PHYSICS

Formula Book for

Engineering Entrance Examinations

Best Wishes for

Your Success in Competitive Examinations ahead !!!

SHORT FORMULA (GYAN SUTRA)

PHYSICS

UNIT AND DIMENSIONS

Unit :

Measurement of any physical quantity is expressed in terms of an internationally accepted certain basic standard called unit.

* **Fundamental Units.**

S.No.	Physical Quantity	SI Unit	Symbol
1	Length	Metre	m
2	Mass	Kilogram	Kg
3	Time	Second	S
4	Electric Current	Ampere	A
5	Temperature	Kelvin	K
6	Luminous Intensity	Candela	Cd
7	Amount of Substance	Mole	mol

* **Supplementary Units :**

S.No.	Physical Quantity	SI Unit	Symbol
1	Plane Angle	radian	r
2	Solid Angle	Steradian	Sr

* **Metric Prefixes :**

S.No.	Prefix	Symbol	Value
1	Centi	c	10^{-2}
2	Mili	m	10^{-3}
3	Micro	μ	10^{-6}
4	Nano	n	10^{-9}
5	Pico	p	10^{-12}
6	Kilo	K	10^{3}
7	Mega	M	10^{6}

RECILINEAR MOTION

Average Velocity (in an interval) :

$$v_{av} = \bar{v} = \langle v \rangle = \frac{\text{Total displacement}}{\text{Total time taken}} = \frac{\vec{r}_f - \vec{r}_i}{\Delta t}$$

Average Speed (in an interval)

$$\text{Average Speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Instantaneous Velocity (at an instant) :

$$v_{inst} = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t}$$

Average acceleration (in an interval):

$$= \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t}$$

Instantaneous Acceleration (at an instant):

$$a = \frac{dv}{dt} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t}$$

Graphs in Uniformly Accelerated Motion along a straight line (a 0)

x is a quadratic polynomial in terms of t. Hence x – t graph is a parabola.

x-t graph

v is a linear polynomial in terms of t. Hence v–t graph is a straight line of slope a.

v-t graph

a–t graph is a horizontal line because a is constant.

a-t graph

Maxima & Minima

$\frac{dy}{dx} = 0$ & $\frac{d}{dx}\frac{dy}{dx} < 0$ at maximum and $\frac{dy}{dx} = 0$ & $\frac{d}{dx}\frac{dy}{dx} > 0$ at minima.

Equations of Motion (for constant acceleration)

(a) $v = u + at$

(b) $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $x_f = x_i + ut + \frac{1}{2}at^2$

(c) $v^2 = u^2 + 2as$

(d) $s = \frac{(u+v)}{2}t$

(e) $s_n = u + \frac{a}{2}(2n - 1)$

For freely falling bodies : (u = 0)

(taking upward direction as positive)

(a) $v = \quad gt$

(b) $s = \quad \frac{1}{2} gt^2$ $\qquad s = vt + \frac{1}{2} gt^2$ $\qquad h_f = h_i \quad \frac{1}{2} gt^2$

(c) $v^2 = \quad 2gs$

(d) $s_n = \quad \frac{g}{2} (2n - 1)$

PROJECTILE MOTION & VECTORS

Time of flight : $T = \frac{2u\sin\theta}{g}$

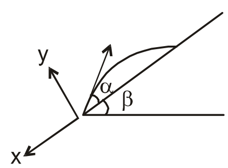
Horizontal range : $R = \frac{u^2 \sin 2\theta}{g}$

Maximum height : $H = \frac{u^2 \sin^2\theta}{2g}$

Trajectory equation (equation of path) :

$$y = x\tan\theta \quad \frac{gx^2}{2u^2\cos^2\theta} = x\tan\theta\,(1 \quad \frac{x}{R})$$

Projection on an inclined plane



	Up the Incline	Down the Incline
Range	$\frac{2u^2\sin\alpha\cos(\alpha+\beta)}{g\cos^2\beta}$	$\frac{2u^2\sin\alpha\cos(\alpha-\beta)}{g\cos^2\beta}$
Time of flight	$\frac{2u\sin\alpha}{g\cos\beta}$	$\frac{2u\sin\alpha}{g\cos\beta}$
Angle of projection with incline plane for maximum range	$\frac{\pi}{4} - \frac{\beta}{2}$	$\frac{\pi}{4} + \frac{\beta}{2}$
Maximum Range	$\frac{u^2}{g(1+\sin\beta)}$	$\frac{u^2}{g(1-\sin\beta)}$

RELATIVE MOTION

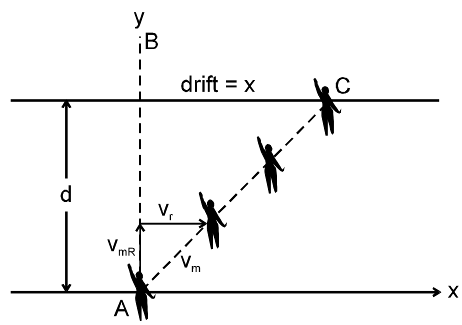
v_{AB}(velocity of A with respect to B) $= v_A - v_B$

a_{AB}(acceleration of A with respect to B) $= a_A - a_B$

Relative motion along straight line - $x_{BA} = x_B - x_A$

CROSSING RIVER

A boat or man in a river always moves in the direction of resultant velocity of velocity of boat (or man) and velocity of river flow.

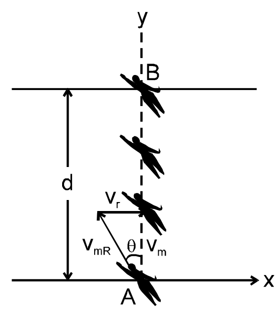


1. **Shortest Time :**

   Velocity along the river, $v_x = v_R$.

   Velocity perpendicular to the river, $v_y = v_{mR}$

   The net speed is given by $v_m = \sqrt{v_{mR}^2 + v_R^2}$



2. **Shortest Path :**

   velocity along the river, $v_x = 0$

   and velocity perpendicular to river $v_y = \sqrt{v_{mR}^2 - v_R^2}$

   The net speed is given by $v_m = \sqrt{v_{mR}^2 - v_R^2}$

   at an angle of 90º with the river direction.

   velocity v_y is used only to cross the river,

   therefore time to cross the river, $t = \dfrac{d}{v_y} = \dfrac{d}{\sqrt{v_{mR}^2 - v_R^2}}$

   and velocity v_x is zero, therefore, in this case the drift should be zero.

   $v_R - v_{mR}\sin\theta = 0$ or $v_R = v_{mR}\sin\theta$

   or $\theta = \sin^{-1}\left(\dfrac{v_R}{v_{mR}}\right)$

RAIN PROBLEMS

$$\vec{v}_{Rm} = \vec{v}_R - \vec{v}_m \quad \text{or} \quad v_{Rm} = \sqrt{v_R^2 + v_m^2}$$

NEWTON'S LAWS OF MOTION

1. **From third law of motion**

   $\vec{F}_{AB} = -\vec{F}_{BA}$ $\vec{F}_{AB}$ = Force on A due to B $\vec{F}_{BA}$ = Force on B due to A

2. From second law of motion

$$F_x = \frac{dP_x}{dt} = ma_x \qquad F_y = \frac{dP_y}{dt} = ma_y \qquad F_z = \frac{dP_z}{dt} = ma_z$$

5. WEIGHING MACHINE :

A weighing machine does not measure the weight but measures the force exerted by object on its upper surface.

6. SPRING FORCE $F = -kx$

x is displacement of the free end from its natural length or deformation of the spring where K = spring constant.

7. SPRING PROPERTY $K\ell$ = constant

ℓ = Natural length of spring.

8. If spring is cut into two in the ratio m : n then spring constant is given by

$$\ell_1 = \frac{m\ell}{m+n}; \qquad \ell_2 = \frac{n.\ell}{m+n} \qquad k\ell = k_1\ell_1 = k_2\ell_2$$

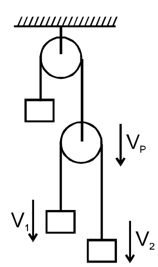
For series combination of springs $\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + ...$

For parallel combination of spring $k_{eq} = k_1 + k_2 + k_3$ ....

9. SPRING BALANCE:

It does not measure the weight. It measures the force exerted by the object at the hook.

Remember :

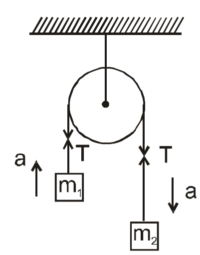


$$V_p = \frac{V_1 + V_2}{2}$$

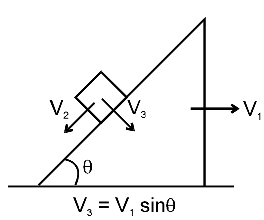
$$a_p = \frac{a_1 + a_2}{2}$$

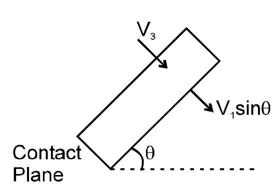
11. $a = \frac{(m_2 - m_1)g}{m_1 + m_2}$

$T = \frac{2m_1m_2g}{m_1 + m_2}$



12. WEDGE CONSTRAINT:





Components of velocity along perpendicular direction to the contact plane of the two objects is always equal if there is no deformations and they remain in contact.

13. NEWTON S LAW FOR A SYSTEM

$\vec{F}_{ext} = m_1a_1 + m_2a_2 + m_3a_3 + ...$

F_{ext} = Net external force on the system.

m_1, m_2, m_3 are the masses of the objects of the system and

a_1, a_2, a_3 are the acceleration of the objects respectively.

14. NEWTON S LAW FOR NON INERTIAL FRAME :

$$\vec{F}_{Real} + \vec{F}_{Pseudo} = m\vec{a}$$

Net sum of real and pseudo force is taken in the resultant force.

a = Acceleration of the particle in the non inertial frame

$$F_{Pseudo} = -m \; a_{Frame}$$

(a) Inertial reference frame: Frame of reference moving with constant velocity.

(b) Non-inertial reference frame: A frame of reference moving with non-zero acceleration.

FRICTION

Friction force is of two types.

(a) Kinetic (b) Static

KINETIC FRICTION : $f_k = \mu_k N$

The proportionality constant μ_k is called the coefficient of kinetic friction and its value depends on the nature of the two surfaces in contact.

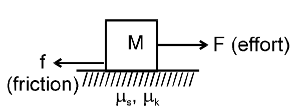
STATIC FRICTION :

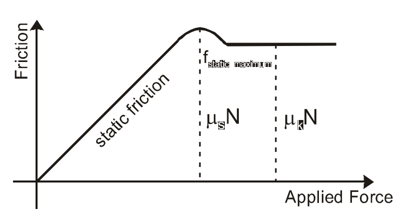
It exists between the two surfaces when there is tendency of relative motion but no relative motion along the two contact surfaces.

This means static friction is a variable and self adjusting force. However it has a maximum value called limiting friction.

$$f_{max} = \mu_s N$$

$$0 \quad f_s \quad f_{smax}$$





WORK, POWER & ENERGY

WORK DONE BY CONSTANT FORCE :

$$\mathbf{W} = F \cdot \vec{S}$$

WORK DONE BY MULTIPLE FORCES

$$\Sigma\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$$

$$W = [\Sigma F] \cdot S \qquad ...(i)$$

$$W = \vec{F}_1 \cdot \vec{S} + \vec{F}_2 \cdot \vec{S} + \vec{F}_3 \cdot \vec{S} + ...$$

or $$W = W_1 + W_2 + W_3 + ...$$

WORK DONE BY A VARIABLE FORCE

$$dW = \vec{F}.d\vec{s}$$

RELATION BETWEEN MOMENTUM AND KINETIC ENERGY

$$K = \frac{p^2}{2m} \quad \text{and} \quad P = \sqrt{2\,m\,K} \quad ; \; P = \text{linear momentum}$$

POTENTIAL ENERGY

$$\int_{U_1}^{U_2} dU = -\int_{r_1}^{r_2} \vec{F}\cdot d\vec{r} \qquad \text{i.e.,} \qquad U_2 - U_1 = -\int_{r_1}^{r_2} \vec{F}\; d\vec{r} = -W$$

$$U = -\int_{\infty}^{r} \vec{F}\cdot d\vec{r} = -W$$

CONSERVATIVE FORCES

$$F = \frac{U}{r}$$

WORK-ENERGY THEOREM

$$W_C + W_{NC} + W_{PS} = \Delta K$$

Modified Form of Work-Energy Theorem

$$W_C = -\Delta U$$

$$W_{NC} + W_{PS} = \Delta K + \Delta U$$

$$W_{NC} + W_{PS} = \Delta E$$

POWER

The average power ($\overline{P}$ or p_{av}) delivered by an agent is given by $\overline{P}$ or $p_{av} = \frac{W}{t}$

$$P = \frac{F\;dS}{dt} = F\;\frac{dS}{dt} = \vec{F} \cdot \vec{v}$$

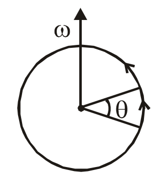
CIRCULAR MOTION

1. Average angular velocity

$$\omega_{av} = \frac{\theta_2 - \theta_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t}$$

2. Instantaneous angular velocity

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



3. Average angular acceleration $\alpha_{av} = \frac{\omega_2 - \omega_1}{t_2 - t_1} = \frac{\Delta\omega}{\Delta\theta}$

4. Instantaneous angular acceleration $\alpha = \frac{d\omega}{dt} = \omega\frac{d\omega}{d\theta}$

5. Relation between speed and angular velocity $v = r\omega$ and $v = \omega \quad r$

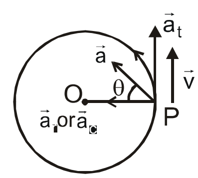
7. Tangential acceleration (rate of change of speed) $a_t = \frac{dV}{dt} = r\,\frac{d\omega}{dt} = \omega\,\frac{dr}{dt}$

8. Radial or normal or centripetal acceleration $a_r = \frac{v^2}{r} = \omega^2 r$

9. Total acceleration

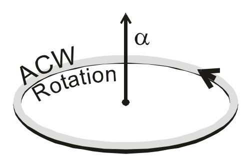
$a = a_t + a_r \qquad a = (a_t^2 + a_r^2)^{1/2}$

Where $a_t = \alpha \quad r$ and $a_r = \omega \quad v$



10. Angular acceleration

$$\alpha = \frac{d\omega}{dt} \text{ (Non-uniform circular motion)}$$

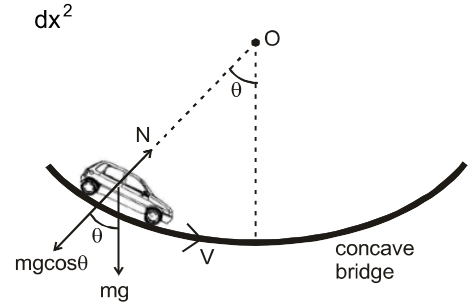


12. Radius of curvature $R = \frac{v^2}{a_\perp} = \frac{mv^2}{F_\perp}$

If y is a function of x. i.e. y = f(x) $R = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\frac{d^2y}{dx^2}}$

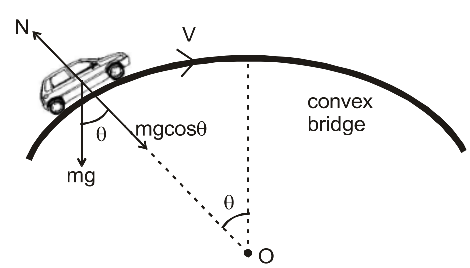
13. Normal reaction of road on a concave bridge

$$N = mg\cos\theta + \frac{mv^2}{r}$$



14. Normal reaction on a convex bridge

$$N = mg\cos\theta \quad \frac{mv^2}{r}$$



15. Skidding of vehicle on a level road

v_{safe} $\sqrt{\mu g r}$

16. Skidding of an object on a rotating platform

$\omega_{max} = \sqrt{\mu g / r}$

17. Bending of cyclist $\tan\theta = \dfrac{v^2}{rg}$

18. Banking of road without friction $\tan\theta = \dfrac{v^2}{rg}$

19. Banking of road with friction $\dfrac{v^2}{rg} = \dfrac{\mu + \tan\theta}{1 - \mu\tan\theta}$

20. Maximum also minimum safe speed on a banked frictional road

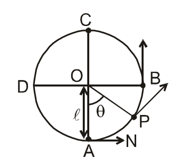
$$V_{max} = \left[\frac{rg(\mu + \tan\theta)}{(1 - \mu\tan\theta)}\right]^{1/2}$$

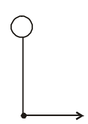
$$V_{min} = \left[\frac{rg(\mu - \tan\theta)}{(1 + \mu\tan\theta)}\right]^{1/2}$$

21. Centrifugal force (pseudo force) $f = m\omega^2 r$, acts outwards when the particle itself is taken as a frame.

22. Effect of earths rotation on apparent weight $N = mg \quad mR\omega^2\cos^2\theta$;
where θ latitude at a place

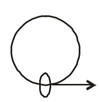
23. Various quantities for a critical condition in a vertical loop at different positions
(True for a string or on a smooth track.)



(1) 

$V_{min} = \sqrt{4gL}$

(for completing the circle)

(2) 

$V_{min} = \sqrt{4gL}$

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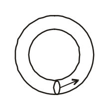
(3) 

$V_{min} = \sqrt{4gL}$

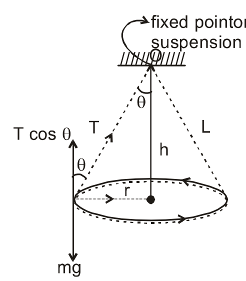
(for completing the circle)

24. Conical pendulum :

$T\cos\theta = mg$

$T\sin\theta = m\omega^2 r$

$\therefore$ Time period = $2\pi\sqrt{\dfrac{L\cos\theta}{g}}$



25. Relations amoung angular variables :

ω_0 Initial ang. velocity $\omega = \omega_0 + \alpha t$

ω Find angular velocity $\theta = \omega_0 t + \dfrac{1}{2}\alpha t^2$

ω Const. angular acceleration $\omega^2 = \omega_0^2 + 2\alpha\theta$