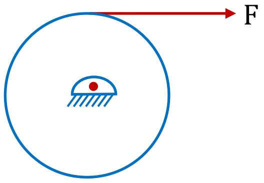
EXERCISE - O

SINGLE CORRECT TYPE QUESTIONS

Concept of w, α, v, a

1. A pulley is hinged at the centre and a massless thread is wrapped around it. The thread is pulled with a constant force F starting from rest. As time increases,



(A) its angular velocity increases, but force on hinge remains constant
(B) its angular velocity remains same, but force on hinge increases
(C) its angular velocity increases and force on hinge increases
(D) its angular velocity remains same and force on hinge is constant

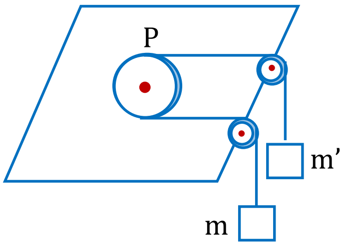
PRM152

2. In the previous question, if $dv/dt = 0$, then the angular acceleration of the ladder when $\alpha = 45°$ is :-

(A) $2v^2/L^2$ (B) $v^2/2L^2$ (C) $\sqrt{2}\left[\frac{v^2}{L^2}\right]$ (D) None

PRM158

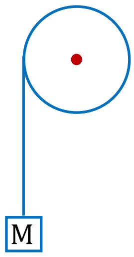
3. A smooth pulley P of mass $M = 2\ kg$ is lying on a smooth table. A light string passes round the pulley and has mass $m = 1\ kg$ and $m' = 2kg$ attached to its ends, the two portions of the string being perpendicular to the edge of the table so that the masses hang vertically. Acceleration of pulley is–



(A) $\frac{g}{2}$ (B) $\frac{2g}{3}$ (C) $\frac{4g}{9}$ (D) $\frac{4g}{7}$

PRM234

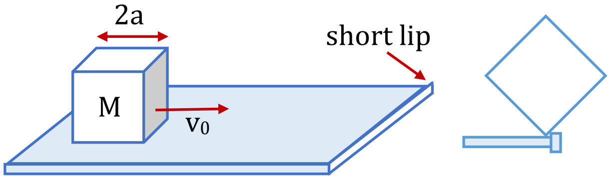
4. A fixed pulley of radius 20 cm and moment of inertia 0.32 $kg.m^2$ about its axle has a massless cord wrapped around its rim. A mass M of 2 kg is attached to the end of the cord. The pulley can rotate about its axis without any friction. The acceleration of the mass M is :- (Assume $g = 10\ m/s^2$)



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

PRM235

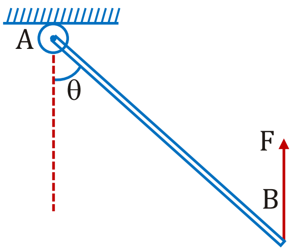
5. A cube with sides of length $2a$ and mass M is moving with an initial speed v_0 along a frictionless table. When the cube reaches the end of the table it is caught abruptly by a short lip and begins to rotate. The minimum speed v_0 such that the cube falls off the table is :-



(A) $\sqrt{\dfrac{16ag(\sqrt{2}-1)}{3}}$ (B) $\sqrt{16ag(\sqrt{2}-1)}$ (C) $\sqrt{ag\left(\sqrt{2}-1\right)}$ (D) $\sqrt{\dfrac{ag}{3}\left(\sqrt{2}-1\right)}$

PRM236

6. As shown in the figure, a uniform rod can be rotated freely about point A in the vertical plane. When a vertical upward force F lifts up the rod slowly from position shown, which of the following statements is correct till the rod becomes horizontal ?



(A) The pulling force is unchanged, its moment of force increases.

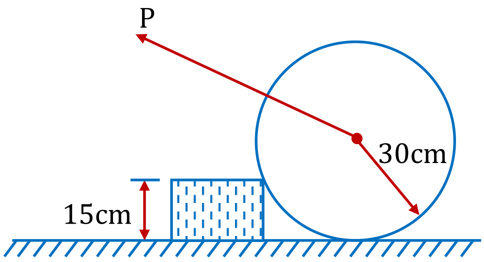
(B) The pulling force is unchanged, its moment of force decreases.

(C) The pulling force increases, its moment of force decreases.

(D) The pulling force decreases, its moment of force decreases.

PRM237

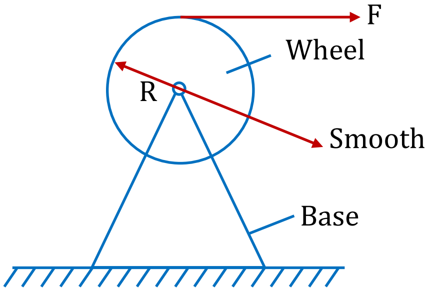
7. In the given figure a uniform wheel of radius $30cm$ rests against a rigid rectangular block $15cm$ high. All the surfaces are smooth. The wheel weighs $1000\ N$. The minimum pull P through the center which will turn the wheel over the block is :-



(A) $500\sqrt{3}\ N$ (B) $1000\sqrt{3}\ N$ (C) $1000\ N$ (D) $400\sqrt{3}\ N$

PRM238

8. A wheel (disc of mass m, radius R) is mounted on a base of mass M. The whole system is placed on rough horizontal surface. The coefficient of friction between the base & the surface is μ. Initially the system is at rest. A time varying horizontal force $F = 2t$ is applied tangentially on the wheel, where t is time in second & force F is in newton. The kinetic energy of the disc when the system is about to slide on ground is :-

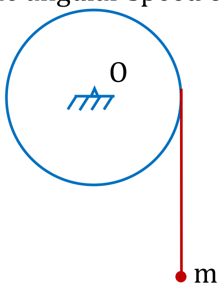


(A) $\frac{1}{m}\left(\frac{\mu(M)g}{2}\right)^4$ (B) $\frac{1}{m}\left(\frac{\mu(m+M)g}{2}\right)^4$

(C) $\frac{1}{m}\left(\frac{\mu(m+M)g}{2}\right)^2$ (D) $\frac{1}{m}\left(\frac{\mu(M)g}{2}\right)^2$

PRM239

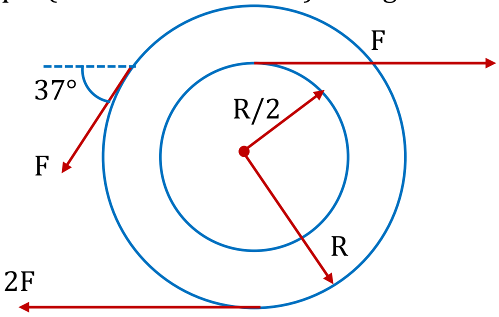
9. A uniform disc of mass M and radius R is smoothly pivoted at 'O'. A light inextensible strings wrapped over the disc hangs a particle of mass m. If the system is released from rest, assuming string does not slide, what will be the angular speed of the disc as a function of time.



(A) $\omega=\frac{2mgt}{(M+2m)R}$ (B) $\omega=\frac{4mgt}{(M+2m)R}$ (C) $\omega=\frac{mgt}{(M+2m)R}$ (D) $\omega=\frac{mgt}{(M+m)R}$

PRM240

10. On a disc of radius R a concentric circle of radius $R/2$ is drawn. The disc is free to rotate about a frictionless axis through its centre and perpendicular to plane of the disc. All the three forces (in plane of the disc) shown in figure are act tangentially to their respective circular periphering. The magnitude of the net torque (about centre of disc) acting on the disc is :-

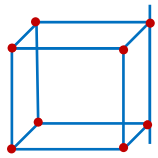


(A) 1.9 FR (B) 2.3 FR (C) 2.5 FR (D) 1.5 FR

PRM241

Moment of Inertia

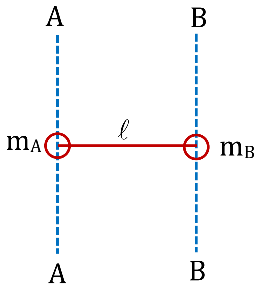
11. Eight point objects, each of mass M, are at the vertices of a rigid, massless framework in the form of a cube; each side is of length a. What is the moment of inertia of this arrangement about an axis passing through one edge of the cube?



(A) 4 Ma^2 (B) 6 Ma^2 (C) 8 Ma^2 (D) 10 Ma^2

PRM090

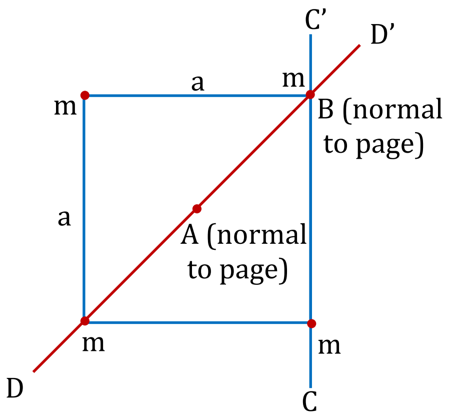
12. A point mass m_A is connected to a point mass m_B by a massless rod of length ℓ as shown in the figure. It is observed that the ratio of the moment of inertia of the system about the two axes BB and AA, which is parallel to each other and perpendicular to the rod is $\frac{I_{BB}}{I_{AA}}=3$. The distance of the centre of mass of the system from the point mass m_A is



(A) (3/4) ℓ (B) (2/3) ℓ (C) (1/2) ℓ (D) (1/4) ℓ

PRM091

13. The square structure shown in figure consists of four point masses connected by rods of negligible mass. Mark the **CORRECT** option regarding the moment of inertia of the structure about the following axes:



(A) Axis A, passing through the centre of the structure and normal to its plane $I_A = ma^2$

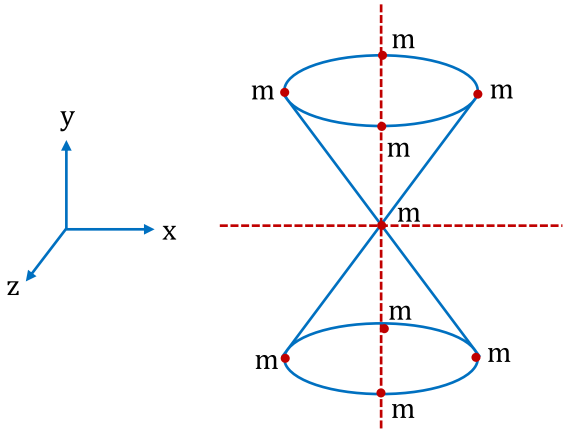
(B) Axis B, passing through one of the point masses and normal to the plane of the structure $I_B = 3ma^2$

(C) Axis CC', passing through two adjacent point masses $I_C = 2ma^2$ and

(D) Axis DD', along the diagonal of the structure $I_D = 2ma^2$

PRM092

14. Nine point mass m are arranged in an double-cone system as shown in diagram. Radius of each cone is R and height of each cone is H. The moment of inertia about the x-axis passing through the common vertex is :



(A) $8\ mH^2$ (B) $8\ m(H^2 + R^2)$ (C) $8\ mH^2 + 4\ mR^2$ (D) None of these

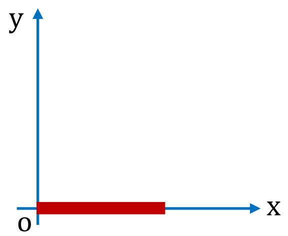
PRM093

15. A rigid body can be hinged about any point on the x-axis. When it is hinged such that the hinge is at x, the moment of inertia is given by $I = 2x^2 - 12x + 27$. The x-coordinate of centre of mass is

(A) $x = 2$ (B) $x = 0$ (C) $x = 1$ (D) $x = 3$

PRM094

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



(A) an ellipse (B) a circle (C) a parabola (D) a straight line

PRM097

17. A thin uniform rod of mass M and length L has its moment of inertia I_1 about its perpendicular bisector. The rod is bend in the form of a semi-circular arc. Now its moment of inertia through the centre of the semi-circular arc and perpendicular to its plane is I_2. The ratio of $I_1 : I_2$ will be ______.

(A) < 1 (B) > 1 (C) = 1 (D) can't be said

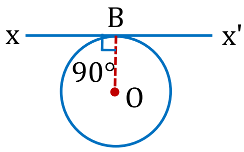
PRM098

18. A circular disc X of radius R is made from an iron plate of thickness t and another disc Y of radius $4R$ is made from an iron plate of thickness $t/4$. Then the relation between the moment of inertia I_X and I_Y is

(A) $I_Y = 32\ I_X$ (B) $I_Y = 16\ I_X$ (C) $I_Y = I_X$ (D) $I_Y = 64\ I_X$

PRM099

19. 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) $\rho L^3/8\pi^2$ (B) $\rho L^3/16\pi^2$ (C) $5\ \rho L^3/16\pi^2$ (D) $3\ \rho L^3/8\pi^2$

PRM100

20. One solid sphere A and another hollow sphere B are of same mass and same outer radii. Their moment of inertia about their diameters are respectively I_A and I_B such that-
(Where d_A and d_B are their densities)

(A) $I_A = I_B$ (B) $I_A > I_B$ (C) $I_A < I_B$ (D) $\frac{I_A}{I_B} = \frac{d_A}{d_B}$

PRM101

21. Three bodies have equal mass m. Body A is solid cylinder of radius R, body B is a square lamina of side R, and body C is a solid sphere of radius R. Which body has the smallest moment of inertia about an axis passing through their centre of mass and perpendicular to the plane (in case of lamina)

(A) A (B) B (C) C (D) A and C both

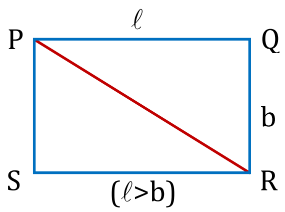
PRM102

22. For the same total mass which of the following will have the largest moment of inertia about an axis passing through its centre of mass and perpendicular to the plane of the body

(A) a disc of radius a (B) a ring of radius a
(C) a square lamina of side $2a$ (D) four rods forming a square of side 2a

PRM103

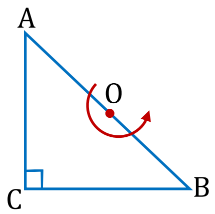
23. Moment of inertia of a rectangular plate about an axis passing through P and perpendicular to the plate is I. Then moment of PQR about an axis perpendicular to the plane of the plate:



(A) about $P = I/2$ (B) about $R = I/2$ (C) about $P > I/2$ (D) about $R > I/2$

PRM105

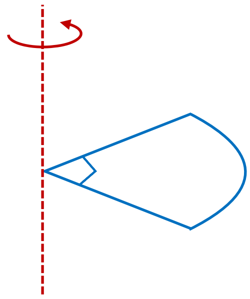
24. Find the moment of inertia of a plate cut in shape of a right angled triangle of mass M, about an axis perpendicular to the plane of the plate and passing through the mid point of side AB.
(Side $AC = BC = a$)



(A) $\frac{Ma^2}{12}$ (B) $\frac{Ma^2}{6}$ (C) $\frac{Ma^2}{3}$ (D) $\frac{2Ma^2}{3}$

PRM110

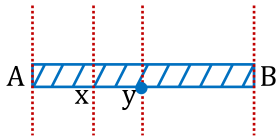
25. One quarter sector is cut from a uniform circular disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the center of the original disc. Its moment of inertia about the axis of rotation is



(A) $\frac{1}{2}MR^2$ (B) $\frac{1}{4}MR^2$ (C) $\frac{1}{8}MR^2$ (D) $\sqrt{2}MR^2$

PRM111

26. A rod non uniform mass distribution. The mass increases from left end (A) to right end (B) . It is easiest to rotate the rod about an axis

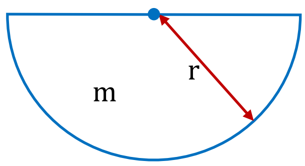


(A) Passing through A (B) Passing through B

(C) Passing through x (D) Passing through y

PRM242

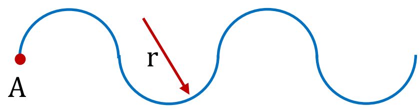
27. A semicircular lamina of mass m has radius r and centre C. Its moment of inertia about an axis through its centre of mass and perpendicular to its plane is–



(A) $\frac{1}{2}mr^2$ (B) $\left(\frac{1}{2}-\frac{4}{\pi^2}\right)mr^2$ (C) $\left(\frac{1}{2}-\frac{8}{9\pi^2}\right)mr^2$ (D) $\left(\frac{1}{2}-\frac{16}{9\pi^2}\right)mr^2$

PRM243

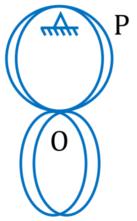
28. A uniform rod of mass $2M$ is bent into four adjacent semicircles each of radius r, all lying in the same plane. The moment of inertia of the bent rod about an axis through one end A and perpendicular to plane of rod is :-



(A) $22Mr^2$ (B) $88Mr^2$ (C) $44Mr^2$ (D) $66Mr^2$

PRM244

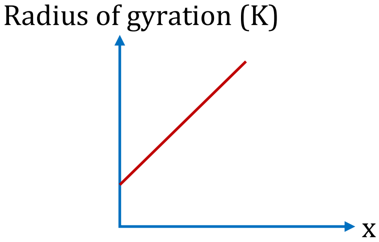
29. Two identical rings each of mass m with their planes nutually perpendicular, radius R are welded at their point of contact O. If the system is free to rotate about an axis passing through the point P perpendicular to the plane of the paper the moment of inertia of the system about this axis is equal to

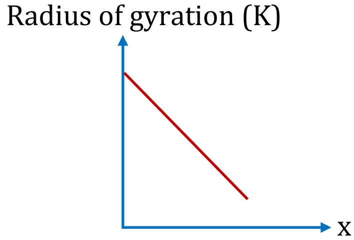


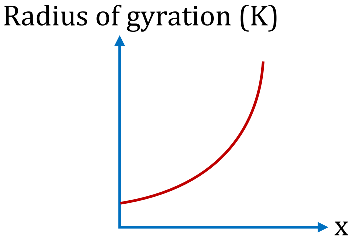
(A) 6.5 mR^2 (B) 12 mR^2 (C) 6 mR^2 (D) 11.5 mR^2

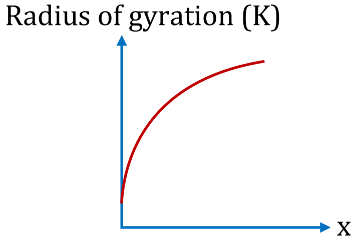
PRM245

30. A uniform disc has radius R. If a concentric smaller disc of radius x is removed from the bigger disc then radius of gyration of the remaining disc about an axis passing through centre and perpendicular to plane of disc varies with x, according to the graph :-

(A)


(B)


(C)


(D)


PRM246

Equilibrium

31. A weightless rod is acted on by upward parallel forces of 2N and 4N at ends A and B respectively. The total length of the rod is AB = 3m. To keep the rod in equilibrium a force of 6N should act in the following manner:

(A) Downwards at any point between A and B.

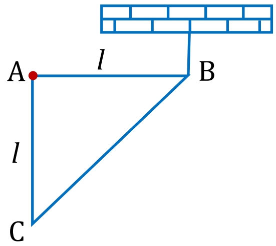
(B) Downwards at mid point of AB.

(C) Downwards at a point C such that AC = 1m.

(D) Downwards at a point D such that BD = 1m.

PRM120

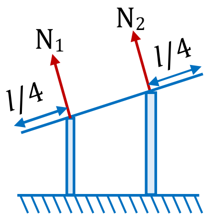
32. A right triangular plate ABC of mass m is free to rotate in the vertical plane about a fixed horizontal axis through A. It is supported by a string such that the side AB is horizontal. The reaction at the support A in equilibrium is:



(A) $\frac{mg}{3}$ (B) $\frac{2mg}{3}$ (C) $\frac{mg}{2}$ (D) mg

PRM121

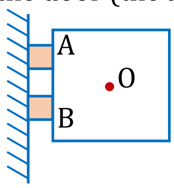
33. A uniform rod of length l is placed symmetrically on two walls as shown in figure. The rod is in equilibrium. If N_1 and N_2 are the normal forces exerted by the walls on the rod then :-

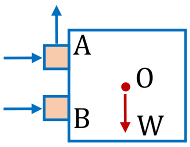


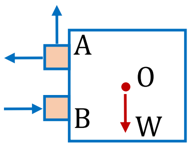
(A) $N_1 > N_2$
(B) $N_1 < N_2$
(C) $N_1 = N_2$
(D) N_1 and N_2 would be in the vertical directions

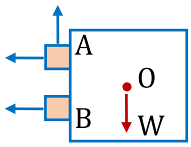
PRM122

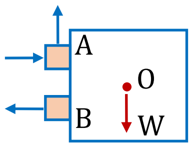
34. A vertical rectangular door with its centre of gravity at O (see figure) is fixed on two hinges A and B along one vertical length side of the door. The entire weight of the door is supported by the hinge A. Then the free body force diagram for the door (the arrows indicate the direction of the forces) is:



(A) 

(B) 

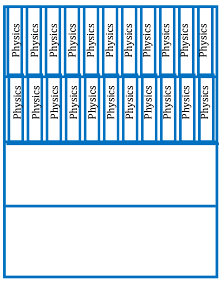
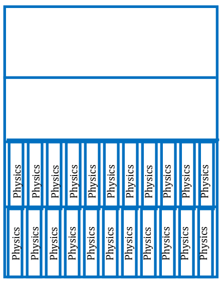
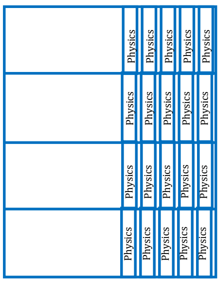
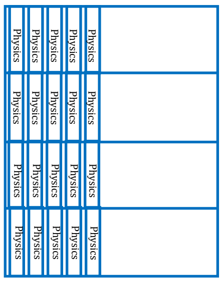
(C) 

(D) 

PRM123

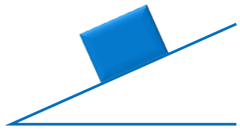
Toppling

35. Same number of books are placed in four book cases as shown. Which bookcase is most likely to topple forward if pulled a little at the top towards right :

(A) 
(B) 
(C) 
(D) 

PRM126

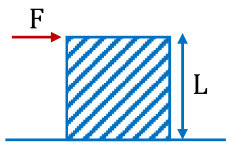
36. A homogeneous cubical brick lies motionless on a rough inclined surface. The half of the brick which applies greater pressure on the plane is :



(A) left half
(B) right half
(C) both applies equal pressure
(D) the answer depend upon coefficient of friction

PRM127

37. A cubical block of side L rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the block as shown. If the coefficient of friction is sufficiently high so that the block does not slide before toppling, the minimum force required to topple the block is

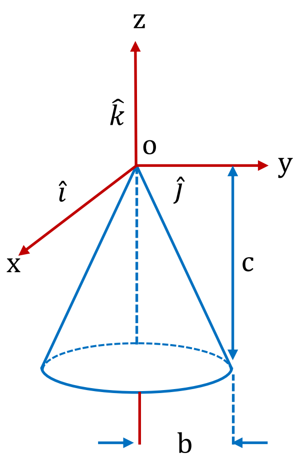


(A) Infinitesimal
(B) $mg/4$
(C) $mg/2$
(D) $mg(1 - m)$

PRM128

$\tau = I\alpha$ *Torque*

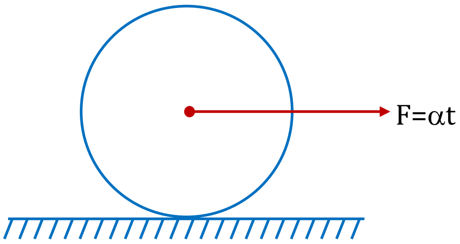
38. A solid cone hangs from a frictionless pivot at the origin O, as shown. If $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$ are unit vectors, and a, b, and c are positive constants, which of the following forces F applied to the rim of the cone at a point P results in a torque τ on the cone with a negative component τ_z?

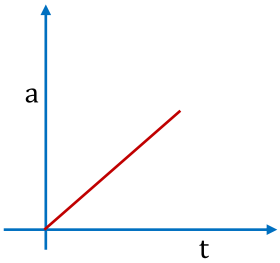


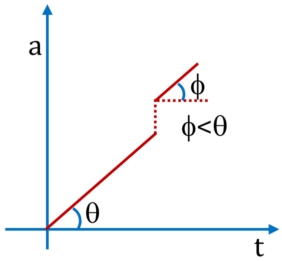
(A) $F = a\hat{k}$, P is $(0, b, -c)$
(B) $F = -a\hat{k}$, P is $(0, -b, -c)$
(C) $F = a\,\hat{\jmath}$, P is $(-b, 0, -c)$
(D) None

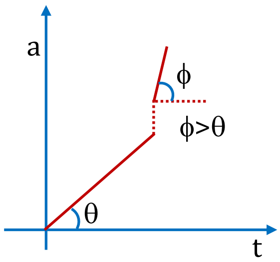
PRM124

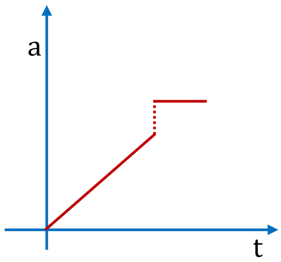
39. A sphere of mass m and radius R is kept on a rough horizontal surface and pulled with a horizontal force $F = \alpha t$ where α is a constant and t is time. The coefficient of static friction is μ_s and coefficient of kinetic friction is μ_k. Which of the following graph correctly shows the variation of acceleration of sphere with time ?



(A) 

(B) 

(C) 

(D) 

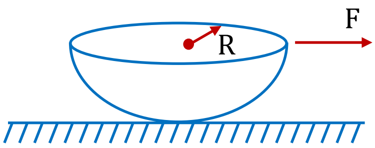
PRM247

40. A homogeneous disc with a radius 0.2 m and mass 5 kg rotates around an axis passing through its centre. The angular velocity of the rotation of the disc as a function of time is given by the formula $\omega = 2 + 6t$. The tangential force applied to the rim of the disc is

(A) 1 N (B) 2 N (C) 3 N (D) 4 N

PRM248

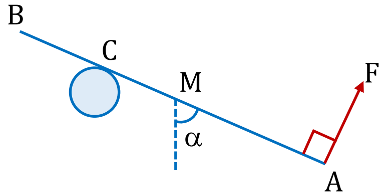
41. A thin uniform hemispherical bowl of mass m and radius R is lying on a smooth horizontal surface. A horizontal force F is now applied perpendicular to the rim of the bowl (see figure). The instantaneous angular acceleration of the bowl will be :-



(A) $\frac{20}{3}\frac{F}{MR}$ (B) $\frac{10}{3}\frac{F}{MR}$ (C) $\frac{40}{3}\frac{F}{MR}$ (D) $\frac{6}{5}\frac{F}{MR}$

PRM249

42. A uniform rod AB of weight 100 N rests on a rough peg at C and a force F acts at A as shown in figure. $BC = CM$, M is the midpoint of AB and $\tan\alpha = 4/3$. The minimum coefficient of friction at C is



(A) 9/8 (B) 3/2 (C) 8/7 (D) 4/3

PRM250

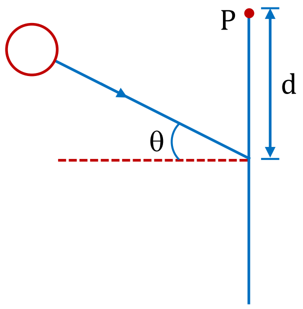
Angular Momentum & its Conservation

43. A particle of mass 2 kg located at the position $(\hat{\imath} + \hat{\jmath})\ m$ has a velocity $2\ (+\hat{\imath} - \hat{\jmath} + \hat{k})\ m/s$. Its angular momentum about z-axis in $kg\text{-}m^2/s$ is:

(A) zero (B) +8 (C) 12 (D) –8

PRM131

44. A ball of mass m moving with velocity v, collide with the wall elastically as shown in the figure. After impact the change in angular momentum about P is:



(A) 2 mvd (B) 2 mvd cos θ (C) 2 mvd sin θ (D) zero

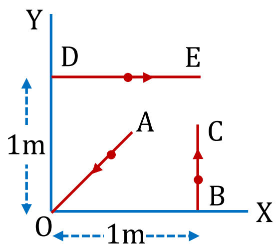
PRM132

45. Two uniform spheres of mass M have radii R and $2R$. Each sphere is rotating about a fixed axis through a diameter. The rotational kinetic energies of the spheres are identical. What is the ratio of the magnitude of the angular momenta of these spheres? That is, $\frac{L_{2R}}{L_R} =$

(A) 4 (B) $2\sqrt{2}$ (C) 2 (D) $\sqrt{2}$

PRM133

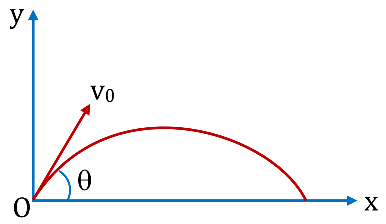
46. A particle of mass m moves with a constant velocity. Which of the following statements is not correct about its angular momentum about point O :



(A) it is zero when it is at A and moving along OA
(B) is the same at all points along the line DE
(C) is of the same magnitude but oppositely directed at B and D
(D) increases as it moves along the line BC

PRM135

47. A projectile of mass 'm' is thrown from the origin O with a velocity v_0 at an angle θ. Identify the **CORRECT** statement :-



(A) Angular momentum of the particle about O is always zero

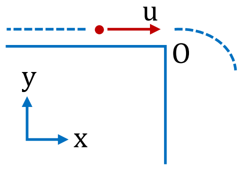
(B) Angular momentum of the particle about O increases with time.

(C) A constant torque acts on the particle about O in the clockwise sense.

(D) Angular momentum of the particle is least when it is at the highest position.

PRM136

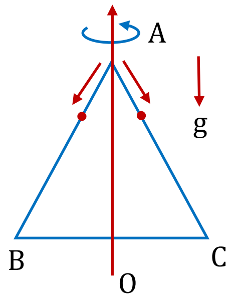
48. A particle of mass m is projected from point O with a horizontal velocity 'u' at time t = 0. What is its angular momentum relative to point O as a function of time?



(A) $-\frac{1}{2}mgut^2\hat{k}$ (B) $\frac{1}{2}mgut^2\hat{k}$ (C) $-mgut^2\hat{k}$ (D) $+mgut^2\hat{k}$

PRM138

49. 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)

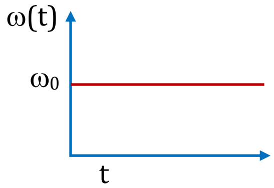
(B) Total angular momentum and total energy

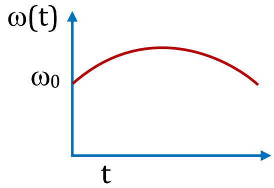
(C) Angular velocity and moment of inertia about the axis of rotation.

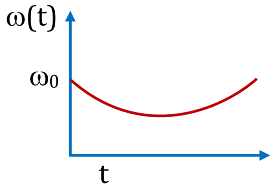
(D) Total angular momentum and moment of inertia about the axis of rotation.

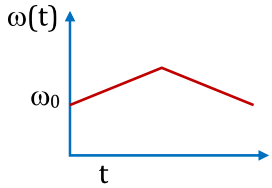
PRM141

50. A circular platform is free to rotate in a horizontal plane about a vertical axis passing through its centre. A tortoise is sitting at the edge of the platform. Now, the platform is given an angular velocity ω_0. When the tortoise moves along a chord of the platform with a constant velocity (with respect to the platform), the angular velocity of the platform $\omega(t)$. will vary with time t as

(A) 

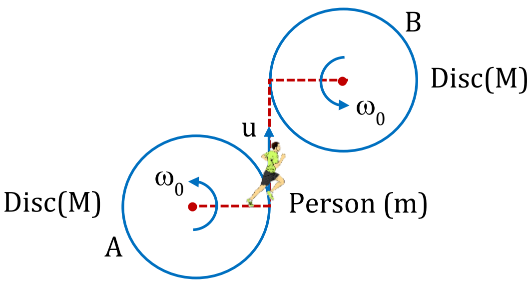
(B) 

(C) 

(D) 

PRM142

51. Two identical discs each of mass $M(= 4m)$ and radius R are rotating in opposite sense with equal angular speed ω_0 about vertical axes passing through their centres, (as shown in figure). A person of mass m sitting on circumference of disc A jumps with a tangential relative velocity u (after jumping) w.r.t one rotating disc (A) and lands on other disc (B) also tangential. Now the second disc (B) comes to a stop. Find the relative velocity u.



(A) $u = \frac{\omega_0 R}{2}$ (B) $u = \omega_0 R$ (C) $u = \frac{3\omega_0 R}{2}$ (D) $u = 2\omega_0 R$

PRM143

52. A spinning ice skater can increase his rate of rotation by bringing his arms and free leg closer to his body. How does this procedure affect the skater's angular momentum and kinetic energy and what is the work done by the skater?

(A) angular momentum remains the same while kinetic energy increases and work done is positive.

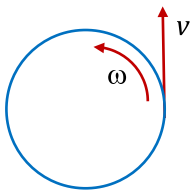
(B) angular momentum remains the same while kinetic energy decreases and work done is negative.

(C) both angular momentum and kinetic energy remain the same and work done is zero.

(D) angular momentum increases while kinetic energy remains the same and work done may be positive or negative.

PRM145

53. A child with mass m is standing at the edge of a disc with moment of inertia I, radius R, and initial angular velocity ω. See figure given below. The child jumps off the edge of the disc with tangential velocity v with respect to the ground. The new angular velocity of the disc is



(A) $\sqrt{\dfrac{I\omega^2 - mv^2}{I}}$ (B) $\sqrt{\dfrac{(I+mR^2)\omega^2 - mv^2}{I}}$

(C) $\dfrac{I\omega - mvR}{I}$ (D) $\dfrac{(I+mR^2)\omega - mvR}{I}$

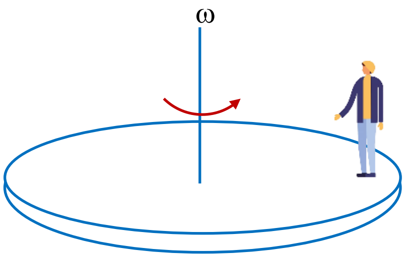
PRM146

54. A rod of mass M and length ℓ stands along z-axis. Its lower end is hinged at the centre of a disc of same mass M and radius R. The whole arrangement is rotating freely about z-axis with an angular velocity ω_0. The rod falls on disc & rotates with disc. Find the angular speed of the arrangement.

(A) $\dfrac{\omega_0 R^2}{\ell^2 + R^2}$ (B) $\dfrac{3\omega_0 R^2}{2\ell^2 + 3R^2}$ (C) $\dfrac{6\omega_0 R^2}{\ell^2 + 6R^2}$ (D) $\dfrac{6\omega_0 R}{\ell + 6R}$

PRM147

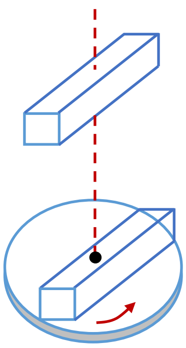
55. A child is standing on the edge of a merry-go-round that has the shape of a disk, as shown in the figure above. The mass of the child is 40 kilograms. The merry-go-round has a mass of 200 kilograms and a radius of 2.5 meters, and it is rotating with an angular velocity of ω = 2.0 radians per second. The child then walks slowly toward the center of the merry-go-round. What will be the final angular velocity of the merry-go-round when the child reaches the center ? (The size of the child can be neglected)



(A) 2.0 rad/s (B) 2.2 rad/s (C) 2.4 rad/s (D) 2.8 rad/s

PRM148

56. A uniform disk turns at 2.4 rev/s around a frictionless axis. A nonrotating rod, of the same mass as the disk and length equal to the disk's diameter is dropped onto the freely spinning disk figure. They then both turn around the axis with their centres superposed. What as the angular frequency in rev/s of the combination.

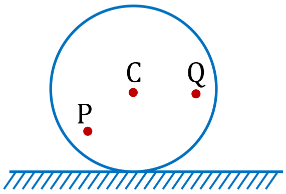


(A) 1.2 rev/s (B) 2.0 rev/s (C) 1.44 rev/s (D) 0.96 rev/s

PRM251

CRTM Kinematics

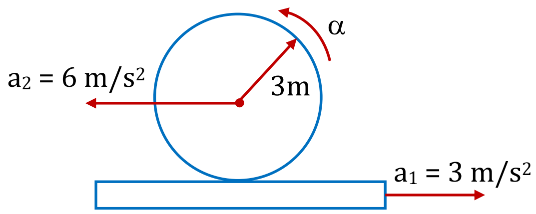
57. A disc is rolling without slipping with angular velocity ω. *P* and *Q* are two points equidistant from the centre *C*. The order of magnitude of velocity is :-



(A) $v_Q > v_C > v_p$ (B) $v_P > v_C > v_Q$ (C) $v_P = v_C$, $v_Q = v_C/2$ (D) $v_P < v_C > v_Q$

PRM159

58. In the following figure, a sphere of radius 3 *m* rolls on a plank. The accelerations of the sphere and the plank are indicated. The value of α is



(A) 3 rad/s^2

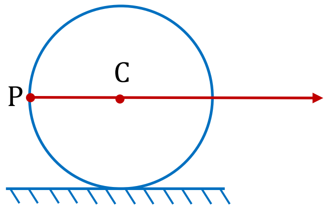
(B) 6 rad/s^2

(C) 3 rad/s^2 (opposite to the direction shown in figure)

(D) 1 rad/s^2

PRM160

59. 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

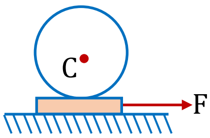


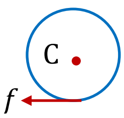
(A) zero (B) 45° (C) 135° (D) $\tan^{-1}(1/2)$

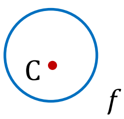
PRM161

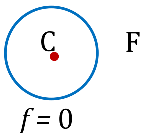
Dynamics

60. A cylinder is placed on a rough plank which in turn is placed on a smooth surface. The plank is pulled with a constant force *F*. The friction force can be given by which of the following diagrams



(A) 

(B) 

(C) 

(D) cannot be interpreted

PRM166

Kinetic Energy

61. A body kept on a smooth horizontal surface is pulled by a constant horizontal force applied at the top point of the body. If the body rolls purely on the surface, its shape can be :

(A) thin pipe (B) uniform cylinder (C) uniform sphere (D) thin spherical shell

PRM171

62. A hollow sphere of radius R and mass m is fully filled with non viscous liquid of mass m. It is rolled down a horizontal plane such that its centre of mass moves with a velocity v. If it purely rolls

(A) Kinetic energy of the sphere is $\frac{5}{6}mv^2$

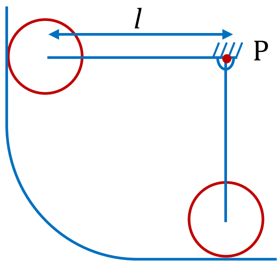
(B) Kinetic energy of the sphere is $\frac{4}{5}mv^2$

(C) Angular momentum of the sphere about a fixed point on ground is $\frac{8}{3}mvR$

(D) Angular momentum of the sphere about a fixed point on ground is $\frac{14}{5}mvR$

PRM172

63. A sphere of mass M and radius R is attached by a light rod of length ℓ to a point P. The sphere rolls without slipping on a circular track as shown. It is released from the horizontal position. The angular momentum of the system about P when the rod becomes vertical is :



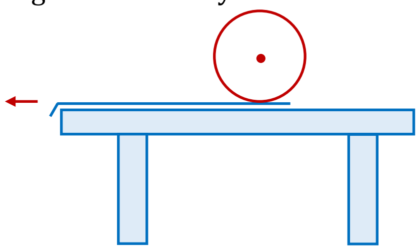
(A) $M\sqrt{\frac{10}{7}gl}[l+R]$ (B) $M\sqrt{\frac{10}{7}gl}\left[l+\frac{2}{5}R\right]$

(C) $M\sqrt{\frac{10}{7}gl}\left[l+\frac{7}{5}R\right]$ (D) $M\sqrt{\frac{10}{7}gl}\left[l-\frac{2}{5}R\right]$

PRM173

64. A thin table cloth covers a horizontal table and a uniform body of round shape lies on top of it. The table cloth is pulled from under the body, and friction causes the body to slide and rotate. What is the body's final motion on the table?

(Assume that the table is so large that the body does not fall off it.)



(A) Body will finally roll towards left

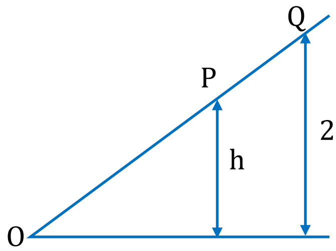
(B) Body will finally roll towards right

(C) Body will finally come to rest

(D) Any of the above is possible depending on shape of body

PRM174

65. A ball rolls down an inclined plane as shown in figure. The ball is first released from rest from P and then later from Q. Which of the following statement is/are correct?



(i) The ball takes twice as much time to roll from Q to O as it does to roll from P to O.

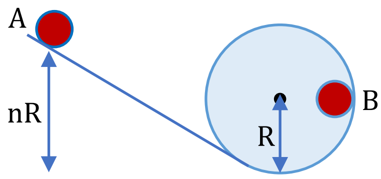
(ii) The acceleration of the ball at Q is twice as large as the acceleration at P.

(iii) The ball has twice as much K.E. at O when rolling from Q as it does when rolling from P.

(A) i, ii only
(B) ii, iii only
(C) i only
(D) iii only

PRM187

66. A metal ball of mass m is put at the point A of a loop tract and the vertical distance of A from the lower most point of tract is n times the radius R of the circular part. The linear velocity of ball when it rolls to the point B to a height R in the circular tract will be

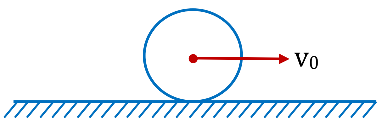


(A) $\sqrt{\frac{5g(n-1)R}{7}}$
(B) $\sqrt{\frac{10g(n-1)R}{7}}$
(C) $\sqrt{\frac{5g(n+1)R}{7}}$
(D) $\sqrt{\frac{10g(n+1)R}{7}}$

PRM252

Angular Momentum in CRTM

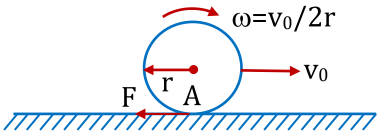
67. A ring of mass m is thrown in horizontal direction on a rough horizontal surface with a speed v_0. The speed of the ring, when it start pure rolling, is –



(A) $\frac{v_0}{2}$
(B) $\frac{v_0}{3}$
(C) $\frac{2v_0}{3}$
(D) $\frac{3v_0}{3}$

PRM192

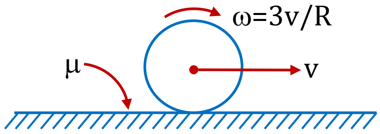
68. A solid sphere of mass M and radius r slips on a rough horizontal plane. At some instant it has translational velocity v_0 and rotational velocity about the centre $v_0/2r$. The translational velocity after the sphere starts pure rolling



(A) $6v_0/ 7$ in forward direction
(B) $6v_0/ 7$ in backward direction
(C) $7v_0/ 6$ in forward direction
(D) $6v_0/ 6$ in backward direction

PRM193

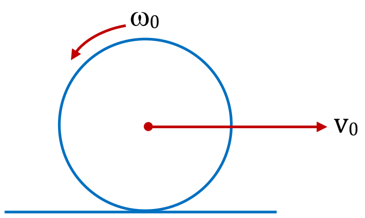
69. A hollow sphere is moving with linear velocity and angular velocity as shown in figure. The time after which pure rolling starts is :



(A) $\frac{2v}{3\mu g}$ (B) $\frac{4v}{7\mu g}$ (C) $\frac{4v}{5\mu g}$ (D) $\frac{5v}{4\mu g}$

PRM194

70. A uniform circular disc placed on a rough horizontal surface has initially a velocity v_0 and an angular velocity ω_0 as shown in the figure. The disc comes to rest after moving some distance in the direction of motion. Then $\frac{v_0}{r\omega_0}$ is



(A) $\frac{1}{2}$ (B) 1 (C) $\frac{3}{2}$ (D) 2

PRM197

Rolling

71. A solid sphere is under pure rolling on a rough fixed incline plane of angle θ. Choose the correct options if only contact forces and gravity are acting :

(A) Frictional force will be down the incline if sphere rolls up the incline and it will be up the incline if sphere rolls down the incline.
(B) Frictional force will be down the incline whether spheres rolls up the incline or down the incline
(C) Frictional force and acceleration of the body will increase with the increase in angle of incline plane
(D) Velocity and acceleration of the point of contact of sphere with incline will be zero during the motion.

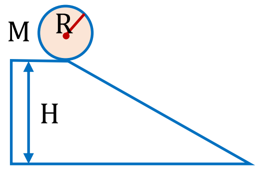
PRM180

72. A solid uniform disk of mass m rolls without slipping down a fixed inclined plane with an acceleration a. The frictional force on the disk due to surface of the plane is :

(A) 2 ma (B) 3/2 ma (C) ma (D) 1/2 ma

PRM181

73. The cylinder shown, with mass M and radius R, has a radially dependent density. The cylinder starts from rest and rolls without slipping down an inclined plane of height H. At the bottom of the plane its translational speed is $(8gH/7)^{1/2}$. Which of the following is the rotational inertia of the cylinder?



(A) $\frac{1}{2}MR^2$ (B) $\frac{3}{4}MR^2$ (C) $\frac{7}{8}MR^2$ (D) MR^2

PRM182

74. A uniform disk of mass m and radius R rolls without slipping down an incline plane of length l and inclination θ. Initially the disk was at rest at the top of the incline plane. Its angular momentum about the point of contact with the inclined plane when it reaches the bottom will be equal to :-

(A) $\sqrt{4m^2R^2gl\sin\theta}$ (B) $\sqrt{3m^2R^2gl\sin\theta}$ (C) $\sqrt{\frac{m^2R^2gl\sin\theta}{4}}$ (D) zero

PRM183

75. 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

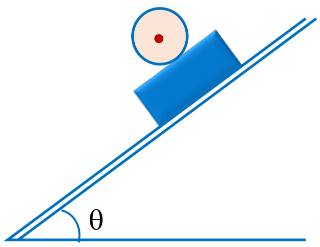
(B) Up the incline while ascending as well as descending

(C) down the incline while ascending and up the incline while descending

(D) down the incline while ascending as well as descending

PRM185

76. A plank of mass M is placed over smooth inclined plane and a sphere is also placed over the plank. Friction is sufficient between sphere and plank. If plank and sphere are released from rest, the frictional force on sphere is:

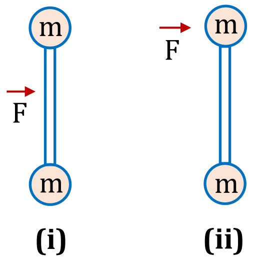


(A) up the plane (B) down the plane (C) horizontal (D) zero

PRM188

Impulse & Angular Impulse

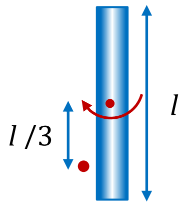
77. A force F is applied to a dumbbell for a time interval, t, first as in (i) and then as in (ii). In which case does the dumbbell acquire the greater centre-of-mass speed?



(A) (i)
(B) (ii)
(C) there is no difference
(D) the answer depends on the rotational inertia of the dumbbell

PRM204

78. A uniform rod of length l and mass M rotating about a fixed vertical axis on a smooth horizontal table. It elastically strikes a particle placed at a distance $l/3$ from its axis and stops. Mass of the particle is



(A) $3M$ (B) $\frac{3M}{4}$ (C) $\frac{3M}{2}$ (D) $\frac{4M}{3}$

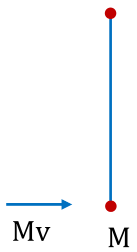
PRM210

79. A mass m is moving at speed v perpendicular to a rod of length d and mass $M = 6m$ 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 right after the collision is

(A) $2v/d$ (B) $2v/(3d)$ (C) v/d (D) $3v/(2d)$

PRM211

80. Two particles each of mass M are connected by a massless rod of length l. The rod is lying on the smooth surface. If one of the particle is given an impulse MV as shown in the figure then angular velocity of the rod would be



(A) v/l (B) $2v/l$ (C) $v/2l$ (D) None

PRM212

81. A uniform rod AB of mass m and length l is at rest on a smooth horizontal surface. An impulse J is applied to the end B, perpendicular to the rod in the horizontal direction. Speed of particle P at a distance $\frac{l}{6}$ from the centre towards A of the rod after time $t = \frac{\pi m\, l}{12J}$ is

(A) $2\frac{J}{m}$

(B) $\frac{J}{\sqrt{2}m}$

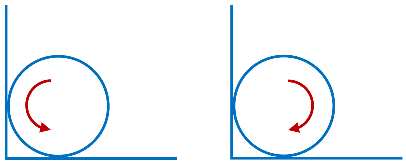
(C) $\frac{J}{m}$

(D) $\sqrt{2}\frac{J}{m}$

PRM213

Miscellaneous

82. A sphere is placed rotating with its centre initially at rest in a corner as shown in figure (a) and (b). Coefficient of friction between all surfaces and the sphere is 1/3. Find the ratio of the frictional force $\frac{f_a}{f_b}$ by ground in situations (a) and (b).



(a) **(b)**

(A) 1

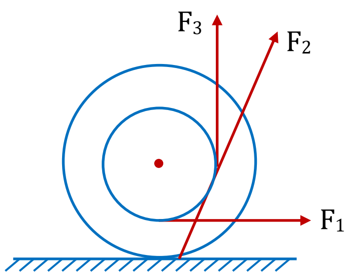
(B) $\frac{9}{10}$

(C) $\frac{10}{9}$

(D) none

PRM224

83. A yo-yo is resting on a perfectly rough horizontal table. Forces F_1, F_2 and F_3 are applied separately as shown. The correct statement is :-



(A) when F_3 is applied the centre of mass will move to the right.

(B) when F_2 is applied the centre of mass will move to the left.

(C) when F_1 is applied the centre of mass will move to the right.

(D) when F_2 is applied the centre of mass will move to the right.

PRM225

84. One ice skater of mass m moves with speed $2v$ to the right, while another of the same mass m moves with speed v toward the left, as shown in figure I. Their paths are separated by a distance b. At $t = 0$, when they are both at $x = 0$, they grasp a pole of length b and negligible mass. For $t > 0$, consider the system as a rigid body of two masses m separated by distance b, as shown in figure II. Which of the following is the correct formula for the motion after $t = 0$ of the skater initially at $y = b/2$?

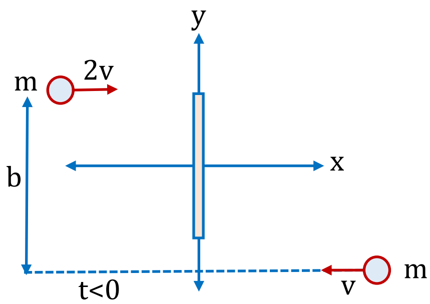


Figure I

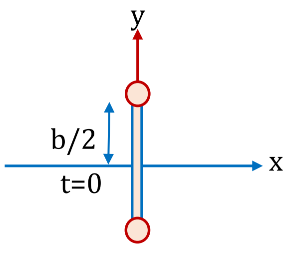


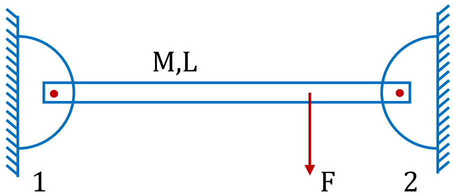
Figure II

(A) $x = 2vt, y = b/2$
(B) $x = vt + 0.5b\sin(3vt/b), y = 0.5b\cos(3vt/b)$
(C) $x = 0.5vt + 0.5b\sin(3vt/b), y = 0.5b\cos(3vt/b)$
(D) $x = 0.5vt + 0.5b\sin(6vt/b), y = 0.5b\cos(6vt/b)$

PRM233

MULTIPLE CORRECT TYPE QUESTIONS

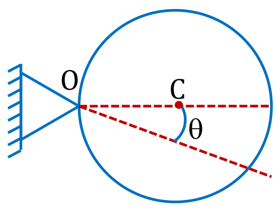
85. A uniform rod of mass $M = 2\ kg$ and length L is suspended by two smooth hinges 1 and 2 as shown in the figure. A force $F = 4N$ is applied downward at a distance from the hinge 2. Due to the application of force F, the hinge 2 breaks. At this instant, applied force F is also removed. The rod starts to rotate downward about hinge 1. ($g = 10\ m/s^2$). Choose the correct statement(s) :-



(A) The reaction at hinge 1, before hinge 2 breaks, is 11 N
(B) The reaction at hinge 1, before hinge 2 breaks, is 24 N
(C) The reaction at hinge 1, just after breaking of hinge 2 is 5N
(D) The reaction at hinge 1, just after breaking of hinge 2 is 8N

PRM253

86. A thin ring is free to rotate in the vertical plane about O. Ring is released from rest at $\theta = 0$, when ring rotates through angle θ :-



(A) Angular acceleration of ring is $\frac{g}{2}\frac{\cos\theta}{R}$

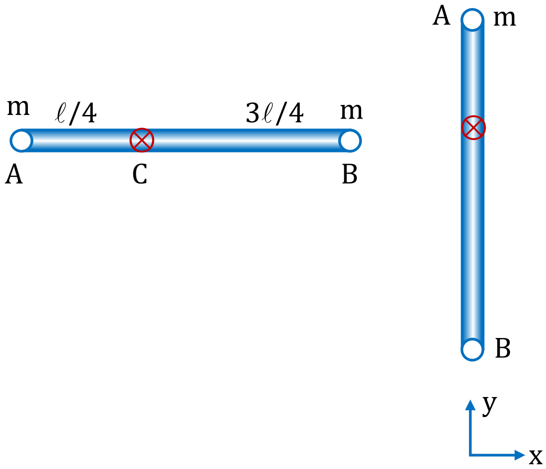
(B) Centripetal acceleration of ring is $2g\sin\theta$

(C) Net force by hinge is $\frac{mg}{2}\sqrt{15\sin^2\theta+1}$

(D) Net force by hinge is $mg\sqrt{4\sin^2\theta+\frac{3}{4}\cos^2\theta}$

PRM254

87. Two particles each of mass m are attached at end points of a massless rod AB of length ℓ. Rod is hinged at point C as shown. Rod is released from rest from horizontal position. At the instant when rod reaches its vertical position as shown, which of the following is/are **CORRECT** :-



(A) Speed of the particle at B is thrice the speed of particle at A

(B) Net force on particle B is $\frac{6mg}{5}$

(C) Angular accelration of the system is zero

(D) Both x & y components of hinge force are nonzero

PRM153

88. A rod is connected with the (rigid body) disc at centre of disc point 'P'. The disc can freely rotate about point P where it is hinged with rod and rod can rotate freely about fixed hinge Q. Now whole arrangement is released from horizontal position as shown in the diagram.

(A) Initial angular acceleration of (rigid body) disc is zero.

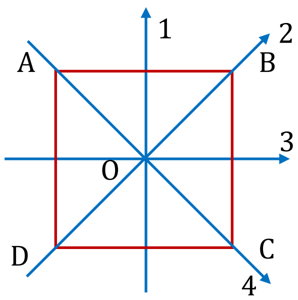
(B) Initial angular acceleration of (rigid body) disc is $\frac{9g}{8\ell}$.

(C) Angular speed of (rigid body) disc when rod becomes vertical is zero.

(D) Angular speed of (rigid body) disc when rod becomes vertical is $\frac{3}{2}\sqrt{\frac{g}{\ell}}$ rad/s.

PRM154

89. $ABCD$ is a square plate with centre O. The moments of inertia of the plate about the perpendicular axis through O is I and about the axes 1, 2, 3 and 4 are I_1, I_2, I_3 and I_4 respectively. It follows that:



(A) $I_2 = I_3$ (B) $I = I_1 + I_4$ (C) $I = I_2 + I_4$ (D) $I_1 = I_3$

PRM104

90. A block with a square base measuring 'a' × 'a' and height h, is placed on an inclined plane. The coefficient of friction is μ. The angle of inclination (θ) of the plane is gradually increased. The block will

(A) topple before sliding if $\mu > \frac{a}{h}$ (B) topple before sliding if $\mu < \frac{a}{h}$

(C) slide before toppling if $\mu > \frac{a}{h}$ (D) slide before toppling if $\mu < \frac{a}{h}$

PRM129

91. A particle falls freely near the surface of the earth. Consider a fixed point O (not vertically below the particle) on the ground.

(A) Angular momentum of the particle about O is increasing.

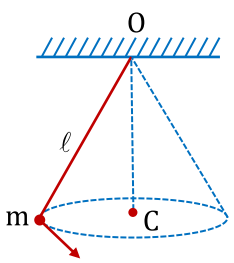
(B) Torque of the gravitational force on the particle about O is decreasing.

(C) The moment of inertia of the particle about O is decreasing.

(D) The angular velocity of the particle about O is increasing.

PRM134

92. A small ball of mass m suspended from the celling at a point O by a thread of length ℓ moves along a horizontal circle with a constant angular velocity ω.



(A) angular momentum is constant about O

(B) angular momentum is constant about C

(C) vertical component of angular momentum about O is constant

(D) Magnitude of angular momentum about O is constant

PRM139

93. A block of mass m moves on a horizontal rough surface with initial velocity v. The height of the centre of mass of the block is h from the surface. Consider a point A on the surface.

(A) angular momentum about A is mvh initially

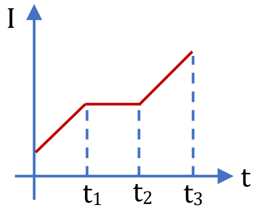
(B) the velocity of the block decreases at time passes.

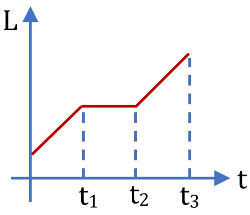
(C) torque of the forces acting on block is zero about A

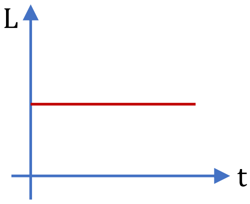
(D) angular momentum is not conserved about A.

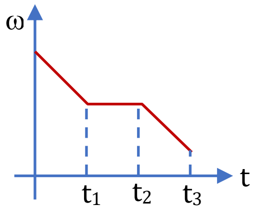
PRM144

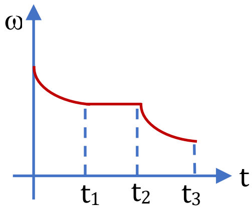
94. A satellite in outer-space is at an initial rotation speed of ω = 4 rad/sec at t = 0. As it deploys its solar panels, it changes its rotational inertia as shown in graph below. The correct plot of magnitude of angular momentum and angular velocity as functions of time :



(A) 

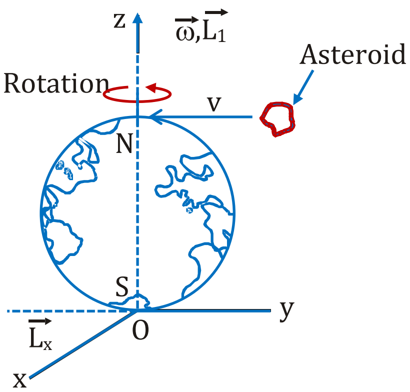
(B) 

(C) 

(D) 

PRM255

95. In making a science-fiction movie about an asteroid that collides with Earth, a studio constructs a model Earth pivoted at a support fixed at the south Pole and spinning rapidly about the (vertical) south-to-north axis with angular speed ω pointing out of the North Pole. A Model asteroid approaches horizontally and strikes a grazing blow with the model Earth just at the North Pole. Describe the new motion of the Model Earth.



(A) The earth now rotates about an axis which is initially in *YZ* plane but rotates about the *Z* axis.

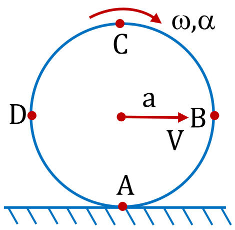
(B) The earth now rotates about an axis which is initially in *XZ* plane but rotates about the *Z* axis.

(C) The angular velocity of earth in *Z* direction remains the same

(D) The angular momentum of earth in *Z* direction remains the same.

PRM256

96. A circular disc of radius R rolls without slipping on a rough horizontal surface. At the instant shown its linear velocity is V, linear acceleration a, angular velocity ω and angular acceleration α. Four points A, B, C and D lie on its circumference such that the diameter AC is vertical and BD horizontal then choose the correct option(s).

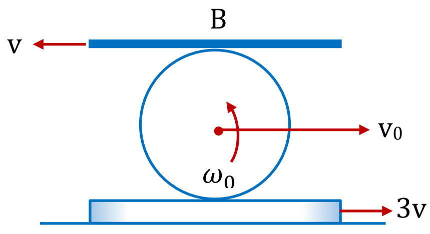


(A) $V_B = \sqrt{V^2 + (R\omega)^2}$ (B) $V_C = V + R\omega$

(C) $a_A = \sqrt{(a - R\alpha)^2 + (\omega^2 R)^2}$ (D) $a_D = \sqrt{(a + \omega^2 R)^2 + (R\alpha)^2}$

PRM162

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

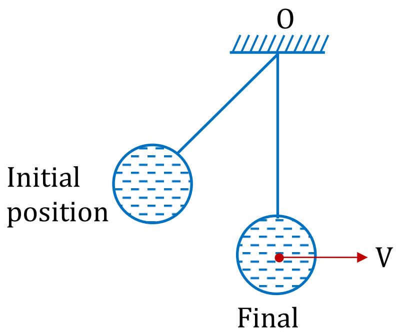


(A) linear velocity $v_0 = v$ (B) angular velocity of disc is $\frac{3v}{2r}$

(C) angular velocity of disc is $\frac{2v}{r}$ (D) None of these

PRM168

98. A massless rod has a massless hollow sphere attached to it. This sphere can be fully filled either with a liquid (non viscous) or with a solid (rigidly fitted into sphere) of same mass. System is released from rest from initial position (as shown). When it reaches final position which of the following is/are true for the system.



(A) Kinetic energy in case of liquid will be more than in case of solid.

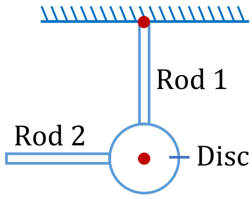
(B) Velocity of centre (V) in case of liquid will be more than in case of solid.

(C) About C angular momentum in case of liquid will be more than in case of solid.

(D) About C angular momentum in case of liquid will be less than in case of solid.

PRM175

99. A disc of radius a is rigidly attached at its circumference by two rods each of length $3a$, two rods are always perpendicular to each other. The combination is suspended vertically from the free end of one rod (as shown in figure). It is swinging in the plane of the disc such that the centre of disc have velocity v. If mass of disc and each rod is m.



(A) Kinetic energy of the disc $\frac{1}{2}mV^2+\frac{1}{2}\left(\frac{ma^2}{2}\right)\left(\frac{V}{4a}\right)^2$

(B) Kinetic energy of the rod 2 is $\frac{1}{2}mV^2+\frac{1}{2}\times\left(\frac{m(3a)^2}{12}\right)\times\left(\frac{V}{4a}\right)^2$

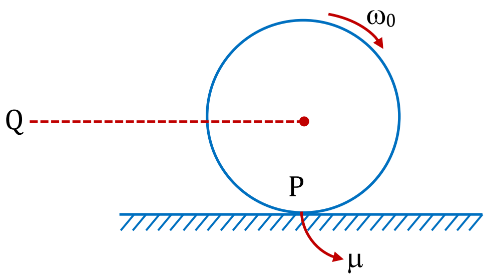
(C) Kinetic energy of the rod 1 is $\frac{1}{2}\times\left(\frac{m(3a)^2}{3}\right)\times\left(\frac{V}{4a}\right)^2$

(D) Kinetic energy of the system of (disc and both rod) is

$$\frac{1}{2}\left[\left(\frac{m(3a)^2}{3}\right)+\left(\frac{ma^2}{2}+m(4a)^2\right)+\left(\frac{m(3a)^2}{12}+m\frac{89}{4}a^2\right)\right]\left(\frac{V}{4a}\right)^2$$

PRM257

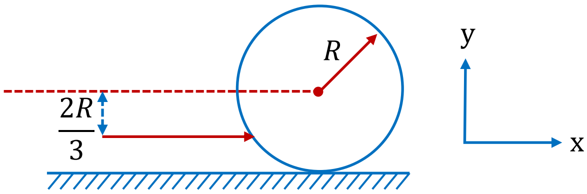
100. A disc of mass 'm' and radius 'R' is rotating with angular speed ω_0 and speed zero as shown and then placed on a rough surface (coefficient of friction=μ) and left. Then



(A) angular momentum of disc is conserved about point Q.
(B) angular momentum of disc is conserved about point P on the ground.
(C) initially the force of friction is μmg leftward.
(D) initially the force of friction is μmg rightward.

PRM195

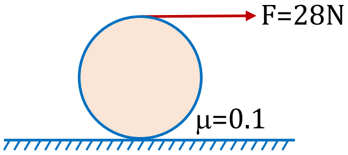
101. A billiard ball initially at rest is given a sharp blow by a cue stick. The impulse is horizontal and is applied at a distance $2R/3$ below the centreline, as shown in figure. The initial speed of the ball is υ_0, and the coefficient of kinetic friction is μ_k.



(A) Initially kinetic friction acts in $-\hat{\imath}$ direction
(B) Initially kinetic friction acts in $\hat{\imath}$ direction.
(C) Ball instantaneously starts pure rolling.
(D) Initial angular velocity of ball is $\frac{5v_0}{3R}$

PRM196

102. A solid sphere of mass 10 kg is placed on a rough horizontal surface with coefficient of friction $\mu = 0.1$. If a force of 28 N is applied at the top of the sphere then,



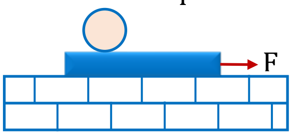
(A) friction force will be 10 N in forward direction.
(B) friction force will be less than 10N in backward direction.
(C) Acceleration of centre of mass will be $\frac{29}{7}\,m/s^2$.
(D) Acceleration of centre of mass will be 3.8m/s^2.

PRM203

103. If a cylinder is rolling down the incline with sliding.
(A) after some time it may start pure rolling
(B) after sometime it will start pure rolling
(C) it may be possible that it will never start pure rolling
(D) none of these

PRM189

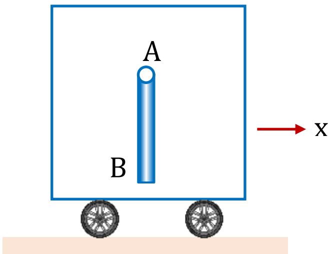
104. A plank with a uniform sphere placed on it rests on a smooth horizontal plane. Plank is pulled to right by a constant force F. If sphere does not slip over the plank. Which of the following is correct.



(A) Acceleration of the centre of sphere is less than that of the plank.
(B) Work done by friction acting on the sphere is equal to its total kinetic energy.
(C) Total kinetic energy of the system is equal to work done by the force F.
(D) None of the above

PRM226

105. A uniform rod AB of length ℓ and mass M hangs from point A at which it is freely hinged in a car moving with velocity v_0. The rod can rotate in vertical plane about the axis at A. If the car suddenly stops,



(A) The angular speed ω with which the rod starts rotating is $\frac{3v_0}{2\ell}$.
(B) The minimum value of v_0 so that the rod completes the rotation $\sqrt{\frac{8}{3}g\ell}$.
(C) Loss of energy during the process $\frac{1}{8}Mv_0^2$.
(D) There is no loss of energy.

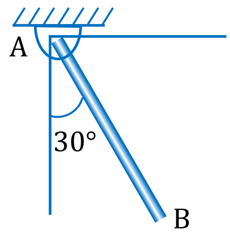
PRM227

COMPREHENSION TYPE QUESTIONS

Concept of w, α, v, a

PARAGRAPH FOR QUESTION NO. 106 TO 108

A rod of length ℓ and mass m is hinged at A. It is released from horizontal position from rest. When it comes to position AB, and makes and angle of 30° with vertical



106. Then the angular velocity in this position is :-

(A) $\left(\frac{3\sqrt{3}g}{2\ell}\right)^{1/2}$ (B) $\left(\frac{3g}{2\ell}\right)^{1/2}$ (C) $\left(\frac{9g}{2\ell}\right)^{1/2}$ (D) $\left(\frac{3\sqrt{3}g}{4\ell}\right)^{1/2}$

PRM155

107. Force applied by the hinge on the rod along the rod is :-

(A) $\frac{3mg}{4}$ (B) $\frac{5\sqrt{3}mg}{4}$ (C) $\frac{3\sqrt{3}mg}{4}$ (D) $\frac{\sqrt{3}mg}{2}$

PRM156

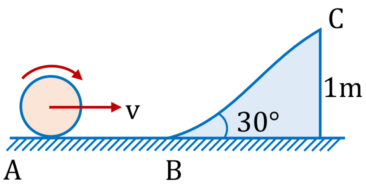
108. A ladder of length L is slipping with its ends against a vertical wall and a horizontal floor. At a certain moment, the speed of the end in contact with the horizontal floor is v and the ladder makes an angle α = 30° with the horizontal. Then the speed of the ladder's center must be :-

(A) $\frac{2v}{\sqrt{3}}$ (B) $v/2$ (C) v (D) None

PRM157

PARAGRAPH FOR QUESTION NO. 109 AND 110

A small sphere of mass 1 kg is rolling without slipping on a rough stationary base with linear speed $v = \sqrt{\frac{200}{7}}\ m/s$. It leaves the inclined plane at point C.



109. Find its linear speed at point C :-

(A) $\sqrt{\frac{100}{7}}\ m/s$ (B) $\sqrt{\frac{50}{7}}\ m/s$ (C) $\sqrt{\frac{100}{35}}\ m/s$ (D) $\sqrt{\frac{200}{35}}\ m/s$

PRM178

110. Find ratio of rotational and translational kinetic energy of the sphere when it strikes the ground after leaving from point C :-

(A) $\frac{2}{5}$ (B) $\frac{2}{3}$ (C) $\frac{1}{6}$ (D) $\frac{1}{2}$

PRM179

Moment of Inertia

PARAGRAPH FOR QUESTION NO. 111 AND 112

In the treatment of moments of inertia, introductory textbooks often present two theorems, generally called the parallel axis theorem and the perpendicular axis theorem. There is another theorem of this same genre, which is not usually included, but which is interesting and useful. It is

$$I_x + I_y + I_z = 2\sum_i m_i r_i^2$$

Here, I_x, I_y and I_z are the moments of inertia about three mutually perpendicular intersecting axes, m_1 is the mass of the i^{th} particle and r_i is the distance from the intersection. The proof is simple: Taking the three axes as coordinate axes, we have :

$$I_x + I_y + I_z$$

$$= \sum_i m_i\left(y_i^2 + z_i^2\right) + \sum_i m_i\left(z_i^2 + x_i^2\right) + \sum_i m_i\left(x_i^2 + y_i^2\right)$$

$$= 2\sum_i m_i\left(x_i^2 + y_i^2 + z_i^2\right) = 2\sum_i m_i r_i^2$$

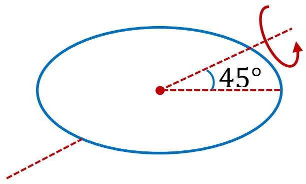
One important application is the calculation of the moment of inertia I_d of a uniform thin-walled spherical shell, of mass M and radius R, about a diameter. Taking the centre as the origin of coordinates, we have $I_x = I_y = I_z = I_d$, and $r_i = R$. The theorem gives $3I_d = 2\Sigma_i m_i R^2 = 2(\Sigma_i m_i)R^2 = 2MR^2$, where $I_d = 2MR^{2/3}$.

111. Consider a solid cube of mass m and side L. What will be the value of $\sum m_i r_i^2$ for this body when the point of intersection of axes is the centre of the cube :

(A) $\frac{ML^2}{2}$ (B) $\frac{ML^2}{4}$ (C) $\frac{ML^2}{3}$ (D) $\frac{ML^2}{6}$

PRM106

112. Find the moment of inertia of ring of mass m and radius R about an axis passing through its centre and making an angle 45° with its plane :

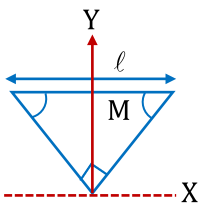


(A) $\frac{MR^2}{4}$ (B) $\frac{MR^2}{2}$ (C) $\frac{3}{4}MR^2$ (D) MR^2

PRM107

PARAGRAPH FOR QUESTION NO. 113 TO 116

The figure shows an isosceles triangular plate of mass M and base L. The angle at the apex is 90°. The apex lies at the origin and the base is parallel to X-axis



113. The moment of inertia of the plate about the z-axis is :-

(A) $\frac{ML^2}{12}$ (B) $\frac{ML^2}{24}$ (C) $\frac{ML^2}{6}$ (D) none of these

PRM112

114. The moment of inertia of the plate about the x-axis is :-

(A) $\frac{ML^2}{8}$ (B) $\frac{ML^2}{32}$ (C) $\frac{ML^2}{24}$ (D) $\frac{ML^2}{6}$

PRM113

115. The moment of inertia of the plate about its base parallel to the x-axis is :-

(A) $\frac{ML^2}{18}$ (B) $\frac{ML^2}{36}$ (C) $\frac{ML^2}{24}$ (D) none of these

PRM114

116. The moment of inertia of the plate about the y-axis is :-

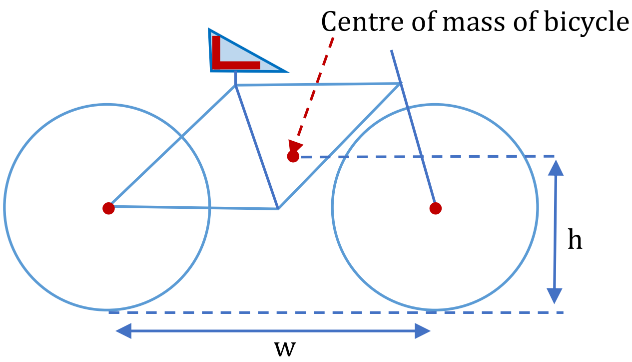
(A) $\frac{ML^2}{6}$ (B) $\frac{ML^2}{8}$ (C) $\frac{ML^2}{24}$ (D) None of these

PRM115

τ = Iα Torque

PARAGRAPH FOR QUESTION 117 TO 119

A simplified model of a bicycle of mass M has two tyres that each comes into contact with the ground at a point. The wheelbase of this bicycle (the distance between the points of contact with the ground) is w, and the center of mass of the bicycle is located midway between the tyres and at height h above the ground. Air resistance may be ignored.



Case - 1 (Q. 117): Assume that cycle is moving rightwards & has acceleration a. Both tyres roll purely.

117. The direction of friction on the tyres is

(A) forward on both (B) backward on both

(C) forward on front & backward on rear (D) forward on rear & backward on front.

PRM258

Case - 2 (Q. 118 and 119) : The bicycle is moving to the right, but slowing down at a constant rate. The acceleration has a magnitude a. Assume that the coefficient of sliding friction between each tyre and the ground is μ, and that both tyres are skidding (sliding without rotating). Express your answers in terms of w, h, M and g.

118. What is the maximum value of μ so that both tyres remain in contact with the ground?

(A) $\frac{w}{2h}$ (B) $\frac{h}{2w}$ (C) $\frac{2h}{w}$ (D) $\frac{w}{h}$

PRM259

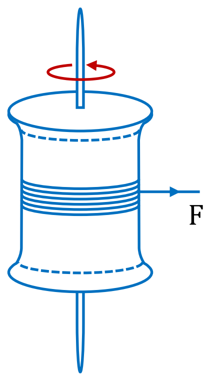
119. What is the maximum value of a so that both tyres remain in contact with the ground?

(A) $\frac{wg}{h}$ (B) $\frac{wg}{2h}$ (C) $\frac{hg}{2w}$ (D) $\frac{2hg}{w}$

PRM260

PARAGRAPH FOR QUESTION NO. 120 AND 121

A thread is wrapped around a cylindrical spool of radius 1.5 *cm* whose central axis is fixed on a support. The thread is pulled with a constant acceleration. It is seen that it takes 2 sec to pull 6.28 *cm* of thread starting from rest.



120. What is the angular velocity of the spool at 1.5 sec ?

(A) π rad/s (B) $\frac{\pi}{2} rad / s$ (C) $\frac{3\pi}{4} rad / s$ (D) $\frac{\pi}{4} rad / s$

PRM261

121. If the thread was pulled with a constant speed so that it takes 2 sec to pull 6.28 *cm* of thread. The angular velocity of spool at 1.5 sec is :

(A) $\frac{4}{3}$ of what was obtained in previous question.

(B) $\frac{2}{3}$ of what was obtained in previous question.

(C) Same as what was obtained in previous question.

(D) Cannot be predicted

PRM262

Angular Momentum & its Conservation

PARAGRAPH FOR QUESTION NO. 122 AND 123

When an athelete takes off from the ground in a long jump, the force on the launching foot gives her an angular momentum in clockwise direction around the horizontal axis. This rotation would not allow her to land properly. In the landing, the legs should be together and extended forward at an angle so that heels marks the sand at greatest distance. Once in air the angular momentum cannot change. However, the jumper can shift most of the angular momentum to the arms by rotating them clockwise as shown in the figure. Then the body comes to proper orientation for landing. Assume that in 0.7 sec one arm covers 1/2 a revolution and another arm covers 1 revolution. Each arm is a thin rod of mass 4 *kg* and length 0.6 *m* rotating at one end. Assume that this 0.7 sec. is time of flight.

122. What is the angular momentum of both arms in athelete's frame (in SI units)

(A) $\frac{14.4\pi}{7}$ (B) $\frac{7.2\pi}{7}$ (C) $\frac{4.8\pi}{7}$ (D) $\frac{2.4\pi}{7}$

PRM263

123. If rest of the athelete's body is assumed to be a rigid body having a moment of inertia of 18 $kg\ m^2$ about its centre of mass, what is its change in angular velocity due to this rotation of arms?

(A) $\frac{\pi}{35}$ rad/*s* (B) $\frac{2\pi}{35}$ rad/*s* (C) $\frac{8\pi}{35}$ rad/*s* (D) $\frac{4\pi}{35}$ rad/*s*

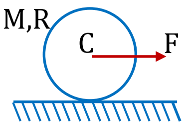
PRM264

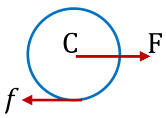
Dynamics

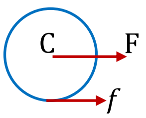
PARAGRAPH FOR QUESTION NO. 124 TO 126

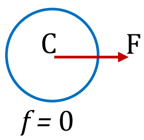
In the following problems, indicate the correct direction of friction force acting on the cylinder, which is pulled on a rough surface by a constant force *F*.

124. A cylinder of mass *M* and radius *R* is pulled horizontally by a force *F*. The friction force can be given by which of the following diagrams :-



(A) 

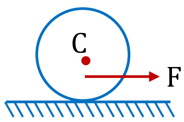
(B) 

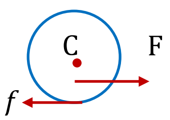
(C) 

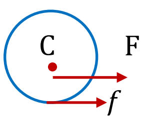
(D) Cannot be interpreted

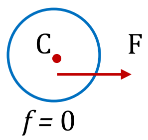
PRM163

125. A cylinder is pulled horizontally by a force *F* acting at a point below the centre of mass of the cylinder, as shown in figure. The friction force can be given by which of the following diagrams :-



(A) 

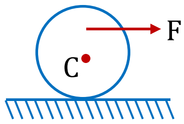
(B) 

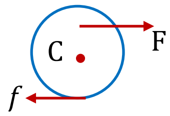
(C) 

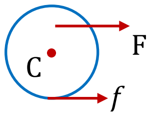
(D) cannot be interpreted

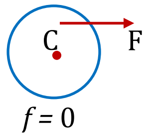
PRM164

126. A cylinder is pulled horizontally by a force F acting at a point above the centre of mass of the cylinder, as shown in figure. The friction force can be given by which of the following diagrams



(A) 

(B) 

(C) 

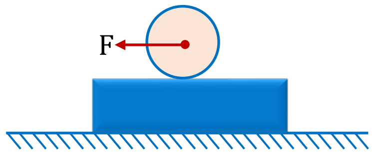
(D) cannot be interpreted

PRM165

Angular Momentum in CRTM

PARAGRAPH FOR QUESTION NO. 127 AND 128

A disc of mass m and radius R is placed over a plank of same mass m. There is sufficient friction between disc and plank to prevent slipping. A force F is applied at the centre of the disc.



127. Acceleration of the plank is :-

(A) $\frac{F}{2m}$ (B) $\frac{3F}{4m}$ (C) $\frac{F}{4m}$ (D) $\frac{3F}{2m}$

PRM198

128. Force of friction between the disc and the plank is :-

(A) $\frac{F}{2}$ (B) $\frac{F}{4}$ (C) $\frac{F}{3}$ (D) $\frac{2F}{3}$

PRM199

Impulse & Angular Impulse

PARAGRAPH FOR QUESTION NO. 129 TO 131

A uniform rod of mass $4m$ and length L lies on a smooth horizontal table. A particle of mass m moving on the table with speed v_0 strikes the rod perpendicularly at an end and stops.

129. Velocity of centre of mass of the rod after collision is

(A) v_0 (B) $\frac{v_0}{2}$ (C) $\frac{v_0}{4}$ (D) $\frac{v_0}{6}$

PRM215

130. Angular velocity of the rod after collision is

(A) $\frac{3v_0}{2L}$ (B) $\frac{3v_0}{4L}$ (C) $\frac{v_0}{2L}$ (D) $\frac{v_0}{4L}$

PRM216

131. Distance travelled by the centre of rod by the time it turns through one revolution is

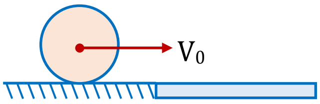
(A) πL (B) $2\pi L$ (C) $\frac{\pi L}{12}$ (D) $\frac{\pi L}{3}$

PRM217

Miscellaneous

PARAGRAPH FOR QUESTION NO. 132 TO 135

A ring of mass M and radius R sliding with a velocity v_0 suddenly enters into rough surface where the coefficient of friction is μ, as shown in figure.



132. Choose the correct statement(s)

(A) As the ring enters on the rough surface, the limiting friction force acts on it.

(B) The direction of friction is opposite to the direction of motion.

(C) The friction force accelerates the ring in the clockwise sense about its centre of mass.

(D) As the ring enters on the rough surface it starts rolling.

PRM228

133. Choose the correct statement(s)

(A) The momentum of the ring is conserved

(B) The angular momentum of the ring is conserved about its centre of mass

(C) The angular momentum of the ring conserved about any point on the horizontal surface in line of friction.

(D) The mechanical energy of the ring is conserved

PRM229

134. Choose the correct statement(s):

(A) The ring starts its rolling motion when the centre of mas stationary.

(B) The ring starts rolling motion when the point of contact becomes stationary.

(C) The time after which the ring starts rolling is $\frac{v_0}{2\mu g}$.

(D) The rolling velocity is $\frac{v_0}{2}$.

PRM230

135. Choose the correct alternative(s) :-

(A) The linear distance moved by the centre of mass before the ring starts rolling is $\frac{3v_0^2}{8\mu g}$.

(B) The net work done by friction force is $-\frac{3}{8}mv_0^2$.

(C) The loss is kinetic energy of the ring is $\frac{mv_0^2}{4}$.

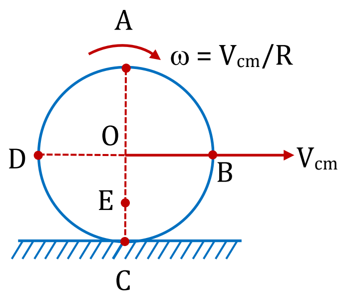
(D) The gain in rotational kinetic energy is $+\frac{mv_0^2}{8}$.

PRM231

MATRIX MATCH TYPE QUESTION

CRTM Kinematics

136. Consider a body rolling on a horizontal surface as shown in figure (Symbols have their usual meaning)



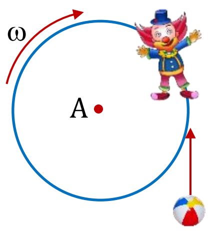
Column-I	**Column-II**
(A) Velocity is zero	(P) Point *A*
(B) Speed in maximum	(Q) Point *B*
(C) $0 <$ speed $< v_{cm}$	(R) Point *C*
(D) $1.3v_{cm} <$ speed $< 2\ v_{cm}$	(S) Point *D*
	(T) Point *E*

PRM167

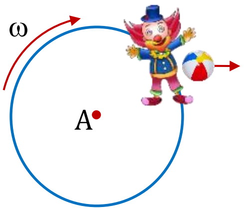
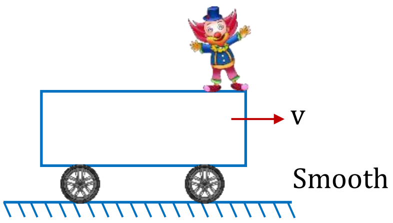
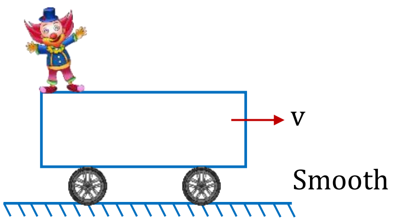
Miscellaneous

137. Column-I depicts various situations where some sudden events are taking place. Column-II describes changes in various parameters of systems immediately after the events taking place in column-I.

Column-I	**Column-II**
(A) Joker is standing on revolving platform and batman throws the ball and joker catches the ball while it was moving horizontally.	(P) Linear momentum remains conserved.



Joker, ball and platform is system.

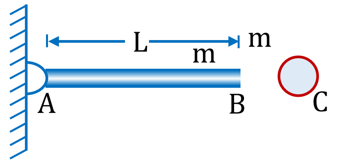
Column-I	Column-II
(B) Joker throws the ball horizontally and perpendicular to his motion while standing on the revolving platform.  Joker, ball and platform is system.	(Q) Mechanical energy is conserved
(C) Joker jumps horizontally towards right from the cart which is moving at speed v on smooth horizontal floor.  Joker and cart is the system	(R) Mechanical energy increases.
(D) Joker drops himself vertically from the moving cart with no horizontal velocity relative to cart.  Joker and cart is the system	(S) Mechanical energy decreases.
	(T) v or ω changes

PRM232

EXERCISE - S

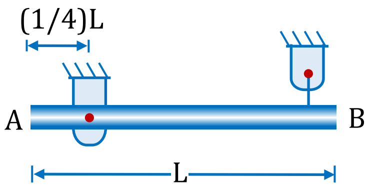
Concept of w, α, v, a

1. A uniform bar AB of mass m and a ball of the same mass are released from rest from the same horizontal position. The bar is hinged at end A. There is gravity downwards. What is the distance of the point from point B that has the same acceleration as that of ball, immediately after release?



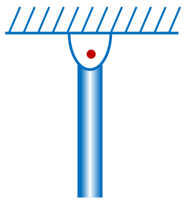
PRM149

2. A uniform beam of length L and mass m is supported as shown. If the cable at B suddenly breaks, determine; (a) the acceleration of end B. (b) the reaction at the pin support.



PRM150

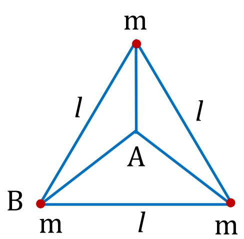
3. A rod of mass m *and* length ℓ is hinged at it's upper end. It can rotate in vertical plane. It is given angular velocity ω so that it can complete vertical circle. Find (a) ω (b) Tension at centre of rod at initial moment.



PRM151

Moment of Inertia

4. Three equal masses m are rigidly connected to each other by massless rods of length l forming an equilateral triangle, as shown in the figure. What is the ratio of the moment of inertia of the assembly for an axis through B compared with that for an axis through A (centroid). Both the axis are perpendicular to the plane of triangle.



PRM089

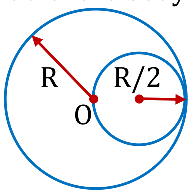
5. Two rods of equal mass m and length l lie along the x axis and y axis with their centres at origin. What is the moment of inertia of the system about the line $x = y$

PRM095

6. Find the *MI* of a rod about an axis through its centre of mass and perpendicular to the length whose linear density varies as $\lambda = ax$ where a is a constant and x is the position of an element of the rod relative to its left end. The length of the rod is ℓ.

PRM096

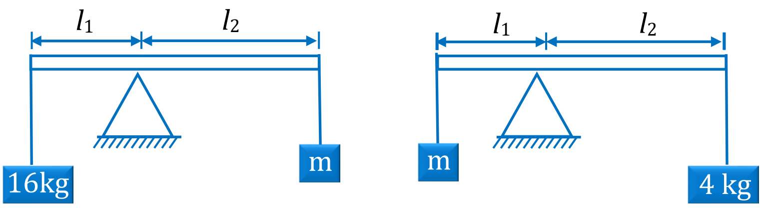
7. A hole of radius $R/2$ is cut from a solid sphere of radius R. If the mass of the remaining part of sphere is M, then find moment of inertia of the body about an axis through O.



PRM108

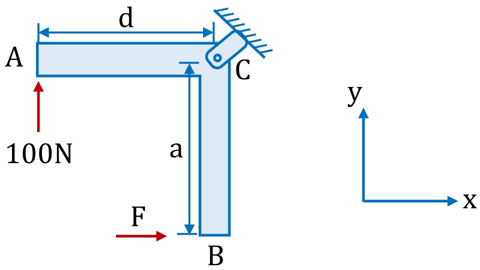
Equilibrium

8. In an experiment with a massless beam balance an unknown mass m is balanced by two known masses of 16kg and 4 kg as shown in figure. Find the value of the unknown mass m.



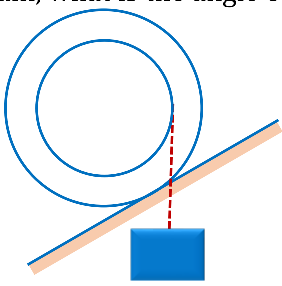
PRM117

9. Find the force F required to keep the system in equilibrium. The dimensions of the system are d = 0.3 m and a = 0.2 m. Assume the rods to be massless.



PRM118

10. A 3.0 kg bobbin consists of a central cylinder of radius 5.0 cm and two end plates each of radius 6.0 cm. It is placed on a slotted incline, where friction is sufficient to prevent sliding. A block of mass 4.5 kg is suspended from a cord wound around the bobbin and passing through the slot under the incline. If the bobbin is in static equilibrium, what is the angle of tilt of the incline?



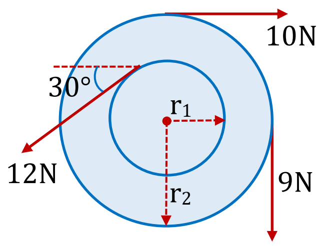
PRM125

$\tau = I\alpha$ Torque

11. A force $\vec{F} = 2\hat{\imath} + 3\hat{\jmath} N$ is applied to an object that is pivoted about a fixed axle aligned along the z coordinate axis. If the force is applied at the point $\vec{r} = 4\hat{\imath} + 5\hat{\jmath} m$, find (a) the magnitude of the net torque about the z-axis and (b) the direction of the torque vector τ.

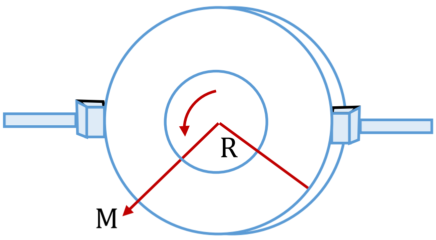
PRM116

12. In the following figure r_1 and r_2 are 5 cm and 30 cm respectively. If the moment of inertia of the wheel is 5100 $kg\text{-}m^2$ about the axis passing through its centre and perpendicular to the plane of wheel, then what will be its angular acceleration?



PRM119

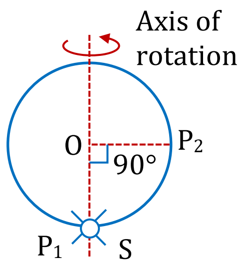
13. A turning moment of 100 Nm is applied to a shaft which passes through a wheel of radius $R = 50cm$. The minimum force with which brakes must be applied to the wheel perpendicular to the surface (see figure) so that the wheel does not rotate is...... × 10^2 N. The coefficient of friction equals 0.25.



PRM265

Angular Momentum & its Conservation

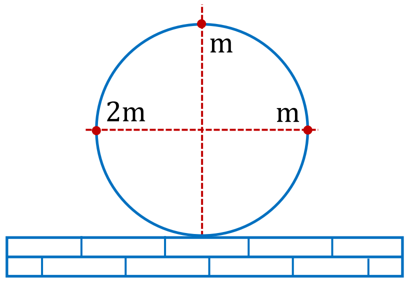
14. A uniform ring is rotating about vertical axis with angular velocity ω initially. A point insect (S) having the same mass as that of the ring starts walking from the lowest point P_1 and finally reaches the point P_2(as shown in figure). What is the final angular velocity of the ring?



PRM140

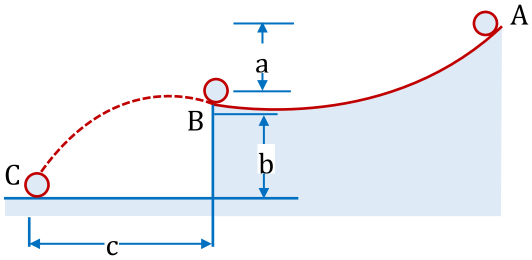
Kinetic Energy

15. A ring of mass m and radius R has three particles attached to the ring as shown in the figure. The centre of the ring has a speed v_0. Find the kinetic energy of the system. (Slipping is absent)



PRM169

16. A small sphere of mass m and radius r is released from rest at A and rolls without sliding on the curved surface to point B where it leaves the surface with a horizontal velocity. Knowing that $a = 1.5\ m$ and $b = 1.2\ m$, determine;

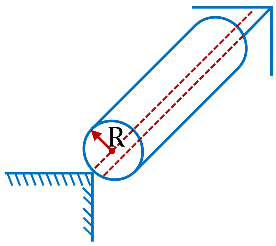


(a) the speed of the sphere as it strikes the ground at C.

(b) the corresponding distance c.

PRM170

17. A rectangular rigid fixed block has a long horizontal edge. A solid homogeneous cylinder of radius R is placed horizontally at rest with its length parallel to the edge such that the axis of the cylinder and the edge of the block are in the same vertical plane as shown in figure. there is sufficient friction present at the edge so that a very small displacement cause the cylinder to roll of the edge without slipping. Determine:



(a) the angle θ_C through which the cylinder rotates before it leaves contact with the edge,

(b) the speed of the centre of mass of the cylinder before leaving contact with the edge, and

(c) the ratio of the translational to rotational kinetic energies of the cylinder when its centre of mass is in horizontal line with the edge.

PRM176

Angular Momentum in CRTM

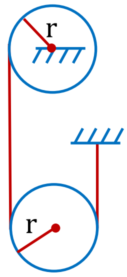
18. A solid sphere of mass m and radius R is placed on a smooth horizontal surface. A sudden blow is given horizontally to the sphere at a height $h = 4R/5$ above the centre line. If I is the impulse of the blow then find

(a) the minimum time after which the highest point B will touch the ground

(b) the displacement of the centre of mass during this internal.

PRM191

19. Two uniform cylinders, each of mass $m = 10\ kg$ and radius $r = 150\ mm$, are connected by a rough belt as shown. If the system is released from rest, determine:

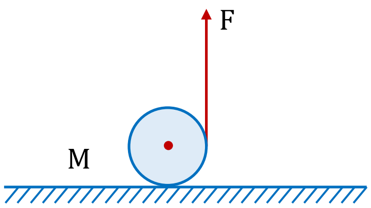


(a) the velocity of the centre of cylinder A after it has moved through 1.2 m.

(b) the tension in the portion of the belt connecting the two cylinders.

PRM200

20. The free end of the string wound on the surface of a solid cylinder of mass M and radius r is pulled up by a force F as shown. If there is sufficient friction between cylinder and floor so that the cylinder is able to roll without slipping, find the maximum angular acceleration that the cylinder can have (without cylinder leaving contact with surface).

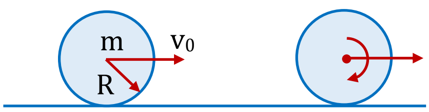


PRM201

21. A uniform disk of mass m and radius R is projected horizontally with velocity v_0 on a rough horizontal floor so that it starts off with a purely sliding motion at $t = 0$. After t_0 seconds it acquires a purely rolling motion as shown in figure.

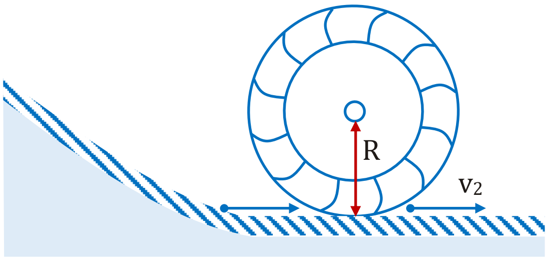
(i) Calculate the velocity of the centre of mass of the disk at t_0.

(ii) Assuming the coefficient of friction to be μ calculate t_0. Also calculate the work done by the frictional force as a function of time and the total work done by it over a time t much longer than t_0.



PRM202

22. Water flowing along an open channel drives an undershot waterwheel of radius 2 *m* (figure). The water approaches the wheel with a speed of 5.0 *m/s* and leaves with a speed of 2.5 *m/s*; the amount of water passing by is 200 kg per second. At what rate does the water deliver angular momentum to the wheel (in *kJ*) ?



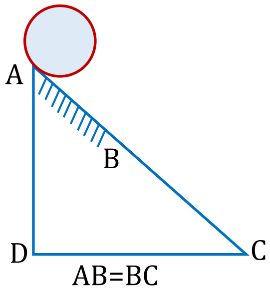
PRM267

Rolling

23. A solid uniform disk of mass *m* rolls down a fixed inclined plane without slipping with an acceleration *a*. Find the frictional force on the disk due to surface of the plane:

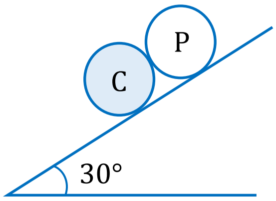
PRM184

24. Portion *AB* of the wedge shown in figure is rough and *BC* is smooth. A solid cylinder rolls without slipping from *A* to *B*. Find the ratio of translational kinetic energy to rotational kinetic energy, when the cylinder reaches point *C*.



PRM186

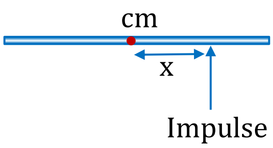
25. A solid cylinder *C* and a hollow pipe *P* of same diameter are in contact when they are released from rest as shown in the figure on a long incline plane. Cylinder *C* and pipe *P* roll without slipping. Determine the clear gap (in *m*) between them after 6 seconds.



PRM190

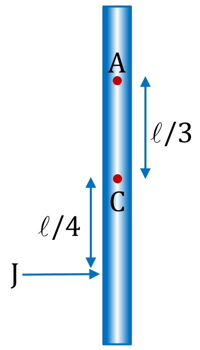
Impulse & Angular Impulse

26. A uniform rod of length *l* is given an impulse at right angle to its length as shown. Find the distance of instantaneous centre of rotation from the centre of the rod.



PRM205

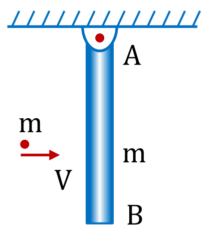
27. A uniform rod of mass m and length ℓ is placed in gravity free space and linear impulse J is given to the rod at a distance $x = \ell/4$ from centre 'C' and perpendicular to the rod. Point A is at a distance $\ell/3$ from centre as shown in the figure. Then find



(i) Speed of centre of rod
(ii) Speed of point A
(iii) Speed of upper end of rod
(iv) Speed of lower end of rod

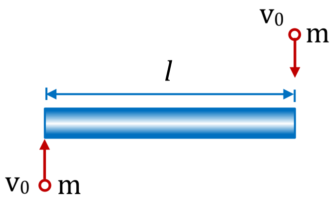
PRM206

28. A uniform rod AB of length L and mass m is suspended freely at A and hangs vertically at rest when a particle of same mass m is fired horizontally with speed v to strike the rod at its mid point. If the particle comes to rest after the impact, then find the impulsive reaction at A.



PRM207

29. On a smooth table two particles of mass m each, travelling with a velocity v_0 in opposite directions, strike the ends of a rigid massless rod of length l, kept perpendicular to their velocity. The particles stick to the rod after the collision. Find the tension in rod during subsequent motion.



PRM208

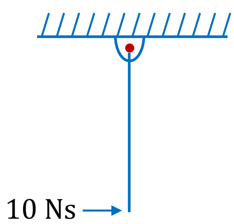
30. A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m travelling along the surface hits the end 'A' of the rod with a velocity v_0 in the direction perpendicular to AB. The collision is completely elastic. After the collision the particle comes to rest.

(a) Find the ratio m/M.

(b) A point P on the rod is at rest immediately after the collision. Find the distance AP.

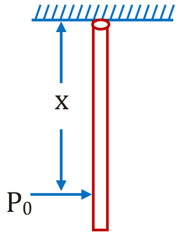
PRM209

31. A thin uniform straight rod of mass 2 kg and length 1 m is free to rotate about its upper end when at rest. It receives an impulsive blow of 10 Ns at its lowest point, normal to its length as shown in figure. Find the kinetic energy of rod just after impact.



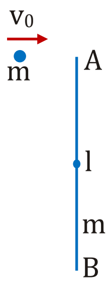
PRM214

32. A uniform rod of length 0.72 *m* is pivoted at one end and is hanging as shown. It receives a horizontal impulse at a distance *x* below the pivot as shown. If impulse applied by the pivot is zero, then find the value of *x* (in *cm*).



PRM268

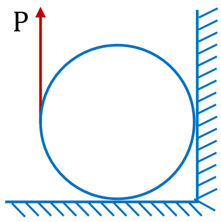
33. A mass *m* travelling at speed v_0 strikes perpendicularly to a stick of mass *m* and length ℓ = 1.2*m*, which is initially at rest as shown in the figure. The mass collides completely inelastically with the stick at one of its ends, and sticks to it. The location of point from end *A* (in *cm*) which is at instantaneous rest just after collision is x_0. Value of $x_0/10$ is



PRM269

Miscellaneous

34. Figure shows a vertical force applied tangentially to a uniform cylinder of weight F_g. The coefficient of static friction between the cylinder and both surfaces is 0.500. In terms of F_g, find the maximum force *P* that can be applied that does not cause the cylinder to rotate.

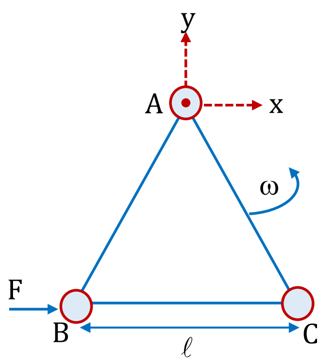


PRM218

35. Three particles *A*, *B*, and *C* each of mass *m*, are connected to each other by three massless rigid rods to form a rigid, equilateral triangular body of side ℓ. This body is placed on a horizontal frictionless table (*x*-*y* plane) and is hinged to it at the point *A*, so that it can move without friction about the vertical axis through *A* (see figure). The body is set into rotational motion on the table about *A* with a constant angular velocity ω.

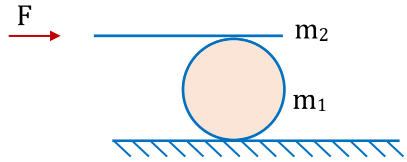
(a) Find the magnitude of the horizontal force exerted by the hinge on the body.

(b) At time *T*, when the side *BC* is parallel to the *x*-axis, a force *F* is applied on *B* along *BC* (as shown). Obtain the *x*-component and the *y*-component of the force exerted by the hinge on the body, immediately after time *T*.



PRM219

36. A man pushes a cylinder of mass m_1 with help of a plank of mass m_2 as shown. There is no slipping at any contact. the horizontal component of the force applied by the man is F. Find:

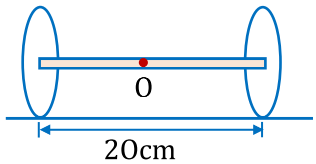


(a) the accelerations of the plank and the centre of mass of the cylinder, and

(b) the magnitudes and directions of frictional forces at contact points.

PRM220

37. Two thin circular disks of mass 2 *kg* and radius 10 *cm* each are joined by a rigid massless rod of length 20 *cm*. The axis of the rod is along the perpendicular to the planes of the disks through their centre. The object is kept on a truck in such a way that the axis of the object is horizontal and perpendicular to the direction of motion of the truck. Its friction with the floor of the truck is large enough so that the object can roll on the truck without slipping. Take x-axis as the direction of motion of the truck and z-axis as the vertically upwards direction. If the truck has an acceleration of 9 m/s^2 calculate :

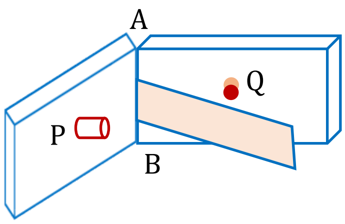


(a) the force of friction on each disk.

(b) the magnitude and the direction of the frictional torque acting on each disk about the centre of mass O of the object. Express the torque in the vector form of unit vectors in the x-y and z directions.

PRM221

38. Two heavy metallic plates are joined together at 90° to each other. A laminar sheet of mass 30 *Kg* is hinged at the line *AB* joining the two heavy metallic plates. The hinges are frictionless. The moment of inertia of the laminar sheet about an axis parallel to *AB* and passing through its centre of mass is 1.2 Kg-m^2. Two rubber obstacles *P* and *Q* are fixed, one on each metallic plate at a distance 0.5 *m* from the line *AB*. This distance is chosen so that the reaction due to the hinges on the laminar sheet is zero during the impact. Initially the laminar sheet hits one of the obstacles with an angular velocity 1 rad/*s* and turns back. If the impulse on the sheet due to each obstacle is 6 *N–s*.



(a) Find the location of the centre of mass of the laminar sheet from *AB*.

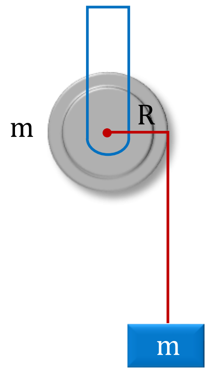
(b) At what angular velocity does the laminar sheet come back after the first impact?

(c) After how many impacts, does the laminar sheet come to rest?

PRM222

EXERCISE - JEE (Main) PYQ

1. A mass 'm' is supported by a massless string wound around a uniform hollow cylinder of mass m and radius R. If the string does not slip on the cylinder, with what acceleration will the mass fall on release? **[JEE (Main) 2014]**



(1) $\frac{5g}{6}$ (2) g (3) $\frac{2g}{3}$ (4) $\frac{g}{2}$

PRM031

2. A particle of mass m is moving along the side of a square of side 'a', with a uniform speed υ in the x-y plane as shown in the figure. **[JEE (Main) 2016]**

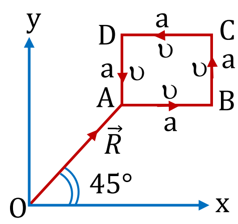
Which of the following statement is false for the angular momentum $\vec{L}$ about the origin ?

(1) $\vec{L} = \frac{mv}{\sqrt{2}}R\hat{k}$ when the particle is moving from D to A

(2) $\vec{L} = -\frac{mv}{\sqrt{2}}R\hat{k}$ when the particle is moving from A to B

(3) $\vec{L} = mv\left[\frac{R}{\sqrt{2}} - a\right]\hat{k}$ when the particle is moving from C to D

(4) $\vec{L} = mv\left[\frac{R}{\sqrt{2}} + a\right]\hat{k}$ when the particle is moving from B to C



PRM032

3. The moment of inertia of a uniform cylinder of length ℓ and radius R about its perpendicular bisector is I. What is the ratio ℓ/R such that the moment of inertia is minimum ? **[JEE (Main) 2017]**

(1) 1 (2) $\frac{3}{\sqrt{2}}$ (3) $\sqrt{\frac{3}{2}}$ (4) $\frac{\sqrt{3}}{2}$

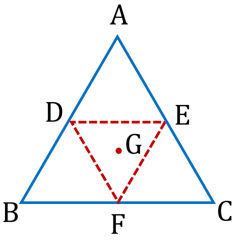
PRM033

4. To mop-clean a floor, a cleaning machine presses a circular mop of radius R vertically down with a total force F and rotates it with a constant angular speed about its axis. If the force F is distributed uniformly over the mop and if coefficient of friction between the mop and the floor is μ, the torque, applied by the machine on the mop is : **[JEE (Main) 2019]**

(1) $\frac{2}{3}\mu FR$ (2) $\mu FR/3$ (3) $\mu FR/2$ (4) $\mu FR/6$

PRM034

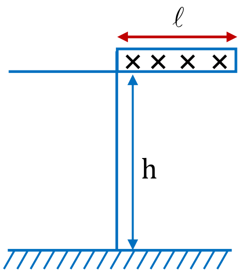
5. An equilateral triangle *ABC* is cut from a thin solid sheet of wood. (see figure) *D, E* and *F* are the mid-points of its sides as shown and *G* is the centre of the triangle. The moment of inertia of the triangle about an axis passing through *G* and perpendicular to the plane of the triangle is I_0. If the smaller triangle *DEF* is removed from *ABC*, the moment of inertia of the remaining figure about the same axis is *I*. Then: **[JEE (Main) 2019]**



(1) $I=\frac{9}{16}I_0$ (2) $I=\frac{3}{4}I_0$ (3) $I=\frac{I_0}{4}$ (4) $I=\frac{15}{16}I_0$

PRM035

6. A rectangular solid box of length 0.3 *m* is held horizontally, with one of its sides on the edge of a platform of height 5*m*. When released, it slips off the table in a very short time τ = 0.01*s*, remaining essentially horizontal. The angle by which it would rotate when it hits the ground will be (in radians) close to :- **[JEE (Main) 2019]**



(1) 0.02 (2) 0.28 (3) 0.5 (4) 0.3

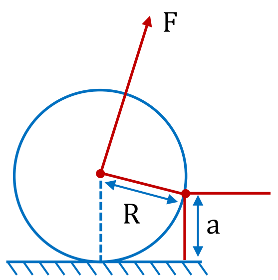
PRM036

7. A stationary horizontal disc is free to rotate about its axis. When a torque is applied on it, its kinetic energy as a function of θ, where θ is the angle by which it has rotated, is given as $k\theta^2$. If its moment of inertia is *I* then the angular acceleration of the disc is : **[JEE (Main) 2019]**

(1) $\frac{k}{2I}\theta$ (2) $\frac{k}{I}\theta$ (3) $\frac{k}{4I}\theta$ (4) $\frac{2k}{I}\theta$

PRM037

8. A uniform cylinder of mass *M* and radius *R* is to be pulled over a step of height a ($a < R$) by applying a force *F* at its centre '*O*' perpendicular to the plane through the axes of the cylinder on the edge of the step (see figure). The minimum value of *F* required is : **[JEE (Main) 2020]**



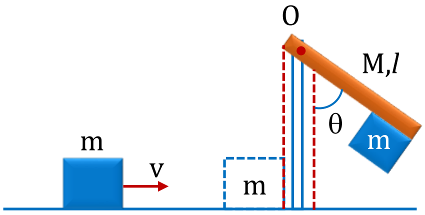
(1) $Mg\sqrt{1-\frac{a^2}{R^2}}$ (2) $Mg\sqrt{\left(\frac{R}{R-a}\right)^2-1}$

(3) $Mg\frac{a}{R}$ (4) $Mg\sqrt{1-\left(\frac{R-a}{R}\right)^2}$

PRM038

9. A block of mass $m = 1\ kg$ slides with velocity $v = 6\ m/s$ on a frictionless horizontal surface and collides with a uniform vertical rod and sticks to it as shown. The rod is pivoted about O and swings as a result of the collision making angle θ before momentarily coming to rest. If the rod has mass $M = 2\ kg$, and length $l = 1\ m$, the value of θ is approximately :

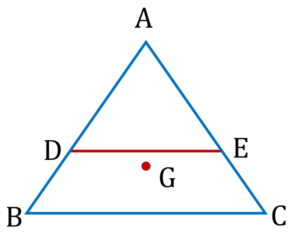
(Take $g = 10\ m/s^2$) **[JEE (Main) 2020]**



(1) 69° (2) 63° (3) 55° (4) 49°

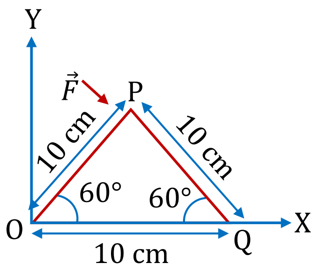
PRM039

10. ABC is a plane lamina of the shape of an equilateral triangle. D, E are mid points of AB, AC and G is the centroid of the lamina. Moment of inertia of the lamina about an axis passing through G and perpendicular to the plane ABC is I_0. If part ADE is removed, the moment of inertia of the remaining part about the same axis is $\frac{NI_0}{16}$ where N is an integer. Value of N is _____. **[JEE (Main) 2020]**



PRM040

11. A triangular plate is shown. A force $\vec{F} = 4\hat{i} - 3\hat{j}$ is applied at point P. The torque at point P with respect to point 'O' and 'Q' are : **[JEE (Main) 2021]**



(1) $-15 - 20\sqrt{3}, 15 - 20\sqrt{3}$

(2) $15 + 20\sqrt{3}, 15 - 20\sqrt{3}$

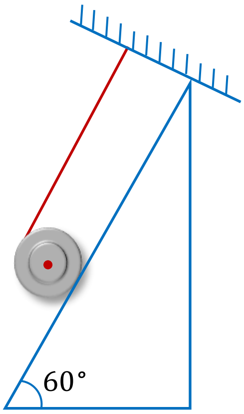
(3) $15 - 20\sqrt{3}, 15 + 20\sqrt{3}$

(4) $-15 + 20\sqrt{3}, 15 + 20\sqrt{3}$

PRM041

12. A solid cylinder of mass m is wrapped with an inextensible light string and, is placed on a rough inclined plane as shown in the figure. The frictional force acting between the cylinder and the inclined plane is :

[The coefficient of static friction, μ_s, is 0.4] **[JEE (Main) 2021]**



(1) $\frac{7}{2}mg$

(2) 5 mg

(3) $\frac{mg}{5}$

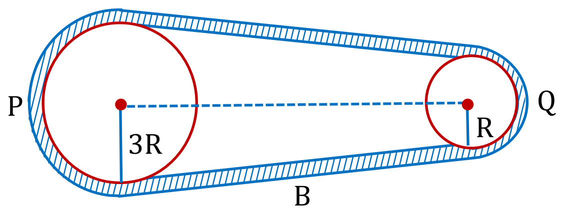
(4) 0

PRM042

13. A rod of mass M and length L is lying on a horizontal frictionless surface. A particle of mass 'm' travelling along the surface hits at one end of the rod with a velocity 'u' in a direction perpendicular to the rod. The collision is completely elastic. After collision, particle comes to rest. The ratio of masses $\left(\frac{m}{M}\right)$ is $\frac{1}{x}$. The value of 'x' will be _____. **[JEE (Main) 2021]**

PRM043

14. In the given figure, two wheels P and Q are connected by a belt B. The radius of P is three times as that of Q. In case of same rotational kinetic energy, the ratio of rotational inertias $\left(\frac{I_1}{I_2}\right)$ will be x : 1. The value of x will be ____. **[JEE (Main) 2021]**



PRM044

15. Two discs have moments of inertia I_1 and I_2 about their respective axes perpendicular to the plane and passing through the centre. They are rotating with angular speeds, ω_1 and ω_2 respectively and are brought into contact face to face with their axes of rotation coaxial. The loss in kinetic energy of the system in the process is given by : **[JEE (Main) 2021]**

(1) $\frac{I_1 I_2}{(I_1+I_2)}(\omega_1-\omega_2)^2$

(2) $\frac{(I_1-I_2)^2\omega_1\omega_2}{2(I_1+I_2)}$

(3) $\frac{I_1 I_2}{2(I_1+I_2)}(\omega_1-\omega_2)^2$

(4) $\frac{(\omega_1-\omega_2)^2}{2(I_1+I_2)}$

PRM045

16. Mass per unit area of a circular disc of radius a depends on the distance r from its centre as $\sigma(r) = A + Br$. The moment of inertia of the disc about the axis, perpendicular to the plane and passing through its centre is : **[JEE (Main) 2020]**

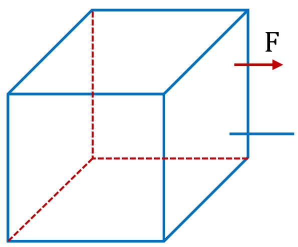
(1) $2\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$ (2) $\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$

(3) $2\pi a^4\left(\frac{aA}{4}+\frac{B}{5}\right)$ (4) $2\pi a^4\left(\frac{A}{4}+\frac{B}{5}\right)$

PRM046

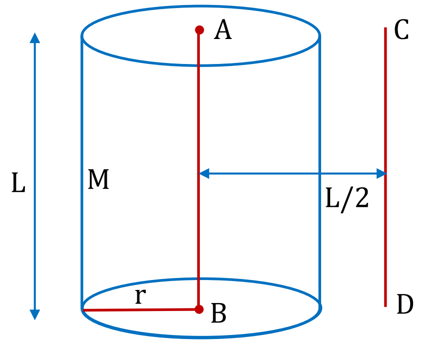
17. Consider a uniform cubical box of side a on a rough floor that is to be moved by applying minimum possible force F at a point b above its centre of mass (see figure). If the coefficient of friction is $\mu = 0.4$, the maximum possible value of $100 \times \frac{b}{a}$ for a box not to topple before moving is _____ .

[JEE (Main) 2020]



PRM047

18. The solid cylinder of length 80 cm and mass M has a radius of 20 cm. Calculate the density of the material used if the moment of inertia of the cylinder about an axis CD parallel to AB as shown in figure is 2.7 $kg\ m^2$. **[JEE (Main) 2021]**

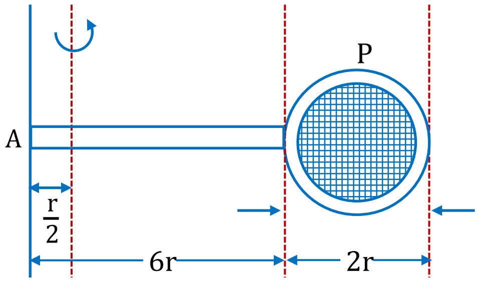


(1) 14.9 kg / m^3 (2) $7.5 \times 10^1\ kg / m^3$

(3) $7.5 \times 10^2\ kg/m^3$ (4) $1.49 \times 10^2\ kg / m^3$

PRM048

19. Consider a badminton racket with length scales as shown in the figure. **[JEE (Main) 2021]**



If the mass of the linear and circular portions of the badminton racket are same (M) and the mass of the threads are negligible, the moment of inertia of the racket about an axis perpendicular to the handle and in the plane of the ring at, $\frac{r}{2}$ distance from the end A of the handle will be .... Mr^2.

PRM049

20. A metre scale is balanced on a knife edge at its centre. When two coins, each of mass 10 g are put one on the top of the other at the 10.0 cm mark the scale is found to be balanced at 40.0 cm mark. The mass of the metre scale is found to be $x \times 10^{-2}$ kg. The value of x is **[JEE (Main) 2022]**

PRM050

21. A ring and a solid sphere rotating about an axis passing through their centers have same radii of gyration. The axis of rotation is perpendicular to plane of ring. The ratio of radius of ring to that of sphere is $\sqrt{\frac{2}{x}}$. The value of x is ______. **[JEE (Main) 2023]**

PRM270

22. For a rolling spherical shell, the ratio of rotational kinetic energy and total kinetic energy is $\frac{x}{5}$. The value of x is________. **[JEE (Main) 2023]**

PRM271

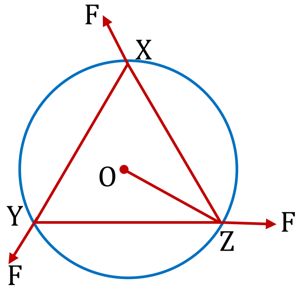
23. A uniform solid cylinder with radius R and length L has moment of inertia I_1, about the axis of cylinder. A concentric solid cylinder of radius $R' = \frac{R}{2}$ and length $L' = \frac{L}{2}$ is caned out of the original cylinder. If I_2 is the moment of inertia of the carved-out portion to the cylinder then $\frac{I_1}{I_2}$ = _________.

(Both I_1 and I_2 are about the axis of the cylinder) **[JEE (Main) 2023]**

PRM272

EXERCISE - JEE (Advanced) PYQ

1. A uniform circular disc of mass 1.5 kg and radius 0.5 m is initially at rest on a horizontal frictionless surface. Three forces of equal magnitude $F = 0.5\ N$ are applied simultaneously along the three sides of an equilateral triangle XYZ with its vertices on the perimeter of the disc (see figure). One second after applying the forces, the angular speed of the disc in rad s^{-1} is **[JEE (Advanced) 2014]**



PRM069

2. The densities of two solid spheres A and B of the same radii R vary with radial distance r as $\rho_A(r) = k\left(\frac{r}{R}\right)$ and $\rho_B(r) = k\left(\frac{r}{R}\right)^5$, respectively, where k is a constant. The moments of inertia of the individual spheres about axes passing through their centres are I_A and I_B, respectively. If $\frac{I_B}{I_A} = \frac{n}{10}$, the value of n is. **[JEE (Advanced) 2015]**

PRM070

3. A uniform wooden stick of mass 1.6 kg and length ℓ rests in an inclined manner on a smooth, vertical wall of height h ($<\ell$) such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio h/ℓ and the frictional force f at the bottom of the stick are: ($g = 10\ ms^{-2}$) **[JEE (Advanced) 2016]**

(A) $\frac{h}{\ell} = \frac{\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3} N$

(B) $\frac{h}{\ell} = \frac{3}{16}, f = \frac{16\sqrt{3}}{3} N$

(C) $\frac{h}{\ell} = \frac{3\sqrt{3}}{16}, f = \frac{8\sqrt{3}}{3} N$

(D) $\frac{h}{\ell} = \frac{3\sqrt{3}}{16}, f = \frac{8\sqrt{3}}{3} N$

PRM071

4. The position vector of a particle of mass m is given by the following equation $\vec{r}(t) = \alpha t^3 \hat{\imath} + \beta t^2 \hat{\jmath}$, where $\alpha = \frac{10}{3} ms^{-3}$, $\beta = 5\ ms^{-2}$ and $m = 0.1\ kg$. At $t = 1\ s$, which of the following statement(s) is(are) true about the particle? **[JEE (Advanced) 2016]**

(A) The velocity $\vec{v}$ is given by $\vec{v} = (10\hat{\imath} + 10\hat{\jmath}) ms^{-1}$.

(B) The angular momentum $\vec{L}$ with respect to the origin is given by $\vec{L} = -\left(\frac{5}{3}\right) \hat{k}\ Nms$.

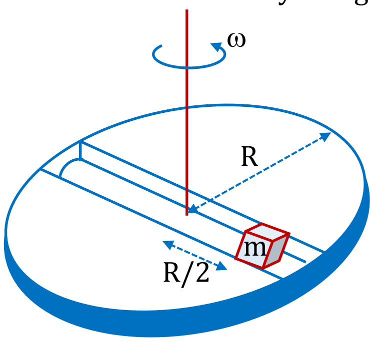
(C) The force $\vec{F}$ is given by $\vec{F} = (\hat{\imath} + 2\hat{\jmath}) N$.

(D) The torque $\vec{\tau}$ with respect to the origin is given by $\vec{\tau} = -\left(\frac{20}{3}\right) \hat{k}\ Nm$.

PRM072

PARAGRAPH FOR QUESTION NO. 5 AND 6

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{\text{rot}}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{\text{in}}$ experienced by the particle in an inertial frame of reference is $\vec{F}_{rot} = \vec{F}_{in} + 2m(\vec{v}_{rot} \times \vec{\omega}) + m(\vec{\omega} \times \vec{r}) \times \vec{\omega}$, where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc. Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the centre of the disc, the x-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis $(\vec{\omega} = \omega\hat{k})$. A small block of mass m is gently placed in the slot at $\vec{r} = (R/2)\hat{\imath}$ at $t = 0$ and is constrained to move only along the slot. **[JEE (Advanced) 2016]**



5. The distance r of the block at time t is :

(A) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$ (B) $\frac{R}{2}\cos 2\omega t$ (C) $\frac{R}{2}\cos \omega t$ (D) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$

PRM073

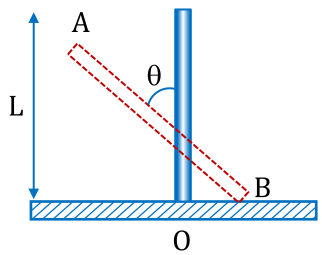
6. The net reaction of the disc on the block is :

(A) $-m\omega^2 R\cos\omega t\hat{\jmath} - mg\hat{k}$ (B) $m\omega^2 R\sin\omega t\hat{\jmath} - mg\hat{k}$

(C) $\frac{1}{2}m\omega^2 R\left(e^{\omega t} - e^{-\omega t}\right)\hat{\jmath} + mg\hat{k}$ (D) $\frac{1}{2}m\omega^2 R\left(e^{2\omega t} - e^{-2\omega t}\right)\hat{\jmath} + mg\hat{k}$

PRM074

7. A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct ? **[JEE (Advanced) 2017]**



(A) When the bar makes an angle θ with the vertical, the displacement of its midpoint from the initial position is proportional to (1 – cos θ).

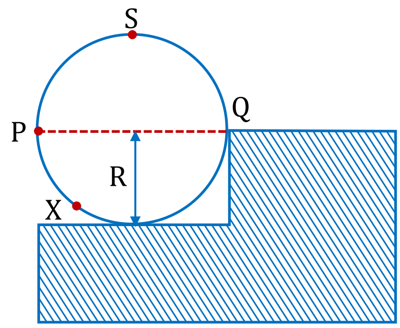
(B) The midpoint of the bar will fall vertically downward.

(C) Instantaneous torque about the point in contact with the floor is proportional to sin θ.

(D) The trajectory of the point A is a parabola.

PRM075

8. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct ? **[JEE (Advanced) 2017]**



(A) If the force is applied normal to the circumference at point X then τ is constant.

(B) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step.

(C) If the force is applied normal to the circumference at point P then τ is zero.

(D) If the force is applied at point P tangentially then τ decreases continuously as the wheel climbs.

PRM076

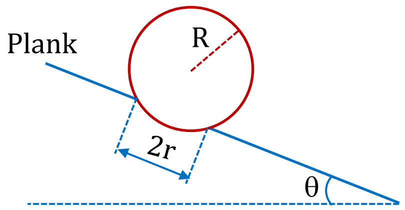
9. The potential energy of a particle of mass m at a distance r from a fixed point O is given by $V(r) = kr^2/2$, where k is a positive constant of appropriate dimensions. This particle is moving in a circular orbit of radius R about the point O. If v is the speed of the particle and L is the magnitude of its angular momentum about O, which of the following statements is (are) true ?

[JEE (Advanced) 2018]

(A) $v = \sqrt{\frac{k}{2m}}R$ (B) $v = \sqrt{\frac{k}{m}}R$ (C) $L = \sqrt{mk}R^2$ (D) $L = \sqrt{\frac{mk}{2}}R^2$

PRM077

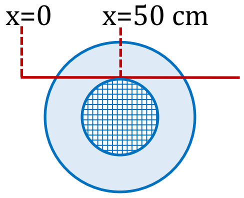
10. A football of radius R is kept on a hole of radius r ($r < R$) made on a plank kept horizontally. One end of the plank is now lifted so that it gets tilted making an angle θ from the horizontal as shown in the figure below. The maximum value of θ so that the football does not start rolling down the plank satisfies (figure is schematic and not drawn to scale) – **[JEE (Advanced) 2020]**

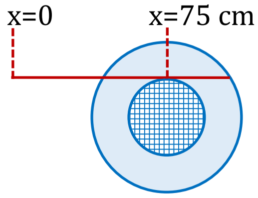


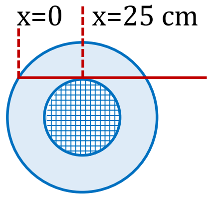
(A) $\sin\theta = \frac{r}{R}$ (B) $\tan\theta = \frac{r}{R}$ (C) $\sin\theta = \frac{r}{2R}$ (D) $\cos\theta = \frac{r}{2R}$

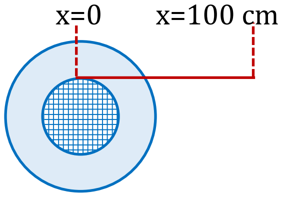
PRM078

11. A small roller of diameter 20 *cm* has an axle of diameter 10 *cm* (see figure below on the left). It is on a horizontal floor and a meter scale is positioned horizontally on its axle with one edge of the scale on top of the axle (see figure on the right). The scale is now pushed slowly on the axle so that it moves without slipping on the axle, and the roller starts rolling without slipping. After the roller has moved 50 *cm*, the position of the scale will look like (figures are schematic and not drawn to scale)- **[JEE (Advanced) 2020]**

(A) 

(B) 

(C) 

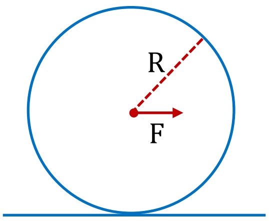
(D) 

PRM079

12. Put a uniform meter scale horizontally on your extended index fingers with the left one at 0.00 *cm* and the right one at 90.00 *cm*. When you attempt to move both the fingers slowly towards the center, initially only the left finger slips with respect to the scale and the right finger does not. After some distance, the left finger stops and the right one starts slipping. Then the right finger stops at a distance x_R from the center (50.00 *cm*) of the scale and the left one starts slipping again. This happens because of the difference in the frictional forces on the two fingers. If the coefficients of static and dynamic friction between the fingers and the scale are 0.40 and 0.32, respectively, the value of x_R (in *cm*) is ________. **[JEE (Advanced) 2020]**

PRM080

13. A horizontal force *F* is applied at the center of mass of a cylindrical object of mass m and radius *R*, perpendicular to its axis as shown in the figure. The coefficient of friction between the object and the ground is μ. The center of mass of the object has an acceleration *a*. The acceleration due to gravity is *g*. Given that the object rolls without slipping, which of the following statement(s) is(are) correct? **[JEE (Advanced) 2021]**



(A) For the same *F*, the value of *a* does not depend on whether the cylinder is solid or hollow.

(B) For a solid cylinder, the maximum possible value of *a* is $2\mu g$.

(C) The magnitude of the frictional force on the object due to the ground is always μmg.

(D) For a thin-walled hollow cylinder, $a = \frac{F}{2m}$.

PRM081

14. A particle of mass $M = 0.2\ kg$ is initially at rest in the xy-plane at a point $(x = -l, y = -h)$, where $l = 10\ m$ and $h = 1m$. The particle is accelerated at time $t = 0$ with a constant acceleration $a = 10\ m/s^2$ along the positive x-direction. Its angular momentum and torque with respect to the origin, in SI units, are represented by $\vec{L}$ and $\vec{\tau}$, respectively. $\hat{\imath}, \hat{\jmath}$ and $\hat{k}$ are unit vectors along the positive x, y and z-directions, respectively. If $\hat{k} = \hat{\imath} \times \hat{\jmath}$ then which of the following statement(s) is(are) correct ?

[JEE (Advanced) 2021]

(A) The particle arrives at the point $(x = l, y = -h)$ at time $t = 2s$

(B) $\vec{\tau} = 2\hat{k}$ when the particle passes through the point $(x = l, y = -h)$

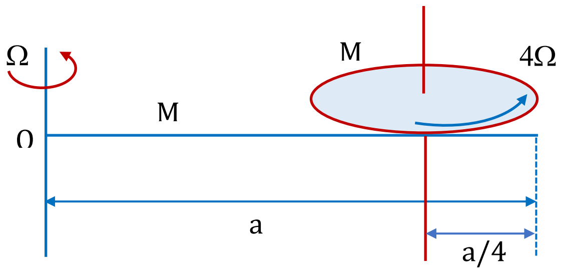
(C) $\vec{L} = 4\hat{k}$ when the particle passes through the point $(x = l, y = -h)$

(D) $\vec{\tau} = \hat{k}$ when the particle passes through the point $(x = 0, y = -h)$

PRM082

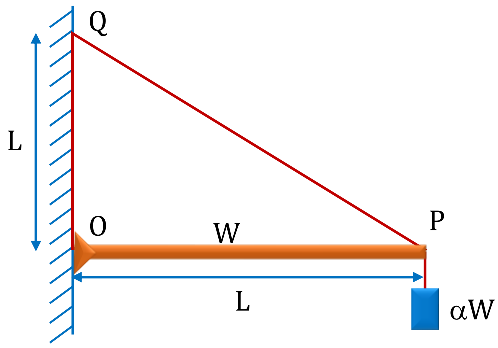
15. A thin rod of mass M and length a is free to rotate in horizontal plane about a fixed vertical axis passing through point O. A thin circular disc of mass M and of radius $a/4$ is pivoted on this rod with its center at a distance $a/4$ from the free end so that it can rotate freely about its vertical axis, as shown in the figure. Assume that both the rod and the disc have uniform density and they remain horizontal during the motion. An outside stationary observer finds the rod rotating with an angular velocity Ω and the disc rotating about its vertical axis with angular velocity 4Ω. The total angular momentum of the system about the point O is $\left(\dfrac{Ma^2\Omega}{48}\right)n$. The value of n is___.

[JEE (Advanced) 2021]



PRM083

16. One end of a horizontal uniform beam of weight W and length L is hinged on a vertical wall at point O and its other end is supported by a light inextensible rope. The other end of the rope is fixed at point Q, at a height L above the hinge at point O. A block of weight αW is attached at the point P of the beam, as shown in the figure (not to scale). The rope can sustain a maximum tension of $(2\sqrt{2})W$. Which of the following statement(s) is(are) correct ? **[JEE (Advanced) 2021]**



(A) The vertical component of reaction force at O does not depend on α.

(B) The horizontal component of reaction force at O is equal to W for $\alpha = 0.5$.

(C) The tension in the rope is $2W$ for $\alpha = 0.5$.

(D) The rope breaks if $\alpha > 1.5$.

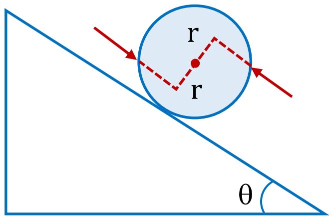
PRM084

17. At time $t = 0$, a disk of radius 1 m starts to roll without slipping on a horizontal plane with an angular acceleration of $\alpha = \frac{2}{3}$ rad s^{-2}. A small stone is stuck to the disk. At $t = 0$, it is at the contact point of the disk and the plane. Later, at time $t = \sqrt{\pi}s$, the stone detaches itself and flies off tangentially from the disk. The maximum height (in m) reached by the stone measured from the plane is $\frac{1}{2} + \frac{x}{10}$. The value of x is_____. [Take $g = 10\ m\ s^{-2}$.] **[JEE (Advanced) 2022]**

PRM085

18. A solid sphere of mass 1 kg and radius 1 m rolls without slipping on a fixed inclined plane with an angle of inclination $\theta = 30°$ from the horizontal. Two forces of magnitude 1 N each, parallel to the incline, act on the sphere, both at distance $r = 0.5\ m$ from the center of the sphere, as shown in the figure. The acceleration of the sphere down the plane is_____ms^{-2}. (Take $g = 10\ m\ s^{-2}$.)

[JEE (Advanced) 2022]



PRM086

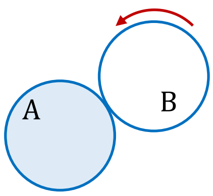
19. A particle of mass 1 kg is subjected to a force which depends on the position as $\vec{F} = -k(x\hat{\imath} + y\hat{\jmath})kgms^{-2}$ with $k = 1\ kgs^{-2}$. At time $t = 0$, the particle's position $\vec{r} = \left(\frac{1}{\sqrt{2}}\hat{\imath} + \sqrt{2}\hat{\jmath}\right)m$ and its velocity $\vec{v} = \left(-\sqrt{2}\hat{\imath} + \sqrt{2}\hat{\jmath} + \frac{2}{\pi}\hat{k}\right)ms^{-1}$. Let v_x and v_y denote the x and the y components of the particle's velocity, respectively. **Ignore gravity.** When $z = 0.5$ m, the value of $(x\,v_y - y\,v_x)$ is_____ m^2s^{-1}.

[JEE (Advanced) 2022]

PRM087

20. A flat surface of a thin uniform disk A of radius R is glued to a horizontal table. Another thin uniform disk B of mass M and with the same radius R rolls without slipping on the circumference of A, as shown in the figure. A flat surface of B also lies on the plane of the table. The center of mass of B has fixed angular speed ω about the vertical axis passing through the center of A. The angular momentum of B is $nM\omega R^2$ with respect to the center of A. Which of the following is the value of n?

[JEE (Advanced) 2022]



(A) 2 (B) 5 (C) $\frac{7}{2}$ (D) $\frac{9}{2}$

PRM088

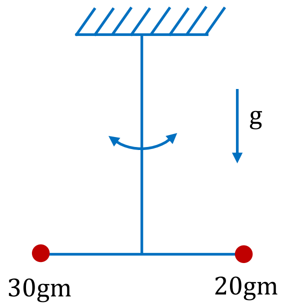
21. A bar of mas $M = 1.00\ kg$ and length $L = 0.20\ m$ is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass $m = 0.10\ kg$ is moving on the same horizontal surface with $5.00\ ms^{-1}$ speed on a path perpendicular to the bar. It hits the bar at a distance $L/2$ from the pivoted end and returns back on the same path with speed v. After this elastic collision, the bar rotates with an angular velocity ω. Which of the following statement is correct? **[JEE (Advanced) 2023]**

(A) $\omega = 6.98$ rad s^{-1} and $v = 4.30\ ms^{-1}$ (B) $\omega = 3.75$ rad s^{-1} and $v = 4.30\ ms^{-1}$

(C) $\omega = 3.75$ rad s^{-1} and $v = 10.0\ ms^{-1}$ (D) $\omega = 6.80$ rad s^{-1} and $v = 4.10\ ms^{-1}$

PRM273

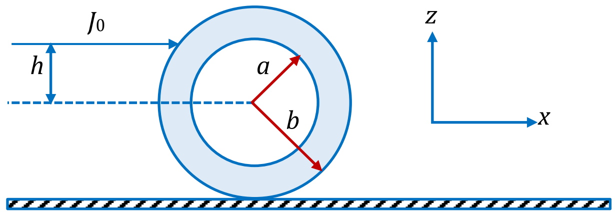
22. Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is $1.2 \times 10^{-8}\ N\ m\ rad^{-1}$. The angular frequency of the oscillations is $n \times 10^{-3}\ rad\ s^{-1}$. The value of n is _____.



[JEE (Advanced) 2023]

PRM274

23. An annular disk of mass M, inner radius a and outer radius b is placed on a horizontal surface with coefficient of friction μ, as shown in the figure. At some time, an impulse $J_0\hat{x}$ is applied at a height h above the center of the disk. If $h = h_m$ then the disk rolls without slipping along the x-axis. Which of the following statement(s) is(are) correct ?



[JEE (Advanced) 2023]

(A) For $\mu \neq 0$ and $a \to 0$, $h_m = b/2$

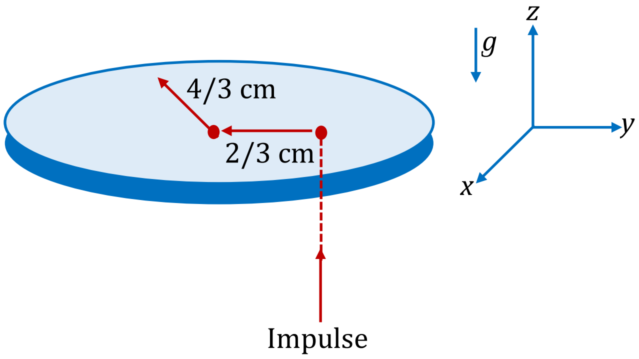
(B) For $\mu \neq 0$ and $a \to b$, $h_m = b$

(C) For $h = h_m$, the initial angular velocity does **not** depend on the inner radius a.

(D) For $\mu = 0$ and $h = 0$, the wheel always slides without rolling.

PRM275

24. A thin circular coin of mass 5 gm and radius 4/3 cm is initially in a horizontal *xy*-plane. The coin is tossed vertically up (+*z* direction) by applying an impulse of $\sqrt{\frac{\pi}{2}} \times 10^{-2} N\text{-}s$ at a distance 2/3 *cm* from its center. The coin spins about its diameter and moves along the +*z* direction. By the time the coin reaches back to its initial position, it completes *n* rotations. The value of *n* is ____.
[Given: The acceleration due to gravity g = 10 ms^{-2}]



[JEE (Advanced) 2023]
PRM276

JEE (Main) Practice Paper

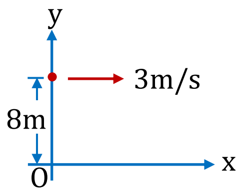
This paper is for yourself practice and assessment the discussion of this paper is optional though you can see PDF solutions or video solutions or solutions in hardcopy whichever is provided.

SECTION–A

- This section contains **TWENTY** questions.
- Each question has **FOUR** options (1), (2), (3) and (4). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks : +4, if only the bubble corresponding to the correct option is darkened.
Zero Marks : 0, if none of the bubbles is darkened.
Negative Marks : –1 in all other cases.

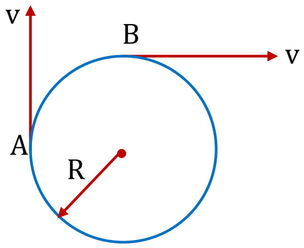
1. A particle starts from the point $(0m, 8m)$ and moves with uniform velocity of $3\hat{i}\ m/s$. After 5 seconds, the angular velocity of the particle about the origin will be:



(1) $\frac{8}{289}$ rad/s (2) $\frac{3}{8}$ rad/s (3) $\frac{24}{289}$ rad/s (4) $\frac{8}{17}$ rad/s

PRM001

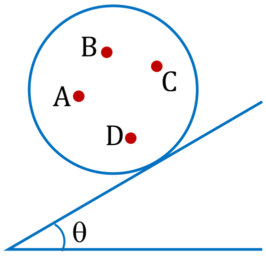
2. Two points of a rigid body are moving as shown. The angular velocity of the body is:



(1) $\frac{v}{2R}$ (2) $\frac{v}{R}$ (3) $\frac{2v}{R}$ (4) $\frac{2v}{3R}$

PRM002

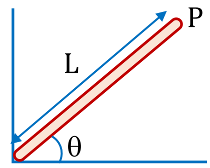
3. A non-uniform sphere can be kept on a rough inclined plane so that it is in equilibrium. In the figure below the dots represents location of centre of mass. In which one of the positions can sphere be in equilibrium?



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

PRM003

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



(1) $(2/3)\,g\cos\theta$ (2) $(2/3)\,g$ (3) g (4) $(3/2)\,g\cos\theta$

PRM004

5. A solid sphere with a velocity (of centre of mass) v and angular velocity ω is gently placed on a rough horizontal surface. The frictional force on the sphere:

(1) must be forward (in direction of v) (2) must be backward (opposite to v)

(3) cannot be zero (4) none of the above

PRM005

6. A hoop and a solid cylinder have the same mass and radius. They both roll, without slipping, on a horizontal surface. If their kinetic energies are equal

(1) the hoop has a greater translational speed than the cylinder

(2) the cylinder has a greater translational speed than the hoop

(3) the hoop and the cylinder have the same translational speed

(4) the hoop has a greater rotational speed than the cylinder

PRM006

7. The moment of inertia of a solid cylinder about its axis is given by $(1/2)MR^2$. If this cylinder rolls without slipping, the ratio of its rotational kinetic energy to its translational kinetic energy is

(1) 1 : 1 (2) 2 : 2 (3) 1 : 2 (4) 1 : 3

PRM007

8. A rod of weight w is supported by two parallel knives at end points A and B and is in equilibrium in a horizontal position. The knives are at a distance 'd' from each other. The centre of mass of the rod is at a distance 'x' from A.

(1) the normal reaction at A is $\frac{wx}{d}$ (2) the normal reaction at A is $\frac{w(d-x)}{2d}$

(3) the normal reaction at B is $\frac{wx}{d}$ (4) the normal reaction at B is $\frac{w(d-x)}{d}$

PRM008

9. A man spinning in free space changes the shape of his body, eg. by spreading his arms or curling up. By doing this, he can not change his

(1) moment of inertia (2) angular momentum

(3) angular velocity (4) rotational kinetic energy

PRM009

10. A heavy seesaw (i.e., not massless) is out of balance. A light girl sits on the end that is tilted downward, and a heavy body sits on the other side so that the seesaw now balances. If they both move forward so that they are one-half their original distance from the pivot point (the fulcrum) what will happen to the seesaw?

(1) The side the body is sitting on will tilt downward

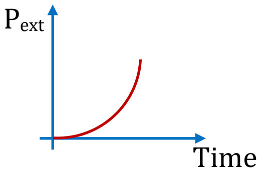
(2) The side the girl is sitting on will once again tilt downward

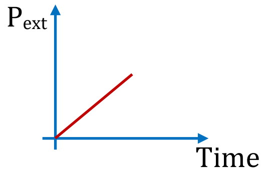
(3) Nothing; the seesaw will still be balanced

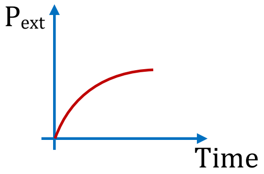
(4) It is impossible to say without knowing the masses and the distances

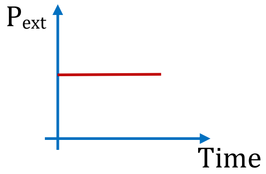
PRM010

11. A rod is hinged at its centre and rotated by applying a constant torque starting from rest. The power developed by the external torque as a function of time is:

(1) 

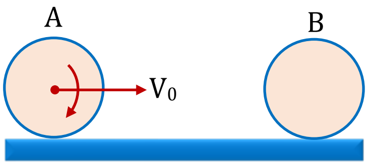
(2) 

(3) 

(4) 

PRM011

12. A hollow smooth uniform sphere A of mass '*m*' rolls without sliding on a smooth horizontal surface. It collides head on elastically with another stationary smooth solid sphere *B* of the same mass *m* and same radius. The ratio of kinetic energy of '*B*' to that of '*A*' just after the collision is :



(1) 1 : 1 (2) 2 : 3 (3) 3 : 2 (4) None

PRM012

13. A wheel of radius r rolling on a straight line, the velocity of its centre being *v*. At a certain instant the point of contact of the wheel with the grounds is *M* and *N* is the highest point on the wheel (diametrically opposite to *M*). The incorrect statement is:

(1) The velocity of any point *P* of the wheel is proportional to *MP*.

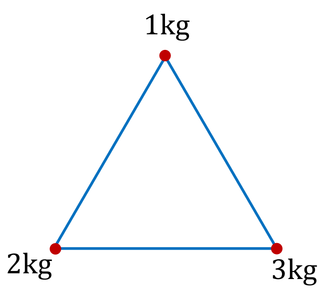
(2) Points of the wheel moving with velocity greater than v form a larger area of the wheel than points moving with velocity less than *v*.

(3) The point of contact *M* is instantaneously at rest.

(4) The velocities of any two parts of the wheel which are equidistant from centre are equal.

PRM013

14. Particles of masses 1, 2 and 3*kg* respectively are arranged at the corners of an equilateral triangle as shown in figure. Obtain the moment of inertia of the system about an axis passing through the centre of mass of the system and perpendicular to its plane. The side of the triangle is 1*m*.



(1) 4 $kg\text{-}m^2$ (2) $\frac{5}{6}$ $kg\text{-}m^2$

(3) $\frac{11}{6}$ $kg\text{-}m^2$ (4) 3.5 $kg\text{-}m^2$

PRM014

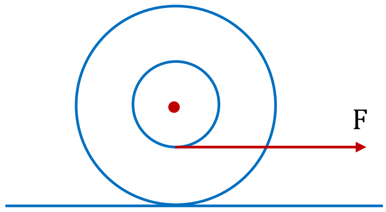
15. Inner and outer radii of a spool are r and R respectively. A thread is wound over its inner surface and placed over a rough horizontal surface. Thread is pulled by a force F as shown in fig. then in case of pure rolling:

(1) Thread unwinds, spool rotates anticlockwise and friction act leftwards.

(2) Thread winds, spool rotates clockwise and friction acts leftwards.

(3) Thread winds, spool moves to the right and friction act rightwards.

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



PRM015

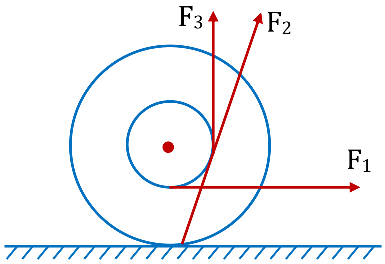
16. A yo-yo is resting on a perfectly rough horizontal table. Forces F_1, F_2 and F_3 are applied separately as shown. The correct statement is :-

(1) when F_3 is applied the centre of mass will move to the right.

(2) when F_2 is applied the centre of mass will move to the left.

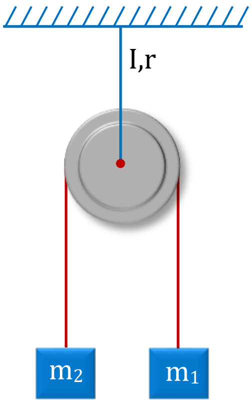
(3) when F_1 is applied the centre of mass will move to the right.

(4) when F_2 is applied the centre of mass will move to the right.



PRM016

17. Pulley is rotating with angular velocity ω. Pulley is sufficiently rough so that string does not slip on the pulley. Then angular momentum of system (pulley + blocks) about axle of pulley is :-

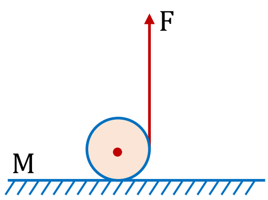


(1) $I\omega$ (2) $(m_1 + m_2 + I)\omega r$

(3) $(m_1 + m_2)r^2\omega + I\omega$ (4) $(m_1r^2 + m_2r^2 + I)\omega^2$

PRM017

18. The free end of the string wound on the surface of a solid cylinder of mass M and radius r is pulled up by a force F as shown. If there is sufficient friction between cylinder and floor so that the cylinder is able to roll without slipping, find the maximum angular acceleration that the cylinder can have (without cylinder leaving contact with surface).



(1) $\frac{g}{r}$ (2) $\frac{2g}{3r}$ (3) $\frac{4g}{3r}$ (4) $\frac{g}{2r}$

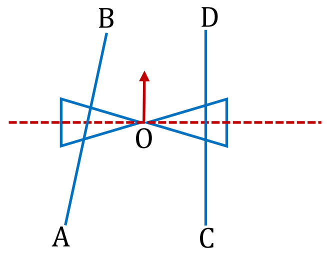
PRM018

19. From a solid sphere of mass M and radius R, a cube of maximum possible volume is cut. Moment of inertia of cube about an axis passing through its centre and perpendicular to one of its faces is:-

(1) $\frac{4MR^2}{9\sqrt{3}\pi}$ (2) $\frac{4MR^2}{3\sqrt{3}\pi}$ (3) $\frac{MR^2}{32\sqrt{2}\pi}$ (4) $\frac{MR^2}{16\sqrt{2}\pi}$

PRM019

20. A roller is made by joining together two cones at their vertices O. It is kept on two rails AB and CD which are placed asymmetrically (see figure), with its axis perpendicular to CD and its centre O at the centre of line joining AB and CD (see figure). It is given a light push so that it starts rolling with its centre O moving parallel to CD in the direction shown. As it moves, the roller will tend to :-



(1) turn left and right alternately (2) turn left
(3) turn right (4) go straight

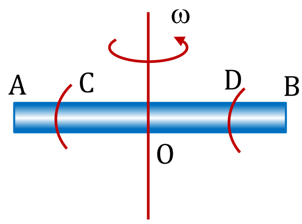
PRM020

SECTION–B

- This section will have **TEN questions**. Candidate can choose to attempt any 5 questions out of these 10 questions. In case if candidate attempts more than 5 questions, first 5 attempted questions will be considered for marking.
- The answer to each question is a **NUMERICAL VALUE.**
- For each question, enter the correct numerical value (Answer should be rounded off to the nearest integer).
- Answer to each question will be evaluated according to the following marking scheme:

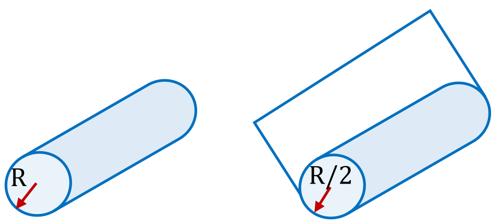
Full Marks	:	+4,	if only correct answer is given.
Zero Marks	:	0,	if no answer is given.
Negative Marks	:	–1	for incorrect answer.

1. A rigid horizontal smooth rod AB of mass 0.75 kg and length 40 cm can rotate freely about a fixed vertical axis through its mid-point O. Two rings each of mass 1 kg are initially at rest at a distance of 10 cm from O on either side of the rod. The rod is set in rotation with an angular velocity of 30 radians per second. Find the velocity of each ring along the length of the rod in m/s when they reach the ends of the rod.



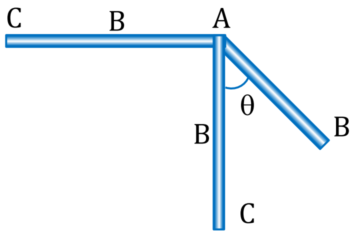
PRM021

2. A carpet of mass 'M' made of inextensible material is rolled along its length in the form of a cylinder of radius 'R' and is kept on a rough floor. The carpet starts unrolling without sliding on the floor when a negligibly small push is given to it. The horizontal velocity of the axis of the cylindrical part of the carpet when its radius reduces to $R/2$ is $\left(\sqrt{\frac{ngR}{3}}\right)$. Find n.



PRM022

3. A rod hinged at one end is released from the horizontal position as shown in the figure. When it becomes vertical its lower half separates without exerting any reaction at the breaking point. Then find the maximum angle 'θ'(in degree) made by the hinged upper half with the vertical.

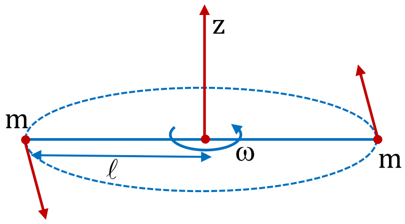


PRM023

4. The door of an automobile is open and perpendicular to the body. The automobile starts with an acceleration of 2 ft/sec^2, and the width of the door is 30 inches. Treat the door as a uniform rectangle, and neglect friction. The speed of its outside edge as seen by the driver when the door closes is $\sqrt{n}\ ft/\sec$. Find n.

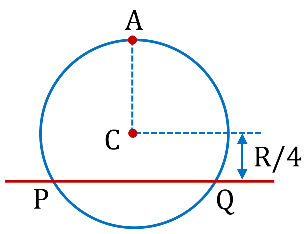
PRM024

5. A dumbbell consists of two identical particles of mass m connected by a rigid light rod of length 2ℓ. The dumbbell is set spinning with angular speed ω_0 on a surface with a small friction coefficient μ_k. If dumbbell stops in time $t = \dfrac{K\omega_0\ell}{2\mu g}$ where K is a constant, then find the value of K.



PRM025

6. A uniform circular disc has radius R and mass m. A particle also of mass m is fixed at a point A on the edge of the disc as in figure. The disc can rotate freely about a fixed horizontal chord PQ that is at a distance $R/4$ from the centre C of the disc. The line AC is perpendicular to PQ. Initially the disc is held vertical with the point A at its highest position. It is then allowed to fall so that it starts rotating about PQ. Find the linear speed (in m/s) of the particle at it reaches its lowest position. Take radius $R = 50\ cm$.

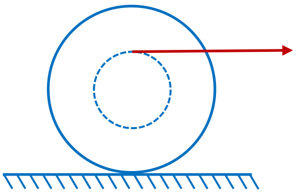


PRM026

7. Two men, each of mass 75 *kg*, stand on the rim of a horizontal large disc, diametrically opposite to each other. The disc has a mass 450 *kg* and is free to rotate about its axis. Each man simultaneously start along the rim clockwise with the same speed and reaches their original starting points on the disc. The angle turned by the disc with respect to the ground in this duration is $\frac{n\pi}{5}$. Find *n*.

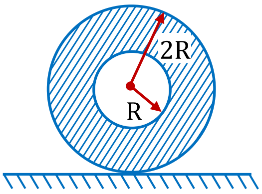
PRM027

8. A spool of inner radius *R* and outer radius 3*R* has a moment of inertia = MR^2 about an axis passing through its geometric centre, where *M* is the mass of the spool. A thread wound on the inner surface of the spool is pulled horizontally with a constant force = *Mg*. Find the acceleration (in m/s^2) of the point on the thread which is being pulled assuming that the spool rolls purely on the floor.



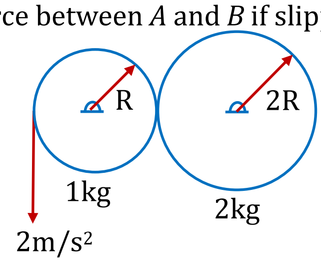
PRM028

9. A hollow cylinder with inner radius *R*, outer radius 2*R* and mass *M* is rolling with speed of its axis *v*. Its kinetic energy is $\frac{n}{16}Mv^2$. Find n



PRM029

10. Two discs *A* and *B* touch each other as shown in figure. A rope tightly wound on *A* is pulled down at 2 m/s^2. Find the friction (in *N*) force between *A* and *B* if slipping is absent



PRM030

JEE (Advanced) Practice Paper

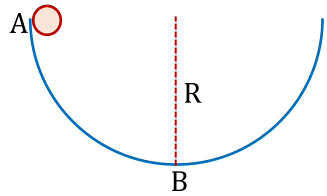
This paper is for yourself practice and assessment the discussion of this paper is optional though you can see PDF solutions or video solutions or solutions in hardcopy whichever is provided.

SECTION–I

- This section contains **TWO** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks : +3 if only the bubble corresponding to the correct option is darkened.
Zero Marks : 0 if none of the bubbles is darkened.
Negative Marks : –1 in all other cases.

1. A small sphere *A* of mass *m* and radius *r* rolls without slipping inside a large fixed hemispherical bowl of radius *R* (>> *r*) as shown in figure. If the sphere starts from rest at the top point of the hemisphere find the normal force exerted by the small sphere on the hemisphere when it is at the bottom *B* of the hemisphere.



(A) $\frac{10}{7}mg$ (B) $\frac{17}{7}mg$ (C) $\frac{5}{7}mg$ (D) $\frac{7}{5}mg$

PRM051

2. A straight rod of length *L* is released on a frictionless horizontal floor in a vertical position. As it falls + slips, the distance of a point on the rod from the lower end, which follows a quarter circular locus is :-

(A) $L/2$ (B) $L/4$ (C) $L/8$ (D) None

PRM052

SECTION-II

- This section contains **THREE** questions.
- Each question has **FOUR** options for correct answer(*s*). **ONE OR MORE THAN ONE** of these four option(*s*) is (are) correct option(*s*).
- For each question, choose the correct option(*s*) to answer the question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 if only (all) the correct option(*s*) is (are) chosen.
Partial Marks : +3 if all the four options are correct but ONLY three options are chosen.
Partial Marks : +2 if three or more options are correct but ONLY two options are chosen, both of which are correct options.
Partial Marks : +1 if two or more options are correct but ONLY one option is chosen and it is a correct option.
Zero Marks : 0 if none of the options is chosen (i.e. the question is unanswered).
Negative Marks : –2 in all other cases.

For Example : If first, third and fourth are the **ONLY** three correct options for a question with second option being an incorrect option; selecting only all the three correct options will result in +4 marks. Selecting only two of the three correct options (e.g. the first and fourth options), without selecting any incorrect option (second option in this case), will result in +2 marks. Selecting only one of the three correct options (either first or third or fourth option), without selecting any incorrect option (second option in this case), will result in +1 marks. Selecting any incorrect option(*s*) (second option in this case), with or without selection of any correct option(*s*) will result in –2 marks.

3. A ring rolls without slipping on the ground. Its centre C moves with a constant speed u. P is any point on the ring. The speed of P with respect to the ground is v.

(A) $0 \le n \le 2u$

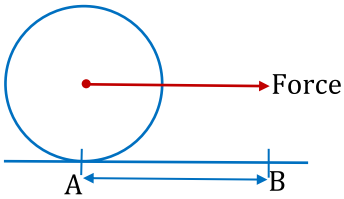
(B) $v = u$, if CP is horizontal

(C) $v = u$, if CP makes an angle of 30° with the horizontal and P is below the horizontal level of C.

(D) $v = \sqrt{2}u$, if CP is horizontal

PRM053

4. 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.

PRM054

5. A body is in equilibrium under the influence of a number of forces. Each force has a different line of action. The minimum number of forces required is

(A) 2, if their lines of action pass through the centre of mass of the body.

(B) 3, if their lines of action are not parallel.

(C) 3, if their lines of action are parallel.

(D) 4, if their lines of action are parallel and all the forces have the same magnitude.

PRM055

SECTION-III

- This section contains **THREE** paragraphs.
- Based on each paragraph, there are **TWO/THREE/FOUR** questions.
- Each question has **FOUR** options (A), (B), (C) and (D) **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :

Full Marks : +3 if only the bubble corresponding to the correct answer is darkened.

Zero Marks : 0 in all other cases.

PARAGRAPH FOR QUESTION NO. 6 TO 8

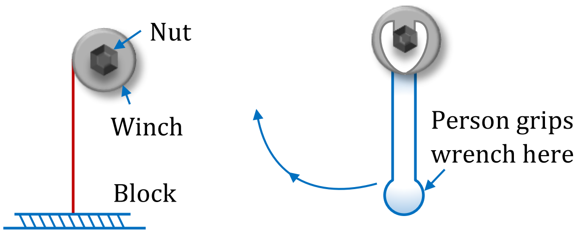
In figure, the winch is mounted on an axle, and the 6-sided nut is welded to the winch. By turning the nut with a wrench, a person can rotate the winch. For instance, turning the nut clockwise lifts the block off the ground, because more and more rope gets wrapped around the winch.

Three students agree that using a longer wrench makes it easier to turn the winch. But they disagree about why. All three students are talking about the case where the winch is used, over a 10 *s* time interval, to lift the block one metre off the ground.

Student 1 : By using a longer wrench, the person decreases the average force he must exert on the wrench, in order to lift the block one metre in 10*s*.

Student 2 : Using a longer wrench reduces the work done by the person as he uses the winch to lift the block 1m in 10*s*.

Student 3 : Using a longer wrench reduces the power that the person must exert to lift the block 1*m* in 10*s*.



Wrench turns which clockwise

6. Student 1 is :-

(A) correct, because the torque that the wrench must exert to lift the block doesn't depend on the wrench's length.

(B) correct, because using a longer wrench decreases the torque it must exert on the winch.

(C) incorrect, because the torque that the wrench must exert to lift the block doesn't depend on the wrench's length.

(D) Incorrect, because using a longer wrench decreases the torque it must exert on the winch.

PRM056

7. Which of the following is true about student 2 and 3 :

(A) Student 2 and 3 are both correct

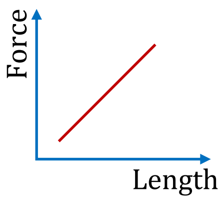
(B) Student 2 is correct, but student 3 is incorrect

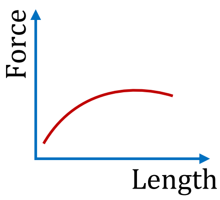
(C) Student 3 is correct, but student 2 is incorrect

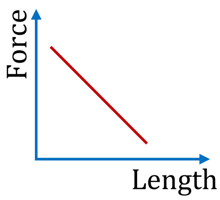
(D) Student 2 and 3 are both incorrect

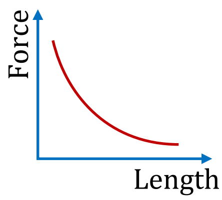
PRM057

8. If several wrenches all apply the same torque to a nut, which graph best expresses the relationship between the force the person must apply to the wrench, and the length of the wrench :-

(1) 

(2) 

(3) 

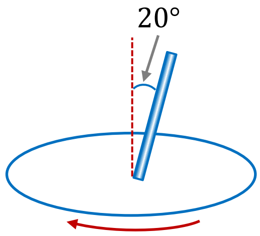
(4) 

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

PRM058

PARAGRAPH FOR QUESTION NO. 9 AND 10

A uniform rod is fixed to a rotating turntable so that its lower end is on the axis of the turntable and it makes an angle of 20° to the vertical. (The rod is thus rotating with uniform angular velocity about a vertical axis passing through one end.) If the turntable is rotating clockwise as seen from above.



9. What is the direction of the rod's angular momentum vector (calculated about its lower end)?

(A) vertically downwards
(B) down at 20° to the horizontal
(C) up at 20° to the horizontal
(D) vertically upwards

PRM059

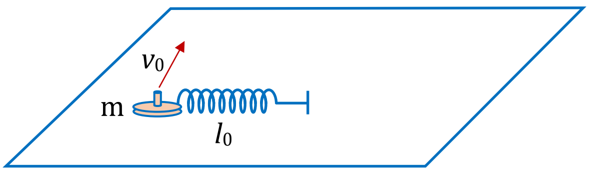
10. Is there a torque acting on it, and if so in what direction?

(A) yes, vertically
(B) yes, horizontally
(C) yes at 20° to the horizontal
(D) no

PRM060

PARAGRAPH FOR QUESTION NO. 11 TO 14

A spring having initial unstretched length ℓ_0 is lying on a smooth table. It's one end is fixed and the other one is fastened to a small particle of mass m. The particle is imparted an initial speed v_0 horizontally in a direction perpendicular to the spring. In the course of the motion in horizontal plane, the maximum elongation of the spring is $\Delta\ell = \ell_0/10$. (Given: $m = 0.1\ kg$, $\ell_0 = 1m$, $v_0 = 11\ m/s$).



11. In the course of motion, which of the quantities relating to spring block system are conserved?

(A) kinetic energy
(B) momentum
(C) angular momentum
(D) potential energy

PRM061

12. Which of the following is correct about initial situation and situation at maximum elongation?

(A) the orientation of spring in both positions should be perpendicular to each other.
(B) the velocity at maximum extension should be zero.
(C) the velocity at maximum extension as well as at initial position should be perpendicular to spring.
(D) Acceleration should be zero at the maximum extension as well as at initial position.

PRM062

13. **Student-A :** At maximum extension $mv'(\ell_0 + \Delta\ell) = mv_0\ell_0$.

Student-B : at maximum extension $k\Delta\ell = \dfrac{mv'^2}{(\ell_0 + \Delta\ell)}$.

Student-C : $\dfrac{1}{2}mv_0^2 = \dfrac{1}{2}mv'^2 + \dfrac{1}{2}k\Delta\ell^2$.

Where v' is velocity at instant of maximum extension:

(A) Only Student-*A* and *B* are correct (B) Only Student-*A* and *C* are correct

(C) Only Student-*B* and *C* are correct (D) All are correct

PRM063

14. The value of spring constant (in N/m) is:

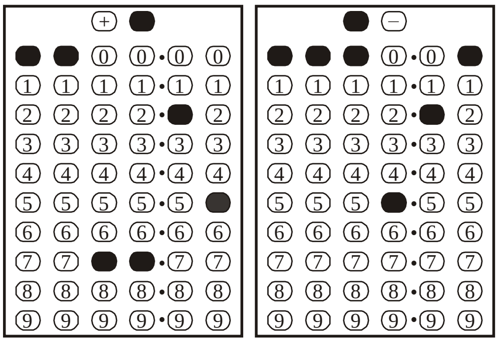
(A) 100 (B) 210 (C) 420 (D) 105

PRM064

SECTION-IV

- This section contains **THREE** questions.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the **second decimal place**; e.g. 6.25, 7.00, –0.33, –.30, 30.27, –127.30, if answer is 11.36777..... then both 11.36 and 11.37 will be correct) by darken the corresponding bubbles in the ORS.

For Example : If answer is –77.25, 5.2 then fill the bubbles as follows:

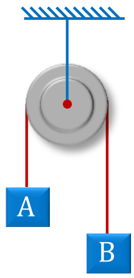


- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 if ONLY the correct numerical value is entered as answer.

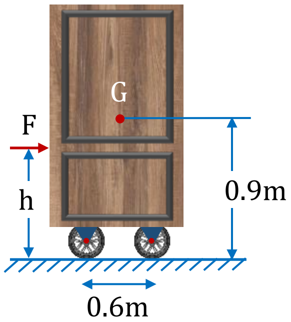
Zero Marks : 0 in all other cases.

15. In the figure, *A* and *B* are two blocks of mass 4 *kg* and 2 *kg* respectively attached to the two ends of a light string passing over a disc *C* of mass 40 *kg* and radius 0.1 *m*. The disc is free to rotate about a fixed horizontal axis, coinciding with its own axis. The system is released from rest and the string does not slip over the disc. The number of revolutions made by the disc at the end of 10 sec. from the start is $n \times 10^3/26\pi$. Find *n*.



PRM065

16. A 20 *kg* cabinet is mounted on small casters that allow it to move freely ($\mu = 0$) on the floor. If a 100 *N* force is applied as shown. The maximum value of h for which cabinet will not tip is $0.5 \times n$. Find the value of *n*.



PRM066

17. A uniform disc of mass *m* and radius *R* rotates about a fixed vertical axis passing through its centre with angular velocity ω. A particle of same mass *m* and having velocity $2\,\omega R$ towards centre of the disc collides with the disc moving horizontally and sticks to its rim the angular velocity of the disc is ω/n. Find *n*.

PRM067

SECTION-V

- This section contains **ONE** question.
- Each question contains two columns, **Column-I** and **Column-II.**
- **Column-I** has **four** entries (A), (B), (C) and (D).
- **Column-II** has **four** entries (P), (Q), (R) and (S).
- Match the entries in **Column-I** with the entries in **column-II.**
- One or more entries in **Column-I** may match with one or more entries in **Column-II.**
- The ORS contains a 4 × 4 matrix whose layout will be similar to the one shown below:

(A)	(P)	(Q)	(R)	(S)
(B)	(P)	(Q)	(R)	(S)
(C)	(P)	(Q)	(R)	(S)
(D)	(P)	(Q)	(R)	(S)

- For each entry in **column-I,** darken the bubbles of all the matching entries. For example, if entry (A) in **Column-I** matches with entries (Q), (R) and (S), then darken these three bubbles in the ORS. Similarly, for entries (B), (C) and (D).
- For each question, marks will be awarded in <u>one of the following categories</u> :

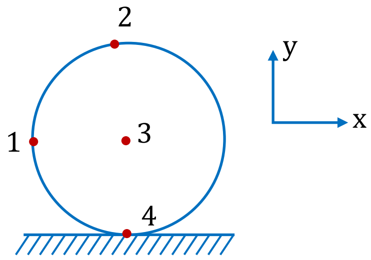
For each entry in **Column-I**

Full Marks : +2 if only the bubble(s) corresponding to all the correct match(es) is (are) darkened.

Zero Marks : 0 if none of the bubbles is darkened.

Negative Marks : –1 in all other cases.

18. A rigid cylinder is kept on a smooth horizontal surface as shown. If **Column-I** indicates velocities of various points (3-centre of cylinder, 2- top point, 4-bottom point, 1- on the level of 3 at the rim) on it shown, choose correct state of motion from **Column-II**.



	Column-I		Column-II
(A)	$\vec{v}_1 = \hat{\imath} + \hat{\jmath}, \vec{v}_2 = 2\hat{\imath}$	(P)	Pure rotation about centre.
(B)	$\vec{v}_1 = \hat{\imath} + \hat{\jmath}, \vec{v}_3 = -\hat{\imath}$	(Q)	Rolling without slipping to left.
(C)	$\vec{v}_2 = \hat{\imath}, \vec{v}_3 = 0$	(R)	Rolling without slipping to right.
(D)	$\vec{v}_4 = 0, \vec{v}_1 = -\hat{\imath} - \hat{\jmath}$	(S)	Not possible.

PRM068

ANSWER KEY

EXERCISE - O

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A	A	D	C	A	A	A	B	A	D
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	C	D	C	C	D	B	A	D	D	C
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	B	D	C	B	A	B	D	C	D	C
Que.	31	32	33	34	35	36	37	38	39	40
Ans.	D	B	C	B	C	A	C	C	C	C
Que.	41	42	43	44	45	46	47	48	49	50
Ans.	D	A	D	B	C	D	B	A	B	B
Que.	51	52	53	54	55	56	57	58	59	60
Ans.	C	A	D	B	D	C	A	A	B	B
Que.	61	62	63	64	65	66	67	68	69	70
Ans.	A	C	D	C	D	B	A	A	C	A
Que.	71	72	73	74	75	76	77	78	79	80
Ans.	C	D	B	B	B	D	C	B	B	A
Que.	81	82	83	84	85	86	87	88	89	90
Ans.	D	B	C	C	AC	AC	ABC	AC	ABCD	AD
Que.	91	92	93	94	95	96	97	98	99	100
Ans.	ACD	BCD	ABD	BD	BD	ABCD	AC	BD	ACD	BD
Que.	101	102	103	104	105	106	107	108	109	110
Ans.	AD	AD	AC	ABC	ABC	A	B	C	A	C
Que.	111	112	113	114	115	116	117	118	119	120
Ans.	B	C	C	A	C	C	D	A	B	A
Que.	121	122	123	124	125	126	127	128	129	130
Ans.	B	A	D	A	A	D	C	B	C	A
Que.	131	132	133	134	135					
Ans.	D	ABC	C	BCD	ACD					
Que.	136					137				
Ans.	(A-R), (B-P), (C-T), (D-Q,S)					(A-ST), (B-R), (C-PRT), (D-PQ)				

EXERCISE - S

1. $\frac{L}{3}$

2. (a)$\downarrow \frac{9g}{7}$ (b)$\uparrow \frac{4mg}{7}$

3. (a) $\omega = \sqrt{\frac{6g}{\ell}}$, (b) $T = \frac{11mg}{4}$

4. 2

5. $\frac{ml^2}{12}$

6. $\frac{a\ell^4}{36}$

7. $57/140MR^2$

8. 8 kg

9. $150(+\hat{\imath})$

10. 30°

11. (a) 2.00 $N \cdot m$, (b) $\hat{k}$

12. 10^{-3} rad/s^2 clockwise

13. 4

14. $\frac{\omega}{3}$

15. $6\, mv_0^2$

16. (a) 6.68 m/s (b) 2.27 m

17. (a) $\theta_C = \cos^{-1}(4/7)$, (b) $v = \sqrt{\frac{4}{7}gR}$, (c) $\frac{K_T}{K_R} = 6$

18. (a) $t = \frac{\pi Rm}{2I}$; (b) $s = \frac{\pi R}{2}$

19. (a) $4\sqrt{\frac{3}{7}}\, m/s$, (b) $\frac{200}{7} N$

20. $\alpha_{max} = \frac{2g}{3r}$

21. (i) $\frac{2V_0}{3}$, (ii) $t = \frac{v_0}{3\mu g}$, $W = \frac{1}{2}[3\mu^2 mg^2t^2 - 2\mu\, m\, g\, t\, v_0]$ $(t < t_0)$, $W = -\frac{1}{6}mv_0^2$ $(t > t_0)$

22. 1

23. 1/2 ma

24. 5

25. 15

26. $\frac{l^2}{12x}$

27. (i) $\frac{J}{m}$ (ii) zero (iii) $\frac{J}{2m}$ (iv) $\frac{5}{2}\frac{J}{m}$

28. $\frac{mv}{4}$

29. $\frac{2mv_0^2}{l}$

30. (a) $\frac{m}{M} = \frac{1}{4}$; (b) $x = \frac{2L}{3}$; (c) $\frac{v_0}{2\sqrt{2}}$

31. 75 J

32. 48

33. 8

34. (3/8) F_g

35. (a) $\sqrt{3}\, ml\omega^2$, (b) $(F_{net})_x = -\frac{F}{4}$, $(F_{net})_y = \sqrt{3}\, ml\omega^2$

36. (a) $a_c = \frac{4F}{3m_1+8m_2}$, $a_p = 2a_c$

    (b) Friction at the top of the cylinder = $3m_1F(3\, m_1 + 8\, m_2)$ towards right;
    friction at the bottom = $m_1F/(3\, m_1 + 8\, m_2)$ towards right.

37. $6N$, $-0.6\hat{\jmath} \pm 0.6\hat{k}$

38. (a) 0.1 m, (b) 1 rad/s, (c) laminar plate will never come to rest.

EXERCISE - JEE (Main) PYQ

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	4	3	3	1	4	3	4	4	2	11
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	1	3	4	9	3	1	75	4	52	6
Que.	21	22	23							
Ans.	5	2	32							

EXERCISE - JEE (Advanced) PYQ

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	2	6	D	ABD	D	C	ABC	BC or C	BC	A
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	B	25.60	BD	ABC	49	ABD	0.52	2.85 to 2.86	3	B
Que.	21	22	23	24						
Ans.	A	10	ABCD	30						

JEE (Main) Practice Paper

Section-A	Q.	1	2	3	4	5	6	7	8	9	10
	A.	3	2	3	4	4	2	3	3	2	2
	Q.	11	12	13	14	15	16	17	18	19	20
	A.	2	3	4	4	2	3	3	2	1	2
Section-B	Q.	1	2	3	4	5	6	7	8	9	10
	A.	3	14	60	15	2	5	4	16	13	2

JEE (Advanced) Practice Paper

Section-I	Q.	1	2						
	A.	B	B						
Section-II	Q.	3	4	5					
	A.	ACD	BCD	BCD					
Section-III	Q.	6	7	8	9	10	11	12	13	14
	A.	A	D	D	B	B	C	C	B	B
Section-IV	Q.	15	16	17					
	A.	5	3	3					
Section-V	Q.	18							
	A.	(A-R), (B-S), (C-P), (D-Q)							

Important Notes

Important Notes