PHYSICS

MED EASY 2.0

By Dr. Manish Raj (MR Sir)

Class Notes in Handwritten Format

Updated as per latest NMC NTA Syllabus

Formulae | Special Mnemonics | Important Examples

Clear and Concise Concepts | Special Tips & Tricks | Problem-solving emphasis

Helpful for NEET, JEE and Board Exams

New Edition

Contents

1. Basic Maths 1-15
2. Vector 16-21
3. Units & Dimensions 22-32
4. Motion in 1-D 33-42
5. Motion in a Plane 43-49
6. Newton's Laws of Motion 50-58
7. Friction 59-64
8. Circular Motion 65-70
9. Work, Energy, and Power 71-77
10. Center of Mass 78-82
11. Collision 83-87
12. Rotational Motion 88-102
13. Gravitation 103-110
14. Elasticity 111-116
15. Fluid Mechanics 117-129
16. Thermal Properties of Matter 130-136
17. Heat Transfer 137-140
18. KTG & Thermodynamics 141-152
19. Simple Harmonic Motion 153-160
20. Wave and Sound Motion 161-170
21. Electrostatics 171-179
22. Electric Potential 180-185
23. Capacitor 186-192

24. Current Electricity 193-200
25. Magnetic Effect of Electric Current 201-212
26. Magnetism & Matter 213-219
27. Electromagnetic Induction 220-227
28. Alternating Current 228-236
29. Electromagnetic Wave 237-241
30. Ray Optics 242-254
31. Wave Optics 255-263
32. Dual Nature 264-271
33. Atoms 272-278
34. Nuclei 279-288
35. Semiconductor 289-298

11 Rotational Motion

1> MOMENT OF INERTIA:-

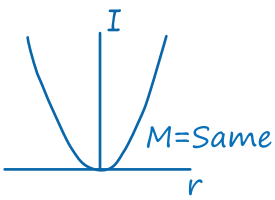
Ghumane ka कष्ट

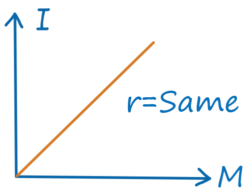
MR*

$I \propto$ (कितना Mass) × (कितनी Dur)

→ Tensor. → Calculated from Axis of Rotation.

- I v/s r Graph:-



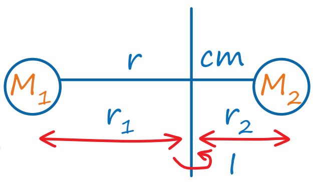


- Mass:-

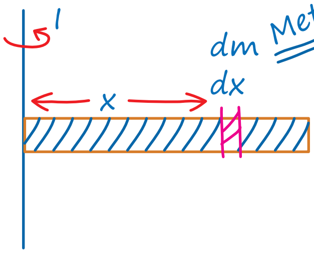
1. Point:- $I = Mr^2$ ⊥er distn from AOR
2. "n":- $I = M_1r_1^2 + M_2r_2^2 + ...$

- M.O.I. about C.O.M. & ⊥er to line:-

$$I = \frac{M_1M_2}{M_1 + M_2} r^2$$



- M.O.I. of Continuous body:-



dm Method

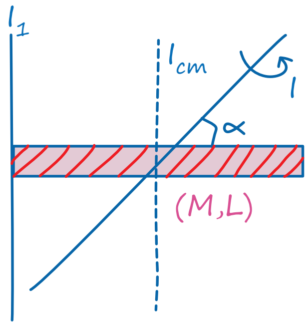
$$\int_0^l dI = \int x^2 . dm$$

$$\lambda = \frac{dm}{dx}$$

Non Uniform body.

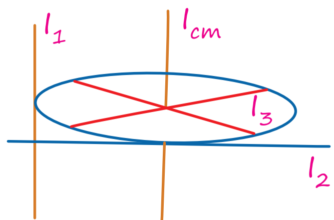
$$I = \int x^2 . \lambda.dx = \int x^2.dm....$$

MOI OF ROD:-



- $I_{cm} = \frac{ML^2}{12}$
- $I_1 = \frac{ML^2}{3}$
- $I = \frac{ML^2}{12} \sin^2 \alpha$ *

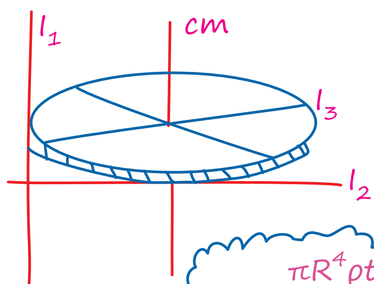
MOI OF RING:-



$I_{cm} = 2\pi A\rho R^3$

- $I_{cm} = MR^2$
- $I_1 = 2MR^2$
- $I_2 = \frac{3MR^2}{2}$
- $I_3 = \frac{MR^2}{2}$

MOI OF DISC:-

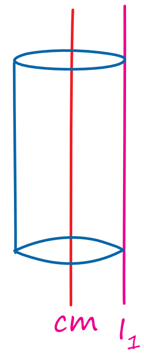


$$I_{cm} = \frac{\pi R^4 \rho t}{2}$$

- $I_{cm} = \frac{MR^2}{2}$
- $I_1 = \frac{3MR^2}{2}$
- $I_2 = \frac{5MR^2}{4}$
- $I_3 = \frac{MR^2}{4}$

MOI OF HOLLOW CYLINDER:-

(a)



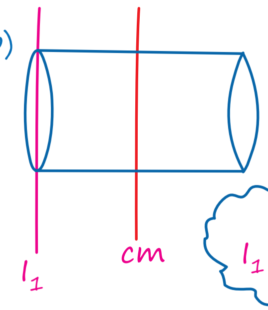
$I_{cm} = MR^2$

$I_1 = 2\,MR^2$

$$I_{cm} = \frac{ML^2}{12} + \frac{MR^2}{2}$$

Rod Ring

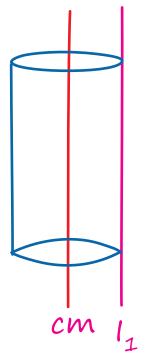
(b)



$$I_1 = \frac{ML^2}{3} + \frac{MR^2}{2}$$

MOI OF SOLID CYLINDER:-

(a)



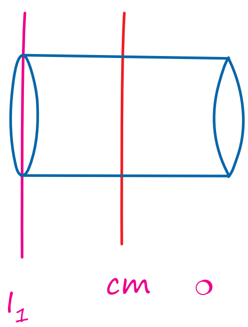
$$I_{cm} = \frac{MR^2}{2}$$

$$I_1 = \frac{3MR^2}{2}$$

o $I_{cm} = \dfrac{ML^2}{12} + \dfrac{MR^2}{4}$

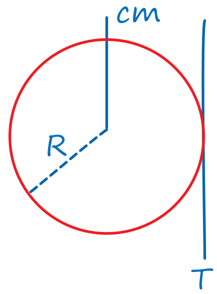
Rod Disc

(b)



o $I_1 = \dfrac{ML^2}{3} + \dfrac{MR^2}{4}$

MOI OF SOLID SPHERE:-

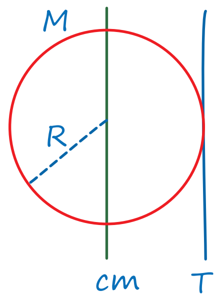


$$I_{cm} = \frac{2}{5}MR^2$$

$$I_T = \frac{7}{5}MR^2$$

$$I_{cm} = \frac{176}{105}\rho R^5$$

MOI OF HOLLOW SPHERE:-

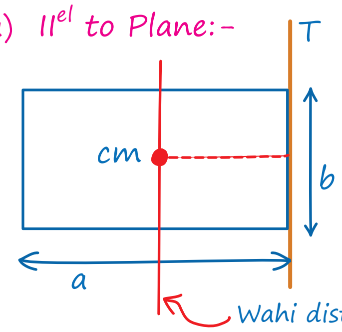


o $I_{cm} = \dfrac{2}{3}MR^2$

o $I_T = \dfrac{5MR^2}{3}$

MOI OF RECTANGULAR PLATE:-

(a) II^{el} to Plane:-

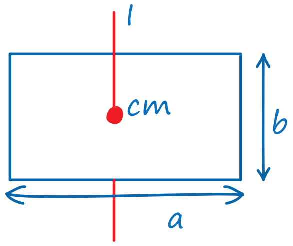


$$I_{cm} = \frac{Ma^2}{12}$$

$$I_T = \frac{Ma^2}{3}$$

Wahi distance Kaam ka hoga joh AOR के $\perp^{er}$ hoga.

(b) $\perp^{er}$ to Plane:-

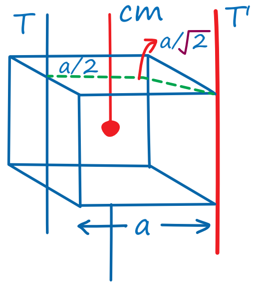


$$I = \frac{M}{12}(a^2 + b^2)$$

*Square Plane Sheet:- a = b.

$$I = \frac{Ma^2}{6}$$

MOI OF CUBE:-

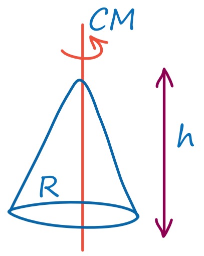


$I_{cm} = \frac{Ma^2}{6}$

$I_{T'} = \frac{2Ma^2}{3}$

$I_T = \frac{5Ma^2}{12}$

MOI OF CONE:-

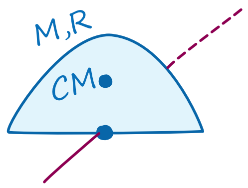


$I_{cm} = \frac{3}{10} MR^2$

*Triangular Plate.

$I_{cm} = \frac{Ma^2}{6}$

MOI OF SEMICIRCULAR DISC:-



$I = \frac{MR^2}{2}$

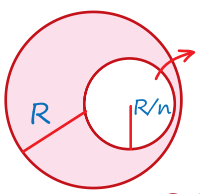
$r_{com} = \frac{4R}{3\pi}$

$*I_{cm} = MR^2\left[\frac{1}{2} - \frac{16}{9\pi^2}\right]$

THEOREMS:-

Parallel axis → valid for all type of body	Perpendicular axis → valid for planer object
$I_O = I_{cm} + Md^2$	$I_z = I_x + I_y$
d = distance b/w axis passing through C.O.M. and 'O'	I_x & I_y → axis parallel to plane
	I_z → I_r to plane

CONCEPT OF M.O.I. OF CUTTING SECTION:-



M' → For Area = M/n^2

→ For Volume = M/n^3 (Solid Sphere)

$I_{remain} = I_{complete} - I_{removed}$

RADIUS OF GYRATION:-

→ COM : not valid. So we use it.

- $I = MK^2$ * Yaad rakhna
  → Mass dyan से lena.

TORQUE:-

\# Torque → Cause of change in rotational state of the body

\# Torque oppose rotational motion → false

\# Axial vector

\# Unit → Nm

\# Dim^n → $[ML^2T^{-2}]$

$\vec{\tau} = \vec{r} \times \vec{F} = rF\sin\theta$ → CW ⊗ / ACW ⊙

Thumb, Four Fingers, Slap

$\vec{\tau}_{net} = \vec{r}_1 \times \vec{F}_1 + \vec{r}_2 \times \vec{F}_2 + \ldots$

$\vec{\tau} \perp \vec{r} \perp \vec{F}$

$\vec{\tau} = I\vec{\alpha}$ $\quad \vec{\tau} = \frac{d\vec{L}}{dt}$

STATEMENT:-

If $F_{net} = 0$ then τ_{net} must be zero → False

If $F_{net} \neq 0$ then τ_{net} must be non-zero → False

If $\tau_{net} = 0$ then net force must be zero → False

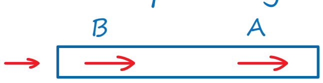
If $\tau_{net} \neq 0$ then net force must be non-zero → False

MR*

Torque hamesha hinge point के about lagega aur who ek toh body Ko Ghumayega ya toh Ghumte huye object Ka state change Karega.

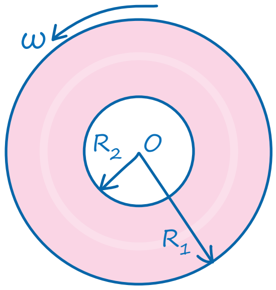
$\vec{\tau}_{net} = 0$ } Rotational Eq^n.

- Concept of Rigid body:-



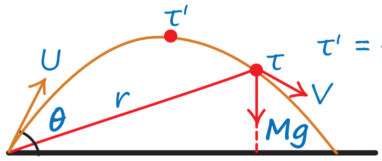
$V_B = V_A$

M.O.I. OF ANNULAR DISC:-



$$^*I_O = \frac{M}{2}(R_2^2 + R_1^2)$$

Imp Que:-



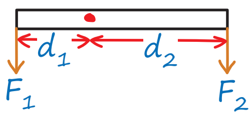
$$\tau = Mg\,(U\cos\theta)t$$

$$\tau' = \frac{Mg\,U^2 \sin 2\theta}{2g}$$

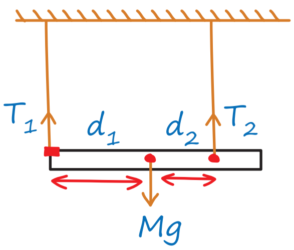
at Hmax

ROTATIONAL EQUILIBRIUM:-

$\tau_{net} = 0 \quad F_1 d_1 = F_2 d_2$



$$\text{M. Advantage} = \frac{F_1}{F_2} = \frac{d_2}{d_1} \quad (\text{M.A.} > 1)$$



ROTATIONAL KINEMATICS:-

U.C.M.:-

$\vec{\omega} = \text{const}^n \qquad \alpha = 0 = a_t.$

Speed = Const^n $\quad \vec{a}_c = \frac{v^2}{r}$

$\theta = \omega t.$

Non-UCM:-

(a) $\alpha = \text{const}^n.$

Eqn of Motion:

$$\omega_2 - \omega_1 = \alpha t$$

$$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$$

$$\omega_2^2 - \omega_1^2 = 2\alpha\theta$$

$$\theta = \left(\frac{\omega_2 + \omega_1}{2}\right) t = n2\pi.$$

(b) α = Variable

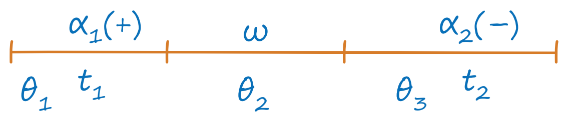
$\Delta\theta = \int \omega.dt \qquad \Delta\omega = \int \alpha.dt$

$\theta \qquad \omega \qquad \alpha$

$\alpha = \frac{d\omega}{dt}$

$\omega = \frac{d\theta}{dt} \qquad \alpha = \omega\frac{d\omega}{d\theta}$

- Rest to Rest Motion:-



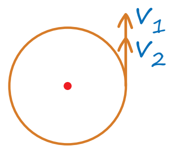
$\alpha_1 t_1 = \alpha_2 t_2$, $\alpha_1\theta_1 = \alpha_2\theta_3$

$\theta_1 = \frac{1}{2}\alpha_1 t_1^2 \qquad \theta_2 = \omega t_2$

$\theta_2 = \frac{1}{2}\alpha_2 t_2^2$

- The time at which two particle with different speed, start moving from same position Meet?

$$V_{relative} = \frac{2\pi R}{T}$$



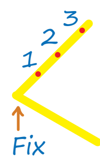
- Pure Motion:-

1> Rotational Motion:-

$\omega_1 = \omega_2 = \omega_3$

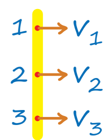
$\alpha_1 = \alpha_2 = \alpha_2$

$v_1 \neq v_2 \neq v_3$



2> Translational Motion:-

$v_1 = v_2 = v_3$



ANALOGY

Translation	Rotational
* S	* θ
* $V = \frac{dx}{dt}$	* $\omega = \frac{d\theta}{dt}$
* $a = \frac{dv}{dt}$	* $\alpha = \frac{d\omega}{dt}$
* $F = \frac{dP}{dt} = ma$	* $\tau = \frac{dL}{dt} = I\alpha$
* $P = mV$	* $L = I\omega$
* $w = F.s.$	* $W = \tau.\theta$
* $KE = \frac{1}{2} mv^2$	* $KE = \frac{1}{2} I\omega^2$
* $P = F.v.$	* $P = \tau.\omega$
* Impulse = m.V.	Impulse = $I\omega$

* $V = U + at$	$\omega = \omega_0 + \alpha t$
* $V^2 - U^2 = 2as$	$\omega^2 - \omega_0^2 = 2\alpha\theta$
* $S_{n^{th}} = U + \frac{a}{2}(2n-1)$	$\theta_{n^{th}} = \omega_0 + \frac{\alpha}{2}(2n-1)$
* $S = \left(\frac{U+V}{2}\right)T$	MR* $\theta = \left(\frac{w_i + \omega_f}{2}\right)T$
* $S = \frac{1}{2}\left(\frac{\alpha\beta}{\alpha+\beta}\right)T^2$	$S = \frac{1}{2}\left(\frac{\alpha\beta}{\alpha+\beta}\right)T^2$
* Stoping dist^n. $= \frac{U^2}{2a}$	* $\theta = \frac{\omega_0^2}{2\alpha}$
$V_{max} = \left(\frac{\alpha\beta}{\alpha+\beta}\right)T$	$\omega_{max} = \left(\frac{\alpha\beta}{\alpha+\beta}\right)T$

ANALOGY

Translation	Rotational
* $S = ut + \frac{1}{2} at^2$	$\theta = \omega t + \frac{1}{2}\alpha t^2$

MR**

- Jab tak "Rod" Nai!

  Tab Tak α, ω, θ. नही!

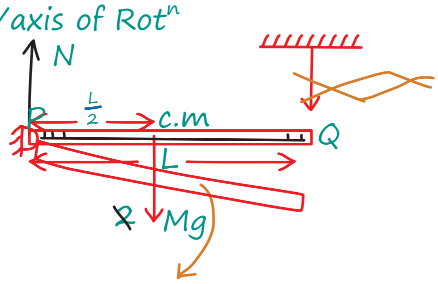
Note:-

$a_t = R\alpha \qquad a_c = R\omega^2 = \frac{V^2}{R}$

$|\vec{a}| = \sqrt{a_t^2 + a_c^2}$

Q. A rod PQ of mass M and length L is hinged at end P. The rod is kept horizontal by a massless string tied to point Q as shown in figure. When string is cut, the initial angular acceleration of the rod is (NEET 2013, AIP MT – 07/11/ IIT-4 X).

$[\tau_P = I_P \alpha_P]$ hinged point/axis of Rot^n



(a) $\frac{2g}{L}$

(b) $\frac{2g}{2L}$

(c) $\frac{3g}{2L}$

(d) $\frac{g}{L}$

$NX0 + \cancel{m}g\frac{\cancel{L}}{2} = \frac{\cancel{M}L^{\cancel{2}\,L}}{3}\alpha$

$\frac{g}{2} = \frac{L\alpha}{3}$

Angular acc^n of Rod (every ponit) or Rod about 'p'

* $\alpha = \frac{3g}{2L}$

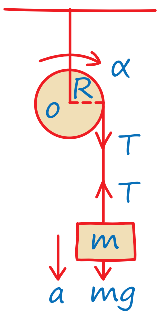
Find liner acc^n of C.O.M.??

at = r(α) same for all Points

$a_{c.m} = \frac{L}{2}\left(\frac{3g}{2L}\right) = \frac{3g}{4}$ m/s^2

(Ask 4X in IIT) (Most Imp. Que.)

MR**

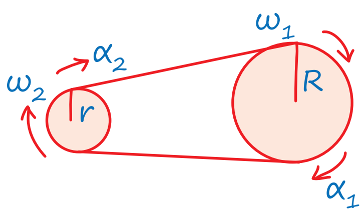


$$*\ accl^n = \frac{F_{net}}{\text{Transl}^n\ \text{Mass} + \text{Rotat}^n\ \text{Mass}}\ *$$

$$a = \frac{mg}{m + I/R^2}$$

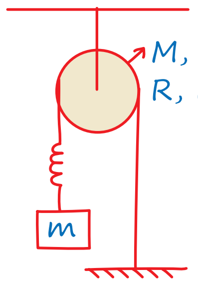
- **Relation b/n ω_1 & ω_2:-**

  * $V_1 = V_2$
  * $\omega_1 R = \omega_2 r$
  * $a_{t_1} = a_{t_2}$
  * $\alpha_1 R = \alpha_2 r$



- **T.P. of SHM:-**

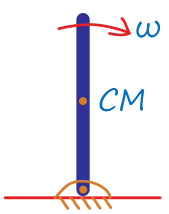
$$T = 2\pi\sqrt{\frac{m + I/R^2}{K}}$$



APPLICATION OF COM IN PURE ROTATIONAL MOTION:-

$$KE = \frac{1}{2} I\omega^2 = \frac{L^2}{2I}$$

e.g.:- Rod is released from vertical position Find ω when rod becomes horizontal.



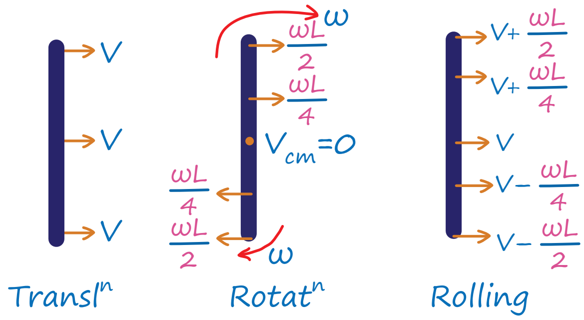
$$\frac{MgL}{2} + 0 = \frac{1}{2} I\omega^2 + 0$$

$$\frac{\cancel{M}g\cancel{L}}{\cancel{2}} = \frac{1}{2}\,\frac{\cancel{M}L^{\cancel{2}}}{\cancel{3}}\,\omega^2$$

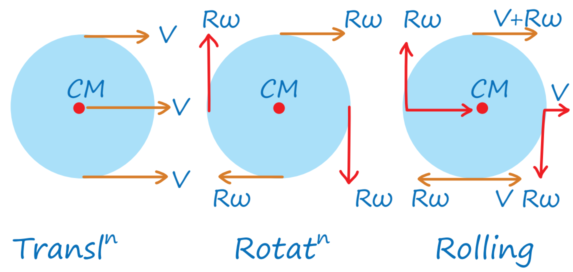
$$V_{cm} = \frac{L}{2}\omega$$

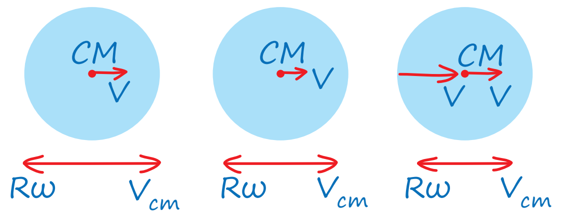
$$\omega = \sqrt{\frac{3g}{L}}$$

ROLLING MOTION:-



$$*KE = \frac{1}{2} mV_{cm}^2 + \frac{1}{2} I\omega^2 .\ *$$

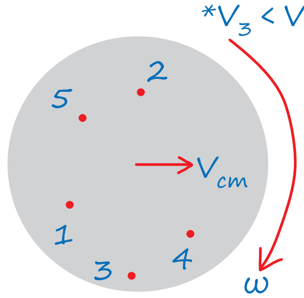




Forward Sliping	Backward Sliping	No Sliping
$V_{cm} > R\omega$	$V_{cm} < R\omega$	$V_{cm} = R\omega$
f_k = Back	f_k = Front	Lowest point at rest

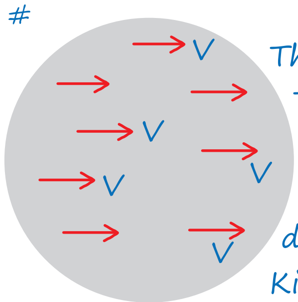
NOTE:-

$$*V_3 < V_4 < V_1 < V_5 < V_2*$$



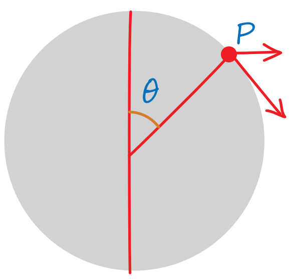
Speed.

#

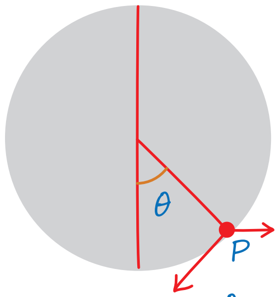


Thara bhai Translation Motion itni jagah "v" dedega Kishine sochi nai hogi!

o Note:-



$\vec{V}_P = 2V\cos\dfrac{\theta}{2}$



$\vec{V}_P = 2V\sin\dfrac{\theta}{2}$

TE:- MR**

$$KE_{Total} = KE_{Trans} + KE_{Rot.}$$

$$KE_{Total} = \frac{1}{2} m V_{cm}^2 + \frac{1}{2} I\omega^2$$

$$KE_{Total} = \frac{1}{2} m V_{cm}^2 \left[1 + \frac{K^2}{R^2}\right]$$

MR*

$$\frac{KE_{Trans}}{KE_{Total}} = \frac{1}{1 + \dfrac{K^2}{R^2}} = \beta$$

MR * TABLE (THE PRO VERSION)

Physical quantity	Ring hollow cylinder	Hollow sphere	Disc, solid cylinder	Solid sphere
β	$0.5 = \frac{1}{2}$	$0.6 = \frac{3}{5}$	$0.66 = \frac{2}{3}$	$0.71 = \frac{5}{7}$
KE_{Trans}/KE_{Total}	0.5 = 50%	0.6 = 60%	0.66 = 66%	0.71 = 71%
KE_{Rot}/KE_{Total}	0.5 = 50% (1/2)	0.4 = 40% (2/5)	0.33 = 33% (1/3)	0.28 = 28% (2/7)
KE_{Trans}/KE_{Rot}	1 : 1	3 : 2	2 : 1	5 : 2
Accl^n on inclined → $g\sin\theta\,\beta$	$\frac{g\sin\theta}{2}$	$\frac{3}{5} g\sin\theta$	$\frac{2}{3} g\sin\theta$	$\frac{5}{7} g\sin\theta$
Time req. to come down →	$t = \sqrt{\frac{2S}{g\sin\theta\beta}}$ →	→	→	
Velocity at bottom of inclined $V = \sqrt{2gh\beta}$	$V = \sqrt{gH}$	$V = \sqrt{\frac{6gH}{5}}$	$V = \sqrt{\frac{4gH}{3}}$	$V = \sqrt{\frac{10gH}{7}}$

H_{max} attained by particle	$H = \frac{V_{cm}^2}{2g\beta}$ $H = \frac{V_{cm}^2}{g}$	$H = \frac{5V_{cm}^2}{6g}$	$H = \frac{3V_{cm}^2}{4g}$	$H = \frac{7V_{cm}^2}{10g}$
Friction on inclined	$f_r = Mg\sin\theta\,(1-\beta)$ $f_r = Mg\sin\theta/2$	$f_r = \frac{2}{5} Mg\sin\theta$	$f_r = \frac{Mg\sin\theta}{3}$	$f_r = \frac{2}{7} Mg\sin\theta$
μ_{min} to start pure rolling	$\mu = (1-\beta)\tan\theta$ $\mu = \tan\theta/2$	$\mu_s = \frac{2}{5}\tan\theta$	$\mu = \frac{\tan\theta}{3}$	$\mu = \frac{2}{7}\tan\theta$

* Jahan "g" wahi "β" * Konse bhi sawaal mein Rolling aayega toh β lagado.*

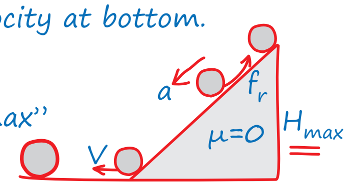
○ Caution:-

Rolling on Smooth inclined plane:-

* $a = g\sin\theta$ → independent of Mass, Shape, Size.

* $V = \sqrt{2gh}$ → Velocity at bottom.

* $H = \frac{V_{cm}^2}{2g}$ → "Hmax"



○ Rolling Motion on Rough inclined plane:-

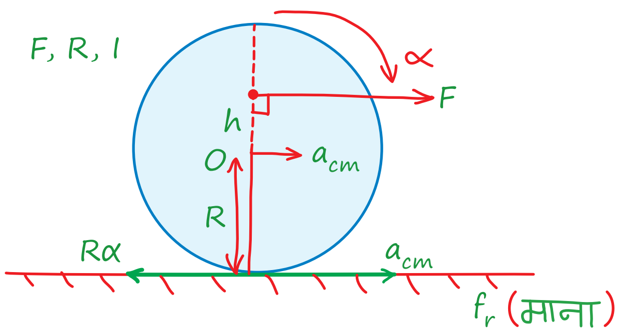
$V = \sqrt{2gh\beta}$ $\quad a = \beta g\sin\theta$

$H = \frac{V_{cm}^2}{2g\beta}$

Object Upar jaye ya niche

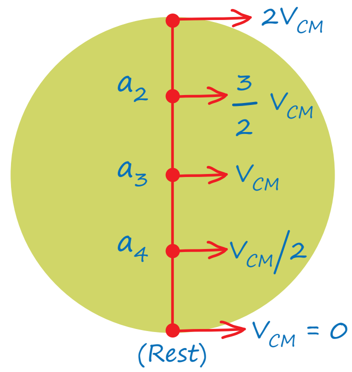
*f_r always acts upwards!

PURE ROLLING ON A HORIZONTAL PLANE:-



MR**

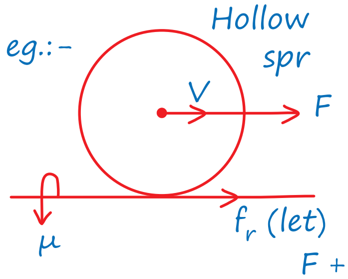
$a_{cm} = \frac{F\beta}{m}$ (β = Coefficient of velocity where force acts)



$a_1 = \frac{F\beta\,(2)}{m}$ $\qquad a_2 = \frac{F\beta}{m}\left(\frac{3}{2}\right)$

$a_3 = \frac{F\beta\,(1)}{m}$ $\qquad a_4 = \frac{F\beta}{m}\left(\frac{1}{2}\right)$

eg.:-



$a_{cm} = \frac{F}{m}\left(\frac{3}{5}\right)$

$F + f_r = ma_{CM}$

$$f_r = \frac{3F}{5} - F = -\frac{2F}{5} \text{ (backward)}$$

* Pure rolling motion can start on smooth horizontal surface

ANGULAR MOMENTUM:-

- Depends on Frame of Ref.

  $L = rmv \sin\theta$

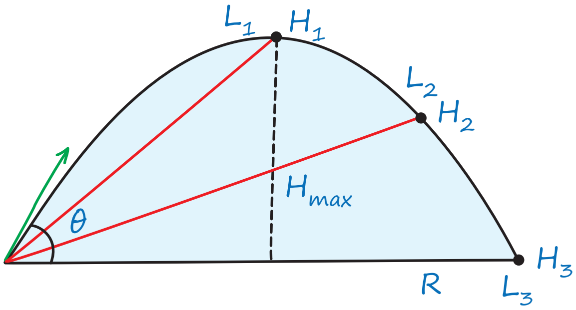
  $L = rP \sin\theta$

  $\vec{L} = \vec{r} \times \vec{P}$ (Axial Vector)

  θ = Angle b/n $\vec{r}$ & $\vec{P}$

→ When object is moving on straight line with const. velocity then:- L = same.

- Object is projected with speed "U" at an angle "θ" with horizontal then find angular momentum in projectile:-



$$L_1 = mu\cos\theta \times H_{max} = mu\cos\theta . \frac{U^2\sin^2\theta}{2g}$$

$$L_3 = 4L_1 = mu\cos\theta . \frac{2U^2\sin^2\theta}{g}$$

L when about to Collide = 4 L at H_{max} *

General point

$$L_2 = \frac{mg\, U\cos\theta t^2}{2}$$

$\tau = Mg\, U\cos\theta t$

$\int dL = \int MgU\cos\theta t.dt$

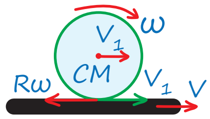
- Pure Rotational Motion:-

  $L = I\omega \qquad KE = \frac{1}{2} I\omega^2 = \frac{L^2}{2I}$

- A rolling body is rolling without slipping on a moving plank.

  $v_1 - R\omega = v$

  $v_1 - v = R\omega.$

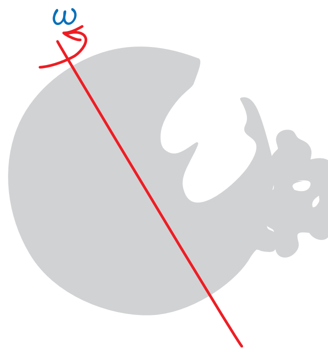


CONSERVATION OF ANG. MOMENTUM:-

$\tau = 0 \qquad \vec{L} = \text{const}^n$

$I_1\omega_1 = I_2\omega_2$

1>

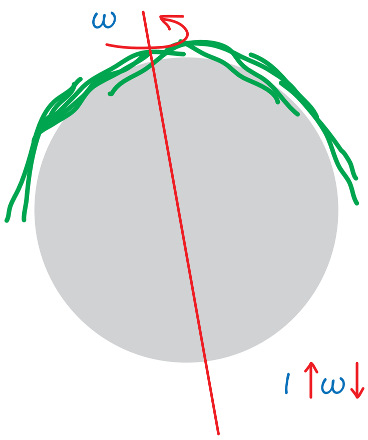


$I\uparrow \omega\downarrow = \text{Const}^n$

$\downarrow\omega = \frac{2\pi}{T\uparrow}$

T.P. will inc.

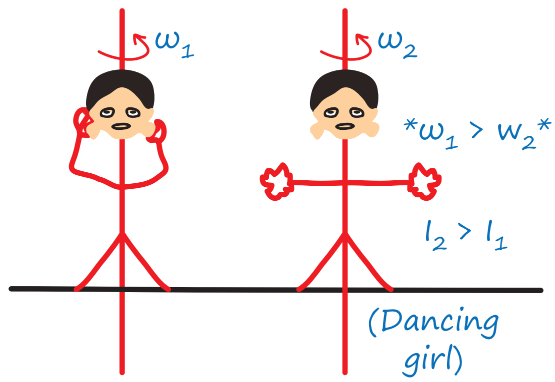
2>



Ice on pole will melt, then.

$I\uparrow \omega\downarrow \quad \underline{\underline{T\uparrow}}$

3>



$*\omega_1 > \omega_2*$

$I_2 > I_1$

(Dancing girl)

Imp:-

Same dir^n = +

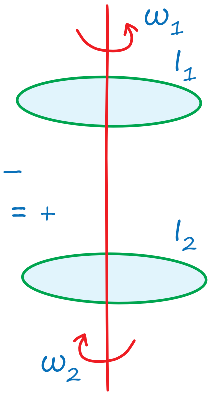
Oppo = −

$$\omega = \frac{I_1\omega_1 \pm I_2\omega_2}{I_1 + I_2}$$

Same = −

Oppo = +

$$\underset{loss}{\Delta KE} = \frac{1}{2}\,\frac{I_1 I_2}{I_1 + I_2}\,\omega_{rel}^2$$



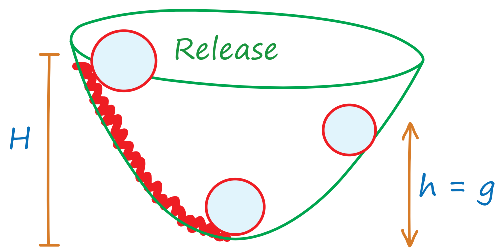
Imp. Model Problems MR*

1> A heavy body is thrown on a horizontal rough surface with initial velocity "U" without rolling. Find "V" when it start pure rolling:-

MR*

$$\boxed{V = \beta U} \qquad \beta = \frac{1}{1 + \frac{K^2}{R^2}}$$

2> IIT - Adv 2014.



$$\boxed{h = H\beta} \quad h = \frac{V_o^2}{2g},\; V_o = \sqrt{2gH\beta}.$$

3> A Rotating body with "ω_o" Placed on rough surface then find Angular velocity when it starts pure rolling motion:-

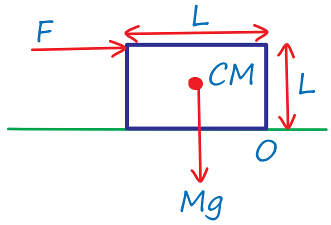
$$* \;\boxed{\omega = (1-\beta)\omega.}$$

4> A body rolls on horizontal floor. Find ω to stop it:-

$$\boxed{\omega = \frac{KE_{Transl}}{\beta}}$$

TOPPLING:-

MR*



$\tau_o = 0$

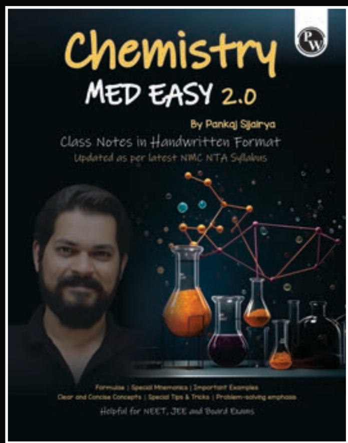
$$Mg\,\frac{\cancel{L}}{2} = F.\cancel{L}$$

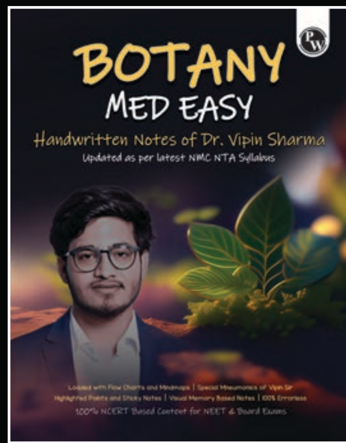
Don't take $\tau_{CM} = 0$ take

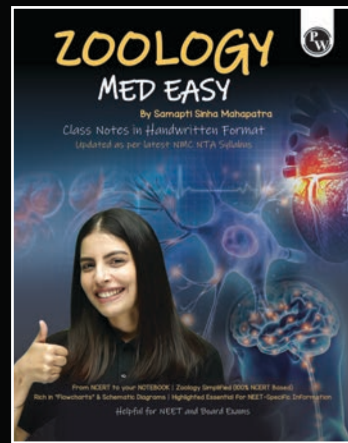
$\tau_o = 0$

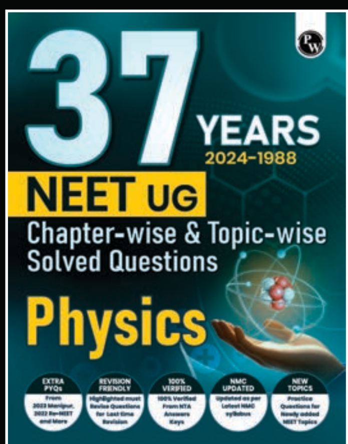
Toppling में Normal Ko Shift KrKe Object apne appko palatne se bachata hai!

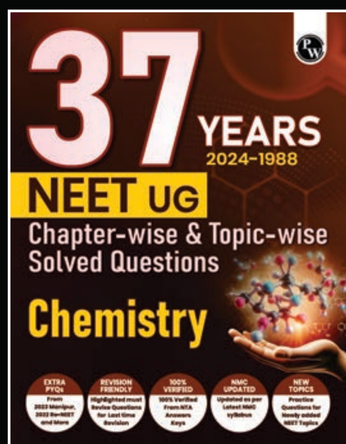
Books In The Series

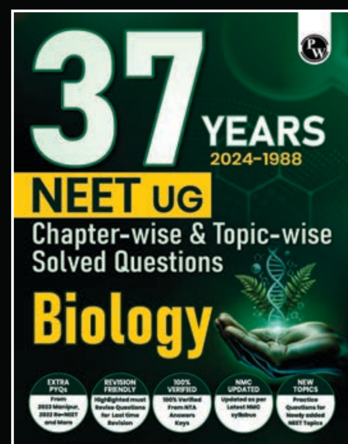


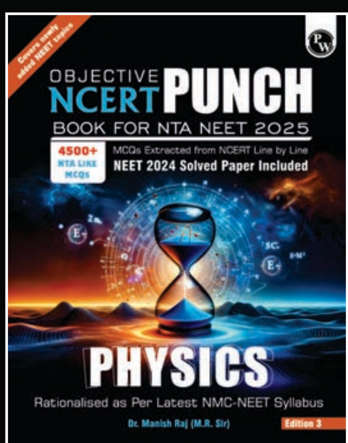


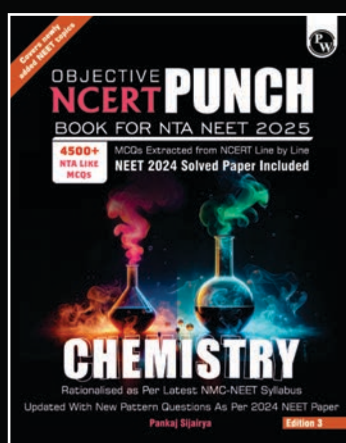


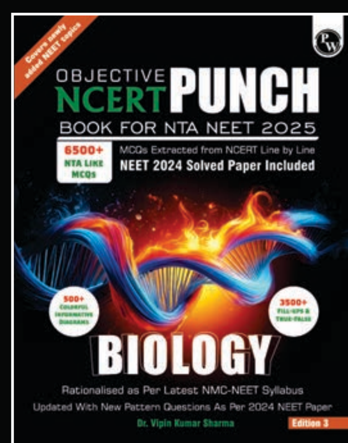












₹ 525/-

PHYSICS WALLAH PUBLICATION

If you have any Doubt
SCAN ME!

To Buy PW Books
SCAN ME!

To share Feedback
SCAN ME!

ISBN 978-81-19352-94-4
9 788119 352944