Formula Sheet

PHYSICS

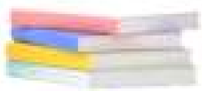
CLASS 11

UNO test prep

Medical
IIT-JEE
Foundations

Physical World

ONLY THEORY



Units and Measurement

- Determination of Radius of atom using avogadro Hypothesis $r = \left(\frac{VM}{2\pi N m}\right)^{1/3}$

  V = Volume
  M = Molecular weight
  N = Avogadro's No.

- Diameter of Moon $D = s\theta$ θ = Angle of Deviation

- Angle = $\frac{\text{Curve}}{\text{Radius}}$

- Absolute Error $\Delta a_n = a_{mean} - a_n$ $a_{mean} = \sum_{i=1}^{n} a_i/n$

- Mean Absolute Error $\Delta a_{mean} \quad \Delta \bar{a} = \frac{1}{n}\sum_{i=1}^{n} |\Delta a_i|$

- Relative or Fractional Error $= \frac{\Delta a_{mean}}{a_{mean}}$

- Percentage Error $\delta a = \frac{\Delta a_{mean}}{a_{mean}} \times 100\%$

- Error in addition and Subtraction $\Delta Z_{max} = \Delta A + \Delta B$

- Error in Multiplication and Divison $\left|\frac{\Delta Z}{Z}\right|_{max} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$

- Error in a power of measured quantity

  - If $Z = A^m$

    $\left|\frac{\Delta Z}{Z}\right|_{max} = m\frac{\Delta A}{A}$

  - If $Z = \frac{A^m B^n}{C^p}$

    $\left|\frac{\Delta Z}{Z}\right|_{max} = m\frac{\Delta A}{A} + n\frac{\Delta B}{B} + p\frac{\Delta C}{C}$

- Experimental % Error $\frac{\text{Real Value} - \text{Experimental Value}}{\text{Real Value}} \times 100\%$

Motion in a straight line

- Speed $\boxed{v = \frac{s}{t}}$
- Average speed $\boxed{\bar{v} = \frac{\Delta s}{\Delta t}}$
- Average velocity $\boxed{\vec{v}_{av} = \frac{\Delta \vec{s}}{\Delta t}}$
- Instantaneous speed $\boxed{v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}}$

s = displacement, t = time
v = initial velocity
u = final velocity

- Instantaneous velocity $\boxed{\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{s}}{\Delta t} = \frac{d\vec{s}}{dt}}$
- Acceleration $\boxed{a = \frac{\Delta v}{\Delta t}}$
- $\boxed{\vec{v}_{av} = \frac{\vec{u} + \vec{v}}{2}}$ OR $\boxed{\vec{v}_{av} = \frac{\vec{v}_1 t_1 + \vec{v}_2 t_2}{t_1 + t_2}}$
- Instantaneous Acceleration $\boxed{\vec{a} = \frac{d(\vec{v})}{dt}}$ OR $\boxed{a = \frac{d^2 s}{dt^2}}$
- Equations of Motion or Equations of Kinematics

1. $\boxed{v = v_0 + at}$ (Velocity-time Relation)
2. $\boxed{s = v_0 t + \frac{1}{2} a t^2}$ (Position-Time Relation)
3. $\boxed{v^2 = v_0^2 + 2as}$ (Position-velocity Relation)

- Motion under gravity

(A) When down to up $s = h$, $a = -g$

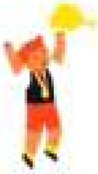
1. $\boxed{v = v_0 - gt}$
2. $\boxed{h = v_0 t - \frac{1}{2} g t^2}$
3. $\boxed{v^2 = v_0^2 - 2gh}$

- (B) When up to down $s = h$, $a = g$

1. $\boxed{v = v_0 + gt}$
2. $\boxed{h = v_0 t + \frac{1}{2} g t^2}$
3. $\boxed{v^2 = v_0^2 + 2gh}$

- Stopping distance of vehicles $\boxed{d_s = -\frac{v_0^2}{2a}}$
- Distance traveled in n^{th} sec $\boxed{\Delta s = v_0 + \frac{1}{2} a (2n-1)}$
- Relative velocity A to B $\boxed{\vec{V}_{AB} = \vec{V}_A - \vec{V}_B}$ $\boxed{\vec{V}_{AB} = \vec{V}_A + \vec{V}_B}$ (Object move in the opposite direction)

$\boxed{\vec{V}_{AB} = -\vec{V}_{BA}}$



Motion in a Plane

- Equal vectors $\boxed{\vec{A} = \vec{B} = \vec{C}}$
- Opposite vectors $\boxed{\vec{A} = -\vec{D}}$
- Unit vector $\boxed{\hat{A} = \dfrac{\vec{A}}{|\vec{A}|} = \dfrac{\vec{A}}{A}}$
- Orthogonal unit vector $\boxed{|\hat{i}| = |\hat{j}| = |\hat{k}| = 1}$

$\boxed{\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}}$

- Magnitude $\boxed{A = \sqrt{A_x^2 + A_y^2 + A_z^2}}$
- Vector addition $\boxed{\vec{R} = \vec{A} + \vec{B}}$
- vector subtraction $\boxed{\vec{R} = \vec{A} - \vec{B}}$
- Analytical Method

$$\boxed{R = \sqrt{A^2 + B^2 + 2AB\cos\theta}}$$

$$\boxed{\tan\alpha = \frac{B\sin\theta}{A + B\cos\theta}}$$

- Resolution of Vectors

$$\boxed{A = \sqrt{A_x^2 + A_y^2}}$$

$$\boxed{\theta = \tan^{-1}\frac{A_y}{A_x}}$$

- Properties of Vectors

1. $\boxed{|\lambda \vec{A}| = \lambda |\vec{A}|}$ If $\lambda > 0$ (λ = Real no.)
2. $\boxed{\vec{A} + \vec{B} = \vec{B} + \vec{A}}$
3. $\boxed{\vec{A} \times \vec{B} \neq \vec{B} \times \vec{A}}$ $\boxed{\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}}$
4. $\boxed{(\vec{A} + \vec{B}) + \vec{C} = \vec{A} + (\vec{B} + \vec{C})}$
5. $\boxed{\vec{A} - \vec{A} = \vec{0}}$ $|\vec{0}| = 0$ (zero vector)
6. $\boxed{\vec{A} - \vec{B} = \vec{A} + (-\vec{B})}$
7. $\boxed{\vec{A} + \vec{0} = \vec{A}}$
8. $\boxed{0\vec{A} = \vec{0}}$
9. $\boxed{\lambda \vec{0} = \vec{0}}$

- Scalar or dot products of two vectors $\boxed{\vec{A} \cdot \vec{B} = AB\cos\theta}$
- Properties of Scalar Product

1. (a) $\theta < 90^\circ$ $\boxed{\vec{A} \cdot \vec{B}\ (+ve)}$ (b) $\theta = 90^\circ$ $\boxed{\vec{A} \cdot \vec{B}\ (\text{zero})}$ (c) $\theta > 90^\circ$ $\boxed{\vec{A} \cdot \vec{B}\ (-ve)}$
2. $\boxed{\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}}$ (Commutative)
3. $\boxed{\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}}$ (Distributive)
4. $\boxed{\vec{A} \cdot \vec{B} = 0}$ $\theta = 90^\circ$ (two perpendicular vectors)

5. $\vec{A}\cdot\vec{B} = AB$ $\theta = 0$ (two parallel vectors)
$\vec{A}\cdot\vec{B} = -AB$ $\theta = 180^\circ$

6. $\vec{A}\cdot\vec{A} = A^2$ (Product of a vector with itself is equal to square)

7. $\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$ $\quad$ $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$ (unit orthogonal vector relations)

8. $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$ (two vectors is equal to the sum of the product)

Vector or cross product of two vectors $\vec{A}\times\vec{B} = AB\sin\theta\,\hat{n}$

Properties of Vector product

1. $\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$ (not commutative)

2. $\vec{A}\times(\vec{B}+\vec{C}) = \vec{A}\times\vec{B} + \vec{A}\times\vec{C}$ (Distributive)

3. $(m\vec{A})\times\vec{B} = \vec{A}\times(m\vec{B}) = mAB\sin\theta\,\hat{n}$ (two vector is multiplied by scalar)

4. $|\vec{A}\times\vec{B}| = AB$ $\theta = 90^\circ$ (two perpendicular vectors)

5. $\vec{A}\times\vec{B} = 0$ $\theta = 0$ (two parallel vectors)

6. $\vec{A}\times\vec{A} = 0$ (Product of a vector by itself)

7. $\hat{i}\times\hat{j} = -\hat{j}\times\hat{i} = \hat{k}$ $\quad$ $\hat{j}\times\hat{k} = -\hat{k}\times\hat{j} = \hat{i}$ $\quad$ $\hat{k}\times\hat{i} = -\hat{i}\times\hat{k} = \hat{j}$

$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}\times\hat{k} = 0$

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

where $\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$

$\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$

Motion in a plane

1. Position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ $\quad$ $|\vec{r}| = \sqrt{x^2+y^2+z^2}$

2. Displacement vector $\Delta\vec{r} = \vec{r}' - \vec{r} = \Delta x\hat{i} + y\hat{j} + z\hat{k}$

3. Velocity $\vec{v} = \frac{\Delta\vec{r}}{\Delta t}$ $\quad$ $\vec{v} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$

4. Acceleration $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$ $\quad$ $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ $\quad$ $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$

Motion in plane with constant velocity $\vec{r} = \vec{r}_0 + \vec{v}t$

Motion in plane with constant Acceleration

$\vec{v} = \vec{v_0} + \vec{a}t$

$\vec{r} = \vec{r_0} + \vec{v_0} + \frac{1}{2}\vec{a}t^2$

In direction of x - axis

$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$

Projectile Motion

horizontal component $u_x = v_0 \cos\theta_0$

Vertical Component $u_y = v_0 \sin\theta_0$

↳ Path of Projectile

$$y = (\tan\theta_0)x - \frac{g}{2v_0^2\cos^2\theta_0}x^2$$

↳ Flight time of Projectile

$t = \frac{v_0\sin\theta_0}{g}$ $\quad T = 2t = \frac{2v_0\sin\theta_0}{g}$

↳ Height of Projectile

$h = \frac{v_0^2\sin^2\theta_0}{2g}$ $\quad h_{max} = \frac{v_0^2}{2g}$

↳ Range of Projectile

$R = \frac{v_0^2\sin 2\theta_0}{g}$

If $\theta = 45°$ $\quad R_{max} = \frac{v_0^2}{g}$

Uniform circular motion

$a_c = \frac{v^2}{R}$ $\quad a_c = \omega^2 R$ $\quad a_c = 4\pi^2\nu^2 R$

a_c = Centripetal force
R = Radius of Circle
ν = frequency

Angular velocity

$\omega = \frac{d\theta}{dt}$ $\quad \omega = 2\pi\nu$ $\quad v = 2\pi R\nu$

Relation between v and ω

$v = r\omega$

v = linear velocity
ω = Angular velocity
∵ $(v = r\omega)$

Centripetal force

$F = \frac{mv^2}{r}$ $\quad F = mr\omega^2$

Motion of a Conical pendulum

$$\text{time period } (t) = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

Motion of particle tied to a string in a vertical Circle

$v = \sqrt{(3 + 2\cos\theta)gl}$ $\quad T = 3mg(1 + \cos\theta)$

1. If $\theta = 90°$ $\quad v = \sqrt{5gl}$ $\quad T = 6mg$ (At bottom of circle)
2. If $\theta = 90°$ $\quad v = \sqrt{3gl}$ $\quad T = 3mg$
3. If $\theta = 180°$ $\quad v = \sqrt{gl}$ $\quad T = 0$ (At top of circle)

Laws of Motion

- **Momentum** $p = m \times v$
- **Force** $F = ma = \frac{dp}{dt}$; $\vec{F}_{AB} = -\vec{F}_{BA}$
- **Impulse** $J = mv$
- **Law of Conservation of Momentum** $\vec{p} = \text{constant}$ [if $F_{ext} = 0$]
- **Equilibirium of a particle** $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$
- **Limiting friction** $f_s = \mu_s R$ μ_s = Cofficient of Static friction
- **Kinetic friction** $f_k = \mu_k R$ μ_k = Cofficient of Kinetic friction
- **Angle of friction** $\tan\theta_s = \mu_s$
- **Friction on an inclined Plane** $\mu_s = \tan\theta_s$; $\mu_k = \tan\theta_k$

$$\mu_s = \frac{f_s}{R} = \frac{f_s}{mg}$$

$$f = \frac{mv^2}{R}$$

- **Motion of a car on a level road** $v_{max} = \sqrt{\mu_s R g}$
- **Motion of a car on a banked road** $v_{max} = \left[Rg\,\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}\right]^{1/2}$

Work, Energy And Power

- **Work Energy Theorem** $\boxed{K_f - K_i = W}$ OR $\boxed{\Delta K = W}$
- **Work** $\boxed{W = \vec{F} \cdot \vec{S}}$
- **Kinetic Energy** $\boxed{K = \frac{1}{2} m v^2}$
- **Work done by a variable force** $\boxed{W = \int_{x_1}^{x_2} F\,dx}$
- **Power** $\boxed{P = \frac{dW}{dt}}$ OR $\boxed{P = Fv}$
- **Gravitational Potential Energy** $\boxed{U = mgh}$
- **Potential Energy of Spring** $\boxed{U = \frac{1}{2} k x^2}$
- **Conservative Forces as Negative gradient of Potential Energy**

$$\boxed{\frac{dU}{dx} = -F} \quad \text{OR} \quad \boxed{\frac{dU}{dx} = F'}$$

- **Equivalence of Mass and Energy** $\boxed{E = mc^2}$
- **Conservation of Energy** $\boxed{\Delta K + \Delta U = 0}$ OR $\boxed{\Delta E = 0}$

- **Elastic collision in 1D**

$$\boxed{u_1 - u_2 = v_2 - v_1 = -(v_1 - v_2)}$$

$$\boxed{v_1 = \left[\frac{m_1 - m_2}{m_1 + m_2}\right] u_1 + \left[\frac{2m_2}{m_1 + m_2}\right] u_2}$$

$$\boxed{v_2 = \left[\frac{2m_1}{m_1 + m_2}\right] u_1 + \left[\frac{m_2 - m_1}{m_1 + m_2}\right] u_2}$$

1. If $m_1 = m_2 = m$

   then $\boxed{v_1 = u_2}$ and $\boxed{v_2 = u_1}$

2. If m_2 is in rest i.e. $u_2 = 0$

$$\boxed{v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1} \quad \boxed{v_2 = \left(\frac{2m_1}{m_1 + m_2}\right) u_1}$$

- **Elastic Collision in 2D**

Along X-axis,

$$\boxed{m_1 u_1 = m_1 v_1 \cos\theta + m_2 v_2 \cos\theta}$$

Along Y-axis,

$$\boxed{0 = m_1 v_1 \sin\theta + m_2 v_2 \sin\theta}$$

$$\boxed{m_1 u_1^2 = m_1 v_1^2 + m_2 v_2^2}$$

- **Perfectly inelastic collision**

$$\boxed{m_1 u_1 + m_2 u_2 = (m_1 + m_2) v}$$

$$\boxed{\frac{K_2}{K_1} = \frac{m_1}{m_1 + m_2}}$$

System of Particle And Rotational Motion

- Centre of Mass of a two-particle system $\vec{r}_{cm} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$
- Centre of Mass of a system of n-particles $\vec{r}_{cm} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2 + \dots m_n\vec{r}_n}{m_1 + m_2 + \dots + m_n}$
- Centre of Mass of a Rigid body $\vec{r}_{cm} = \dfrac{1}{M}\int \vec{r}\, dm$
- Centre of Mass of a uniform rod $x_{cm} = \dfrac{l}{2}$
- Motion of the centre of mass $\vec{v}_{cm} = \dfrac{1}{M}(m_1\vec{v}_1 + m_2\vec{v}_2 + \dots + m_n\vec{v}_n)$

  and $M\vec{a}_{cm} = \vec{F}_{ext}$
- Momentum conservation $\vec{P} = M\vec{v}_{cm}$
- Centre-of-Mass motion $\dfrac{d\vec{P}}{dt} = \vec{F}_{ext}$
- Torque $\vec{\tau} = \vec{r} \times \vec{F}$
- Acceleration of Centre of Mass $\vec{a}_{cm} = \dfrac{\vec{F}}{M}$
- Angular Acceleration $\alpha = \dfrac{d\omega}{dt}$ $a = r\alpha$ $v = r\omega$
- Equations of Rotational Motion

  $\omega = \omega_0 + \alpha t$ $\theta = \omega_0 t + \dfrac{1}{2}\alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\theta$
- Moment of Inertia $I = \Sigma m r^2$
- Radius of Gyration $k = \sqrt{\dfrac{I}{M}}$
- Relation between τ and α $\vec{\tau} = \vec{I} \times \vec{\alpha}$
- Theorem of Parallel axis $I = I_{cm} + Ma^2$
- Theorem of Perpendicular axis $I_z = I_y + I_x$
- Relation between L and I $\vec{L} = \vec{I} \times \vec{\omega}$
- Rate of Change of Angular Momentum $\dfrac{d\vec{L}}{dt} = \vec{\tau}_{ext}$
- Law of Conservation of Angular momentum $\vec{L} = \text{constant}$ (If $\vec{\tau}_{ext} = 0$)

Equilibrium of rigid body 1) $\boxed{\sum_{i=1}^{n} \vec{F_i} = 0}$ 2) $\boxed{\sum_{i=1}^{n} \vec{\tau_i} = 0}$

some of all forces & Torque must be zero.

Kinetic Energy of Rotation $\boxed{K = \frac{1}{2} I\omega^2}$

Condition of Rolling of a body without sliding over an inclined Plane

$$\boxed{f_s = \frac{Ia}{r^2}} \qquad \boxed{a = \frac{g\sin\theta}{\left(1 + \frac{K^2}{R^2}\right)}}$$

(i) If the rolling body is a solid cyclinder

$$\boxed{\mu_s = \frac{1}{3}\tan\theta}$$

(ii) If the rolling body is a solid Sphere

$$\boxed{\mu_s = \frac{2}{7}\tan\theta}$$

Total Energy of a body Rolling without sliping

$$\boxed{K_{total} = K_{rot} + K_{trans}} \text{ and } \boxed{K_{total} = \frac{1}{2} I\omega^2 + \frac{1}{2} Mv^2}$$

Rolling Motion $\boxed{V_{cm} = R\omega}$

1. Rolls without slip $V_{cm} = R\omega$
2. Rolls with sliping in forward direction $V_{cm} > R\omega$
3. Rolls with sliping in Backword direction $V_{cm} < R\omega$

Gravitation

Kepler's law

First law (law of orbits) Planets move in elliptical orbits around sun

Second law (Law of Areal velocity) $\boxed{\frac{dA}{dt} = \frac{L}{2m}}$

Third law (Law of Periods) $\boxed{T^2 \propto a^3}$

Universal law of Gravitation

$\boxed{F = G\frac{m_1 m_2}{r^2}}$ Vector form, $\boxed{\vec{F} = -G\frac{m_1 m_2}{|\vec{r}|^3}\hat{r}}$

$G = 6.67 \times 10^{-11}\ N\,m^2/kg^2$ (Universal Gravitational Constant)

Intensity of Gravitational field

$\boxed{\vec{I} = \frac{\vec{F}}{m}}$

Relation between 'g' and 'G'

$\boxed{g = \frac{GM_e}{R_e^2}}$

g = Acceleration due to earth's gravity
M_e = Mass of Earth
R_e = Radius of Earth
ρ = Density of Earth

Computation of Mass and Density of Earth

$\boxed{M_e = \frac{gR_e^2}{G}}$ $M_e = 6.0 \times 10^{24}$

$\boxed{\rho = \frac{3g}{4\pi R_e G}}$ $\rho = 5.5 \times 10^3\ kg/m^3$

Variation in Acceleration due to gravity above the surface of the earth

$\boxed{g' = \frac{g}{\left(1 + \frac{h}{R_e}\right)^2}}$

Variation in Acceleration due to gravity below the surface of the earth

$\boxed{g' = g\left(1 - \frac{h}{R_e}\right)}$

Gravitational Potential

$\boxed{V = -\frac{W}{m}}$ OR $\boxed{V = -\frac{GM}{r}}$

Gravitational Potential Energy

$\boxed{U = -\frac{GMm}{r}}$

Speed of Satellite

$\boxed{V_0 = \sqrt{gR_e}}$ V_0 = orbital velocity

Period of Revolution of Satellite

$\boxed{T = \sqrt{\frac{3\pi}{G\rho}}}$

Total Energy of Satellite

$\boxed{E = -\frac{1}{2}\frac{GM_e m}{R_e}}$

⭐ Binding Energy of a Satellite $\boxed{= +\frac{1}{2}\frac{GM_e m}{R_e} = +\frac{1}{2} mgR_e}$

⭐ Geostationary Satellite $\boxed{R_e + h = \left(\frac{T^2 g R_e}{4\pi^2}\right)^{1/3}}$

for $T = 24$ hours

$h = 35745$ km

⭐ Escape Energy $\boxed{= +\frac{GM_e m}{R_e}}$

Escape velocity $\boxed{V_e = \frac{2GM_e}{R_e}}$

OR

$\boxed{V_e = \sqrt{2gR_e}}$

⭐ Relation between v_o and v_e $\boxed{V_e = \sqrt{2}\, v_o}$

Mechanical Properties of Solids

- **Stress** = $\boxed{\dfrac{\text{Restoring force}}{\text{Area}} = \dfrac{F}{A}}$

- **Strain**
  - $\boxed{\text{Longitudinal strain} = \dfrac{\Delta L}{L}}$
  - $\boxed{\text{Shearing strain} = \dfrac{\Delta x}{L} = \tan\theta}$
  - $\boxed{\text{Volume strain} = \dfrac{\Delta V}{V}}$

- **Hooke's Law** $\boxed{E = \dfrac{\text{Stress}}{\text{Strain}}}$

  E = Modulus of Elasticity

- **Young's Modulus of Elasticity**

  $\boxed{Y = \dfrac{\sigma}{\varepsilon} = \dfrac{MgL}{\pi r^2 \Delta L}}$

  σ = longitudinal stress
  ε = longitudinal strain

  $\boxed{Y_{steel} > Y_{rubber}}$

- **Bulk Modulus of Elasticity**

  $\boxed{B = \dfrac{\text{Normal Stress}}{\text{Volume Strain}} = \dfrac{-PV}{\Delta V}}$

- **Compressibility** $\boxed{\beta = \dfrac{1}{B} = \dfrac{-\Delta V}{PV}}$

- **Modulus of Rigidity** $\boxed{\eta = \dfrac{F}{A\theta}}$

- **Possion's Ratio** $\boxed{\sigma = \dfrac{\Delta r\, L}{\Delta L\, r}}$

- **Force produced in cooling a wire streched between two rigid supports** $\boxed{F = YA\alpha\Delta t}$

- **Work done in stretching a wire and Elastic potential Energy**

  $\boxed{W = U = \dfrac{1}{2} \times \text{Stress} \times \text{Strain} \times \text{Volume}}$ $\boxed{W = \dfrac{1}{2}\dfrac{YA}{L}x^2}$

- **Energy density** $\boxed{u = \dfrac{1}{2} \times \text{Stress} \times \text{Strain}}$ and $\boxed{u = \dfrac{1}{2} \times \text{Young's Modulus} \times (\text{Strain})^2}$

Mechanical Properties of fluids

- **Pressure** $P = \frac{F}{A}$ OR $P = \frac{dF}{dA}$
- **Volume density** $\rho = \frac{m}{V}$
- **Effect of gravity on fluid pressure** $p = p_2 - p_1 = h\rho g$

η = viscosity
D = Diameter of pipe
R_e = Reynold No.

- **Critical velocity of a liquid** $v_c = \frac{R_e \eta}{\rho D}$
- **Reynold number** $R_e = \frac{\rho v d}{\eta}$
- **Cofficient of viscocity** $F = \pm \eta A \frac{\Delta v_x}{\Delta z}$ $\quad \eta = \frac{F l}{v A}$
- **Terminal velocity** $v = \frac{2}{9} \frac{r^2 (\rho - \sigma) g}{\eta}$
- **Kinetic Energy** $K = \frac{1}{2} \rho v^2$
- **Potential Energy** $U = \rho g h$
- **Principal of Continuity** $A \times v = \text{constant}$
- **Stroke's Law** $F = 6 \pi \eta r v$
- **Bernoullis Theorem**

$$P + \frac{1}{2} \rho v^2 + \rho g h = \text{constant}$$

OR

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$$

$$\frac{P}{\rho g} + \frac{v^2}{2g} + h = \text{constant}$$

$\frac{P}{\rho g}$ = Pressure head, $\frac{v^2}{2g}$ = velocity head

$$P + \frac{1}{2} \rho v^2 = \text{constant}$$

If $(h_1 = h_2)$

h = gravitational head

- **Venturimeter** $v_1 = \sqrt{\frac{2 \rho_m g h}{\rho}} \left[\left(\frac{A}{a} \right)^2 - 1 \right]^{-1/2}$
- **Velocity Gradient** $= \frac{\Delta v}{\Delta z}$
- **Velocity of Efflux of a liquid** $v = \sqrt{2gh}$ (Torricelli's Theorem)

$$t = \sqrt{\frac{2(H-h)}{g}} \qquad x = 2\sqrt{h(H-h)} \qquad x_{max} = H$$

H = height of fluid level
h = height of orifice from top

- **Work done in increasing the surface area of free surface of the liquid**

$$F = T \times 2l \qquad W = T \times 2l \times \Delta x \qquad W = T \times \Delta A$$

T = Surface Tension
ΔA = Increment in surface Area

- **Excess of Pressure**

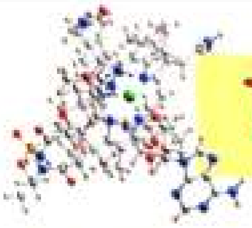
(i) Excess of Pressure inside a liquid drop $P = \frac{2T}{R}$

(ii) Excess of Pressure inside in an air bubble in a liquid $P = \frac{2T}{R}$

(iii) Excess of Pressure inside a bubble of a Soap Solution $P = \frac{4T}{R}$

- **Capillary** $h \rho g = \frac{2T}{R}$ $\quad h = \frac{2T \cos\theta}{r \rho g}$

r = radius of capillary
R = Radius of meniscus



Thermal Properties of Matter

- Scale of Temperature $\boxed{T_F = 32^\circ + \frac{9}{5} T_C}$
- Ideal gas Equation
  - For 1 mole $\boxed{PV = RT}$
  - For μ mole $\boxed{PV = \mu RT}$
- Absolute Temperature $\boxed{T = T_C + 273.15}$
- Thermal Expansions of Solids
  - Cofficient of linear Expansion $\boxed{\alpha = \frac{\Delta L}{L \times \Delta t}}$
  - Cofficient of Superficial Expansion $\boxed{\beta = \frac{\Delta A}{A \times \Delta t}}$
  - Cofficient of Volume Expansion $\boxed{\gamma = \frac{\Delta V}{V \times \Delta t}}$
- Relation between α and β $\boxed{\beta = 2\alpha}$
- Relation between γ and α $\boxed{\gamma = 3\alpha}$
- Relation between β and γ $\boxed{3\beta = 2\gamma}$
- Relation between α, β and γ $\boxed{\alpha : \beta : \gamma = 1:2:3}$
- Variation of density with temperature of liquids $\boxed{d_t = d_0(1 - \gamma_r t)}$
- Heat capacity $\boxed{S = \frac{\Delta Q}{\Delta t}}$
- Specific heat capacity $\boxed{s = \frac{S}{m} = \frac{1}{m}\frac{\Delta Q}{\Delta t}}$
- Heat Capacity per mole $\boxed{C = \frac{S}{\mu} = \frac{1}{\mu}\frac{\Delta Q}{\Delta t}}$
- Calorimeter $\boxed{W = mc}$
- Principal of Calorimeter

  $\boxed{\text{Heat lost} = \text{Heat taken}}$

  OR

  $\boxed{m_1 c_1 (t_1 - t) = m_2 c_2 (t - t_2)}$
- Latent Heat $\boxed{L = \frac{m}{Q}}$
- Cofficient of Thermal conductivity $\boxed{Q = KA\frac{(\theta_1 - \theta_2)t}{l}}$ Q = Heat flowed
- Rate of Heat flowed OR Heat current $\boxed{H = \frac{Q}{t} = KA\frac{\theta_1 - \theta_2}{l}}$

☆ Thermal Radiation $I \propto \frac{1}{\lambda^2}$ $\lambda_{radiation} > \lambda_{light}$

☆ Thermal Resistance $R = \frac{\theta_1 - \theta_2}{H} = \frac{l}{KA}$ ☆ Emissivity $e = \frac{Q}{A \times t}$

☆ Kirchoff's law $\frac{e_\lambda}{a_\lambda} = E_\lambda$

☆ Stefan's law $E = \sigma T^4$

e_λ = Spectral Emissive power
a_λ = Spectral absorption power
E_λ = Emissive power of black body
σ = Stefan's constant

☆ Newton's law of cooling $-\frac{dQ}{dt} = K(T_2 - T_1)$ and $\log_e(T_2 - T_1) = -KT + c$

☆ Wein's law $\lambda_m \times T = b$

λ_m = wave length
T = Temperature

Note :- 1. $T_{low} \leq T_{mixture} \leq T_{High}$

2. $T_{mixture} = \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2}$

Thermodynamics

- Equivalence of Work and heat $\boxed{W = JH}$ J = mechanical equivalent of heat

  $\boxed{1 \text{ Kilocalori} = 4.18 \times 10^3 \text{ Joule}}$

- Work $\boxed{W = P(V_2 - V_1)}$ OR $\boxed{\Delta W = P\Delta V}$

- First law of thermodynamics $\boxed{\Delta U = \Delta Q - \Delta W}$ OR $\boxed{\Delta U = \Delta Q - P\Delta V}$

- Mayer's formula $\boxed{C_p - C_v = R}$

$$\boxed{C_v = \left(\frac{\Delta Q}{\Delta T}\right)_v = \left(\frac{\Delta U}{\Delta T}\right)_v}$$

$$\boxed{C_p = \left(\frac{\Delta Q}{\Delta T}\right)_p = \left(\frac{\Delta U}{\Delta T}\right)_p + P\left(\frac{\Delta V}{\Delta T}\right)_p}$$

- Isothermal process (T constant)

$$\boxed{W = \mu RT \ln \frac{V_2}{V_1}}$$

- Isochoric process $\boxed{V = \text{constant}}$

- Isobaric process $\boxed{P = \text{Constant}}$

$$\boxed{W = P(V_2 - V_1) = \mu R(T_2 - T_1)}$$

- Adiabatic Process $\boxed{PV^{\gamma} = \text{constant}}$

$$\boxed{\gamma = \frac{C_p}{C_v}} \qquad \boxed{TV^{\gamma-1} = \text{constant}}$$

$$\boxed{W = \frac{\mu R(T_1 - T_2)}{\gamma - 1}} \qquad \boxed{\frac{T^{\gamma}}{P^{\gamma-1}} = \text{Constant}}$$

- Cyclic Process $\boxed{\Delta U = 0}$

- Total Internal Energy of an ideal gas $\boxed{U = \frac{1}{2} fRT}$

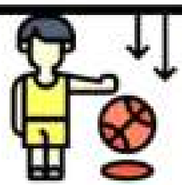
$$\boxed{C_v = \frac{1}{2} fR} \qquad \boxed{C_p = \left(\frac{f}{2} + 1\right)R} \qquad \boxed{\gamma = 1 + \frac{2}{f}}$$

- Second law of thermodynamics $\boxed{W = Q_1 - Q_2}$ $\boxed{\eta = \frac{W}{Q_1}}$

$$\boxed{\eta = 1 - \frac{Q_2}{Q_1}} \text{ OR } \boxed{\eta = 1 - \frac{T_2}{T_1}} \quad \because \boxed{\frac{Q_1}{Q_2} = \frac{T_1}{T_2}}$$

- Heat Engine

1. Isothermal Expansion $\boxed{W_1 = RT_1 \log_e \frac{V_2}{V_1}}$ (T constant)
2. Adiabatic Expansion $\boxed{W_2 = \frac{R}{1-\gamma}(T_2 - T_1)}$ (PV^{γ} = constant)
3. Isothermal compression $\boxed{W_3 = -RT_2 \log_e \frac{V_3}{V_4}}$
4. Adiabatic compression $\boxed{W_4 = \frac{R}{1-\gamma}(T_1 - T_2)}$



Kinetic Theory

- **Boyel's law** — At constant T — $\boxed{V \propto \frac{1}{P}}$ OR $\boxed{PV = \text{Constant}}$ $\boxed{P_1 V_1 = P_2 V_2}$

- **Charle's law** — At constant P — $\boxed{V \propto T}$ OR $\boxed{\frac{V}{T} = \text{Constant}}$ $\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$

- **Ideal Gas Equation** — $\boxed{PV = \mu RT}$ For μ mole $\boxed{PV = RT}$ For 1 mole

  $R = 8.31$ J/mol-K (Universal Gas Constant)

- **Dalton's law of Partial Pressure** — $\boxed{P = \mu_1 \frac{RT}{V} + \mu_2 \frac{RT}{V} + \cdots = P_1 + P_2 + \cdots}$

- **Formula for the pressure of an ideal gas** — $\boxed{P = \frac{1}{3}\frac{mn}{V}\bar{v}^2}$ OR $\boxed{P = \frac{1}{3}\rho \bar{v}^2}$

- **Root mean square velocity** — $\boxed{\bar{v}^2 = \frac{3RT}{M}}$ $\boxed{v_{rms} = \sqrt{\frac{3RT}{M}}}$ $\boxed{v_{rms} \propto \sqrt{T}}$

- **Kinetic Interpretation of Temperature** — $\boxed{\frac{E}{N} = \frac{3}{2}K_B T}$ If $n = 1$ $\boxed{E = \frac{3}{2}K_B T}$ (K.E for 1 atom)

- **Real gas Equation** — $\boxed{\left(P + \frac{a}{V^2}\right)(V - b) = RT}$

- **Graham's law of diffusion** — $\boxed{\frac{V_{1\,rms}}{V_{2\,rms}} = \frac{R_1}{R_2} = \sqrt{\frac{M_2}{M_1}}}$ R = Rate of diffusion

- **Law of Equipartition of Energy**

  $\boxed{E_t = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2}$ $\boxed{E_{xyz} = \frac{3}{2}K_B T}$ K_B = Boltzmann's constant

- **Specific Heat Capacity**

  1.) Monoatomic Gas $\boxed{C_p = \frac{5}{2}R}$ $\boxed{C_v = \frac{3}{2}R}$ $\boxed{\gamma = \frac{5}{3}}$

  2.) Diatomic Gas $\boxed{C_p = \frac{7}{2}R}$ $\boxed{C_v = \frac{5}{2}R}$ $\boxed{\gamma = \frac{7}{5}}$

  3.) Polyatomic Gas $\boxed{C_p = (4+f)R}$ $\boxed{C_v = (3+f)R}$ $\boxed{\gamma = \frac{4+f}{3+f}}$

  4.) Specific Heat capacity of Solids $\boxed{C = 3R}$

  5.) Specific Heat capacity of water $\boxed{C = 9R}$

- **Mean free path** — $\boxed{\lambda = \frac{1}{\sqrt{2}\pi d^2 n}}$

  for N atoms $\boxed{\lambda = \frac{K_B T}{\sqrt{2}\pi d^2 P}}$ where $n = \frac{N}{V} = \frac{P}{K_B T}$

Oscillations

- Relation between ν and T $\boxed{\nu = \frac{1}{T}}$

  ν = frequency

- Time period $\boxed{T = \frac{2\pi}{\omega}}$

- Displacement Equation of Simple Harmonic Motion (S.H.M.)

  $\boxed{x(t) = A\cos(\omega t + \phi)}$ $\boxed{y(t) = a\sin(\omega t + \phi)}$

- Velocity in S.H.M. $\boxed{v(t) = -\omega A\sin(\omega t + \phi)}$ $\boxed{v(t) = \frac{d}{dt}x(t)}$

- Acceleration in S.H.M. $\boxed{a = -\omega^2 x(t)}$

- Time - Displacement curve of S.H.M. $\boxed{y = a\sin\left[2\pi \frac{t}{T}\right]}$

- force law in Simple Harmonic motion (Spring)

  $\boxed{F = -kx}$ $\boxed{\omega = \sqrt{\frac{K}{m}}}$ $\boxed{T = 2\pi\sqrt{\frac{m}{2K}}}$

  ω = angular frequency
  T = Time period

- Potential Energy in S.H.M. $\boxed{U = \frac{1}{2}m\omega^2 y^2}$

- Kinetic Energy in S.H.M. $\boxed{K = \frac{1}{2}m\omega^2(a^2 - y^2)}$

- Total Energy in S.H.M. $\boxed{E = \frac{1}{2}m\omega^2 a^2 = 2\pi^2 m n^2 a^2}$

- Time period of S.H.M. $\boxed{T = 2\pi\sqrt{\frac{m}{K}}}$

- Motion of body suspended by two springs $\boxed{T = 2\pi\sqrt{\frac{m}{K_1 + K_2}}}$ $\boxed{T = 2\pi\sqrt{m\left(\frac{1}{K_1} + \frac{1}{K_2}\right)}}$

- Time period of Simple Pendulam $\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$

- Second's Pendulam $\boxed{l = \frac{g}{\pi^2} = 1\ m}$

- Time period of a simple pendulam of infinite length $\boxed{T = 2\pi\sqrt{\frac{R_e}{g}}}$

  R_e = Radius of Earth (6.4×10^6 m)

- Electromagnetic Resonance frequency $\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$

Damped Simple Harmonic motion

$$\boxed{x(t) = A e^{-bt/2m} \cos(\omega' t + \phi)}$$

$$\boxed{\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}} \qquad \boxed{E(t) = \frac{1}{2} k A^2 e^{-bt/m}}$$

ω' = angular frequency

Forced Oscillations

$$\boxed{F(t) = F_0 \cos \omega_d t} \qquad \boxed{x(t) = A \cos(\omega_d + \phi)}$$

$$\boxed{A = \frac{F_0}{\{m^2(\omega^2 - \omega_d^2)^2 + \omega_d^2 b^2\}^{1/2}}}$$

ω = natural frequency
ω_d = driven frequency
A = Amplitude

(a) Small Damping, Driving frequency far from natural frequency

$$\boxed{A = \frac{F_0}{m(\omega^2 - \omega_d^2)}}$$

(b) Driving frequency close to Natural frequency

$$\boxed{A = \frac{F_0}{\omega_d b}}$$

Waves

- **Wave Speed** $v = \frac{\lambda}{T}$ OR $v = n\lambda$
- **Time period** $T = \frac{2\pi}{\omega}$
- **Wave number** $\bar{\nu} = \frac{1}{\lambda}$
- **Angular frequency** $\omega = 2\pi n$
- **Propagation constant** $K = \frac{2\pi}{\lambda}$ OR $v = \frac{\omega}{K}$
- **frequency** $\nu = \frac{\omega}{2\pi} = \frac{1}{T}$
- **Wave Equation**

$$y(x,t) = a \sin(kx \pm \omega t + \phi)$$

$$y(x,t) = A \sin(kx - \omega t) + B \cos(kx - \omega t)$$

$$a = \sqrt{A^2 + B^2} \qquad \tan\theta = \frac{B}{A}$$

- **Speed of transverse wave in solid** $v = \sqrt{\frac{\eta}{d}}$ η - rigidity coefficient
- **Speed of transverse wave in stretched string** $v = \sqrt{\frac{T}{\mu}}$ T = tension of the string, μ = linear mass density
- **Speed of longitudinal wave in liquid** $v = \sqrt{\frac{\beta}{\rho}}$ β - Bulk modulus
- **Speed of longitudinal wave in solid** $v = \sqrt{\frac{Y}{\rho}}$ Y - Young's modulus
- **Speed of longitudinal wave in gases OR sound in gases** $v = \sqrt{\frac{P}{\rho}}$ P - initial Pressure
- **Laplace correction** $v = \frac{\gamma P}{\rho}$ ρ - density
- **Effect of temperature on the speed of longitudinal wave**

$$v = \frac{\gamma RT}{M} \quad \text{OR} \quad \frac{v_1}{v_2} = \sqrt{\frac{M_2}{M_1}}$$

- **Relation between v and v_{rms}** $v = \left(\sqrt{\frac{\gamma}{3}}\right) v_{rms}$
- **Principle of Superposition** $y(x,t) = y_1(x,t) + y_2(x,t)$

Relation between Phase difference and Path difference of two particles in progressive wave

$$\boxed{\Delta\phi = \frac{2\pi}{\lambda} \times \Delta x}$$ $$\boxed{\Delta\phi = \frac{2\pi}{\lambda} \times \Delta t}$$

Velocity Amplitude and Acceleration amplitude of a particle in a progressive wave

↳ Velocity Amplitude $\boxed{u_{max} = \omega a}$ ↳ Acceleration Amplitude $\boxed{f_{max} = -\omega^2 a}$

Equation of Stationary wave

$$\boxed{y = 2a \cos\frac{2\pi x}{\lambda} \sin\frac{2\pi t}{T}}$$ $$\boxed{y = -2a \sin\frac{2\pi x}{\lambda} \cos\frac{2\pi t}{T}}$$

Beat frequency

$$\boxed{\nu_{beat} = \nu_1 - \nu_2}$$

Modes of vibration of Air column in closed organ pipe

$$\boxed{\lambda = \frac{4l}{2m-1}}$$

1. first mode of Vibration $m=1$, $\boxed{\lambda_1 = 4l}$ $\boxed{f_1 = \frac{v}{4l}}$
2. Second mode of vibration $m=2$, $\boxed{\lambda_2 = \frac{4l}{3}}$ $\boxed{f_2 = \frac{3v}{4l}}$ ⇒ $\boxed{f_2 = 3f_1}$
3. Third mode of vibration $m=3$, $\boxed{\lambda_3 = \frac{4l}{5}}$ $\boxed{f_3 = \frac{5v}{4l}}$ ⇒ $\boxed{f_3 = 5f_1}$

$$\boxed{f_1 : f_2 : f_3 \ldots = 1 : 3 : 5 \ldots}$$

Modes of vibration of Air column in open organ pipe

$$\boxed{\lambda = \frac{2l}{m}}$$ $$\boxed{f_m = \frac{v}{\lambda_m} = \frac{mv}{2l}}$$ $$\boxed{f_1 : f_2 : f_3 = 1 : 2 : 3}$$

End Correction

Open Pipe

$$\boxed{f = \frac{v}{2(l + 1.2r)}}$$

Closed Pipe

$$\boxed{f = \frac{v}{4(l + 0.6r)}}$$

Doppler Effect

1. source moving observer stationary $\boxed{\nu = \nu_0\left(1 + \frac{v_s}{v}\right)}$ $\boxed{\nu = \nu_0\left(1 - \frac{v_s}{v}\right)}$
2. Observer moving source stationary $\boxed{\nu = \nu_0\left(1 + \frac{v_0}{v}\right)}$
3. Both source and observer moving $\boxed{\nu = \nu_0\left(\frac{v + v_0}{v + v_s}\right)}$

ν = frequency of wave
ν_0 = frequency at $t = \sqrt{0}$
v = velocity of wave
v_s = velocity of Source
v_0 = velocity of observer