As the concept of centre of mass is only theoretical, therefore in practice no mass may lie at the centre of mass. For example, centre of mass of a uniform circular ring is at the centre of the ring where there is no mass

414 **(c)**
Net force acting on the wedge and block system is gravity, therefore it is accelerated in downward direction. If external force acting on the system is zero, CM may be in rest or moving with constant velocity

415 **(d)**
If $F > mg \sin \theta$, then friction on disc will be in downward direction and if $F < mg \sin \theta$, then friction on disc will be in upward direction. If $F = mg \sin \theta$, then no friction will act on disc. Hence, statement I is false

Statement II is true because in pure rolling, friction can be either static or no friction

416 **(a)**
$I_1\omega_1 = I_2\omega_2$

$\because I_2 < I_1$

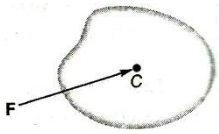
$\therefore \omega_2 > \omega_1$

The diver does work by pulling his limbs and thus, ω increases or rotational kinetic energy increases

417 **(d)**
If the collision is elastic, then masses of both particles should be same. But if masses are different, then collision is inelastic. Further, momentum remains conserved in any kind of collision

418 **(b)**
$\vec{\tau} = \frac{d\vec{L}}{dt}$ and $L = I\omega$

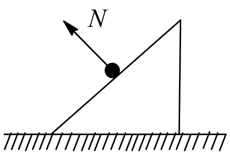
419 **(d)**
If a force is applied at centre of mass of a rigid body,
its torque about centre of mass will be zero, but acceleration
will be non-zero. Hence, velocity will change.



420 **(a)**
Initially the electron and proton were at rest so their centre of mass will be at rest. When they move towards each other under mutual attraction then velocity of centre of mass remains unaffected because external force on the system is zero

421 **(c)**
For a system of two isolated spheres having non–zero initial kinetic energy, the complete kinetic energy can be converted to other forms of energy if the momentum of the system is zero. This is due to the fact that for an isolated system, the net momentum remains conserved. If an isolated system has non–zero momentum, for the momentum to remain constant, complete kinetic energy of the system cannot become zero. Hence, Statement I is true while Statement II is false

422 **(a)**
During collision, force exerted by the wedge on the particle is perpendicular to the inclined face. So linear momentum of wedge is conserved along the face of the wedge



423 **(b)**

In the case of circular ring the mass is concentrated on the rim (at maximum distance from the axis) therefore moment of inertia increases as compared to that in circular disc

424 **(a)**
When a person is high up on the ladder, than a large torque is produced due to his weight about the point of contact between the ladder and the floor. Whereas when he starts climbing up. The torque is small. Due to this reason, the ladder is more apt to slip, when one is high up on it

425 **(a)**
Both, the assertion and reason are true and latter is a correct explanation of the former. Infact, as ice on polar caps of earth melts, mass near the polar axis spreads out, I increases. Therefore, T increases *ie*, duration of day increases

426 **(b)**
The angular momentum under a central force is a constant and inverse square law of force is conservative.

427 **(c)**
The normal force will act non-uniformly to balance the torque of the applied force. Hence, statement I is true. The applied horizontal force F has tendency to rotate the cube in an anticlockwise sense about the centre of the cube. Hence, Statement 2 is false

428 **(b)**
The assertion and reason, both are true. But the reason is not a correct explanation of the assertion. Infact, the centre of mass is related to the distribution of mass of the body

429 **(e)**
There is a difference between inertia and moment of inertia of a body. The inertia of a body depends only upon the mass of the body but the moment of inertia of a body about an axis not only depends upon the mass of the body but also upon the distribution of mass about the axis of rotation

430 **(a)**
As the concept of centre of mass is only theoretical, therefore in practice no mass may lie at the centre of mass. For example, centre of mass of a uniform circular ring is at the centre of the ring where there is no mass.

431 **(d)**
The position of centre of mass of electron and proton remains at rest, at their motion is due to (internal) forces of electrostatic attraction, which are conservative. No external force, what so ever is acting on the two particles

432 **(a)**
At the centre of earth, $g = 0$. Therefore a body has no weight at the centre of earth and have no centre of gravity (centre of gravity of a body is the point where the resultant force of attraction or the weight of the body acts). But centre of mass of a body depends on mass and position of particles and is independent of weight

433 **(b)**
$\tau = r\ F \sin\theta$. If $\theta = 90°$ then $\tau_{max} = rF$

Unit of torque is $N - m$

434 **(a)**
In sliding down, the entire, the potential energy is converted into kinetic energy. Which in rolling, the same part of potential energy is converted into KE of rotation, therefore linear velocity acquired is less

436 **(d)**
Net external force is zero. Therefore, no acceleration for CM. So, CM may move with a constant velocity

437 **(d)**
For a disc rolling without slipping on a horizontal rough surface with uniform angular velocity, the acceleration of the lowest point of disc is directed vertically upward and is not zero(due to translation part of rolling, acceleration of lowest point is zero. Due to rotational part of rolling, the tangential acceleration of the lowest point is zero and centripetal acceleration is non-zero and upwards). Hence, statement I is false. Statement 2 is true

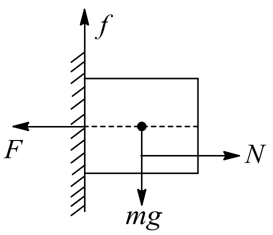
438 **(d)**
Angular momentum is rotational analogue of linear momentum, and torque is rotational analogue of force.

439 **(d)**
The position of centre of mass of a body depends on shape, size and distribution of mass of the

body. The centre of mass does not lie necessarily at the centre of the body

440 **(c)**
Statement II contradicts Newton's third law and hence it is false

441 **(a)**
As the block remains stationary



$\Sigma fx = 0$, i.e., $F = N$

$\Sigma fy = 0$, i.e., $f = mg$

and $\Sigma\tau = 0, \therefore \vec{\tau}_f + \vec{\tau}_N = 0$

As $\vec{\tau}_f \neq 0, \vec{\tau}_N \neq 0$ and torque by friction and normal reaction will be in the opposite direction

442 **(b)**
Rolling occurs only on account of friction which is a tangential force capable of providing torque. When the inclined plane is perfectly smooth, body will simply slip under the effect of its own weight

443 **(d)**
Time of descent from inclined plane

$$t = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}\left(1 + \frac{K^2}{R^2}\right)}$$

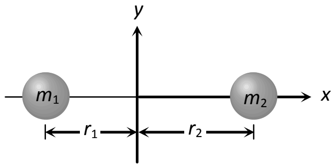
As $\left(\frac{K^2}{R^2}\right)_{\text{solid cylinder}} < \left(\frac{K^2}{R^2}\right)_{\text{Hollow cylinder}}$

Therefore solid cylinder will reach the bottom first

i.*e*., statement 1 is wrong

As they possess equal potential energy initially at the top therefore their kinetic energies will also be equal at the bottom, i.*e*., statement 2 is true

444 **(a)**



If centre of mass of system lies at origin then $\vec{r}_{cm} = 0$

$$\vec{r}_{cm} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$$

$\therefore m_1\vec{r_1} + m_2\vec{r_2} = 0$

Or $m_1r_1 = m_2r_2$

It is clear that if $m_1 > m_1$ then

445 **(a)**
When the earth shrinks, its angular momentum remains constant, i.e.,

$L = I\omega = \frac{2}{5}mR^2 \times \frac{2\pi}{T} = \text{constant}$

$T \propto I \propto R^2$, it means if size of the earth changes, then its moment if inertia also changes

If radius is half, the time period will become /4 . Hence, 24/4 = 6 h

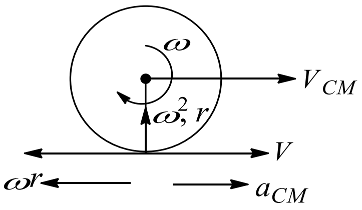
446 **(e)**
Radius of gyration of body is not a constant quantity. Its value changes with the change in location of the axis of rotation. Radius of gyration of a body about a given axis is given as

$$K = \sqrt{\frac{r_1^2 + r_2^2 + \cdots + r_n^2}{n}}$$

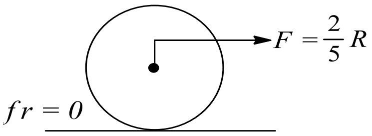
447 **(b)**
Both, assertion and reason are true but the reason is not a correct explanation of the statement-1. Infact, if helicopter has only one propeller, the helicopter itself would turn in opposite direction to conserve the angular momentum

448 **(e)**
The position of centre of mass of electron and proton remains at rest. As their motion is due to internal force of electrostatic attraction, which is conservative force. No external force is acting on the two particles, therefore centre of mass remain at rest

449 **(d)**



During the motion of rolling, there is radial acceleration towards the centre. Hence, the contact point moves vertically upward



451 **(d)**
In rolling all points of rigid body have the same angular speed but different linear speed

452 **(b)**
For an isolated system, no external force is acting in the absence of external force, linear momentum of centre of mass is unchanged. And so velocity of centre of mass remains constant

453 **(c)**
$x_1 = u\cos\,\theta\;t_1; x_2 = u\cos\theta\, t_2$

$$\sqrt{\frac{2h}{g}} = \frac{T}{2} = \frac{t_1+t_2}{2};\ \sqrt{\frac{2h}{2g}} = \frac{t_2-t_1}{2}$$

Dividing, $\frac{t_2+t_1}{t_2-t_1} = \sqrt{2}$

Also, $\frac{x_2-x_1}{x_2+x_1} = \frac{t_2-t_1}{t_2+t_1}$

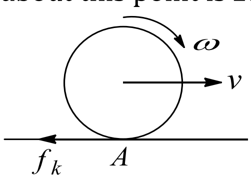
$$T = \frac{2u\sin\theta}{g}; t_1+t_2 = \frac{2u\sin\theta}{g}$$

$$\frac{1}{2} = \frac{u\sin\theta}{g(t_1+t_2)}$$

Also, $x_1 + x_2 = u\cos\theta(t_1+t_2)$

$$\frac{u\cos\theta(t_1+t_2)}{x_1+x_2} = 1$$

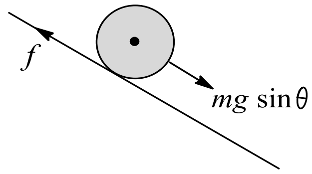
454 **(a)**
a. when the sphere rolls on the rough surface, its angular momentum about contact point A remains constant because torque of friction f_k about this point is zero



b. Here no friction will on the sphere. So here everything will remain the same

c. here also no friction will act, so everything will remain the same

d. Here KE will increase. Potential energy will decrease but the total mechanical energy will remain constant. Angular momentum will not be conserved, because $mg\sin\theta$ will provide the torque about contact point



455 **(d)**
a. Since impulse is given to the body, so its momentum will increase and translation will occur. The impulse J does not pass through the centre of mass. Hence, the dump- bell will rotate and its angular momentum will increase

b. Here J passes through centre of mass. So rotation does not occur and angular momentum remains zero

c. This situation is similar to part (a)

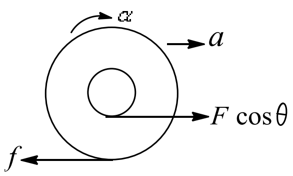
d. Here body is hinged. So translation does not occur, rotation will be there so angular momentum will increase

Linear momentum increases as centre of mass of gains some velocity

456 **(a)**
We know that angular momentum= linear momentum × perpendicular distance. So about O, angular momumtum will remain constant. But about E it will keep on changing. It is maximum about E when the particle is at A, because then the perpendicular distance is maximum

We know that angular velocity$(\omega) = v/r$. So about O, angular velocity will remain constant. But about E it will keep on changing. It is a minimum about E when the particle is at A, because then the perpendicular distance (r) is maximum

457 **(a)**



$F\cos\theta - f = ma$

$$fR - Fr = \frac{Ia}{R}$$

$$F\cos\theta - F\frac{r}{R} = a\left(m + \frac{I}{R^2}\right)$$

If $\cos\theta > r/R$, then a is positive

$$a = \frac{F\left(\cos\theta - \frac{r}{R}\right)}{\left(m + \frac{I}{R^2}\right)}$$

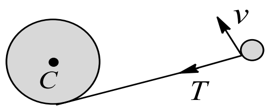
If $\cos\theta < r/R$, then a is negative

In (i), since $a =$ positive, α should be clockwise hence f is towards the left

Similarly for others

458 **(d)**

a. Angular momentum will not be conserved as T will provide torque about C. Kinetic energy will remain conserved as tension is perpendicular to velocity and it does not do any work. Obviously, the total mechanical energy also remains conserved

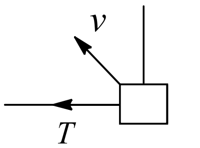


b. Angular momentum remains conserved as no external torque acts. Mechanical energy and kinetic energy of (rod + sleeve) system will remain the same because no work is done by external forces and there is no dissipating force in the system

c. Angular momentum will remain conserved. Because there is no external force (friction is zero because of ice)

Kinetic energy and mechanical energy will decrease because of work done by internal forces (due to muscles) between the icekaters.

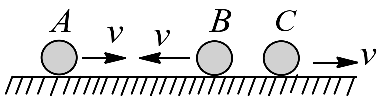
d. Angular momentum will remain conserved, because torque of T will be zero



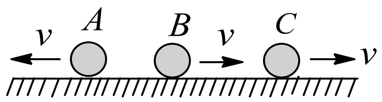
T will do positive work on the block due to which kinetic energy and mechanical energy of the block will increase

459 **(a)**

$$v_{\text{CM}} = \frac{mv + mv + m(-v)}{3m} = \frac{v}{3}$$



After first collision

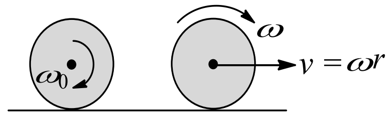


If A and B are connected, then they will act as a mass of $2m$. If A and B are connected by an ideal string, then finally A and B will be rest

460 **(a)**

In each case, the friction force will act in the forward direction. This friction will increase translational velocity and decrease angular velocity

Apply conservation of angular momentum about the lowest point,



$$I\omega_0 = I\omega + mvr$$

$$I\omega_0 = \frac{Iv}{r} + mvr$$

$$v = \frac{I\omega_0 R}{I + mr^2} = \frac{\omega_0 r}{1 + \frac{mr^2}{I}}$$

I is minimum for the solid sphere. So v is minimum for the solid sphere

Similarly, v will be maximum for the ring. From $v = u + at$, time taken by the ring will be maximum, because acceleration is the same for all

461 **(b)**

$$v_{\text{CM}} = \frac{3 \times 2 + 6 \times 0}{3 + 6} = \frac{2}{3}\,\text{m/s}$$

So velocity of centre of mass is always 2/3 m/s

i. If velocity of 3 kg block is 2/3 m/s, then velocity of 6 kg block is also 2/3 m/s. In this situation, spring will be maximum elongated. Their relative velocity will be zero

ii. When the speed is 2/3 m/s, velocity can be 2/3 m/s, if $v_{3\text{kg}} = -2/3$ m/s

$$v_{\text{CM}} = \frac{2}{3} = \frac{3 \times \left(-\frac{2}{3}\right) + 6v_2}{3 + 6}$$

$$v_2 = \frac{4}{3}\,\text{m/s}$$

Let deformation in spring be x. Then

$$\frac{1}{2} \times 3(2)^2 = \frac{1}{2} \times 3\left(\frac{2}{3}\right)^2 + \frac{1}{2} \times 6\left(\frac{4}{3}\right)^2 + \frac{1}{2}kx^2$$

$$\Rightarrow x = 0$$

iii. Minimum speed of 3 kg block is zero. At this speed, spring will have some deformation, but not maximum

iv. Speed of 6 kg block will be maximum when spring returns to its normal length after passing through elongation

462 **(b)**

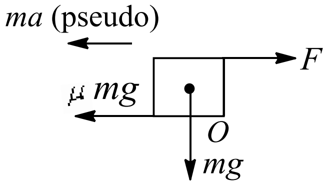
a. Speed of point P change with time

b. Acceleration of point P is equal to $\omega^2 x(\omega =$ angular speed of disc and $x = OP)$. The acceleration is direction from P towards O

c. The angle between acceleration of P(constant in magnitude) and velocity of P changes with time. Therefore, tangential acceleration of P changes with time

d. The acceleration of the lowest point is directed towards the centre of the disc and remains constant with time

463 **(a)**



The force required to topple the block about O,

$Fa = \frac{Ma}{g}g + \frac{Ma}{2} \times 1$

$F = M + \frac{M}{2} = 55$ N

and $f_{max} = \mu mg = 0.1 \times 10 \times 10 = 10$ N

Force between $0 - 10$ N will do neither sliding or slipping

Force between $10 - 55$ N will cause slipping

Force above 55 N will topple the block

464 **(a)**

i. Pure translation motion

ii. Pure rotational motion about centre of mass

iii. No motion as $\Sigma\vec{F} = 0$ and $\Sigma\vec{\tau} = 0$

iv. Combined rotation and translational motion

465 **(c)**

i. Initial velocity of centre of mass of given system is zero and net external force is in vertical direction. Since there is shift of mass downwards, the centre of mass has only downward shift

ii. Obviously, there is shift of centre of mass of given system downwards. Also the pulley exerts a force on string which has a horizontal component towards right Hence, centre of mass of system has rightward shift

iii. Both block and monkey move up, hence centre of mass of the given system shifts vertically upwards

iv. Net external force on given system is zero. Hence, centre of mass of the given system remains at rest

466 **(a)**

$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

But as in rolling, $v = r\omega$

$mgh = \frac{1}{2}mv^2\left[1 + \frac{I}{mr^2}\right]$ $\left[\text{Putting } \beta = 1 + \frac{I}{mr^2}\right]$

$= \frac{1}{2}\beta mv^2$

$\Rightarrow v = \sqrt{\frac{2gh}{\beta}}$

Solving for acceleration, we have

$a = \frac{g \sin\theta}{\beta}$

and time taken

$t = \frac{1}{\sin\theta}\sqrt{\beta\left(\frac{2h}{g}\right)}$

467 **(c)**

Velocity of two sphere will be the same at the bottom

$V_R = \sqrt{\frac{2gh}{\beta}}$, where $\beta = \left[1 + \frac{1}{Mr^2}\right]$

So kinetic energy of smaller mass will be more at the bottom

Also $a_r = \frac{g \sin\theta}{\beta}$ and $a = \alpha r$

$\Rightarrow \alpha = \frac{a}{r}$

As $r = R/2$, for smaller sphere, $\alpha = 2a/R$ and the larger sphere $\alpha = a/R$

Whereas $t = \frac{1}{\sin\theta}\sqrt{\beta\left(\frac{2h}{g}\right)}$, time will be the same for both the spheres as β will be same

468 **(b)**

Total mass : M

Mass of cutout portion; $m_1 = \frac{M}{4}$

$I_1 = \frac{1}{2}MR^2 - \frac{1}{2}m_1\left(\frac{R}{2}\right) = \frac{15}{32}MR^2$

$I_2 = I_1 + \frac{3M}{4}\left(\frac{R}{2}\right)^2 = \frac{21}{32}MR^2$

Also $I_3 + I_4 = I_2$

$I_2 = I_1 + \frac{3M}{4}\left(\frac{R}{2}\right)^2$

$I_3 = \frac{I_1}{2} + \frac{3M}{4}\left(\frac{R}{2}\right)^2$

$\Rightarrow I_2 - I_3 = \frac{I_1}{2}$

469 **(d)**

Since all forces on the disc pass through the point of contact with the horizontal surface, the angular momentum of the disc about the point on the ground in contact with disc is conserved. Also the angular momentum of the disc in all cases is conserved about any point on the line passing through the point of contact and parallel to the velocity of the centre of mass

The KE of the disc is decreased in all cases due to work done by friction. From the calculation of velocity of the lowest point on disc, the direction of friction in case (i), (ii) and (iv) is towards the left and in case r it is towards the right

The direction of frictional force cannot change in any given case

470 **(d)**

1. For earth moving in an elliptical orbit, centripetal force passes through CM, so its torque will be zero at all points of motion. So angular, momentum can be conserved at all points of motion. But as external force is acting, linear momentum will be unconserved

2. Angular momentum can be conserved about the point of contact as work done about this point by force of friction is zero. Linear momentum will not be conserved as force of friction is an external force here

3. External forces acting on the system are normal reaction, ⍰g sin θ and friction. Torque due to normal reaction and ⍰g sin θ will be zero about the centre of mass but not of friction. So, angular momentum will not be conserved. Also in the presence of external forces, the linear momentum will not be conserved

4. For the projected particle, force of gravity which is external in this case will render linear momentum unconserved. But torque of this force will be zero as it will pass through the CM. So angular momentum is conserved instantaneously

471 **(a)**

$M_A = 1\text{ kg}, M_B = 2\text{ kg}$

For bullet, $\int F\,dt = m(v_f - v_i)$

$= 0.25\,[(-100) - (-200) = 25\text{ kg m/s}]$ (i)

This is also impulse by particle on A

For block A, $\int (F - T)dt = M_A(v - 0)$ (ii)

For block B, $\int T dt = M_B(v - 0)$ (iii)

From Eqs. (ii) and (iii), we get

$$\int F dt = (M_A + M_B)v \Rightarrow 25 = 3v$$

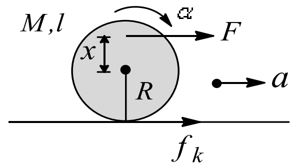
$$v = \frac{25}{3}\text{ m/s}, \int T\,dt = M_B v = \frac{2 \times 25}{3} = \frac{50}{3}$$

Now applying the law of conservation of energy,

$$+M_B gh = +\frac{1}{2}(M_A + M_B)v^2$$

$$\Rightarrow h = \frac{1}{2}\frac{(M_A + M_B)v^2}{M_B g} = 5.21\text{ m}$$

472 **(b)**



$F + f = ma$

$Fx - fR = I\alpha = \frac{a}{R}$

Solve to get $f = \frac{F(MxR - I)}{I + MR^2}$

$f = 0$, if $x = \frac{I}{MR}$

$f > 0$, if $x > \frac{I}{MR}$

So friction will act in the forward direction

$F < 0$ if $x < I/MR$, so friction will act in the backward direction. Also solved to get

$$a = \frac{FR(x + R)}{I + MR^2}$$

A is positive for all cases, hence body will accelerate in the forward direction in all cases

It means α will be in the clockwise direction. Hence, bodies will rotate in the clockwise direction

473 **(b)**

i. If velocity of block A is zero, from conservation of momentum, speed of block B is $2u$. Then KE of block $B = \frac{1}{2}m(2u)^2 = 2mu^2$ is greater than net mechanical energy of the system. Since this is not possible, velocity of A can never be zero

ii. Since initial velocity of B is zero, it shall be zero for many other instants of time

iii. Since momentum of system is non–zero, KE of system cannot be zero. Also KE of system is minimum at maximum extension of the spring

iv. The potential energy of spring shall be zero whenever it comes to natural length. Also PE of spring is maximum at maximum extension of the spring

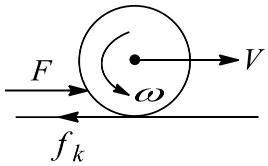
474 **(a)**

i. Internal forces may affect the motion of individual particles of a system, but not that of the centre of mass

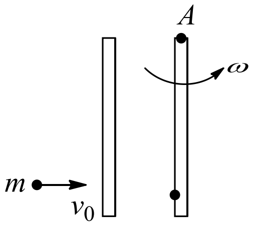
ii. Centre of momentum of a body can be inside or outside the body

iii. Kinetic energy of a system of two blocks may increase, decrease or remain same with time, but it will have no effect on motion of the centre of mass
iv. centre of mass of a solid cylinder is inside the cylinder

475 **(a)**
a. Immediately the sphere will gain velocity, so momentum increases



b. Here angular momentum about the hinged point will remain constant



Applying conservation of angular momentum about A

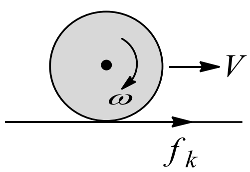
$$mv_0L = \left(mL^2 + \frac{ML^2}{3}\right)\omega$$

Final momentum, $\omega = \frac{mv_0}{\left(m+\frac{M}{3}\right)^2}$

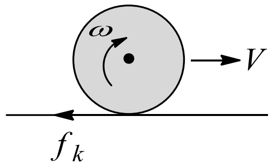
$$m\omega L + M\omega\frac{L}{2} = \left(m + \frac{M}{2}\right)\frac{mv_0}{\left(m+\frac{M}{3}\right)}$$

This is greater than mv_0
c. Here no external force or external torque acts. So all remain conserved, as the collision is elastic
d. Here also momentum increases. As the collision is elastic, so energy is also conserved. Angular momentum is conserved about the hinged point

476 **(a)**
a. v increases, ω decreases, hence translation work by friction is positive and rotational work is negative. But overall work will be negative because the friction is kinetic



b. v decreases, ω increases, overall work by friction will be negative



c. This is pure rolling with constant velocity. No friction will act
d. Here F will pass through the contact point. It will not move. Hence, work by friction is zero

477 **(a)**
In elastic collision, kinetic energy, momentum and total energy all remain conserved. In inelastic collision, kinetic energy is lost but other quantities remain conserved

478 **(b)**
Force F passes through the CM of the discs and hence its torque about CM has to be zero
Also, force of friction will be internal
After the discs stick together, let the final angular speed be ω

$$(I_A\omega_A + I_B\omega_B) = (I_A + I_B)\omega$$

$$\omega = \frac{I_A\omega_A + I_B\omega_B}{I_A + I_B}$$

When the discs rub against each other, the kinetic energy will decrease as there will be some loss of energy in doing work against the non-conservative force of friction

Loss of KE $= \frac{1}{2}(I_A + I_B)\omega^2 - \frac{1}{2}I_A\omega_A^2 - \frac{1}{2}I_B\omega_B^2$

479 **(b)**
The moment of inertia of a ring about its diameter $= \frac{1}{2}MR^2$
The moment of inertia of a disc about its diameter $= \frac{1}{4}Ma^2$
The moment of inertia of an annular disc about its diameter $= \frac{1}{4}M(R_1^2 + R_2^2)$

480 **(b)**
i. $8u_1 + 2(-3) = 8v_1 + 2v_2$

$$\frac{v_2 - v_1}{u_1 - (-3)} = e = 0.5$$

Solving, we get $v_1 = \frac{7u_1 - 9}{10}, v_2 = \frac{12u_1 + 6}{10}$
v_2 is always positive
For $v_1 > 0$ $u_1 > \frac{9}{7}$ m/s
ii. $8u_1 + 2(-3) = 8v_1 + 2v_2$

$$\frac{v_2 - v_1}{u_1 - (-3)} = e = 1$$

For maximum energy to transfer to $m_2, v_1 = 0$
Solving, we get $u_1 = 2$ m/s
iii. For this $v_2 = 0$
iv. Depends upon e

481 **(d)**

In inelastic collision, kinetic energy is always lost.
In elastic collision, kinetic energy remains constant
If total work done is zero, then kinetic energy will remain constant. If non – conservative forces are not present, then kinetic energy may decrease, increase or remain constant, depending upon other forces

482 **(d)**

From theory

i. Momentum= mv

ii. Impulse = change in momentum= $m(v_2 - v_1)$

iii. In elastic collision, momentum and KE both are conserved

iv. In inelastic collision, momentum is conserved but KE is not conserved

483 **(b)**

$$a = \frac{g\sin\theta}{1 + \frac{I}{MR^2}}$$

For a solid cylinder: $I = \frac{1}{2}MR^2$

So $a_1 = \frac{2}{3}g\sin\theta$

For a thin shell: $I = MR^2$

$$a_2 = \frac{g\sin\theta}{2}$$

So, $a_1 > a_2$, hence the solid cylinder reaches earlier. Now $v = \sqrt{2al}$, acceleration for the solid cylinder is more, so v on reaching the bottom is more for the solid cylinder.

F_{tran} is maximum and KE_{rot} is minimum for the solid cylinder

KE_{tran} is minimum and KE_{rot} maximum for the thin cylinder

484 **(d)**

We can not calculate the value of force exerted because time is not known to us.

485 **(d)**

$$\because e = \sqrt{\frac{h_1}{h_0}} = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h_3}{h_2}} \dots = \sqrt{\frac{h_n}{h_{n-1}}}$$

$\therefore\ h_1 = e^2 h_0, h_2 = e^2 h_1$, and so on

$\Rightarrow\ h_m = e^{2n}h_0$

486 **(c)**

For minutes hand, $T = 1, h = 60 \times 60$ s

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{60 \times 60}\ \text{rads}^{-1} = \frac{\pi}{1800}\text{rads}^{-1}$$

487 **(a)**

$$v_{\text{CM}} = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

$$= \frac{2(5) + 4(-5)}{2 + 4} = -\frac{10}{6}\text{ms}^{-1} = -\frac{5}{3}\ \text{ms}^{-1}$$

488 **(d)**

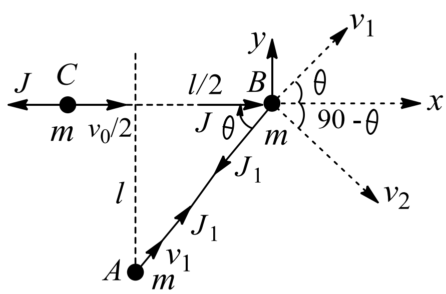
Let after collision, the velocities are as shown in figure

Here $\theta = 60°$. Let impulse between C and B during collision be J

For the system of A and B:

$J\cos\theta = 2mv_1$ (i)

$J\sin\theta = mv_2$ (ii)



$$\Rightarrow v_1 = \frac{J}{m}\frac{\cos\theta}{2}, v_2 = \frac{J}{m}\sin\theta$$

Velocity of B:

$$\vec{V}_B = v_1\cos\theta\hat{\imath} + v_1\sin\theta\hat{\jmath} + v_2\sin\theta\hat{\imath} - v_2\cos\theta$$

$$= (v_1\cos\theta + v_2\sin\theta)\hat{\imath} + (v_1\sin\theta - v_2\cos\theta)$$

$$= \frac{J}{m}\left[\left(\frac{\cos^2\theta}{2} + \sin^2\theta\right)\hat{\imath} + \left(\frac{\cos\theta\sin\theta}{2} - \cos\theta\sin\theta\right)\hat{\jmath}\right]$$

$$= \frac{J}{m}\left[\frac{7}{8}\hat{\imath} - \frac{\sqrt{3}}{8}\hat{\jmath}\right]$$

From here we can find direction of unit vector in the direction of $\vec{v}_B$

489 **(c)**

A vertically upward thrown particle does not feel 'very high force'

490 **(b)**

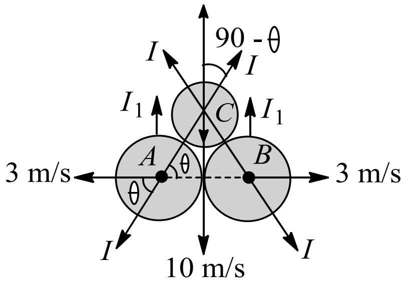
Since the centre of mass will remain at rest

$m(5l - x) = Mx$

$$x = \frac{5ml}{(M + m)}$$

491 **(a)**

First calculate, $\theta = 45°$. As the ball A and B are constrained to move horizontally (immediately after collision), if 'I' be the impulse imparted by ball 'C' to each of A and B, the impulse received by ball C from them would be $2I\sin\theta$



Now, each of ball B and C received impulse ‘I’ as shown in Fig., but moves horizontally as its vertical comp. gets balanced by impulse imparted to ball B and C by the respective strings and hence,

$I\cos\theta = M_A V_A = M_B V_B$

$\Rightarrow\ I = \frac{M_A V_A}{\cos\theta}$ (I =magnitude of impulse)

Now, for ball C, if its final velocity is V_c' downwards, we have

$M_c V_c' = M_c V_c - 2I\sin\theta$

$$\Rightarrow\ V_c' = V_c - 2\frac{MA}{MC}V_A\ \ (\because\ \theta = 45°)$$

$= -2$ m/s ($-$ve sign indicates that it is directed upwards)

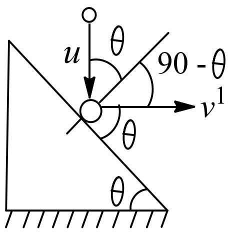
492 **(a)**

Applying conservation of momentum,

$m_1 \times 4 + m_2 \times (-2.5) = m_1 \times 3 + m_2 v_2$

$\Rightarrow\ v_2 = -1.5$ m/s

493 **(c)**



$$e = \frac{v'\cos(90-\theta)}{u\cos\theta}$$

$= \frac{v'}{u}\tan\theta$ (i)

$u\sin\theta = v'\cos\theta$

$$\Rightarrow\ \frac{v'}{u} = \tan\theta$$

From Eqs. (i) and (ii), $e = \tan^2\theta$

494 **(b)**

$u = \sqrt{2gh}$ is the velocity of m just before collision, and v is the velocity of the system $M+m$; just after collision, then $(M+m)$

$v = mu$

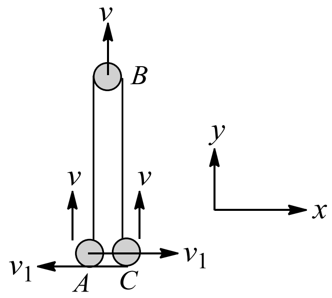
$$\Rightarrow\ v = \frac{m\sqrt{2gh}}{M+m}$$

$$a = \left(\frac{M-m}{M+m}\right)g$$

$$t = \frac{2v}{a} = \left(\frac{2m}{M-m}\right)\sqrt{\frac{2h}{g}}$$

495 **(a)**

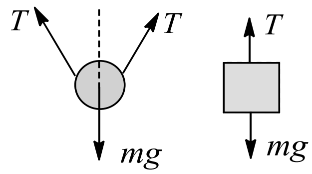
Just before ‘A’ collides with ‘C’, the velocities of all particles will be same and along y-axis. Let it be v. At this time let velocity of ‘A’ be v_1 along +ve x-axis, and that of ‘C’’ be v_1 along – ve x-axis



From conservation of momentum along y-axis,

$$mv_0 = 3mv\ \Rightarrow v = \frac{v_0}{3}$$

496 **(a)**



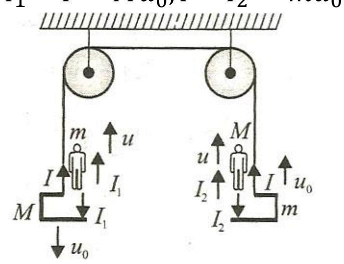
$2T\sin\theta = mg, T = mg$

$$\sin\theta = \frac{1}{2} \Rightarrow \theta = 30°$$

497 **(c)**

$I_1 = mu, I_2 = Mu,$

$I_1 - I = Mu_0, I - I_2 = mu_0$



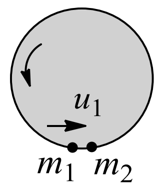
Solve to get: $u_0 = \frac{(m-M)u}{m+M}$

Relative velocity of left man w.r.t. his trolley:

$$u + u_0 = u + \frac{(m-M)u}{m+M} = \frac{2mu}{m+M}$$

498 **(c)**

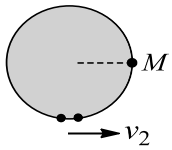
Just before collision, velocity of m_1



$u_1 = \sqrt{2g2a} = 2\sqrt{ga}$

Just after collision, m_1 is brought to rest and let velocity of m_2 be v_2

From conservation of linear momentum,
$m_2 v_2 = m_1 u_1$ (i)



Now $v_2 = \sqrt{2ga}$ so that m_2 can rise up to point M
Putting the value of u_1 and u_2 en Eq. (i), we get
$m_2\sqrt{2ga} = m_1 2\sqrt{ga} \Rightarrow \frac{m_1}{m_2} = \frac{1}{\sqrt{2}}$

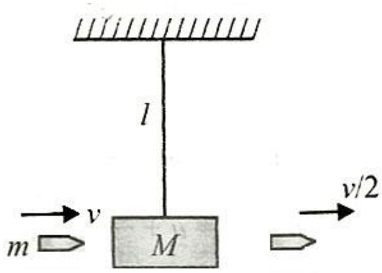
499 **(c)**
The acceleration of the centre of mass is $a_{CM} = \frac{F}{2m}$
The acceleration of the centre of mass at time t will be
$x = \frac{1}{2}a_{CM}\, t^2 = \frac{Ft^2}{4m}$

500 **(d)**
Let u be the initial velocity of the ball of mass m. Then
$mu = mv_1 + nmv_2 \Rightarrow v_1 + nv_2 = u$ (i)
For elastic collision, Newton's experimental formula $(u_2 = 0)$
$v_1 - v_2 = -(u_1 - u_2)$
$\Rightarrow\ v_2 = v_1 + u$ (ii)
Solving Eqs. (i) and (ii), $v_1 = \frac{1-n}{1+n}u$
Fractional loss in K.E.
$f = \frac{K_i - K_f}{K_i} = \frac{\frac{1}{2}mu^2 - \frac{1}{2}mv_1^2}{\frac{1}{2}mu^2} = 1 - \left(\frac{v_1}{u}\right)^2$
$= 1 - \left(\frac{1-n}{1+n}\right)^2 = \frac{4n}{(n+1)^2}$
The transfer of energy is maximum (or 100%) when $f = 1$
$\therefore \frac{4n}{(n+1)^2} = 1 \Rightarrow n = 1$
That is the transfer of energy is maximum when the mass ratio is unity

501 **(a)**
Energy loss: $mgh_1 - mgh_2$
Fractional loss $= \frac{\text{Energy loss}}{\text{Initial energy}} = \frac{mgh_1 - mgh_2}{mgh_1} = \frac{h_1 - h_2}{h_1}$

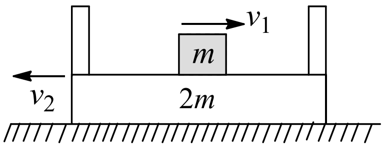
502 **(a)**
$u =$ velocity of sphere A before impact. As the spheres are identical, the triangle ABC formed by joining their centres is equilateral. The spheres B and C will move in direction AB and AC after impact making an angle of 30° with the original lines of motion of ball A
Let v be the speed of the ball B and C after impact
Momentum conservation gives
$\left(\frac{m}{2}\right)u = mv\cos 30° + mv\cos 30°$
$u = 2\sqrt{3}\,v \Rightarrow v = \frac{u}{2\sqrt{3}}$ (i)
From Newton's experimental law, for an oblique collision, we have to take components along normal, i.e., along AB for balls A and B
$v_B - v_A = -e(u_B - u_A)$
$v - 0 = -e\,(0 - u\cos 30°\,)$
$v = eu\cos 30°$
Combining Eqs. (i) and (ii), we get $e = 1/3$
Loss in KE $= \frac{1}{2}\frac{m}{2}u^2 - 2\left(\frac{1}{2}mv^2\right)$
$= \frac{1}{4}mu^2 - m\left(\frac{u}{2\sqrt{3}}\right)^2 = \frac{1}{6}mu^2$

503 **(b)**



Momentum lost by the bullet $= mv - \frac{mv}{2} = \frac{mv}{2}$
This will be transferred to the bob

504 **(c)**
$mv_1 = 2mv_2$
$\Rightarrow\ v_1 = 2v_2$



$\frac{1}{2}mv_1^2 + \frac{1}{2}\times 2mv_2^2 = \frac{1}{2}kx^2$
Solving, we get
$v_1 = 2\left(\sqrt{\frac{k}{6m}}\right)x, v_2 = \left(\sqrt{\frac{k}{6m}}\right)x$
Relative velocity:
$v_1 + v_2 = 3\left(\sqrt{\frac{k}{6m}}\right)x = x\sqrt{\frac{3}{2}\frac{k}{m}}$

505 **(b)**
Using conservation of linear momentum in horizontal direction just before and just after collision
$mu = (m+M)V \Rightarrow V = \frac{mu}{(M+m)}$

506 **(a)**
Let us adopt the vector approach. Let the mass of each particle be 'm' and let they be denoted by A, B and C. Before collision,

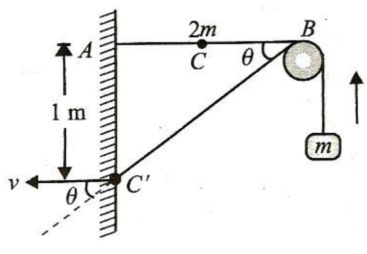
velocity of $A = 10\hat{\imath}$
velocity of $B = 20(\cos 30°\,\hat{\imath} + \sin 30°\,\hat{\jmath})$
$= 10(\sqrt{3}\,\hat{\imath} + \hat{\jmath})$
velocity of $C = 30\hat{\jmath}$
Initial momentum, $\vec{P} = m[10\hat{\imath} + 10(\sqrt{3}\hat{\imath} + \hat{\jmath}) + 30\hat{\jmath}$
$= 10\,m[(1+\sqrt{3})\hat{\imath} + 4\hat{\jmath}]$ (i)
Let the final velocity be $\vec{v}$, then final momentum $\vec{p}_2 = 3m\vec{v}$
According to the law of conservation of linear momentum, we have initial momentum = final momentum
i.e., $10m[(1+\sqrt{3})\hat{\imath} + 2\hat{\jmath}] = 3m\vec{v}$
$\vec{v} = \frac{10}{3}[(1+\sqrt{3})\hat{\imath} + 4\hat{\jmath}]$
Therefore, magnitude of $\vec{v}$, i.e.,
$|\vec{v}| = \frac{10}{3}\sqrt{(1+\sqrt{3})^2 + 4^2} = \frac{10}{3}\sqrt{20 + 2\sqrt{3}}$ m/s
If the final velocity $\vec{v}$ makes an angle α with the positive direction of X-axis, then $\tan\alpha = \frac{4}{1+\sqrt{3}} = 2(\sqrt{3} - 1)$;
$\alpha = \tan^{-1}[2(\sqrt{3} - 1)]$

507 **(d)**
Since the collision is elastic, there is no loss in KE

508 **(b)**
Using area of Δ= change in momentum
$\frac{1}{2}F_{\max}\,\Delta t = 250 \times 10^{-3}(80)$
$\frac{1}{2}F_{\max}(8 \times 10^{-3}) = 250 \times 10^{-3} \times 80$
$F_{\max} = 5000$ N

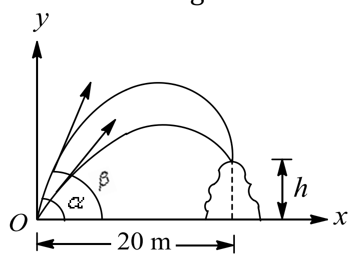
509 **(d)**
Centre of mass will remain at rest because there is no external force on the system of A, B and platform

510 **(a)**
When M strikes the wall, vertically downward component of its displacement from initial position is 1 m and its distance from pulley B is
$C'B = \sqrt{1^2 + 2^2} = \sqrt{5}$ m
While its initial distance from the pulley was $CB = 1$ m. It means vertically upward displacement of mass m is $(\sqrt{5} - 1)$m



Let M strike the wall with velocity v. Since the string between the two blocks always remains taut, therefore at any instant speed of m is equal to that component of velocity of M which is along the string $C'B$. Hence, velocity of m when M strikes the wall is $v\cos\theta$, where
$\cos\theta = \frac{2}{\sqrt{5}}$
$\therefore \frac{v_M}{v_m} = \frac{v}{v\cos\theta} = \frac{\sqrt{5}}{2}$
According to law of conservation of energy, loss of potential energy of M =increase in PE of m + KE of M + KE of m
$Mg \times 1 = mg(\sqrt{5} - 1) + \frac{1}{2}Mv^2 + \frac{1}{2}m(v\cos\theta)^2$
$v = 5\sqrt{\frac{5-\sqrt{5}}{6}}$ m/s

511 **(d)**
Let muzzle velocity be u_0 and height of cliff be h. Assuming horizontal direction to be positive x-axis and vertically upward direction to be positive y-axis, coordinates of top of cliff become $(20, h)$ as shown in the figure



Using equation of trajectory of a projectile for two shells,
$h = 20\tan\alpha - \frac{g(20)^2}{2u_0^2\cos^2\alpha}$
$= 20\tan\beta - \frac{g(20)^2}{2u_0^2\cos^2\beta}$
From the above two equations,
$u_0 = 20$ m/s and $h = 10$ m
Time taken by the shell, fired at angle α, to reach the top of cliff is
$t_1 = \frac{20}{u_0\cos\alpha} = \sqrt{2}$ s
Time taken by the shell is
$t_2 = \frac{20}{u_0\cos\beta} = \sqrt{10}$ s
Hence, the shell having angle of projection β was fired first and the other shell (having angle of projection α) was fired later
Time interval between two firings is
$t_2 - t_1 = (\sqrt{10} - \sqrt{2})$ s = 1.74 s

Consider vertical velocities of shells just before striking the top of cliff

For the first shell,

$$v_{1y} = u_0 \sin\alpha - gt_1 = 20 \times \frac{1}{\sqrt{2}} - 10\sqrt{2} = 0$$

For the second shell,

$$v_{2y} = u_0 \sin\beta - gt_2 = 20 \times \frac{3}{\sqrt{10}} - 10\sqrt{10}$$
$$= -4\sqrt{10}\text{ m}$$

Let v_y be combined vertical velocity of the shell after sticking together, then from conservation of momentum in vertical direction, we get

$(m+m)v_y = m \times 0 + m(-4\sqrt{10}) \Rightarrow v_y = -2\sqrt{10}$ m/s

Collision with the top of cliff is perfectly elastic, so combined shell will rebound with velocity $2\sqrt{10}$ m/s in vertical direction. Maximum height above top of cliff will be $(2\sqrt{10})^2/2g = 2$ m

Net maximum height $= 10 + 2 = 12$ m

512 **(a)**

When two balls collide, their height from ground is same. Let it be h. Then vertical displacement of the first and second balls is $(65-h)$m and $(30-h)$m, respectively. Let the time of flight of the first ball up to the instant be n seconds. Then the time of flight that that of second ball is $(n-1)$ seconds. Considering vertically downward component of motion of first ball,

$u = 10\sqrt{2}\sin 45° = 10$ m/s

$a = g = 10\text{ ms}^{-1}, s = y_1 = (65-h), t = n$ s

$$s = ut + \frac{1}{2}at^2$$

$(65-h) = 10n + 5n^2$ (i)

For vertically downward component of motion of second ball,

$u = 0, a = g = 10\text{ ms}^{-2}, t = (n-1)$

$s = y_2 = (30-h)$

$(30-h) = 5(n-1)^2$ (ii)

From Eqs.(i) and (ii), $n = 2$ s, $h = 25$ m

Displacement AC = Horizontal distance moved by first ball up to the instant of collision + that moved by the second ball up to the same instant

$\therefore\ AC = (10\sqrt{2}\cos 45°)n + 20(n-1) = 40$ m

Just before collision, vertically downward component of velocity of first ball is

$v_{y1} = (10\sqrt{2}\sin 45°) + gn = 30$ m/s

And that of second ball is $v_{y2} = g(n-1) =$ 10 m/s

According to the law of conservation of momentum, vertically downward component v_y of velocity of combined body is given by

$mv_{y1} + mv_{y2} = (m+m)v_y$ or $v_y = 20\text{ ms}^{-1}$

Similarly, horizontally leftward component v_x of velocity of combined body (just after collision) is given by

$m \times 20 - m \times 10\sqrt{2}\cos 45° = (m+m)v_x$

$\Rightarrow\ v_x = 5$ m/s

513 **(a)**

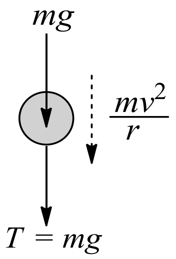
Let velocity of ball A at highest point be v then first considering its FBD at this point

$$mg + T = \frac{mv^2}{r}$$

Where $T = mg$

$\Rightarrow\ v^2 = 2rg$

$\Rightarrow v = \sqrt{2rg} = 2\sqrt{6}$ m/s



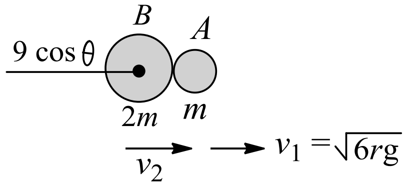
If velocity of ball A just after the collision is v_1 then according to law of conservation of energy,

Its KE at A = (KE + PE) at highest point

$$\frac{1}{2}mv_1^2 = \frac{1}{2}mv^2 + mg\,(2r)$$

$v_1 = \sqrt{6rg}$ or $v_1 = 6\sqrt{2}$ m/s

If angle of projection of ball B is θ, then horizontal component of its velocity will be $9\cos\theta$ and it remains constant



Now considering collision of balls B and A, let velocities of balls A and B, just after the collision, be v_1 and v_2, respectively as shown in Fig.

Then according to the law of conservation of momentum,

$mv_1 + 2mv_2 = 2m\,(9\cos\theta)$ (i)

Since collision is elastic, therefore, $e = 1$

$\frac{v_1 - v_2}{9\cos\theta} = 1$ or $v_1 - v_2 = 9\cos\theta$ (ii)

Solving Eqs. (i) and (ii), we get

$$\cos\theta = \frac{1}{\sqrt{2}} \text{ or } \theta = 45°$$

$$v_2 = \frac{3}{\sqrt{2}}\text{ms}^{-1}$$

Height of initial position of ball A (lowest position) is equal to maximum height ascended by the ball B. It is equal to

$$H=\frac{(9\sin\theta)^2}{2g}=\frac{81}{40}\text{m}$$

Height of point of suspension from the ground is

$$H+r=\frac{129}{40}\text{m}$$

514 **(c)**

Since rear buggy stops and velocity of man relative to this buggy is v, therefore, absolute velocity of man at the time of jump is v. Applying law of conservation of momentum on the system of rear buggy and man

$mv=(150+m)4$ (i)

Kinetic energy of man and front buggy (just before collision) is

$$E_1=\frac{1}{2}mv^2+\frac{1}{2}\times 150\times 4^2$$

Let velocity of the front buggy, after collision, be v_c

Applying law of conservation of momentum on the system of front buggy and man, we get

$mv+150\times 4=(m+150)v_c$ (ii)

Kinetic energy of the system after collision is

$E_2=\frac{1}{2}(m+150)v_c^2$ (iii)

But $E_1-E_2=2700$ J

From above three equations, $v_c=7$ m/s

$m=50$ kg

$v=16$ m/s

515 **(b)**

When ball is released, it moves along a vertical circle with centre at A. Kinetic energy of ball just before collision is equal to loss of its potential energy from point of release to the point of collision. Therefore, velocity v_1 of ball, just before collision, is given by

$$\frac{1}{2}mv_1^2=mg(l-l\cos\theta)\Rightarrow v_1=5\text{ m/s}$$

After collision, the block starts to move towards right. But it is retarded by force of friction and ultimately it comes to rest. According to law of conservation of energy,

Kinetic energy of the block just after collision = Work done by it against friction

Therefore, its velocity v_2 just after collision is given by

$$\frac{1}{2}mv_2^2=\mu mgs$$

Where $m=0.5$ and $s=2.50$ m. $\therefore v_2=5$ m/s

Coefficient of restitution, $e=\frac{v_2-v_1}{u_2-u_1}$

Where $u_2=0, u_1=5$ m/s and $v_2=5$ m/s

$\therefore e=-\frac{5-v_1}{0-5}$ or $v_1=(5-5e)$ (i)

Applying law of conservation of momentum,

$mu_1+mu_2=mv_1+mv_2$

$5m+(m\times 0)=mv_1+5m$ or $v_1=0$

Substituting in Eq. (i), we get $e=1$

516 **(b)**

When shell strikes the ball and gets stuck with it, combined body of mass $2m$ starts to move to the right. Let velocity of the combined body (just after collision) be v_1. According to law of conservation of momentum,

$(m+M)v_1=mv_0$

$$v_1=\frac{v_0}{2}=3\text{ m/s}$$

As soon as the combined body starts to move rightwards, thread becomes inclined to the vertical. Horizontal component of its tension retards to the combined body while trolley accelerates rightwards due to the same component of tension

Inclination of thread with the vertical continues to increase till velocities of both (combined body and trolley) become identical or combined body comes to rest relative to the trolley. Let velocity at that instant of maximum inclination of thread be v. According to law of conservation of momentum,

$(2m+M)v=2\,mv_1$

or $v=1$ m/s

During collision of ball and shell, a part of energy is lost. But after that there is no loss of energy. Hence, after collision, kinetic energy lost is used up in increasing gravitational potential energy of the combined body

If maximum inclination of threads with the vertical is θ, then according to law of conservation of energy

$$\frac{1}{2}(2m)v_1^2-\frac{1}{2}(2m+M)v^2=2\,mg\,(l-l\cos\theta)$$

$\cos\theta=0.8$ or $\theta=37°$

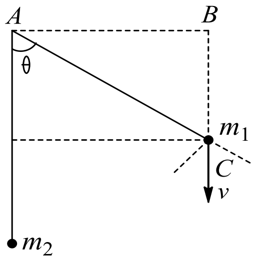
517 **(d)**

Ball of mass m_1 falls freely till thread becomes taut. At that instant inclination θ of the thread with the vertical be given by

$$\sin\theta=\frac{\left(\frac{\sqrt{3}}{2}l\right)}{l}=\frac{\sqrt{3}}{2}\quad\text{or}\quad\theta=60°$$

Ball of mass m_1 falls freely through height

$$l\cos\theta=\frac{l}{2}$$



Velocity of this ball at this instant is $v = \sqrt{2g \times \frac{l}{2}} = \sqrt{gl}$

It can be resolved into two components

i. $v\cos\theta$, along the thread. But thread is inextensible, hence this component decreases to zero (due to tension developed in the thread)

ii. $v\sin\theta$, perpendicular to the thread. Due to this component ball starts to move along a circle whose centre is at A

According to law of conservation of energy,

Kinetic energy of ball m_1 just before collision = Its kinetic energy at AC + Further loss of its potential energy

$$\frac{1}{2}m_1u_1^2 = \frac{1}{2}m_1\left(\sqrt{gl}\sin\theta\right)^2 + m_1g(l - l\cos\theta)$$

$u_1 = 4$ m/s

According to law of conservation of momentum,

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

And coefficient of restitution, $e = -\frac{v_2 - v_1}{u_2 - u_1} = 1$

Substituting $u_1 = 4$ m/s, $u_2 = 0, m_1 = 0.1$ kg and $m_1 = 0.3$ kg,

$v_2 = 2$ m/s, the height to which it rises is

$$h = \frac{v_2^2}{2g} = 0.20 \text{ m}$$

518 **(a)**

When C strikes with B, the combined body starts to rise vertically upward. According to law of conservation of momentum, velocity v_0 of combined body (just after collision) is given by

$(2+1)v_0 = 1 \times 9$ or $v_0 = 3$ m/s

But A is at rest. Therefore, string becomes slack and bodies move under gravity, combined body upwards and A downwards till string again becomes taut. This happens when downward displacement of A becomes equal to upward displacement of combined body. Let it happen at instant t_1. Then,

$$\frac{1}{2}gt_1^2 = 3t_1 - \frac{1}{2}gt_1^2$$

Or $t_1 = 0.3$ s

Displacement of each block at that instant,

$$h_1 = \frac{1}{2}gt_1^2 = 0.45 \text{ m}$$

And velocity of combined body is $3 - gt_1 = 0$ and velocity of A is $gt_1 = 3$ m/s (downward)

Since at this instant, velocities are different, therefore an impulse is developed in the string and magnitude of velocities of bodies becomes equal. Let that velocity magnitude be v' and impulse developed be J. This impulse acts upwards on both the bodies. Hence for A,

$2 \times 3 - J = 2v'$ (i)

And for combined body,

$J = 3v'$ (ii)

From above equations,

$v' = 1.2$ m/s

Now combined body starts to move upwards with velocity $v' = 1.2$ m/s and retardation a, where

$$a = \frac{3-2}{3+2}g = 2 \text{ m/s}^2$$

Combined body comes to an instantaneous rest after time

$$t_2 = \frac{v'}{a} = 0.6 \text{ s}$$

After this instant, combined body starts moving down. Time interval between this instant and instant of collision is given by

$t_1 + t_2 = 0.3 + 0.6 = 0.9$ s

Further height ascended by combined body during time t_2 is

$$h_2 = v't_2 - \frac{1}{2}at_2^2 = 0.36 \text{ m}$$

Maximum height raised by combined body is

$h = h_1 + h_2 = 0.81$ m

Loss of energy during collision of B and C is

$$E_1 = \frac{1}{2} \times 1 \times 9^2 - \frac{1}{2}3v_0^2 = 27 \text{ J}$$

Loss of energy when impulse is developed in string is

$$E_2 = \frac{1}{2} \times 2 \times 3^2 - \frac{1}{2}(2+3)(v')^2 = 5.4 \text{ J}$$

Loss of mechanical energy till B reaches highest point is

$E = E_1 + E_2 = 27 + 5.4 = 32.4$ J

519 **(d)**

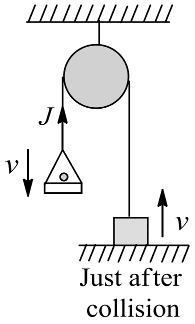
Due to collision, an impulsive tension occurs in the string

For ball + pan system, $-J = (m + m_0)v - m_0v_0$

For block, $J = Mv \Rightarrow v = 2$ m/s

As the string is taut and the mass of the block is greater than the mass of ball + pan, so the block and ball + pan are under deceleration, given by

$$a = \frac{3g - 2g}{5} = 2 \text{ m/s}^2$$



So, block will again come to ground after time t, given by

$0 = 2t - \frac{1}{2} \times 2t^2 \quad \Rightarrow t = 2\text{s}$

At this instant, the pan + ball system is moving with $v = 2$ m/s and the string gets slacked, so the system is moving under gravity

To determine the speed of the system at $t = 2.6$ s, first find the time after which string is again jerked. That will happen when pan + ball system crosses its $t = 2$s instant during its downward journey, i.e., after its time of flight of motion under gravity

$T = \frac{2 \times 2}{10} = 0.4$ s

i.e., string will again jerk at $t = 2.4$ s

For $t > 2.4$ s, the system is again under a retardation of 2 m/s^2

Before this, find the velocity of various components of system just after jerk. We have

$-J' = 2v' - 2 \times 2$ and $J = 3v'$

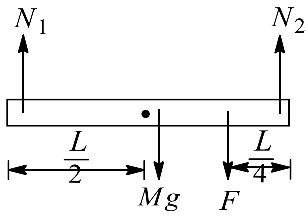
$5v = 4 \Rightarrow v = \frac{4}{5} = 0.8$ m/s

With this velocity, the ball + pan system moves down for 0.2 s under a retardation of 2 m/s^2

$v = 0.8 - 2 \times 0.2 = 0.4$ m/s (downwards)

The maximum height attained by the block after the second jerk is given by $0 = (0.8)^2 - 2 \times 2H \Rightarrow H = 0.16$ m

520 **(c)**



As the rod is in equilibrium,

$\therefore \Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma \tau = 0$

Taking torque about hinge 2, we get

$N_1 \times L = Mg \times \frac{L}{2} + F \times \frac{L}{4}$

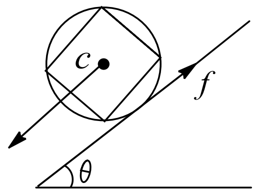
$\therefore N_1 = \frac{Mg}{2} + \frac{F}{4} = 11$ N

521 **(a)**

$I = \left\{\frac{M(R\sqrt{2})^2}{12} + M\left(\frac{R}{\sqrt{2}}\right)^2\right\} 4 + mR^2$

$= \frac{8}{3}MR^2 + mR^2 = 20 \text{ kg m}^2$

$(4M + m)g \sin\theta - f = (4M + m)a \quad$ (i)



$fR = I\frac{a}{R} \qquad$ (ii)

Solving Eqs. (i) and (ii),

$a = \frac{7g}{24}$

$f = 20\ a = \mu \times 28g \cos 30°$

$\mu = \frac{5}{12\sqrt{3}}$

522 **(d)**

Acceleration of the bottom of the cylinder = acceleration of the plank = 2 m/s^2 towards the right

Acceleration of the cylinder = acceleration of $B = 6\ \text{ms}^{-2}$ towards the left

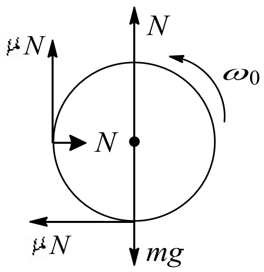
Let linear acceleration of the cylinder be a towards the left and angular acceleration of it α is an anticlockwise sense. Writing constant, we get

$a + R\alpha = 6$ and $R\alpha - a = 2$

$\Rightarrow \alpha = 1 \text{ rad s}^{-2}, a = 2 \text{ m/s}^2$

523 **(b)**

Construct the free-body diagram of the cylinder:



Calculate the force acting on the cylinder: As the centre of mass of the cylinder does not accelerate

$N_2 - \mu_k N_1 = 0 \quad$ (i)

$N_1 + \mu_k N_2 - mg = 0 \quad$ (ii)

Solving these equations:

$N_1 = \frac{mg}{1 + m_k^2}, N_2 = \frac{\mu_k mg}{1 + \mu_k^2}$

524 **(c)**

By conservation of angular momentum on the man-table system,

$L_1 = L_f$

$0 + 0 = L_m\omega_m + I_t\omega_t$

$\Rightarrow \omega_t = -\frac{I_m\omega_m}{I_t}$ where $\omega_m = \frac{v}{r} = \frac{1}{2}$ rad/s

$$\Rightarrow \omega_t = -\frac{100(2)^2 \times \left(\frac{1}{2}\right)}{4000}$$

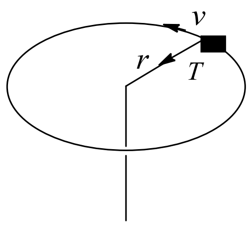
$$\Rightarrow \omega_m = \frac{v}{r} = \frac{1}{2}\text{rad/s}$$

$$\Rightarrow \omega_t = -\frac{1}{20}\text{rad/s}$$

Thus, the table rotates clockwise (opposite to the man) with angular velocity 0.05 rad/s

525 **(d)**

The tension of the rope is the only net force on the block and it does not exert any torque about the axis of rotation. Hence, the angular momentum of the block about the axis should remain conserved



$\Rightarrow$ mvr =constant

Let $r_1 = 5$ m and $v_1 = 4$ m/s

Let r_2, v_2, T_2 be the radius, velocity and tension when the string breaks

$\Rightarrow T_2 = 200$ N

$mv_1r_1 = mv_2\,r_2$ and $T_2 = \frac{mv_2^2}{r_2}$ (i)

$$\Rightarrow mv_1r_1 = m\sqrt{\frac{r_2T_2}{m}r_2}$$

$$r_2 = \left(\frac{mv_1^2r_1^2}{T_2}\right)^{\frac{1}{3}} = \left(\frac{4 \times 16 \times 25}{200}\right)^{\frac{1}{3}}$$

$= 2$ m

Note: The tension in the string is inversely proportional to the cube of the radius

526 **(b)**

Let $OA = x, OB = y$

$x^2 + y^2 = l^2$ and $x = l\cos\theta$

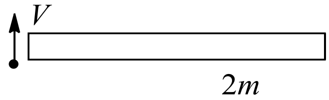
Differentiate $x^2 + y^2 = l^2$ with respect to time

$$2x\frac{dx}{dt} + 2y\frac{dy}{dt} = 0$$

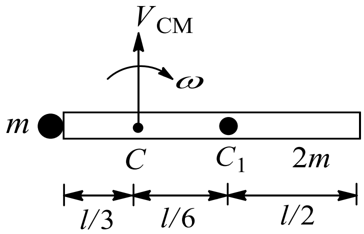
$$V_B = \frac{dy}{dt} = -\frac{x}{y}\frac{dx}{dt} = -V_A\cot\theta = \frac{4}{5}V_0 \downarrow$$

527 **(a)**

After collision, the centre of mass of the composite system will move in a straight line with a constant speed and the system will rotate with a constant angular velocity about the vertical axis passing through (and translating with) the centre of mass of the system. During the collision, the external force and torque about any point (or axis) in an inertial reference frame is zero. The torque acting on the system in the centre of mass reference frame is also zero



(a) Just before collision



(b) Just after collision

There are many (mathematically infinite) points (axes) about which the angular momentum of the system remains constant during the collision. The centre of mass of the composite system is the most convenient point

The distance of the centre of mass of the system from the end where m sticks is given by

$$x_{\text{CM}} = \frac{m \times 0 + 2m \times \frac{l}{2}}{m + 2m} = \frac{l}{3}$$

Let the velocity of the centre of mass of the system after collision be v_{CM} and the angular velocity of the system about the vertical axis through the centre of mass be ω as shown in the figure

From the conservation of the angular momentum about the centre of mass axis

$$\frac{mvl}{3} = \left\{m\left(\frac{l}{3}\right)^2 + \frac{(2m)l^2}{12} + (2m)\left(\frac{l}{6}\right)^2\right\}\omega \quad \text{(i)}$$

Moment of inertia of the composite system about the centre of mass axis is

$$I_{\text{CM}} = m\left(\frac{l}{3}\right)^2 + \frac{(2m)l^2}{12} + (2m)\left(\frac{l}{6}\right)^2 = \frac{ml^3}{3}a \quad \text{(ii)}$$

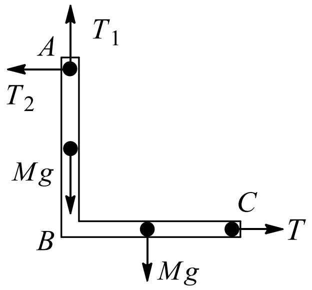
From Eqs. (i) and (ii)

$$\Rightarrow mv\frac{l}{3} = \frac{ml^2}{3}\omega \Rightarrow \omega = \frac{v}{l}$$

528 **(d)**

Taking torque about A: $Mg\frac{L}{2} = TL$

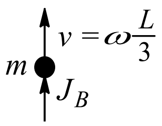
$$\Rightarrow T = \frac{Mg}{2}$$

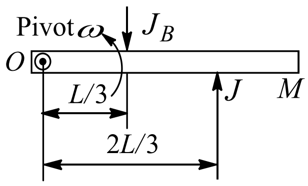


529 **(b)**

Let the system starts with angular velocity ω.
Angular velocity of the ball will also be ω as it remains struck to the rod

Velocity of the ball $v=\omega\frac{L}{3}$





For the rod, angular impulse= change in angular momentum:

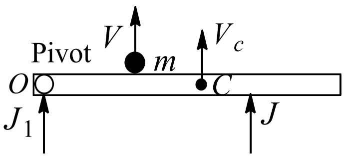
$J\frac{2L}{3}-J_b\frac{L}{3}=\frac{ML^2}{3}\omega$ (i)

For the ball, impulse= change in linear momentum

$J_b=mv=m\omega\left(\frac{L}{3}\right)$ (ii)

From Eqs. (i) and (ii), $\omega=\frac{6J}{(m+3M)L}$

and $J_b=\frac{2mJ}{(m+3M)}$



Let impulse on the pivot be J_1

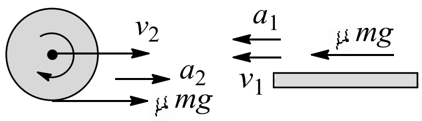
For the rod and ball system, total impulse = change in linear momentum $J+J_1=Mv_c+mv$

Solve to get: $J_1=\frac{mJ}{m+3M}$

530 **(b)**

$a_1=\frac{\mu mg}{m}=\mu g, a_2=\frac{\mu mg}{m}=\mu g$

$v_1=a_1t=\mu gt, v_2=a_2t=\mu gt$



$\tau=\mu mgr$

$\omega=\omega_0+\alpha t$,

Where $\alpha=-\frac{\tau}{I}=-\frac{\mu mgr}{\frac{2}{5}mr^2}=-\frac{5}{2}\frac{\mu g}{r}$

$\Rightarrow \omega=\omega_0-\frac{5}{2}\frac{\mu g}{r}t$

When the pure rolling starts,

$\omega=\frac{v_1+v_2}{r}$

$\Rightarrow \omega_0-\frac{5}{2}\frac{\mu gt}{r}=\frac{2\mu gt}{r}$

$\Rightarrow t=\frac{2\omega_0 r}{9\mu g}$

Velocity of the sphere: $v_2=\mu gt=\frac{2\omega_0 r}{9}$

$s_p=\frac{1}{2}a_1r^2=\frac{1}{2}\mu g\left(\frac{2\omega_0 r}{9\mu g}\right)^2=\frac{2}{81}\frac{\omega_0^2r^2}{\mu g}$

531 **(b)**

Let the angular speed of the disc when the reach the end be ω. From conservation of angular momentum

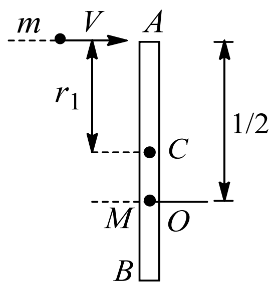
$\frac{1}{2}mR^2\omega_0=\frac{1}{2}mR^2\omega+\frac{m}{2}R^2\omega+\frac{m}{2}R^2\omega$

or $\omega=\frac{\omega_0}{3}$

532 **(d)**

Velocity of the centre of mass of the 'rod + particle' system,

$V_{CM}=\frac{mv}{(M+m)}$



$\vec{v}_{P,CM}=\vec{v}_p-\vec{v}_c$

$v_c=\frac{mv}{M+m}$ and $v_p=v$

$\vec{v}_{p,CM}=\frac{Mv}{M+m}$

$\vec{v}_{rod,CM}=\vec{v}_{rod}-\vec{v}_{CM}=0-\frac{mv}{M+m}$

$v_{rod\ CM}=-\frac{mv}{M+m}$

Location of the centre of mass of the system 'rod +particle' from A

$r_1=\frac{m\times 0+Ml/2}{(m+M)}$

$=\frac{Ml}{2(m+M)}$

Angular momentum of the particle just before collision about C,

$L_{p.c}=mv_{p.c}r_1$

$=\frac{M^2mvl}{2(M+m)^2}$

Angular momentum of the rod about the centre of mass of system C

$L_{\text{rodCM}} = Mv_{\text{rod,CM}}\left(\frac{1}{2} - r_1\right)$

$= M\left(\frac{mv}{M+m}\right)\left(\frac{ml}{2(m+M)}\right)$

$= \frac{Mm^2vl}{2(M+m)^2}$

Moment of inertia about the vertical axis passing through C,

$I_{\text{c,rod}} = I_0 + M\left(\frac{l}{2} - r_1\right)^2$

$I_{\text{c,rod}} = \frac{Ml^2}{12} + M\left(\frac{ml}{2(M+m)}\right)^2$

$I_{\text{c,particle}} = mr_1^2 = m\left(\frac{Ml}{2(M+m)}\right)^2$

$I_c = \frac{Ml^2}{12} + M\left(\frac{ml}{2(M+m)}\right)^2 + m\left(\frac{Ml}{2(M+m)}\right)^2$

$I_c = \frac{M(M+4m)}{12(M+m)}L^2$

As no external forces are acting on the system 'rod + particle', hence the velocity of the centre of mass of the system will remain constant

$v_{\text{CM}} = \frac{mv}{M+m}$

For angular velocity about C,

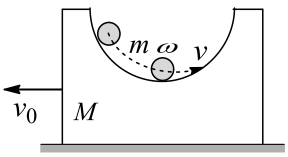
$mvr_1 = I_c\omega$

$\omega = \frac{mvr_1}{I_c} = \frac{mv\left(\frac{ml}{2(M+m)}\right)}{\left(\frac{M(M+4m)L^2}{12(M+m)}\right)}$

$= \frac{6mv}{(M+4m)L}$

533 **(d)**

As no external force is acting on the system (block+ cylinder) in the horizontal direction, the linear momentum of the system remain conserved in the horizontal direction



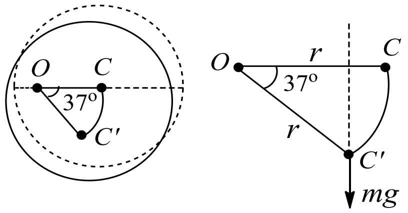
As the cylinder reaches the bottommost point of the track, its centre of mass covers a horizontal distance of 0.25 m $(R - r)$ w.r.t block towards the right. Let the block move by x in backward direction, then

$Mx = m(0.5 - x)$

$x = \frac{2 \times 0.5}{2+3} = 0.2$ m

534 **(a)**

From $\tau = I\alpha$,



$Mg \times r\cos 37° = \left[\frac{MR^2}{2} + Mr^2\right]\alpha$

$\alpha = \frac{8rg}{5[R^2 + 2r^2]}$

From energy conservation,

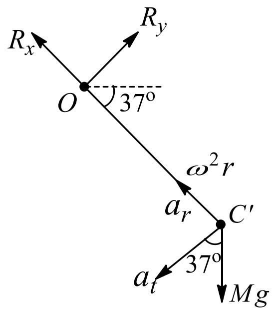
$\frac{I\omega^2}{2} = Mg \times r\sin 37°$

$\left[\frac{MR^2}{2} + Mr^2\right]\frac{\omega^2}{R} = Mgr \times \frac{3}{5}$

$\omega = \sqrt{\frac{12\ gr}{5[R^2 + 2r^2]}}$

For FBD of the disc,

$R_x - Mg\sin 37° = Ma_r = M\omega^2 r$



$Mg\cos 37° - R_y = Ma_t = Mr\alpha$

$R_x = \frac{3Mg}{5}\left[\frac{R^2 + 6r^2}{R^2 + 2r^2}\right], R_y = \frac{Mg}{5}\left[\frac{4R^2}{R^2 + 2r^2}\right]$

$R = \sqrt{R_x^2 + R_y^2} = \frac{Mg}{5[R^2 + 2r^2]}$

$\times \sqrt{9(R^2 + 6r^2)^2 + (4R)^2}$

535 **(c)**

When frictional force is absent, the rigid body does not translate,

$\vec{F}_{\text{external}} = 0$, therefore $\vec{a}_{\text{CM}} = 0$

Taking torque about CM,

$F \times 2R - F \times R = I_{\text{CM}}\alpha$

$10 \times 1 = 4\alpha$

$\alpha = \frac{5}{2}$ rad/s^2

$\omega = \alpha t = 5$ rad/s

$KE_{\text{total}} = \frac{1}{2}I_{\text{CM}}\omega^2 = \frac{1}{2} \times 4 \times 5 \times 5 = 50$J

Taking torque about IC (bottom- most point),

$F \times 4R - F \times 3R = [I_{\text{CM}} + M(2R)^2]\alpha$

$10 \times 1 = [4 + 2 \times (2 \times 1)^2]\alpha$

$\alpha = \frac{10}{12}$ rad/s^2

$\omega = \alpha t = \frac{10}{12} \times 2 = \frac{5}{3}$ rad/s

$KE_{\text{total}} = \frac{1}{2}[I_{\text{CM}} + M(2R)^2]\omega^2$

$= \frac{1}{2}[4 + 2 \times (2 \times 1)^2] \times \left(\frac{5}{3}\right)^2$

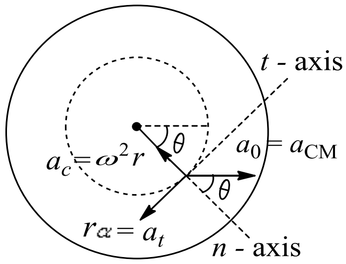
$= 16.67$ J

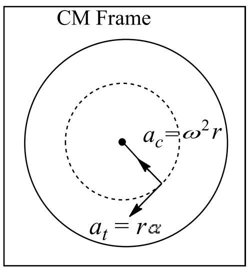
536 **(b)**

As resultant acceleration is zero: resolving all the three components of acceleration and applying $\Sigma a_c = 0$, we get

$a_0 \sin\theta = r\alpha = r\left(\frac{a_0}{R}\right)$

$\sin\theta = \frac{r}{R}$





$\Sigma a_n = a_0 \cos\theta - \omega^2 r = 0$

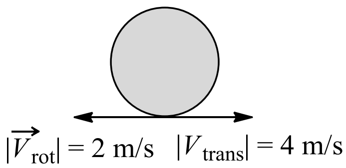
$\sqrt{1 - \frac{r^2}{R^2}} = \left(\frac{v_0}{R}\right)^2 \times \frac{r}{a_0}$

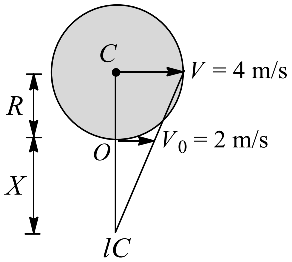
On solving for v_0,we get

$v_0 = \sqrt{\frac{a_0 R}{r}}(R^2 - r^2)^{\frac{1}{4}}$

537 **(a)**

As net velocity of contact point is not zero, the disc rolls with slipping as ω about IC is the same





$\omega = \frac{v_0}{IO} = \frac{v_c}{IC}$

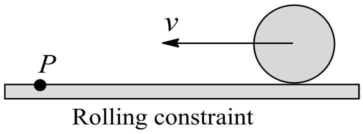
$\frac{2}{x} = \frac{4}{x+R}$ or $x = 0.2$ m

Velocity of P is given by $v_p = (IP)\omega = \sqrt{5}R \times \frac{2}{x} = 2\sqrt{5}$m/s

538 **(b)**

In reference frame of truck, the angular momentum is conserved about P,i.e.,

$MvR = Mv_0R + \frac{2}{5}MR^2\omega_0$ (i)



$v = R\omega$ (ii)

On solving Eqs. (i) and (ii), we get

$v = \frac{5}{7}v_0$

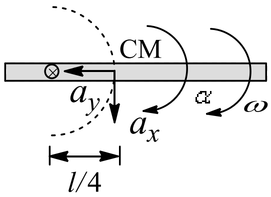
Note that v_0 is the speed is truck frame; in ground frame, the velocity is $v_0 - (5v_0/7) = 2v_0/7$ towards the right

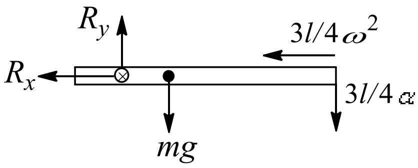
The answer is independent of M or R

539 **(a)**

From conservation of energy, we get

$\frac{mgl}{4} = \frac{1}{2}m\left[\frac{l^2}{12} + \frac{l^2}{16}\right]\omega^2; \omega^2 = \frac{24g}{7l}$





From Newton's law

$\frac{mgl}{4} = \left(\frac{ml^2}{12} + \frac{ml^2}{16}\right)\alpha$ (i)

$mg - R_y = m\left(\frac{1}{4}\alpha\right)$ (ii)

$R_x = \frac{ml}{4}\omega^2$ (iii)

$\alpha = \frac{12g}{7l}; \vec{a}_{\text{CM}} = -\frac{\omega^2 l}{4}\hat{\imath} - \frac{1}{4}\alpha\hat{\jmath}$

$= -\frac{6g}{7}\hat{\imath} - \frac{3g}{7}\hat{\jmath}$

$\vec{a}_B = -\omega^2\left(\frac{3l}{4}\right)\hat{\imath} - \left(\frac{3l}{4}\right)\alpha\hat{\jmath}$

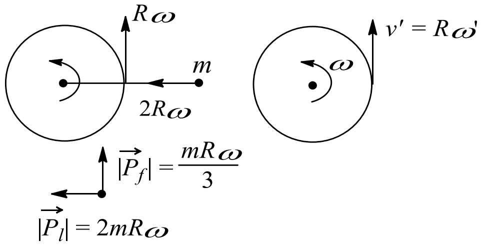
$\vec{R}_x = -\frac{6mg}{7}\hat{\imath}; \vec{R}_y = +\frac{4mg}{7}\hat{\jmath}$

540 **(b)**

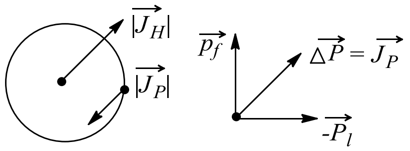
Apply conservation of angular momentum,

$$\frac{mR^2}{2}\omega = \left(\frac{mR^2}{2} + mR^2\right)\omega'$$

$$\omega' = \frac{\omega}{3}$$



Impulse on particle = change in linear momentum



$$\vec{J} = \Delta\vec{p} = \vec{p}_j - \vec{p}_i$$

$$|\Delta\vec{p}| = \sqrt{\left(\frac{mR\omega}{3}\right)^2 + (2mR\omega)^2} = \sqrt{\frac{37}{3}}mR\omega$$

Impulse on hinge is negative of impulse on disc

541 **(d)**

Using torque equation about point A

$$\Rightarrow FR = I_A\alpha$$

$$\Rightarrow FR = \frac{3}{2}MR^2\left(\frac{a}{R}\right) \Rightarrow a_t = \frac{4}{3}\frac{F}{m}$$

542 **(a)**

Conservation of linear momentum

$$mv_0 = m\frac{v_0}{8} - m\frac{v_0}{4}; 8m = M - 2m$$

$$\Rightarrow 10\,m = M$$

$$\Rightarrow \frac{M}{m} = 10$$

Conservation of angular momentum about point of collision

$$0 = \frac{M(8l)^2}{12}\omega - M\frac{v_0}{8}l$$

$$\Rightarrow \omega = \frac{3v_0}{128l}$$

Using coefficient of restitution equation

$$(v_2 - v_1) = e(u_1 - u_2)$$

$$\left[\left(\frac{v_0}{8} + \omega l\right) - \left(-\frac{v_0}{4}\right)\right] = I[v_0 - 0]$$

$$\Rightarrow e = \frac{51}{128}$$

Velocity at end A,

$$v_A = \frac{v_0}{8} + \omega 4l = \frac{28}{128}v_0$$

$$\Rightarrow v_A = \frac{7}{32}v_0$$

Velocity at end B,

$$v_B = \frac{v_0}{8} - \omega 4l = \frac{4}{128}v_0$$

$$= \frac{1}{32}v_0$$

543 **(d)**

If the block does not slip, $f \le \mu N$

$$m\omega^2 L \le \mu mg \Rightarrow \omega \le \left(\frac{\mu g}{L}\right)^{\frac{1}{2}}$$

It is the case of non-uniform circular motion

$$F_{\text{tangential}} = m\frac{dv}{dt} = m\frac{d(\omega l)}{dt} = mL\frac{d\omega}{dt} = m\alpha L$$

$$= m\alpha L \quad \text{(i)}$$

$$F_{\text{radial}} = m\omega^2 L \quad \text{(ii)}$$

Net force, $F_{\text{net}} = \sqrt{(m\alpha L)^2 + (m\omega^2 L)^2}$

Friction force, $f = F_{\text{net}}$

$$= \sqrt{(m\alpha L)^2 + (m\omega^2 L^2)}$$

$$f \le \mu N$$

$$\Rightarrow \sqrt{(m\alpha L)^2 + (m\omega^2 L)^2} \le \mu mg$$

$$\alpha^2 L^2 + \omega^4 L^2 \le \mu^2 g^2$$

$$\Rightarrow \omega^4 \le \frac{\mu^2 g^2}{L^2} - \alpha^2$$

$$\Rightarrow \omega^4 \le \left[\left(\frac{\mu g}{L}\right)^2 - \alpha^2\right]^{\frac{1}{4}}$$

544 **(c)**

Applying conservation of linear momentum,

$$(2 + 1 + 2)v_c = 2 \times 10 + 1 \times 10$$

$$v_c = 6\text{ m/s}$$

545 **(d)**

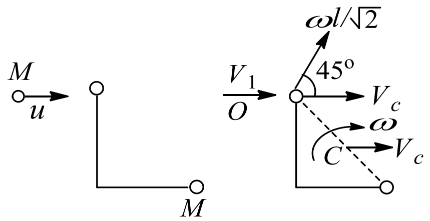
Applying conservation of momentum

$$Mv_1 + 2Mv_c = Mu$$

$$v_1 + 2v_c = u \quad \text{(i)}$$

$$e = 1 = \frac{v_c + \frac{\omega l}{2}\cos 45° - v_1}{u - 0}$$

$$u = v_c + \frac{\omega l}{2} - v_1 \quad \text{(ii)}$$



Applying conservation of angular momentum about C,

$$Mv_1\frac{l}{2} + 2M\left(\frac{l}{\sqrt{2}}\right)^2\omega = Mu\frac{l}{2}$$

$$v_1 + 2\omega l = u \quad \text{(iii)}$$

Solving Eqs. (i), (ii) and (iii), we get

$$v_1 = -\frac{u}{7}; \omega = \frac{4u}{7l}$$

Angle rotated, $\theta = \pi$

$$t = \frac{\theta}{\omega} = \frac{7\pi l}{4u}$$

546 **(d)**

Loss of kinetic energy

$$\Delta K = \left[\frac{1}{2}I(2\omega)^2 + \frac{1}{2}(2I)(\omega)^2\right] - \frac{1}{2}(I + 2I)(4\omega/3)^2$$

$$\Delta K = \frac{I\omega^2}{3}$$

548 **(2)**

Applying conservation of energy, we get

$$mgs\ (\sin\alpha - \sin\beta) = \frac{1}{2}l\omega^2 + 2\left(\frac{1}{2}mv^2 + \frac{1}{2}l\omega^2\right)$$

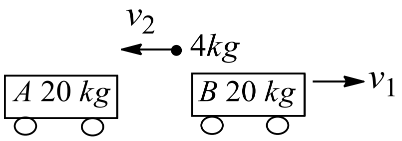
Where $\omega = v/r$ and $I = mr^2/2$

Putting values and solving, we get $v = 2$ m/s

549 **(1)**

All the velocities shown in diagrams are w.r.t. ground

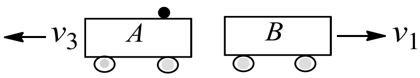
After first jump:



$20v_1 = 4v_2$ and $v_1 + v_2 = 6$ (given)

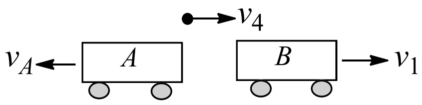
Solve to get $v_1 = 1$ m/s, $v_2 = 5$ m/s

When child arrives on A:



$(20 + 4)v_3 = 4v_2 \Rightarrow v_3 = 5/6$ m/s

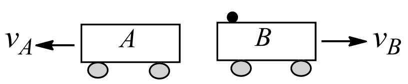
After the second jump:



$v_4 + v_A = 6, 24v_3 = 20v_A - 4v_4$

Solve to get $v_A = \frac{11}{6}$ m/s, $v_4 = \frac{25}{6}$ m/s

When child arrives on B:



$24v_B = 4v_4 + 20v_1$

$$\Rightarrow\ 24v_B = 4\left(\frac{25}{6}\right) + 20 \times 1 \Rightarrow v_B = \frac{55}{36}\ \text{m/s}$$

Now $\frac{6v_B}{5v_A} = \frac{6\times55\times6}{36\times5\times11} = 1$

550 **(3)**

For circular motion of the stone,

$\frac{mv^2}{r} = T$ [as g = 0] (i)

and as A.M. is constant,

$mvr = K$,

i.e., $v = \frac{K}{mr}$ (ii)

Eliminating v between Eqs. (i) and (ii), we get

$$\frac{m}{r}\left[\frac{K}{mr}\right]^2 = T,$$

$$T = \frac{K_2}{m_2}r^{-3}$$

Or $T = Ar^{-3}$ with $A = \left(\frac{K^2}{m}\right)$ (iii)

Comparing Eqs.(iii) with $T = A/r^n$, we find $n = 3$

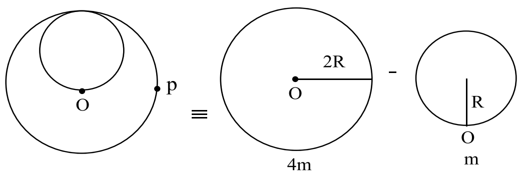
551 **(0)**

Let f be the friction force acting on the disc in the backward direction. Then $2F - f = ma$ and $(F + f)r = I\omega$

$$\Rightarrow (F + f)r = \frac{1}{2}mr^2\frac{a}{r}$$

∴ solving the above equation, we get $f = 0$

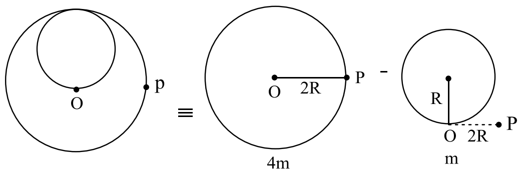
552 **(3)**



$$I_O = \frac{(4m)(2R)^2}{2} - \frac{3}{2}mR^2$$

$$= mR^2\left[8 - \frac{3}{2}\right]$$

$$= \frac{13}{2}mR^2$$



$$I_P = \frac{3}{2}(4m)(2R)^2 - \left[\frac{mR^2}{2} + m[(2R)^2 + R^2]\right]$$

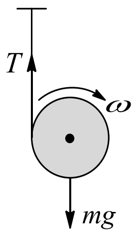
$$= 24mR^2 - \frac{11}{2}mR^2$$

$= \frac{37}{2} mR^2$

$\frac{I_P}{I_O} = \frac{\frac{37}{2}}{\frac{13}{2}} = \frac{37}{13} = 3$

553 **(5)**

Let T be the tension in the thread and f, the linear acceleration of the reel as it fails



For the downward translation

$(mg - T) = mf$ (i)

For the rotational motion of the reel, angular acceleration is $\alpha = \left(\frac{f}{a}\right)$ and $T = \frac{mg}{3}$ (ii)

From Eqs (i) and (ii), $T = mg - mf = mg - ma\alpha$

$= mg - 2T$

$\Rightarrow 3T = mg$

$\therefore T = \frac{mg}{3} = 1.5 \times 10/3 = 5$ N

554 **(6)**

$\frac{L_{\text{total}}}{L_B} = \frac{m_1 r_1^2}{m_2 r_2^2} + 1$

555 **(2)**

Loss in PE = gain in KE

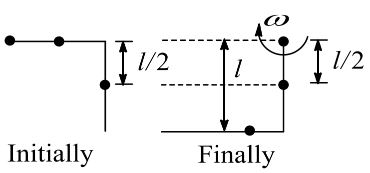
$mgh = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2$

$\Rightarrow mgh = \frac{1}{2} m(\omega r)^2 + \frac{1}{2}\left(\frac{2}{3} mr^2\right)\omega^2$

$m \times 10 \left(\frac{3}{100}\right) = m \frac{5}{6} \times \left(\frac{30}{100}\right)^2 \omega^2 \Rightarrow 2$ rad/s

556 **(6)**

Using conservation of mechanical energy

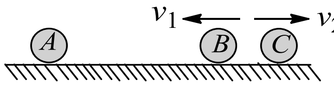


$mgl = \frac{1}{2} \frac{ml^2}{3} \omega^2 + \frac{1}{2}\left[\frac{ml^2}{12} + m\frac{5l^2}{4}\right]\omega^2$

$\Rightarrow \omega = 6$ rad/s

557 **(2)**

For the first collision, $e = 1, v = v_1 + v_2$



$\Rightarrow \ v_2 = v - v_1$ (i)

By momentum conservation

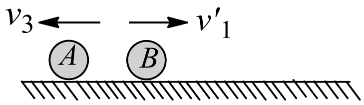
$m_B v = -m_B v_1 + m_C v_2$

$m_B v = -m_B v_1 + 4\, m_B v_2$

$v_2 = \frac{v_1 + v}{4}$ (ii)

From Eqs. (i) and (ii), $v_1 = \frac{3}{5} v$ and $v_2 = \frac{2}{5} v$

For the second collision, $e = 1$



$v_1 = v_1' + v_3 \Rightarrow v_3 = v_1 - v_1'$ (iii)

By momentum conservation, $-m_B v_1 = m_B v_1' - m_A v_3$

Or $-m_B v_1 = m_B v_1' - 4\, m_B v_3$ ($\because m_A = 4m_B$)

$v_3 = \frac{v_1' + v_1}{4}$ (iv)

From Eqs. (iii) and (iv), $v_1' = \frac{3}{5} v_1 = \frac{3}{5}\left(\frac{3}{5} v\right) = \frac{9}{25} v$

Clearly, $\frac{9}{25} v < \frac{2}{5} v$

Therefore, 'B' cannot collide with 'C' for the second time

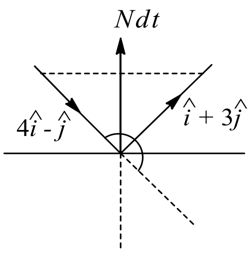
Hence, the total number of collisions is 2

558 **(9)**

$\int N dt = 1[(\hat{\imath} + 3\hat{\jmath}) - (4\hat{\imath} - \hat{\jmath})] = -3\hat{\imath} + 4\hat{\jmath}$

Component of $4\hat{\imath} - \hat{\jmath}$ along $-3\hat{\imath} + 4\hat{\jmath}$

$= \frac{-12 - 4}{25}(-3\hat{\imath} + 4\hat{\jmath}) = -\frac{16}{25}(-3\hat{\imath} + 4\hat{\jmath})$



Speed of approach$= \frac{16}{25}\sqrt{25} = \frac{16}{5}$

Component of $\hat{\imath} + 3\hat{\jmath}$ along $-3\hat{\imath} + 4\hat{\jmath}$ is

$\frac{-3+12}{25}(-3\hat{\imath} + 4\hat{\jmath})$

Speed of separation = 9/5

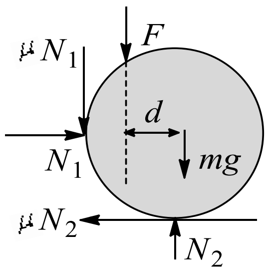
Speed of separation= e ×speed of approach

$e = \frac{9}{16}$ $n = 9$

559 **(6)**

For equilibrium of the cylinder in the horizontal direction

$N_1 = \mu N_2$ (i)



In the vertical direction,

$N_2 + \mu N_1 = F + Mg$ (ii)

Solving these two equation with $F = 40$ N, $M = 2$ kg and μ=1/3, we get

$N_1 = 18$ N

and $N_2 = 54$ N

Now, $Fd = \mu(N_1 + N_1)r$

$$d = \frac{M(N_1 + N_2)r}{F}$$

$$= \frac{(1/3)\ (18 + 54)(0.1)}{40}$$

$= 0.06$ m

560 **(5)**

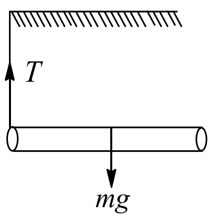
$Mg - T - Ma_y$ (i)

$T\left(\frac{L}{2}\right) = \frac{ML^2}{12}\alpha$ (ii)

and $a_y = \frac{L}{2}\alpha$ (iii)

On solving, we get

$$T = \frac{Mg}{4} = 5 \text{ N}$$



561 **(3)**

For first case: $W = \Delta\text{KE} \Rightarrow -Rd = -\frac{1}{2}mu^2$

$Rd = \frac{1}{2}mu^2$ (i)

For second case: $W = (M + m)v, v$ is common velocity

$$\Rightarrow v = \frac{m}{(M + m)}u$$

$$-Rd' = \frac{1}{2}(M + m)v^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2}\frac{m^2u^2}{(M + m)} - \frac{1}{2}mu^2$$

$\Rightarrow\ Rd' = \frac{1}{2}\frac{Mm}{(M+m)}u^2$ (ii)

Solving Eqs. (i) and (ii), $\frac{Rd}{Rd'} = \frac{M+m}{M} \Rightarrow d' = 3$ cm

562 **(9)**

As the belt does not slip, $v_p = v_Q$

i.e., $r_A\omega_A = r_C\omega_C$ [as $v = r\omega$] (i)

According to the given problem if $r_A = r, r_C = 3r$, so Eq. (i) becomes

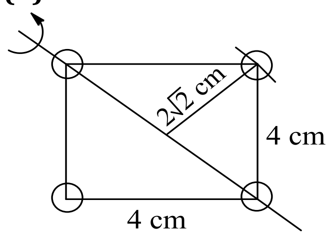
$\omega_A = 3\omega_C$ (ii)

If both the wheels have the same rotational kinetic energy, then

$$\frac{1}{2}I_A\omega_A^2 = \frac{1}{2}I_C\omega_C^2$$

or $\frac{I_A}{I_C} = \left[\frac{\omega_C}{\omega_A}\right]^2 = \left[\frac{1}{3}\right]^2 = \frac{1}{9}$

563 **(9)**



$$I = \left(\frac{2}{5}MR^2\right)2 + \left(\frac{2}{5}MR^2 + Mx^2\right)2$$

$$= \left(\frac{2}{5}MR^2\right)2 + \left(\frac{2}{5}MR^2\right)2 = (Mx^2)2$$

$$= 4\left(\frac{2}{5}MR^2\right) + 2Mx^2 = \frac{8}{5}MR^2 + 2mx^2$$

$$= \left[\frac{8}{5} \times 0.5 \times \left(\frac{\sqrt{5}}{2}\right)^2 + 2 \times (0.5) \times (4 \times 2)\right]10^{-4}$$

$$= \left[\frac{5}{5} + 8\right] \times 10^{-4} = 9 \times 10^{-4} = N \times 10^{-4}$$

So, $N = 9$

564 **(1)**

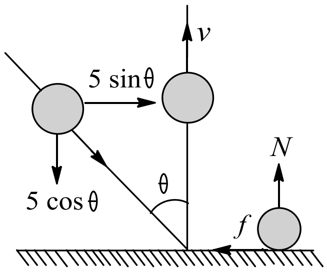
From impulse–momentum theorem,

$\int N\,dt = m(v + 5\cos\theta)$ (i)

$\int f\,dt = m5\sin\theta$

$\mu \int N\,dt = m5\sin\theta$ (ii)

$\Rightarrow \mu m(v + 5\cos\theta) = m5\sin\theta$

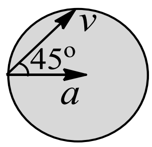


According to Newton's law of restitution,

$v = e\,5\cos\theta$

Solve to get $\mu = 1$

565 **(2)**



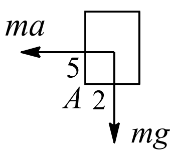
The required angle is 45°, so $\frac{\sqrt{2}}{n} = \frac{1}{\sqrt{2}} \Rightarrow n = 2$

566 **(4)**

Maximum acceleration of the cart so that the cylinder does not slip:

$a_m = \mu g = 0.5 \times 10 = 5\ \text{m/s}^2$

For tipping over. Let acceleration of the cart be a



Considering torque about A, we get

$ma \times 5 \geq mg \times 2 \Rightarrow 2g/5 = 4\ \text{m/s}^2$

567 **(3)**

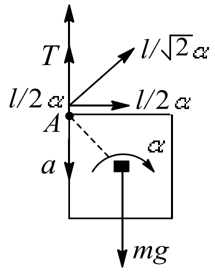
To save himself, the man throws his jacket in opposite direction to the lake According to momentum conservation, he himself gets a velocity in the direction of the lake. During the motion as gravity is the only external force on the system (man plus jacket), centre of mass will not be displaced horizontally. Thus, centre of mass of the system falls vertically and when the man falls in the lake, jacket falls at a point such that the centre of mass of the man and the jacket will be directly below the point from where the man jumps)

As it is given that man falls at a distance d from this point, it implies that jacket will fall at a distance x in the opposite direction such that $mx = Md \Rightarrow x = \frac{M}{m}d = 29$ m, man has to travel a distance $x + d = 29 + 1 = 30$ m to pick his jacket

568 **(6)**

$T\frac{l}{2} = \frac{ml^2}{6} \times \alpha; mg - T = ma$

$\alpha = \frac{3T}{ml} = \frac{3}{ml}(mg - ma)$



Constraint relation: Acceleration of A in the vertical direction should be zero

$\frac{\ell}{2}\alpha = a \Rightarrow a = \frac{2a}{l} = \frac{3(g - a)}{l}$

$5a = 3g \Rightarrow a = 3 \times \frac{g}{5} = 6\ \text{m/s}^2$

569 **(1)**

Let u be the initial velocity of the ball of mass m. Then

$mu = mv_1 + nmv_2 \Rightarrow v_1 + nv_2 = u$ (i)

For elastic collision, Newton's experimental formula is $(u_2 = 0)$

$v_1 - v_2 = -(u_1 - u_2) \Rightarrow v_1 - v_2 = -u$ (ii)

Solving Eqs. (i) and (ii), $v_1 = \frac{1-n}{1+n}u$

Fractional loss in KE (= fractional transfer of KE)

$f = \frac{K_i - K_f}{K_i} - \frac{\frac{1}{2}mu^2 - \frac{1}{2}mv_1^2}{\frac{1}{2}mu^2} = 1 - \left(\frac{v_1}{u}\right)^2$

$f = 1 - \left(\frac{1-n}{1+n}\right)^2 = \frac{4n}{(n+1)^2}$

The transfer of energy is maximum when $f = 1$ or 100%

$\frac{4n}{(n+1)^2} = 1 \Rightarrow n = 1$

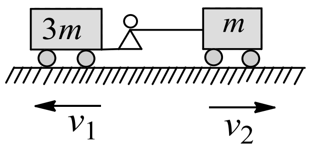
This is, the transfer of energy is maximum when the mass ratio is unity

570 **(9)**

Trolleys gain momentum due to force applied by

man which will be internal force for the system of trolleys and man and there is no other external force. Here we assume that man applies force for a very short time, during which effect of friction can be neglected.
Momentum just before pushing = momentum just after pushing

$0 = 3\,mv_1 - mv_2 \Rightarrow v_1 = \frac{v_2}{3}$



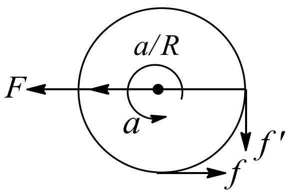
From work–energy theorem for individual trolleys,

$f_1S_1 = \frac{1}{2}3mv_1^2, f_2S_2 = \frac{1}{2}3mv_2^2$

Here $f_1 = \mu\,3mg, f_2 = \mu mg$

Solve to get $\frac{S_2}{S_1} = \left(\frac{v_2}{v_1}\right)^2 = 9$

571 **(4)**
Note : If net force applied by the rod is considered to be 2 N



$\sqrt{f^2 + F^2} = 2$ (i)

$FR - f'R = 2mR^2\frac{a}{R}$

$F - f' = 2ma = 1.2$

From Eqs. (i) and (ii), $(1.2\ + f')^2 + f'^2 = 2^2$

$2f'^2 + 2.4\,f' + 1.44 = 4$

$f'^2 + 1.2\,f' + 0.72 - 2 = 0$

$f'^2 + 1.2\,f' - 1.28 = 0$

$f' = \frac{-1.2 \pm \sqrt{1.44 + 4 \times (1.28)}}{2}$

$= 0.6 \pm \sqrt{0.36 + 1.28} = -0.6 \pm \sqrt{0.64} = 0.68$

From Eq. (ii), $F = 1.88$

$V = \frac{0.68}{1.88} = \frac{P}{10} \Rightarrow P = 3.16 \approx 4$

Note: But if only normal reaction applied by the rod is considered to be 2 N

II Law $\Rightarrow 2 - f = 2[0.3] \Rightarrow f = 2 - 0.6$

$f - 1.4\,Nx$ (i)

$A = R\alpha$

$\Rightarrow 0.3 = \alpha[0.5]$

$\Rightarrow \alpha = \frac{3}{5}$ rad/s (ii)

$\tau_c = I_c\alpha \Rightarrow fR - 2\,\mu R = mR^2\alpha$

$f - 2\mu = mR\alpha$

$1.4 - 2\mu = \frac{2}{2}\left(\frac{3}{2}\right)$

$1.4 - 0.6 = 2\mu$

$0.8 = 2\mu \Rightarrow \mu = 0.4 = \frac{P}{10}$

$\therefore P = 4$

572 **(2)**
$F_1 = 4N = -4\hat{\imath}$ $0 < t \leq 1$ s
$= 2N = -2\hat{\imath}$ $1 \leq t \leq 3$ s
$F_2 = 1N = -\hat{\jmath}$ $0 < t \leq 2$ s
$= 2t - 3N = -(2t-3)\hat{\jmath}$ $2 \leq t \leq 3$ s
Initial velocity f the particle is $\vec{u} = 10\hat{\imath}$
From impulse momentum theorem, $\int d\vec{p} = \int \vec{F}\,dt$

$m\vec{v} - m\vec{u} = \int^3 (\vec{F}_1 + \vec{F}_2)dt$

(Where $\vec{v}$ is the required velocity)
$1 \times \vec{v} - 1 \times 10\hat{\imath} = -8\hat{\imath} - 4\hat{\jmath}$ or $\vec{v} = 2\hat{\imath} - 4\hat{\jmath}$
Or $v = \sqrt{2^2 + 4^2} = 2\sqrt{5}$ m/s

573 **(5)**
When the string is cut, the weight of the rod constitutes torque about the hinge, so

$\tau_A = mg\frac{l}{2}$ (i)

According to Newton's second law,

$\tau_A = I\alpha$ (ii)

Where α is the angular acceleration of the rod about the end A. From Eqs. (i) and (ii), we get

$I\alpha = mg\frac{l}{2}$

Or $\alpha = \frac{mg\frac{l}{2}}{I}$

Here $I = ml^2/3$, therefore

$$\therefore \alpha = \frac{mgl/2}{ml^2/3} = \frac{3}{2}\frac{g}{l}$$

Acceleration of the CM of the rod is

$$a_{CM} = \alpha r = \frac{3}{2}\frac{g}{l} \times \frac{l}{2} = \frac{3g}{4}$$

Again by Newton's second law,

$mg - R_A = ma_{CM}$

Or $mg - R_A = m \times \frac{3g}{4}$

$$\therefore R_A = \frac{Mg}{4} = \frac{2 \times 10}{4} = 5 \text{ N}$$

574 **(4)**

Here the force on the point mass due to the cord is radial and hence the torque about the centre of rotation is zero. Therefore, the angular momentum must remain constant as the cord is shortened

Let m, v_1 and ω_1 be the mass, linear velocity and angular velocity of the point mass, respectively, in the circle of radius r_1. Further let v_2 and ω_2 be the linear and angular velocities, respectively, of the point mass in a circle of radius r_r. Now,

Initial angular momentum= final angular momentum

$I_1\omega_1 = I_2\omega_2$

$$mr_1^2\frac{v_1}{r_1} = mr_2^2\ \frac{v_2}{r_2}$$

$r_1v_1 = r_2v_2$

$v^2 = \frac{r_1}{r_2}v_1 = \frac{2}{1} \times 4 = 8 \text{ m/s}$

and $\omega_2 = \frac{v_2}{r_2} = \frac{8}{1} = 8 \text{ rad/s}$

$$\frac{\text{Final KE}}{\text{Initial KE}} = \frac{\frac{1}{2}I_2\omega_2^2}{\frac{1}{2}I_1\omega_1^2}$$

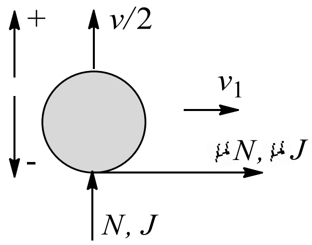
$$= \frac{mr_2^2(v_2/v_1)^2}{mr_1^2(v_1/r_1)^2} = \frac{v_2^2}{v_1^2} = \frac{(8)^2}{(4)^2} = 4$$

575 **(2)**

$J = \int N\,dt = m\frac{v}{2} - (-mv) = \frac{3}{2}mv$ (i)

$\mu JR = \int \mu\ (N\,dt)R = \left(\frac{2}{5}mR^2\omega - 0\right) = \frac{2}{5}mR^2\omega$

(ii)



From Eqs. (i) and (ii), we get

$\frac{3}{2}mv\ R\mu = \frac{2}{3}mR^2\omega$ (iii)

Let V and V_1 be the speeds of the plank and the sphere, respectively, in the horizontal direction

$\mu J = \int \mu\,Ndt = MV = mV_1$ (iv)

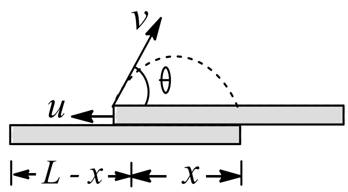
From Eqs. (i) and (iv) , $\mu\left(\frac{3}{2}\right)mv = MV$

$$V = \frac{3}{2}\frac{\mu mv}{M} = \frac{3}{2}\frac{4}{15}\frac{mR\omega}{M} = \frac{2}{5}\frac{m}{M}R\omega$$

and $V_1 = \frac{2}{5}R\omega = 2 \text{ m/s}$

576 **(2)**

Apply conservation of momentum in horizontal direction:



$mv\cos\theta - \text{mu} = 0 \Rightarrow u = v\cos\theta$

$L - x = ut, x = v\cos\theta t$

Solve to get, $x = \frac{L}{2}$

$$x = \frac{v^2\sin 2\theta}{g} \Rightarrow \frac{L}{2} = \frac{v^2\sin 2\theta}{g}$$

$\Rightarrow v = \sqrt{\frac{gL}{2\sin\theta}}$ for minimum $v, \sin 2\theta = 1$

$v_{\min} = \sqrt{\frac{gL}{2}} = \sqrt{\frac{10\times5}{2}} = 2\sqrt{5}$ m/s, Hence n =2