DPP – 8

Video Solution on Website:- https://physicsaholics.com/home/courseDetails/81

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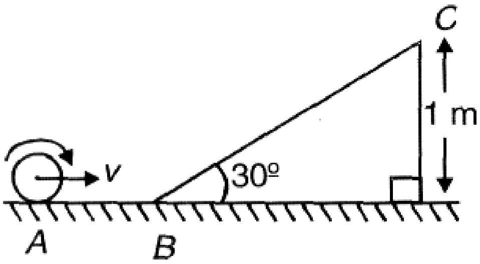
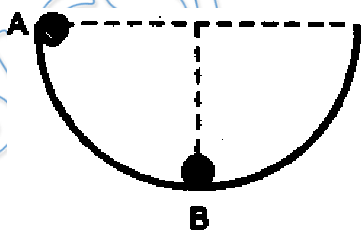
Q 1. A small sphere of mass 1 kg is rolling without slipping with linear speed v = $\sqrt{\frac{200}{7}}$ m/sec. Find the linear speed at C in m/sec ?



(a) $\sqrt{\frac{100}{7}}$ (b) $\sqrt{\frac{50}{7}}$ (c) $\sqrt{\frac{100}{35}}$ (d) $\sqrt{\frac{200}{7}}$

Q 2. A ball of radius r rolls inside a hemispherical shell of radius R. It is released from rest from point A as shown in figure. the normal force between the ball and the shell in position B is:
(m = mass of ball)



(a) $\frac{12}{7}mg$ (b) $\frac{7}{9}mg$ (c) $\frac{17}{7}mg$ (d) $\frac{10}{7}mg$

Q 3. A solid sphere, a ring and a disc all having same mass and radius are placed at the top of an incline and released. The friction coefficient between the objects and the incline are same but not sufficient to allow pure rolling. the smallest kinetic energy at the bottom of the incline will be achieved by:
(a) the solid sphere
(b) the ring
(c) the disc
(d) an will achieve the same kinetic energy

Q 4. A solid sphere and a hollow sphere of equal mass and radius are placed over a rough horizontal surface after rotating it about its mass centre with same angular velocity

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ω_0. Once the pure rolling starts let v_1 and v_2 be the linear speeds of centres of mass. Then:

(a) $v_1 = v_2$
(b) $v_1 > v_2$
(c) $v_1 < v_2$
(d) data is insufficient

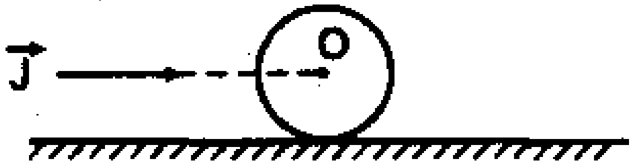
Q 5. A billiard ball is hit by a cue at a height h above the centre. It acquires a linear velocity v_0. Mass of the ball is m and radius is r. The angular velocity ω_0 acquired by the ball is:

(a) $\frac{2v_0h}{5r^2}$
(b) $\frac{5v_0h}{2r^2}$
(c) $\frac{2v_0r^2}{5h}$
(d) $5\frac{v_0r^22}{h}$

Q 6. Two particles of equal mass m at A and B are connected by a rigid light rod AB, lying on a smooth horizontal table. An impulse J is applied at A in the plane of the table and perpendicular at AB. Then the velocity of particle at A is:

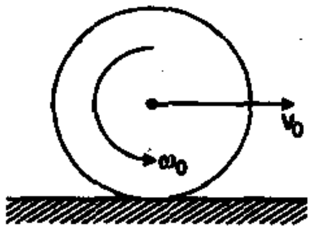
(a) $\frac{J}{2m}$
(b) $\frac{J}{m}$
(c) $\frac{2J}{m}$
(d) zero

Q 7. An impulse J is applied on a ring of mass m along a line passing through its centre O. The ring is placed on a rough horizontal surface. The linear velocity of centre of ring once it starts rolling without slipping is:



(a) J/m
(b) J/2m
(c) J/4m
(d) J/3m

Q 8. A uniform sphere of radius it is placed on a rough horizontal source and given a linear velocity V_0 and angular velocity ω_0 as shown. The sphere comes to rest after moving some distance to the right it blows that:



(a) $v_0 = \omega_0R$
(b) $2v_0 = 5\omega_0R$
(c) $5v_0 = 2\omega_0R$
(d) $2v_0 = \omega_0R$

Q 9. A uniform rod of mass m and length 2a lies at rest on a smooth horizontal table. A perfectly elastic particle of same mass m, moving with speed v on the table in a direction perpendicular to the rod, strikes one end of the rod. The kinetic energy generated in the rod is:

(a) $\frac{4}{13}$ mv^2
(b) $\frac{1}{4}$ mv^2
(c) $\frac{8}{25}$ mv^2
(d) None

Q 10. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown. The magnitude of angular momentum of the disc about the origin O is:

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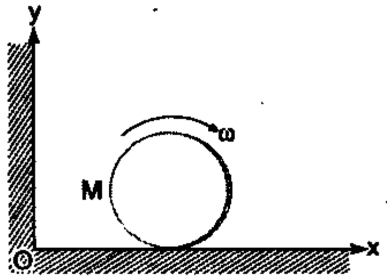
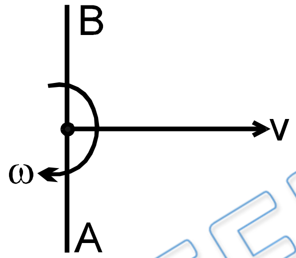


(a) $\left(\frac{1}{2}\right) MR^2\omega$ (b) $MR^2\omega$

(c) $\left(\frac{3}{2}\right) MR^2\omega$ (d) $2\ MR^2\ \omega$

Q 11. A uniform rod of length l rotating with an angular velocity w, while its centre moves with linear velocity $v = \frac{\omega\ell}{6}$. If the end A of the rod is suddenly fixed, the angular velocity of the rod will be:



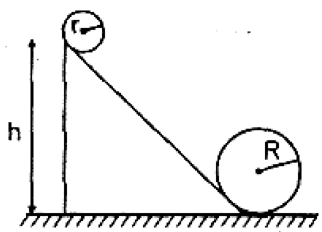
(a) $\frac{3}{4}$w (b) $\frac{\omega}{3}$ (c) $\frac{\omega}{2}$ (d) $\frac{2\omega}{3}$

Q 12. A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be

(a) $\frac{K^2}{R^2}$ (b) $\frac{K^2}{K^2+R^2}$ (c) $\frac{R^2}{K^2+R^2}$ (d) $\frac{K^2+R^2}{R^2}$

Q 13. A sphere rolls without sliding on a rough inclined plane (only mg and contact forces are acting on the body). The angular momentum of the body:
(a) about centre is conserved
(b) is conserved about the point of contact
(c) is conserved about a point whose distance from the inclined plane is greater than the radius of the sphere
(d) is not conserved about any point.

Q 14. A solid sphere rolls without slipping along the track shown in figure. The sphere starts from rest from a height h above the bottom of a loop of radius R which is much larger than the radius of the sphere r. The minimum value of h for the sphere to complete the loop is



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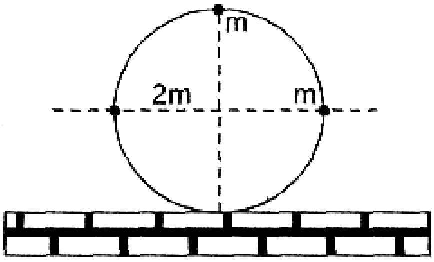
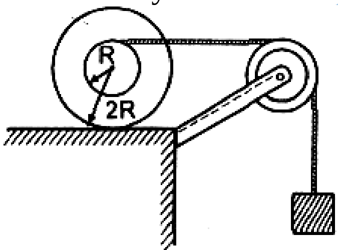
(a) 2.1 R (b)2.3 R (c)2.7 R (d)2.5 R

Q 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. The kinetic energy of the system is : (Slipping is absent).



(a) 6 mv_0^2 (b) 12mv_0^2 (c) 4mv_0^2 (d) 8mv_0^2

Q 16. In the figure shown mass of both, the spherical body and block is m. Moment of inertia of the spherical body about centre of mass is $2mR^2$. The spherical body rolls on the horizontal surface. There is no slipping at any surfaces in contact. The ratio of kinetic energy of the spherical body to that of block is



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

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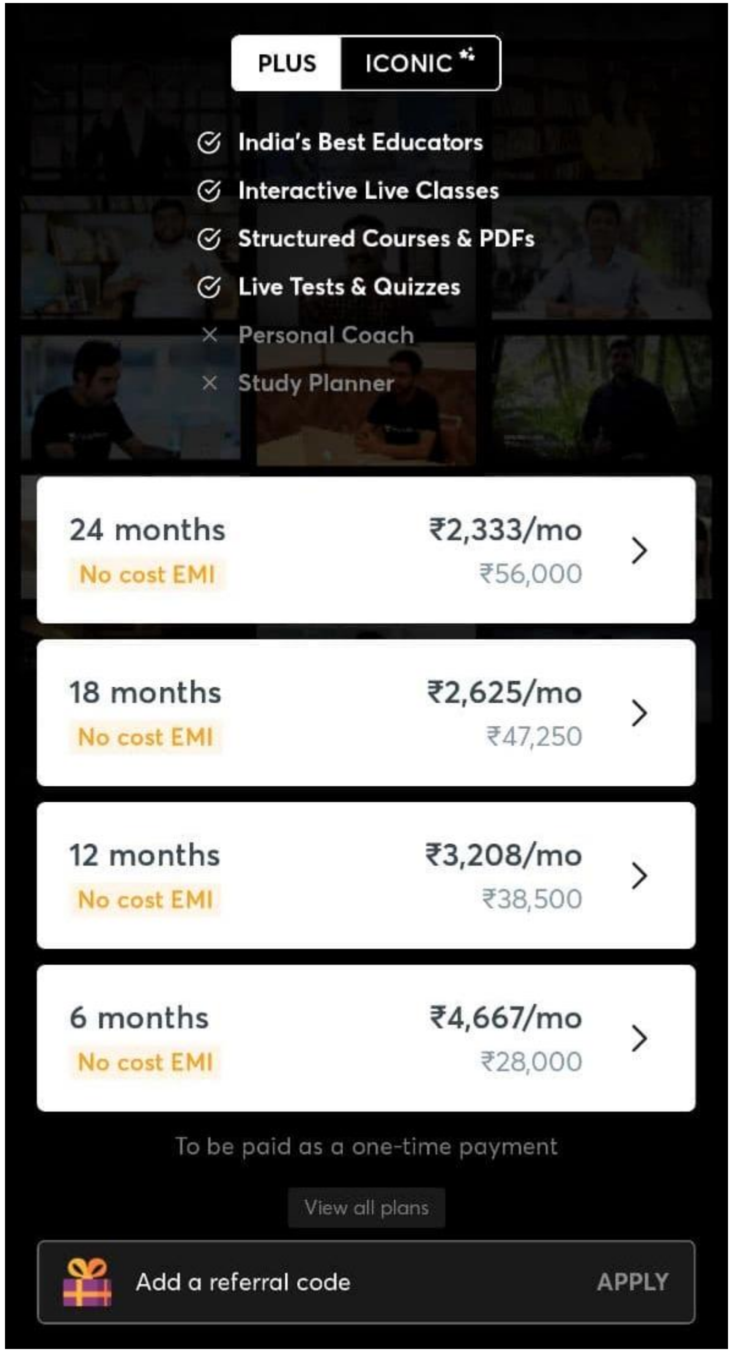
Answer Key

Q.1 a	**Q.2 c**	**Q.3 b**	**Q.4 c**	**Q.5 b**
Q.6 b	**Q.7 b**	**Q.8 c**	**Q.9 c**	**Q.10 c**
Q.11 c	**Q.12 b**	**Q.13 c**	**Q.14 c**	**Q.15 a**
Q.16 c				



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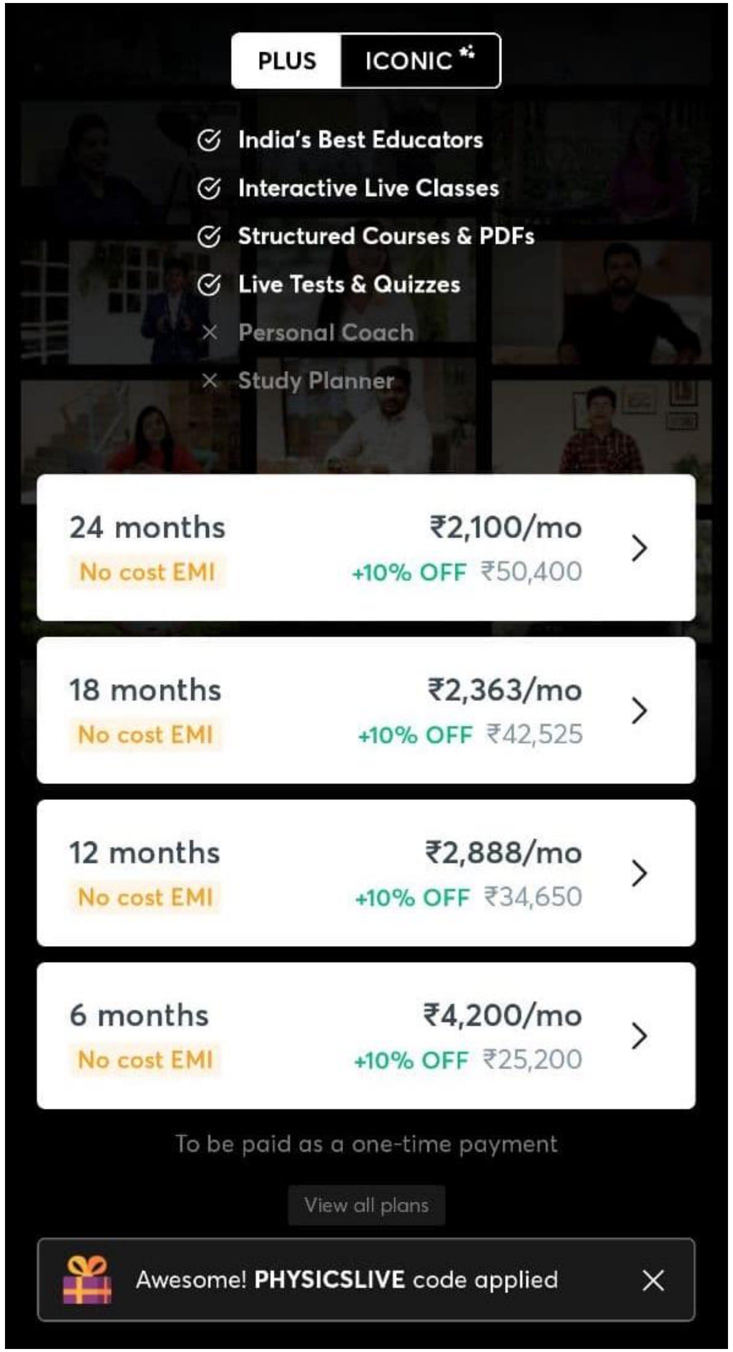


Written Solution

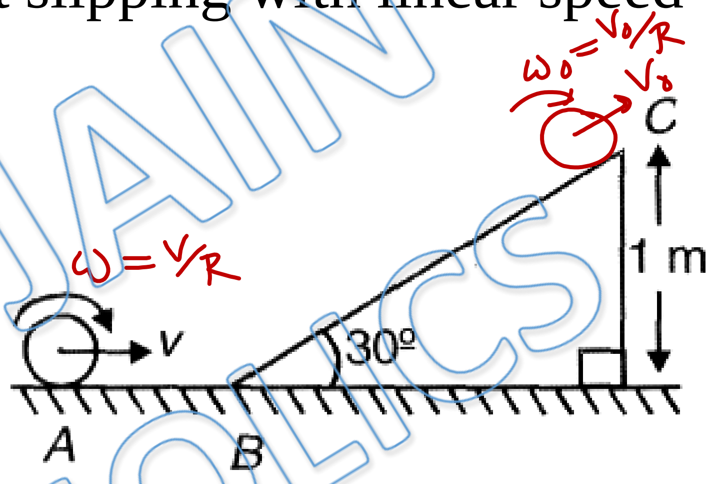
JEE Main & Advanced, NSEP, INPhO, IPhO

Physics DPP

DPP-8 Kinetic energy and angular momentum in combined translation and rotation

By Physicsaholics Team

Q1) A small sphere of mass 1 kg is rolling without slipping with linear speed v = $\sqrt{\frac{200}{7}}$ m/sec. Find the linear speed at C in m/sec ?



$$0 + \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right)\frac{v^2}{R^2}$$

$$= mgh + \frac{1}{2}mV_0^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right)\frac{V_0^2}{R^2}$$

$$\frac{7}{10}V^2 = gh + \frac{7}{10}V_0^2$$

(a) $\sqrt{\frac{100}{7}}$ (b) $\sqrt{\frac{50}{7}}$ (c) $\sqrt{\frac{100}{35}}$ (d) $\sqrt{\frac{200}{7}}$

$$\frac{7}{10} \times \frac{200}{7} = 10 \times 1 + \frac{7}{10}V_0^2$$

$$10 = \frac{7}{10}V_0^2 \Rightarrow V_0 = \sqrt{\frac{100}{7}}$$

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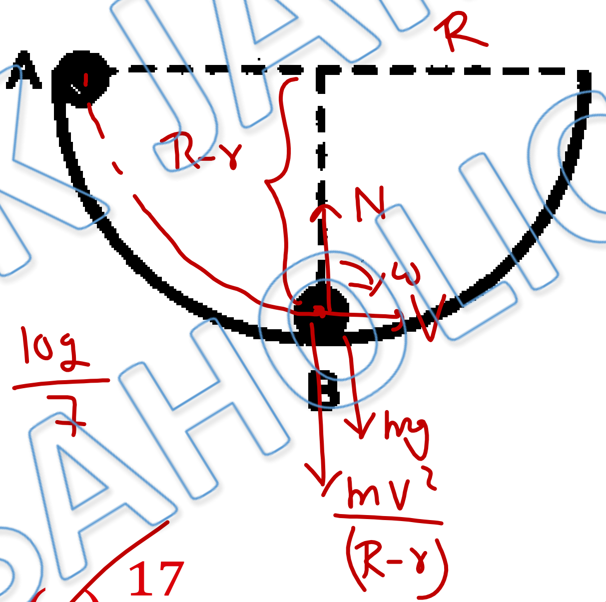
Q2) A ball of radius r rolls inside a hemispherical shell of radius R. It is released from rest from point A as shown in figure. the normal force between the ball and the shell in position B is:
(m = mass of ball)



$mg(R-r) = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\frac{v^2}{r^2}$

$g(R-r) = \frac{7}{10}v^2$

$v^2 = \frac{10g(R-r)}{7} \Rightarrow \frac{v^2}{R-r} = \frac{10g}{7}$

(a) $\frac{12}{7}mg$ (b) $\frac{7}{9}mg$ (c) $\frac{17}{7}mg$ ✓ (d) $\frac{10}{7}mg$

$N = mg + \frac{mv^2}{R-r} = mg + \frac{10mg}{7}$

$= \frac{17mg}{7}$

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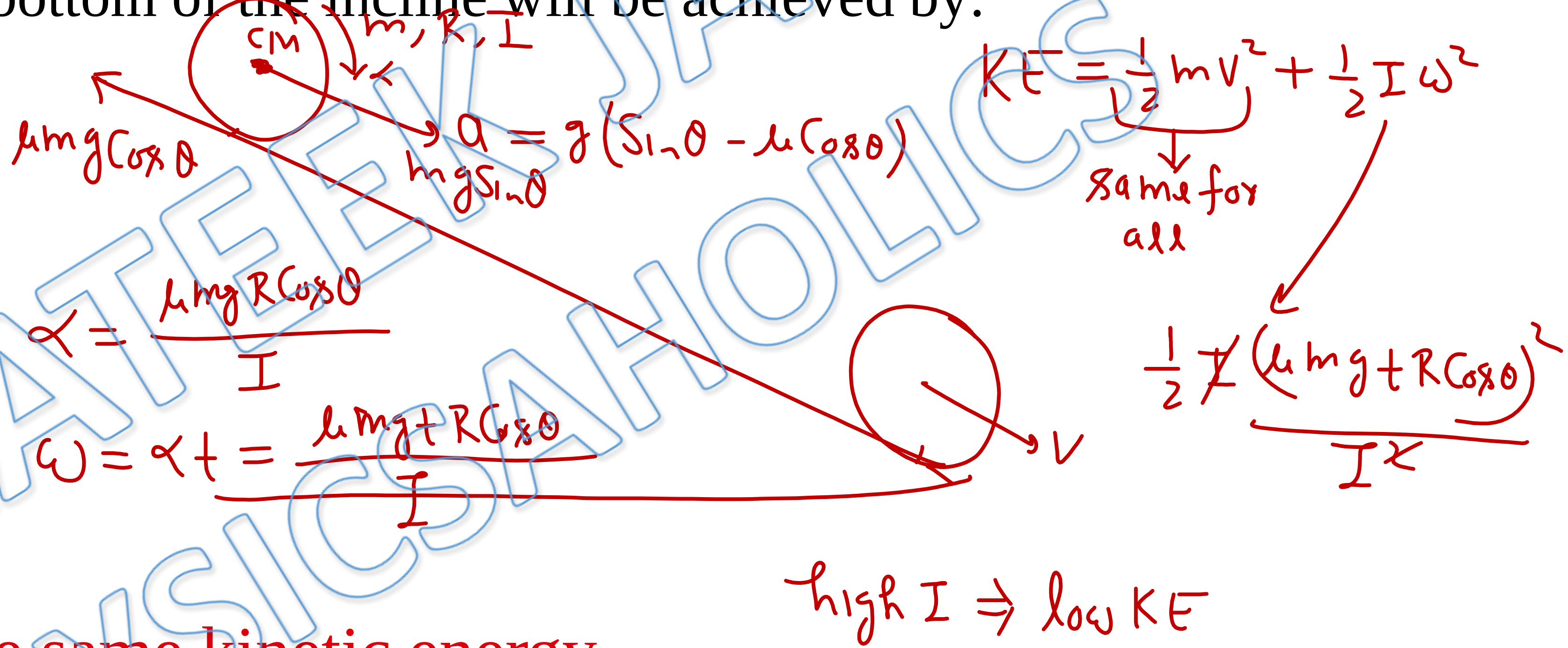
Q3) A solid sphere, a ring and a disc all having same mass and radius are placed at the top of an incline and released. The friction coefficient between the objects and the incline are same but not sufficient to allow pure rolling. the smallest kinetic energy at the bottom of the incline will be achieved by:



(a) the solid sphere

(b) the ring

(c) the disc

(d) an will achieve the same kinetic energy

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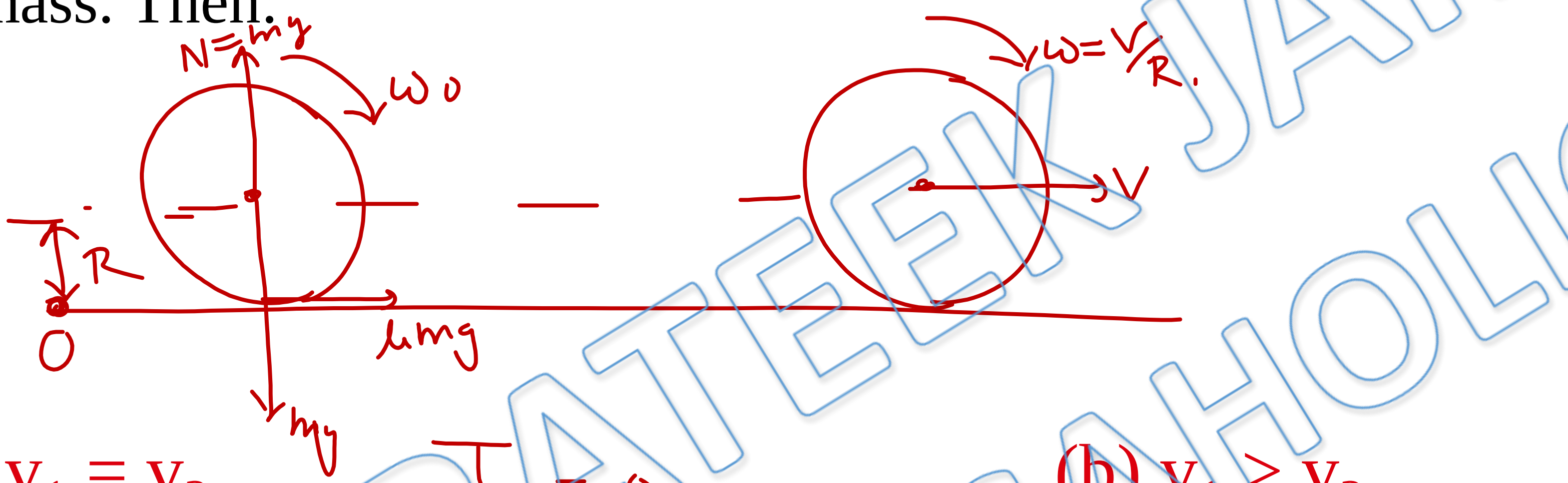
Q4) A solid sphere and a hollow sphere of equal mass and radius are placed over a rough horizontal surface after rotating it about its mass centre with same angular velocity ω_0. Once the pure rolling starts let v_1 and v_2 be the linear speeds of centres of mass. Then:



(a) $v_1 = v_2$

(b) $v_1 > v_2$

(c) $v_1 < v_2$

(d) data is insufficient

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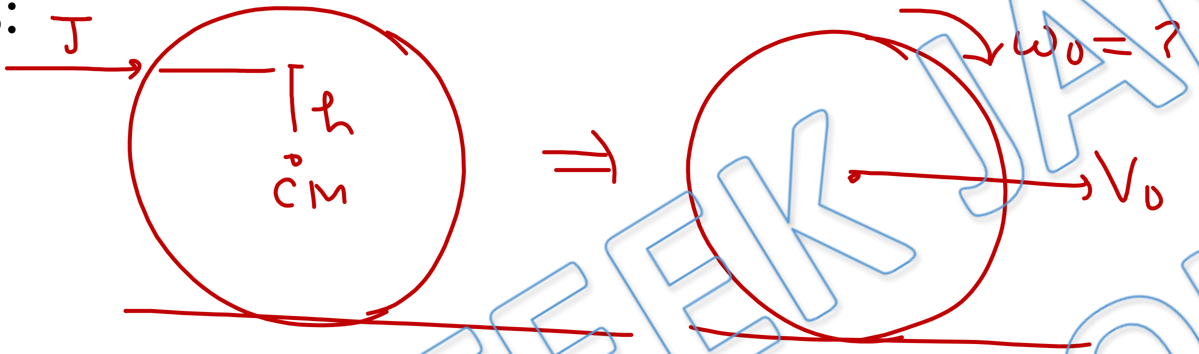
Q5) A billiard ball is hit by a cue at a height h above the centre. It acquires a linear velocity v_0. Mass of the ball is m and radius is r. The angular velocity ω_0 acquired by the ball is:



(a) $\frac{2v_0h}{5r^2}$ (b) $\frac{5v_0h}{2r^2}$ (c) $\frac{2v_0r^2}{5h}$ (d) $5\frac{v_0r^22}{h}$

$J = mV_0$ --- (1)

$Jh = \frac{2}{5}mR^2\omega_0$

$mV_0h = \frac{2}{5}mR^2\omega_0$

$\omega_0 = \frac{5V_0h}{2R^2}$

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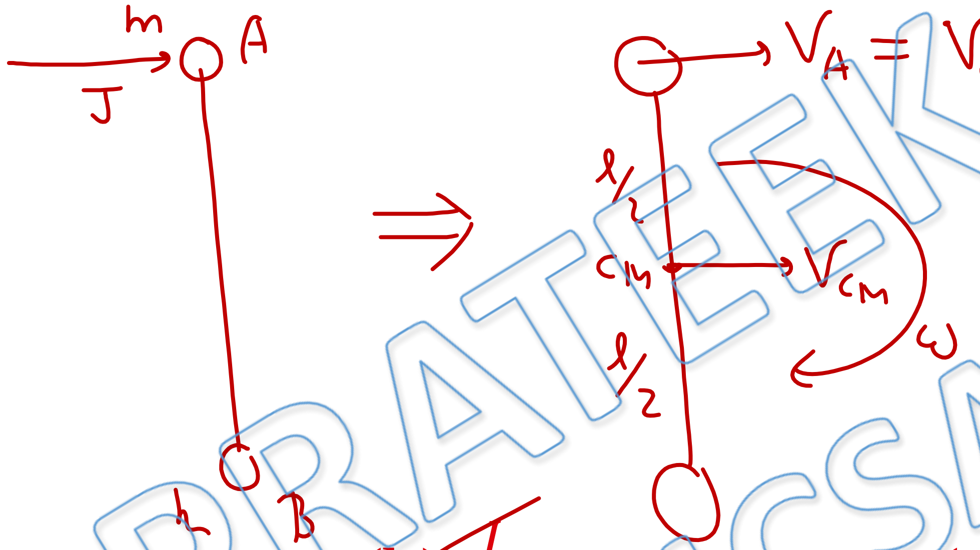
Q6) Two particles of equal mass m at A and B are connected by a rigid light rod AB, lying on a smooth horizontal table. An impulse J is applied at A in the plane of the table and perpendicular at AB. Then the velocity of particle at A is:



$$V_A = V_{cm} + \frac{\omega \ell}{2} = \frac{J}{2m} + \frac{J}{m\ell} \times \frac{\ell}{2}$$

$$= \frac{J}{2m} + \frac{J}{2m}$$

$$= J/m$$

(a) $\frac{J}{2m}$ (b) $\frac{J}{m}$ (c) $\frac{2J}{m}$ (d) zero

$$J = 2mV_{CM} \Rightarrow V_{CM} = J/2m$$

$$J\,\ell/2 = \left(\frac{m\ell^2}{4} + \frac{m\ell^2}{4}\right)\omega \Rightarrow J\ell/2 = \frac{m\ell^2}{2}\omega \Rightarrow \omega = J/m\ell$$

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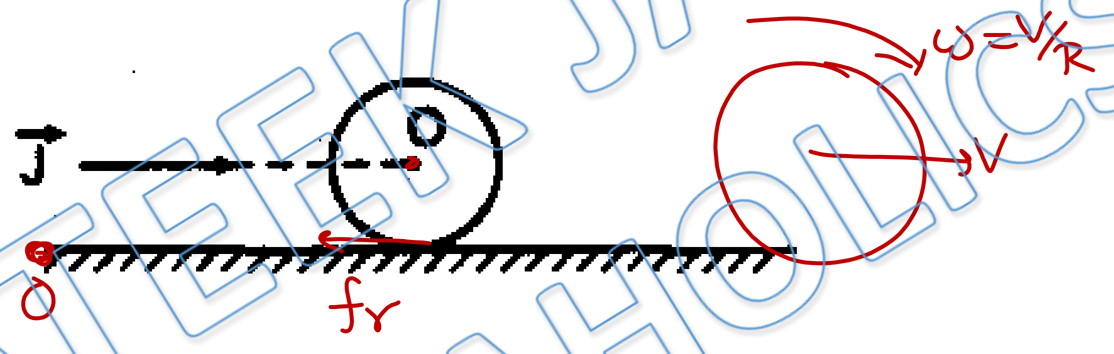
Q7) An impulse J is applied on a ring of mass m along a line passing through its centre O. The ring is placed on a rough horizontal surface. The linear velocity of centre of ring once it starts rolling without slipping is:

$\tau_0 = 0$

$\Rightarrow L_0 = \text{Constant}$



(a) J/m (b) J/2m (c) J/4m (d) J/3m

$JR = mVR + mR^2 \frac{V}{R}$

$JR = 2mVR$

$V = \frac{J}{2m}$

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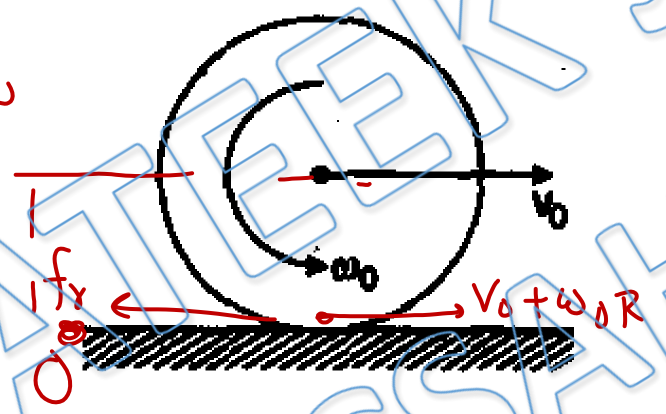
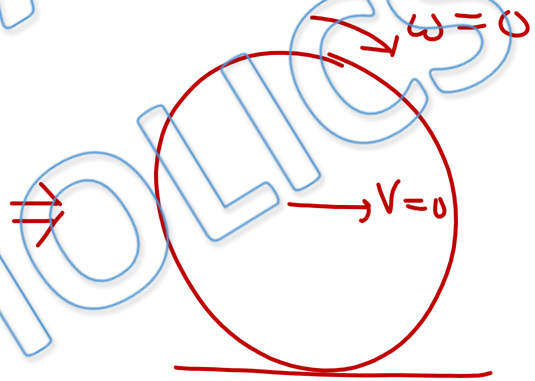
Q8) A uniform sphere of radius it is placed on a rough horizontal source and given a linear velocity V_0 and angular velocity ω_0 as shown. The sphere comes to rest after moving some distance to the right it blows that:

$L_0 = \text{Constant}$

$\Rightarrow mV_0R - \frac{2}{5}mR^2\omega_0 = 0$

$5V_0 = 2R\omega_0$





(a) $v_0 = \omega_0 R$ (b) $2v_0 = 5\omega_0 R$

(c) $5v_0 = 2\omega_0 R$ (d) $2v_0 = \omega_0 R$

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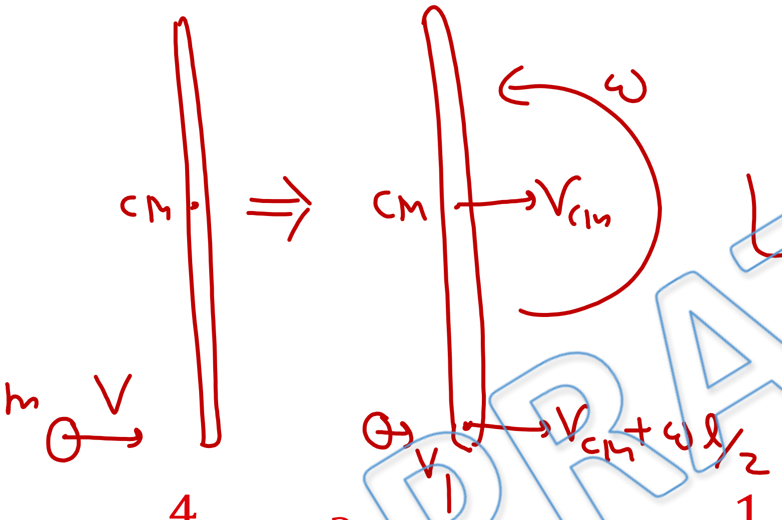
$l = 2a$

Q9) A uniform rod of mass m and length 2a lies at rest on a smooth horizontal table. A perfectly elastic particle of same mass m, moving with speed v on the table in a direction perpendicular to the rod, strikes one end of the rod. The kinetic energy generated in the rod is:



$e = 1 \Rightarrow V_{cm} + \frac{\omega l}{2} - V_1 = V$ --- (I)

$mV = mV_1 + mV_{cm} \Rightarrow V_1 + V_{cm} = V$ --- (II) by Conservation of momentum

$L_{cm} = \text{Constant} \Rightarrow mV\frac{l}{2} = mV_1\frac{l}{2} + \frac{ml^2}{12}\omega \Rightarrow V - V_1 = \frac{\omega l}{6}$ --- (III)

$V_{cm} - V_1 + 3V - 3V_1 = V \Rightarrow 4V_1 - V_{cm} = 2V$ --- (IV)

$V_1 + V_{cm} = V$ --- (II)

(a) $\frac{4}{13}mv^2$ (b) $\frac{1}{4}mv^2$ (c) $\frac{8}{25}mv^2$ (d) None

$5V_1 = 3V \Rightarrow V_1 = 3V/5$

KE of Rod = KE loss of ball $= \frac{1}{2}m(V^2 - V_1^2) = \frac{1}{2}m\left(V^2 - \frac{9V^2}{25}\right) = \frac{8mV^2}{25}$

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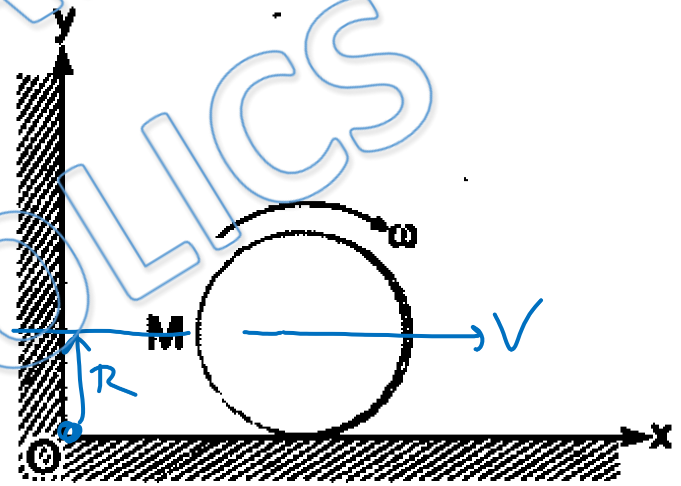
Q10) A disc of mass M and radius R is rolling with angular speed w on a horizontal plane as shown. The magnitude of angular momentum of the disc about the origin O is:

$$L_0 = mvR + \frac{mR^2}{2}\omega$$

$$= mR^2\omega + \frac{mR^2\omega}{2}$$

$$= \frac{3}{2}mR^2\omega$$



(a) $\left(\frac{1}{2}\right) MR^2\omega$

(b) $MR^2\omega$

(c) $\left(\frac{3}{2}\right) MR^2\omega$

(d) $2\ MR^2\ \omega$

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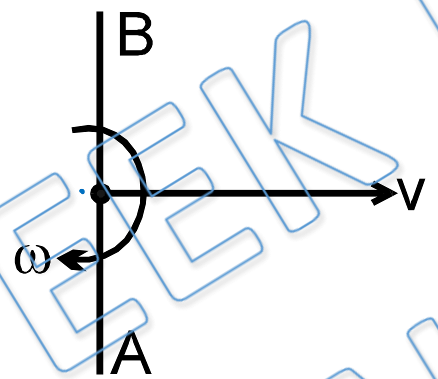
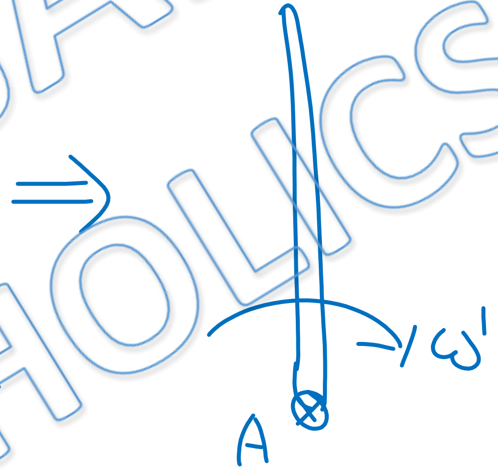
Q11) A uniform rod of length *l* rotating with an angular velocity w, while its centre moves with linear velocity $v = \frac{\omega \ell}{6}$. If the end A of the rod is suddenly fixed, the angular velocity of the rod will be:

$L_A = \text{Constant}$

$mv\frac{\ell}{2} + \frac{m\ell^2}{12}\omega = \frac{m\ell^2}{3}\omega'$

$\frac{m\omega\ell^2}{12} + \frac{m\omega\ell^2}{12} = \frac{m\omega'\ell^2}{3}$





(a) $\frac{3}{4}$w (b) $\frac{\omega}{3}$ (c) $\frac{\omega}{2}$ (d) $\frac{2\omega}{3}$

$\frac{m\omega\ell^2}{6} = \frac{m\omega'\ell^2}{3}$

$\omega' = \omega/2$

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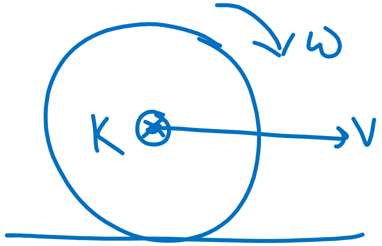
Q12) A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be



$I_{cm} = mK^2$

$$\frac{R.KE}{Total\ KE} = \frac{\frac{1}{2} I_{cm}\omega^2}{\frac{1}{2}mv^2 + \frac{1}{2}I_{cm}\omega^2} = \frac{\frac{1}{2}mK^2\omega^2}{\frac{1}{2}m\omega^2R^2 + \frac{1}{2}mK^2\omega^2}$$

$$= \frac{K^2}{R^2+K^2}$$

(a) $\frac{K^2}{R^2}$ (b) $\frac{K^2}{K^2+R^2}$ (c) $\frac{R^2}{K^2+R^2}$ (d) $\frac{K^2+R^2}{R^2}$

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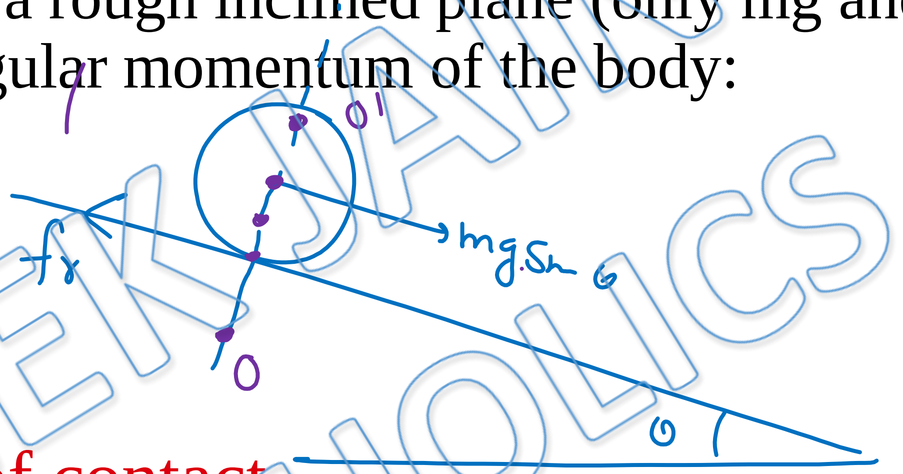
Q13) A sphere rolls without sliding on a rough inclined plane (only mg and contact forces are acting on the body). The angular momentum of the body:

$f_r < mg\sin\theta$



(a) about centre is conserved

(b) is conserved about the point of contact

(c) is conserved about a point whose distance from the inclined plane is greater than the radius of the sphere

(d) is not conserved about any point.

$\tau_{O'}$ may be zero'

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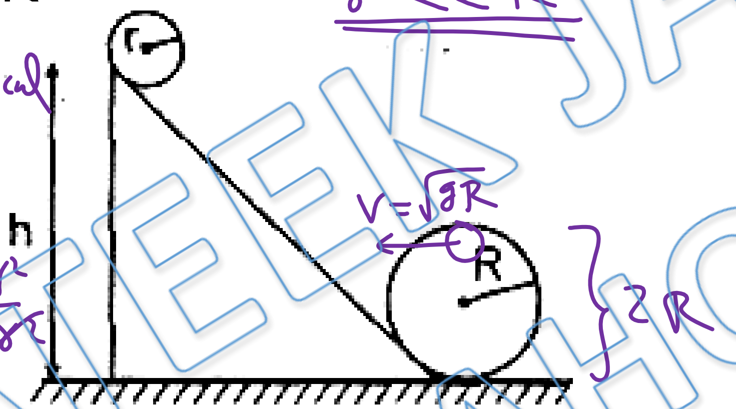
Q14) A solid sphere rolls without slipping along the track shown in figure. The sphere starts from rest from a height h above the bottom of a loop of radius R which is much larger than the radius of the sphere r. The minimum value of h for the sphere to complete the loop is

$r << R$



by Conservation of mechanical Energy →

$mg(h-2R) = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\frac{v^2}{r^2}$

$mg(h-2R) = \frac{7}{10}mv^2$

(a) 2.1 R (b)2.3 R (c)2.7 R (d)2.5 R

$g(h-2R) = .7Rg$

$h = 2.7R$

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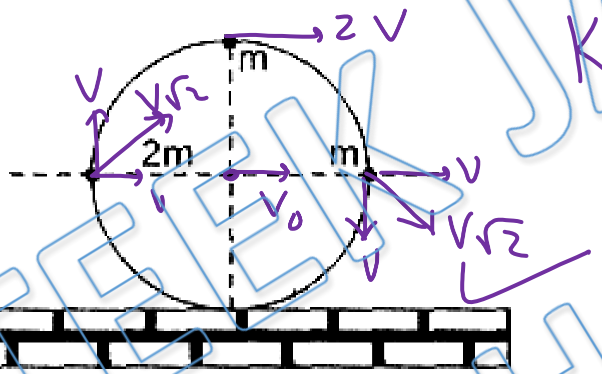
Q15) A ring of mass m and radius R has three particles attached to the ring as shown in the figure. The centre of the ring has a speed v_0. The kinetic energy of the system is : (Slipping is absent).



$$KE = \left(\frac{1}{2}mv_0^2 + \frac{1}{2}(mR^2)\frac{v_0^2}{R^2}\right) + \frac{1}{2}m(v_0\sqrt{2})^2 + \frac{1}{2}\times 2m(v_0\sqrt{2})^2 + \frac{1}{2}m(2v_0)^2$$

(a) $6\,mv_0^2$ (b) $12mv_0^2$ (c) $4mv_0^2$ (d) $8mv_0^2$

$$KE = 6mv_0^2$$

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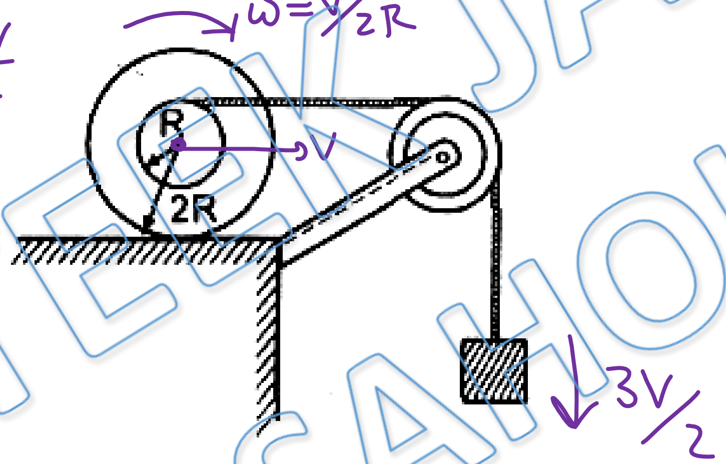
Q16) In the figure shown mass of both, the spherical body and block is m. Moment of inertia of the spherical body about centre of mass is $2mR^2$. The spherical body rolls on the horizontal surface. There is no slipping at any surfaces in contact. The ratio of kinetic energy of the spherical body to that of block is

$V_{block} = V_{string} = V + \omega R = \frac{3V}{2}$



$\omega = V/2R$

$\frac{\text{KE of spherical body}}{\text{KE of block}}$

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

$$= \frac{\frac{1}{2}mV^2 + \frac{1}{2}(2mR^2)\frac{V^2}{4R^2}}{\frac{1}{2}m\left(\frac{3V}{2}\right)^2} = \frac{V^2 + V^2/2}{9V^2/4} = \frac{3V^2/2}{9V^2/4} = \frac{2}{3}$$

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