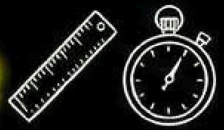
Class - XI : PHYSICS

Chapter–1: Units and UNIT, MEASUREMENTS	Chapter–2: MOTION in a Straight Line	Chapter–3: MOTION in a PLANE
Chapter–4: LAWS of MOTION	Chapter–5: Work, Energy WORK, ENERGY and POWER	Chapter–6: SYSTEMS of Particles and ROTATIONAL MOTION
Chapter–7: GRAVITATION	Chapter–8: Mechanical Properties of SOLIDS	Chapter–9: Mechanical Properties of FLUIDS
Chapter–10: Thermal Properties of MATTER	Chapter–11: THERMODYNAMICS	Chapter–12: KINETIC THEORY
Chapter–13: OSCILLATIONS	Chapter–14: WAVES	Must-Remember Constants & Symbols $G = 6.67 \times 10^{-11}$ N m²/kg² $R = 8.314$ J/mol·K $N_A = 6.022 \times 10^{23}$ mol⁻¹ $\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴ $h = 6.626 \times 10^{-34}$ J·s $g = 9.8$ m/s² [cite: 3, 16, 18]

Chapter–1: Units and Measurements

1. Need for Measurement & Units

- 'Why measure?'
- 'What is a unit?' UNIT



⇨ **Systems of Units**

- 'CGS, FPS, MKS, SI, SI UNITS

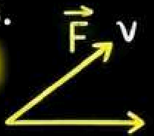
2. SI Units

› 7 Fundamental Quantities & Units

- Length (L)
- Mass (M)
- Time (t)
- Temperature (K)
- Current (A)
- Amount of Substance (A)
- Luminous Intensity (cd)

⇨ **Derived Units**

Are combinations of base units.
Ex: Velocity (m/s) , Force (N)
Force (N)



3. Significant Figures

› **Rules**

- Non-zero digits are significant.
  Ex: 123.4 (4 sig figs) ✓
- Zeros between non-zeros are
  100.5 (4 sig figs)

› **Determining**

Ex: Leading zeros are not
not significant.
Ex: 0.003 (1 sig fig)

Ex: Trailing zeros with a
decimal are significant.
Ex: 4.00 (3 sig figs)

→ Absolute error ernıl
or tinor error = ERROR

☆ → Relative ERROR error
Percentage := 2.0 %

→ Accuracy vs $\frac{\text{Precision}}{\text{Error}}$

4. Uncertainty in Result

- Accuracy vs. Precision is correct
- Absolute error: $|\Delta a| = |a_{mean} - a_i|$
- Absolute error: $\delta a = \frac{\Delta a_{mean}}{a_{mean}}$
- Relative error:
- Percentage error: $\frac{\Delta a_{mean}}{} \times 100\%$

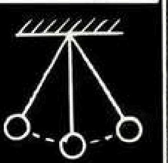
5. Dimensions of Physical Quantities

↳ How to find his dimensions:- (e.g., F=ma)

Length of [L]
Mass of [T]
Force [M L T^{-2}]
→ Momentum [M L T^{-1}]
Rem : = [M L T^{-1}]

6. Dimensional Analysis & Its Applications

- Checking Correctness of Equations
  (e.g., $v^2 - u^2 = 2as$)
- Deriving Relationships:
  (e.g., $T = 2\pi\sqrt{\frac{L}{g}}$)

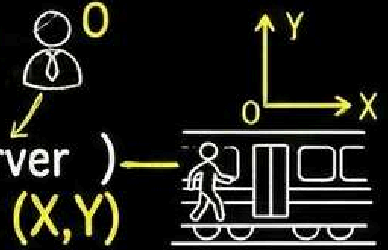


Unit II: Kinematics, Chapter–2: Motion in a Straight Line

1. Frame of Reference & Motion

⇨ Frame of Reference (o observer or):

- Observer (no observer)—
- Coordinate System (X,Y)



⇨ Motion vs. Rest time

⇨ Motion vs. Rest are relative

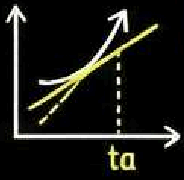
2. Basic Concepts (Rectilinear Motion)

- Position (x)
- Displacement (Δx)
- Path Length: (Distance)
  ↳ Difference between path vector

3. Rates of Change - Calculus Treatment

⇨ Elementary Derivatives & Integrals

- Velocity (v) = $\frac{dx}{dt}$ $\int v\, dt = \Delta x$
- Acceleration (a) = $\frac{dv}{dt} = \frac{d^2x}{dt^2}$

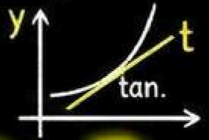


4. Types of Motion

(Uniform vs. Non-uniform)

⇨ Elementary Derivatives

- Velocity (v): $\frac{dx}{dt}$
- Acceleration (a): $\frac{dv}{dt} = \frac{d^2x}{dt^2}$



5. Motion in a Straight Line & Accelerated Motion

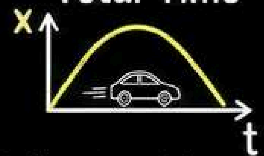
⇨ Uniformly Accelerated Motion (U.A.M.) a = constant

1. $v = v_0 + at$
2. $x = x_0 + v_0 t + \frac{1}{2}at^2$
3. $v^2 = v_0^2 + 2a(x - x_0)$
4. $\frac{v + v_0}{2} = v_{avg}$

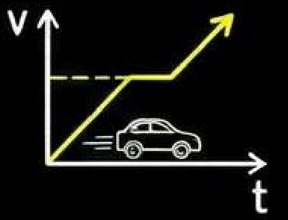
5. Motion in a Straight Line & Accelerated Motion

- Average Speed:: $\frac{\text{Total Path}}{\text{Total Time}}$
- Average Velocity:: $\frac{\text{Total Displacement}}{\text{Total Time}}$

6. Graphs of Position-Time



Position-Time



Velocity-Time

⇨ Find slope for slopey (x-t)

⇨ Area under the curve (v-t)

7. Calculus Treatment & Derivations

↳ Brief mvalus equations:-

$dv = a\,dt \longrightarrow \int dv = \int a\,dt$

$v = v_0 + a \longrightarrow \int v_0 + dt \rightarrow$ $v = v_0 + at$

Chapter-3: Motion in a Plane

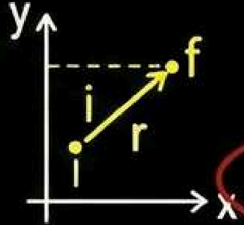
1. Scalars and Vector Quantities

⇨ Scalar: Magnitude only

⇨ Vector: Magnitude + Direction

Notation: $\vec{A} = |A|\,\hat{a}$

2. Basic Vector Concepts



- Position Vector (r)
- Displacement Vector:

$\Delta r = r_{final} - r_{initial}$

- Equality of Vectors
  ↳ Unit Vector: $\hat{a} = \frac{A}{|\vec{A}|}$

3. Vector Operations

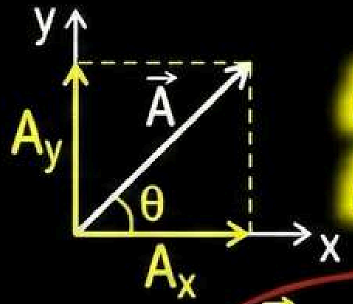
⇨ Multiplication by a Real Number: $k\vec{A}$

- Vector Addition (Triangle Law & Parallelogram Law)

$\vec{R} = \vec{A} + \vec{B}$

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

4. Vector Resolution



$A_x = A\cos\theta$

$A_y = A\sin\theta$

$\vec{A} = A_x\,\hat{i} + A_y\,\hat{j}$

5. Scalar and Vector Products

⇨ Scalar (Dot) Product

$\vec{A}\cdot\vec{B} = |A|\,|B|\cos\theta$

↳ Work done ($W = F\cdot s$)

⇨ Vector (Cross) Product

$\vec{A}\times\vec{B} = |A|\,|B|\sin\theta\,\tilde{n}$

($\tilde{n}$ is unit normal vector)

↳ Torque ($\tau = r\times F$)

6. Motion in a Plane: Cases

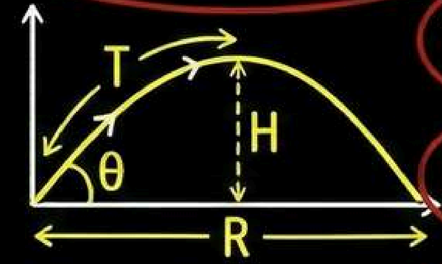
⇨ Uniform Velocity Motion

$R = R_0 + v_0 t$

⇨ Uniform Acceleration Motion

- Example: Torque ($\tau = r\times F$)

↳ Projectile Motion

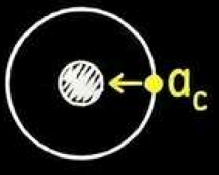


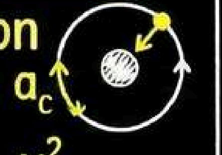
$T = \frac{2u\sin\theta}{g}$

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

$R = \frac{u^2\sin(2\theta)}{g}$

- Uniform Circular Motion
  - v
  - a_c



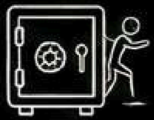


$a_c = \frac{v^2}{r} = \omega^2 r$

Unit III: Laws of Motion, Chapter–4: Laws of Motion

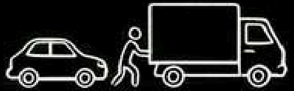
1. Laws of Motion: Key Concepts

⇨ Inertia & Newton's First Law (Law of Inertia)



⇨ Force: mass × acceleration ($\vec{F} = m\vec{a}$)

⇨ MOMENTUM ($\vec{p} = m\vec{v}$)

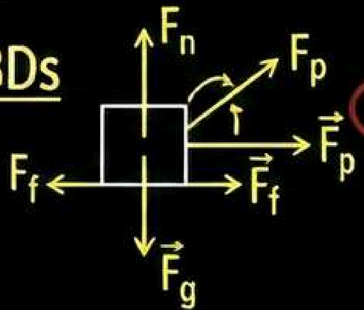


2. Newton's Second Law

$$F_{net} = \frac{d\vec{p}}{dt}$$

- $F_{net} = ma$
- For constant mass,
  ↳ $F_{net} = ma$

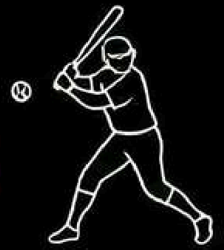
FBDs



3. Impulse & Second Law Application

⇨ Impulse (J)
↳ $\int F dt = \Delta\vec{p}$

$$\int F dt = \Delta\vec{p}$$



4. Newton's Third Law

$F_{action} = -F_{reaction}$

5. Conservation of Momentum

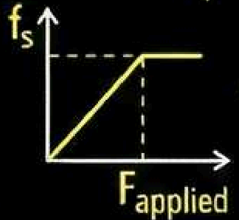
$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

- Exmples: Rocket propulsion
- Recoil of a gun

6. Concurrent Forces' Equilibrium

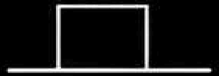
⇨ Static Friction (f_s)
- Rule:

$$f_s \le \mu_s * F_n$$



⇨ Kinetic Friction (f_k)

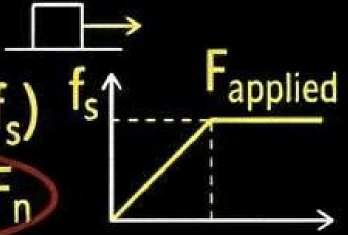
$$f_k = \mu_k * F_n$$



- Rolling Friction < Kinetic Friction
- Use Lubrication to reduce friction

7. Friction

⇨ Static Friction (f_s)
↳ Rule: $f_s \le \mu_s * F_n$



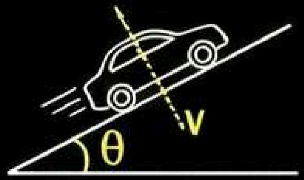
Rolling Friction < Kinetic Friction
- Use of Lubrication to reduce friction

8. Dynamics of Circular Motion

⇨ Centripetal Force (F_c)

$$F_c = \frac{mv^2}{r} = m\omega^2 r$$

⇨ Banking of Roads



$$v_{safe} = \sqrt{rg \tan\theta}$$

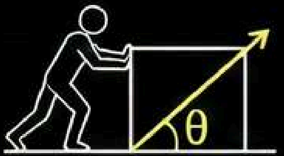
$$\tan\theta = \frac{v^2}{rg}$$

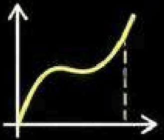
- Level Road Vehicle

$$v_{max} = \sqrt{\mu r g}$$

Unit IV: Chapter-5: Work, Energy and Power

1. Work (W)



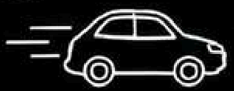


⇨ Variable forces

$W = \int \vec{F} \cdot d\vec{r}$

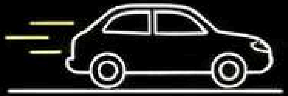
⇨ Constant forces explained

$W = F \cdot s \cos\theta$



2. Kinetic Energy (K.E.)

$K = \frac{1}{2}mv^2$



⇨ Work-Energy Theorem

$W_{net} = \Delta K = K_f - K_i$

3. Power (P)

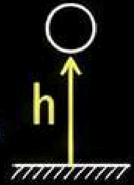
- Rate of doing work

$P = \frac{dW}{dt}$ or $P = F \cdot \vec{v}$

4. Potential Energy (P.E.)

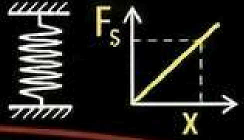
⇨ Notion explained

$\Delta U = -W_{conservative}$



5. Spring Potential Energy

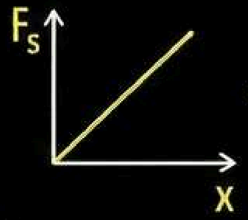
$U_s = \frac{1}{2}kx^2$



6. Conservative & Non-Conservative Forces

⇨ Conservative:

- Gravity
- Gravity, Spring



⇨ Non-Conservative:

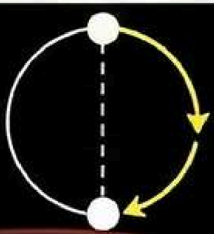
- Friction

$U = mgh$

7. Motion in a Vertical Circle

⇨ Critical speed

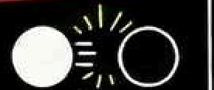
$v_{min\_top} = \sqrt{gr}$



$v_{min\_bottom} = \sqrt{5gr}$

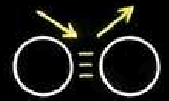
8. Collisions (One & Two Dimensions)

⇨ Elastic



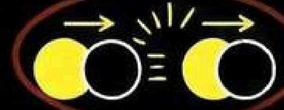
- K.E. is conserved, e=1, e=1

⇨ Inelastic



- K.E. is not conserved, e<1

⇨ coefficient of resttution (e) $e = -\frac{v_{2f} - v_{1f}}{v_{2i} - v_{1i}}$

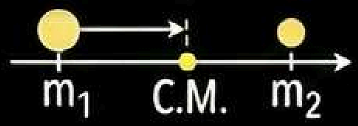


Unit V: Systems of Particles and Rotational Motion

1. Centre of Mass (C.M.)

⇨ Two-particle system (m_1, m_2)

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

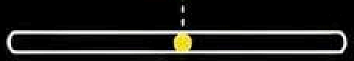


$$y_{cm} = \frac{m_1y_1 + m_2y_2}{m_1 + m_2}$$

⇨ Rigid Body

$$x_{cm} = \frac{1}{M}\int x\,dm \qquad y_{cm} = \frac{1}{M}\int y\,dm$$

⇨ Uniform Rod



$$x_{cm} = \frac{L}{2}$$ (from one end)

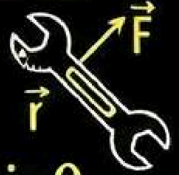
4. Momentum Conservation & C.M. Motion

• If $F_{ext} = 0$, $P_{total} = Mv_{cm} = \text{constant}$

$$M \times a_{cm} = F_{ext}$$

2. Dynamics of Rotation

⇨ Torque ($\vec{\tau}$)



• moment of a force

$$\vec{\tau} = \vec{r} \times \vec{F} \qquad |\vec{\tau}| = rF\sin\theta$$

⇨ Angular Momentum (L)

• moment of momentum

$$\vec{L} = \vec{r} \times \vec{p} \qquad |L| = rp\sin\theta = I\omega$$

3. Rotational Motion Equations of Angular Momentum

$v = u + at$	$\omega = \omega_0 + \alpha t$
$s = ut + \frac{1}{2}at^2$	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$v^2 = u^2 + 2as$	$\omega^2 = \omega_0^2 + 2\alpha\theta$
$\theta_n = \omega + I$	$\theta_n = \omega_0 + \frac{\alpha}{2}(2n-1)$

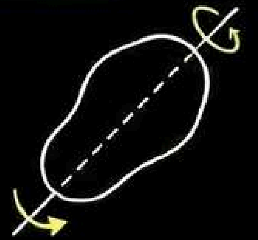
$$K_{rot} = \frac{1}{2}I\omega^2$$

Work in rotation

$$W = \int \tau\, d\theta \qquad P = \tau \cdot \omega$$

4. Moment of Inertia (I)

⇨ System



$$I = \sum m_i r_i^2$$

$$I = \int r^2 dm$$

⇨ Radius of Gyration (K)

$$I = MK^2 \Rightarrow K = \sqrt{\frac{I}{M}}$$

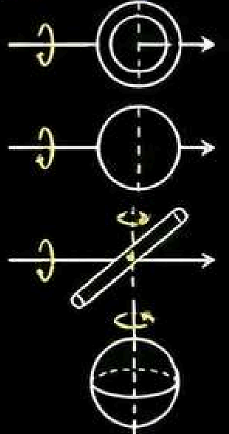
⇨ Values of I for Simple Objects

• Ring: $I = MR^2$

• Disc: $I = \frac{1}{2}MR^2$

• Rod: $I = \frac{1}{12}ML^2$

Sphere: $I = \frac{2}{5}MR^2$



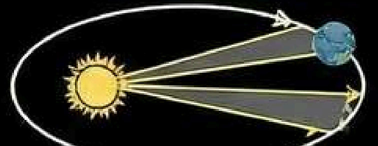
Unit VI: Chapter-7: Gravitation

1. Kepler's Laws of Planetary Motion

⇨ Law of Orbits (1st Law)

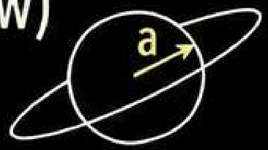
- Planets orbit the Sun in ellipses.

⇨ Law of Areas (2nd Law)



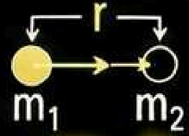
- Equal area per unit time ($A_1 = A_2$, $\Delta t_1 = \Delta t_2$).

⇨ Law of Periods (3rd Law)



$$T^2 \propto a^3$$

2. Universal Law of Gravitation

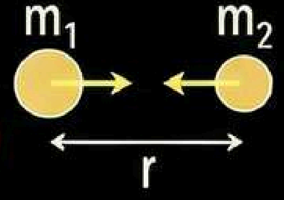


$$F = G\left(\frac{m_1 m_2}{r^2}\right)$$ ⇨ $6.67 \times 10^{-11} \frac{N\,m^2}{kg^2}$

⇨ F is attractive, along line joining C.M.s

2. Universal Law of Gravitation

⇨ Universal Law



$$F = G\frac{(m_1 m_2)}{r^2}$$

- $G = 6.67 \times 10^{-11}\ N\,m^2/kg^2$

⇨ F is attractive, along line joining C.M.s

3. Acceleration Due to Gravity (g)

$$g = \frac{GM}{R^2}$$

⇨ g near Earth's surface $9.8\ m/s^2$

⇨ Variation of g

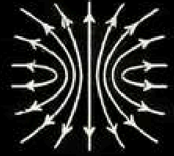
- Altitude (h) $g_h = g\left(1 - \frac{2h}{R}\right)$

- Depth (d) $g_d = g\left(1 - \frac{d}{R}\right)$

- Rotation (θ) $g' = g - \omega^2 R\cos^2\theta$

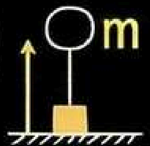
4. Gravitational Fields and

⇨ Field Intensity (E)



$$E = \frac{F}{m} = -\frac{GM}{r^2}$$

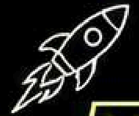
⇨ Potential Energy (U)



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

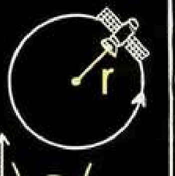
- Potential (V) $E = \frac{U}{m} = -\frac{GM}{r}$

5. Satellite Motion



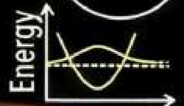
⇨ Escape Speed (v_e) $v_e = \sqrt{2GM}$

- Orbital Velocity (v_o)



$$v_o = \sqrt{GM/r}$$

⇨ Orbital Energy



$$E_{total} = K + U = \frac{1}{2}mv_o^2 - \frac{GMm}{r} = -\frac{GMm}{2r}$$

- Geostationary satellite: T = 24h, above Equator.

CHAPTER–8: MECHANICAL PROPERTIES OF SOLIDS (FORMULA SHEET)

ELASTICITY :– Restoring forces oppose deforming forces. Ability to regain original shape. Ability to regain original shape.

STRESS (σ): $\sigma = \dfrac{\text{Force (F)}}{\text{Area (A)}}$ Units: N/m^2 or Pa

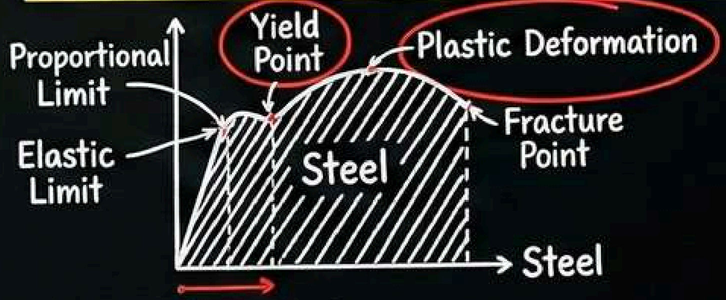
Types: Tensile, Compressive, Shear

STRAIN (ε): $\varepsilon = \dfrac{\Delta L}{L}$ (Tensile/Compressive)

$\dfrac{\Delta V}{V}$ (Volumetric)

Unitless

STRESS–STRAIN RELATIONSHIP



HOOKE'S LAW

Stress ∝ Strain (within elastic limit)

$\sigma = E \times \varepsilon$

YOUNG'S MODULUS (Y): For stretching a wire.

$$Y = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}} = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

BULK MODULUS (K): For volume change under pressure.

$$K = \frac{\text{Hydraulic Stress}}{\text{Volumetric Strain}} = \frac{\Delta P}{-\Delta V/V} = -\frac{PV}{\Delta V} \text{ (Compressebl)}$$

Compressibility $= \dfrac{1}{K}$

SHEAR MODULUS / MODULUS OF RIGIDITY (G or η)

For shearing motion (qualitative idea).

$$G = \frac{\text{Shearing Stress}}{\text{Shearing Strain}} = \frac{F/A}{\theta}$$

POISSON'S RATIO (σ)

$$\frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

$$\sigma = -\frac{\Delta d / d}{\Delta L / L}$$

ELASTIC POTENTIAL ENERGY

Energy Density $\dfrac{U}{V} = \dfrac{1}{2} \times \text{Stress} \times \text{Strain}\; E \times (\text{Strain})^2$

Total Energy $U = \dfrac{1}{2} \times F \times \Delta L$

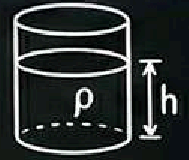
APPLICATION OF ELASTIC BEHAVIOR

1. Cranes (strong steel ropes)
2. Design of Bridges (I-beams)
3. Springs in Vehicles
4. Buildings (withstanding loads

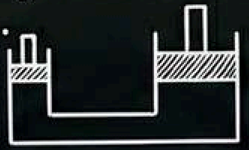
CHAPTER–9: MECHANICAL PROPERTIES OF FLUIDS (FORMULA SHEET)

FLUID PRESSURE:– Pressure due to fluid column: $P = \rho g h$

Pascal's Law: Pressure in an enclosed incompressible fluid is transmitted undiminished throughout the fluid and to the walls of the container.

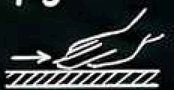


$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$



⇒ Effect of gravity on fluid pressure is $P = P_a + \rho g h$.

VISCOSITY & FLOW



Viscosity: Measure of a fluid's resistance to deformation or

Coefficient of Viscosity (η): $F = -\eta A\left(\frac{dv}{dx}\right)$

Stokes' Law: Viscous force on a sphere: $F = 6\pi\eta r v$

Terminal Velocity (v_t): $v_t = \frac{\frac{2}{9}r^2(\rho - \sigma)g}{\eta}$

Elussinination ally formaed by gravity or a 2.2it m/g

Streamline vs. Turbulent Flow:

$u_e = \frac{1}{2} \times R_e\,(P_a - \rho g h)$

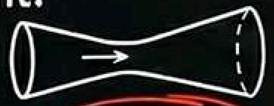
Streamline vs. Turbulent Flow

Critical Velocity: Velocity above which flow becomes turbulent. Formula idea (R_e formula is optional but can be mentioned qualitatively).

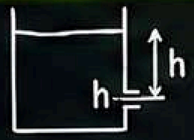
BERNOULLI'S THEOREM

BERNOULLI'S THEOREM: In a streamline flow of an ideal fluid, the total energy (pressure energy + kinetic energy + potential energy) per unit mass is constant.

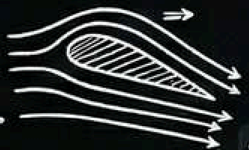
$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant.}$$



Applications: Torricelli's Law (Efflux velocity): $v = \sqrt{2gh}$



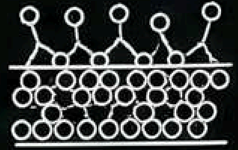
Dynamic Lift: Lift force on a wing (aerofoil). lower pressure).



SURFACE TENSION

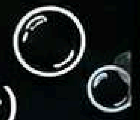
Surface Energy & Surface Tension (T):

$T = \frac{F}{L}$ or $\frac{\text{Surface Energy}}{\text{Area}}$ Units: $\frac{J}{m^2}$ or $\frac{N}{m}$



Angle of Contact (θ):

Excess of Pressure (ΔP): Across a curved surface.



$\Delta P = \frac{2T}{R}$ (bubble in liquid), $\Delta P = \frac{4T}{R}$ (soap bubble in air)

Capillary Rise: Height of liquid column in a capillary tube $h = \frac{2T\cos\theta}{r\rho g}$

Applications: Cranes, Rennies, etc.

Chapter–10: THERMAL PROPERTIES OF MATTER (FORMULA SHEET)

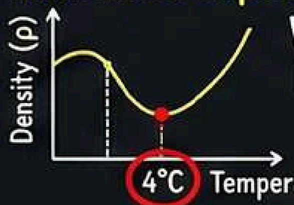
PHYSICS CLASS

BASICS & HEAT EXPANSION

THERMAL EXPANSION

1. SOLIDS
   - Linear Expansion Coefficient (α)
     $\Delta L = \alpha L_0 \Delta T$
   - Area Expansion Coefficient (β)
     $\Delta A = \beta A_0 \Delta T$ ($\beta \approx 2\alpha$)
   - Volume Expansion Coefficient (γ)
     $\Delta V = \gamma V_0 \Delta T$ ($\gamma \approx 3\alpha$)

   ($\alpha < \beta < \gamma$ for same material)
2. LIQUIDS: Real expansion γ_r, Apparent expansion γ_a
   Real expansion (qualitative)
   (qualitative, $\gamma_r = \gamma_a + \gamma_v$ for container)
3. GASES: Coeff. of Volume Expansion (for ideal gas) is $\frac{1}{T}$
   Relation from PV = nRT
4. Anomalous Expansion of Water



Water density max at 4°C, ice forms on top.

HEAT & TEMPERATURE

Heat Q (Joule, unit symbol)
Temperature T (Kelvin K, Celsius °C)
Basic relation: $Q \propto \Delta T$

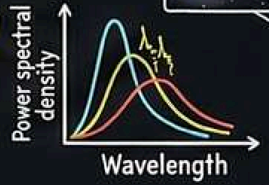
SPECIFIC HEAT CAPACITY & CALORIMETRY

1. SPECIFIC HEAT CAPACITY (s or c)
   Amount of heat to raise T of unit mass by 1°
   $s = \frac{1}{m}\frac{dQ}{dT}$ or $Q = ms\,\Delta T$
2. MOLAR HEAT CAPACITY (C)
   $C = \frac{1}{n}\frac{dQ}{dT}$ Units: $J\,mol^{-1}\,K^{-1}$
   Relation $C = Ms$ (M = molar mass)
3. C_p, C_v (at constant Pressure/Volume)
   For ideal gases
   $C_p - C_v = R$ or
   $\gamma = \frac{C_p}{C_v}$ (adiabatic index)
4. CALORIMETRY PRINCIPLE
   Heat lost = Heat gained
   (in an isolated system)

CHANGE OF STATE & HEAT TRANSFER

1. CHANGE OF STATE
   Heat for phase change
   Lateral Heat Capacity (L) $Q = mL$
   - Latent Heat of Fusion (L_f)
     (ice → water)
   - Latent Heat of Vaporization (L_v)
     (water → steam)

2. HEAT TRANSFER: Qualitative ideas
   - CONDUCTION: Thermal conductivity K
     Heat current $H = \frac{KA\Delta T}{L}$
   - CONVECTION: Fluid motion
   - RADIATION: Energy via EM waves
3. BLACKBODY RADIATION: Qualit. ideas
   A perfect blackbody absorbody
4. WEIN'S DISPLACEMENT LAW
   $\lambda_{max} T$ = Constant (b)



5. STEFAN'S LAW
   Power $P = \sigma e A T^4$
   Constant σ (Stefan's constant) e emissivity e
   $P \propto T^4$ for a blackbody (e=1)

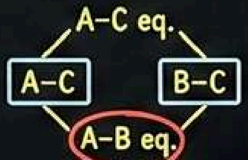
CHAPTER–11: THERMODYNAMICS (FORMULA SHEET)

THERMAL EQUILIBRIUM & TEMP DEF

→ $Q \to 0$ ← Thermal equilibrium & systems
$T_A = T_B$

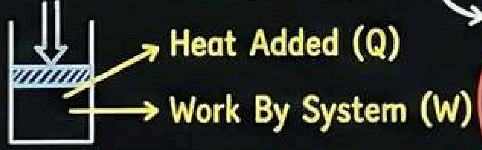
TEMPERATURE (T):
A measure of hotness/coldness is defined as a temperature

ZEROTH LAW OF THERMODYNAMICS:
The statement of it law thermodynamics, define and system it thermodynamic.



FIRST LAW OF THERMODYNAMICS:

$$\Delta U = Q - W$$



- ΔU: Internal Energy Change
- Q : Heat Energy nol change
- W : Work By System (if e pition)

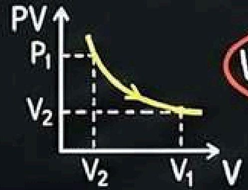
STATE VARIABLES (P, V, T, n, U)
Define state of system

EQUATION OF STATE (Ideal Gas)

$$PV = nRT$$ $R = 8.314$ J/mol·K

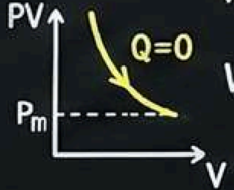
THERMODYNAMIC PROCESSES (Change of Condition)

- **Isothermal Process:**
  T Constant ($\Delta T=0$)



$$W = nRT \ln\left(\frac{V_2}{V_1}\right)$$

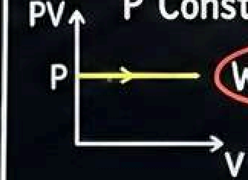
- **Adiabatic Process:**
  No Heat Exchange ($Q=0$)



Work: $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

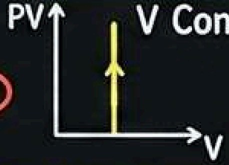
$PV^{\gamma} = \text{constant}$, $\gamma = \frac{C_P}{C_V}$

- **Isobaric Process:**
  P Constant ($\Delta P=0$)

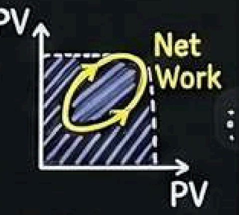


$$W = P\Delta V = P(V_2 - V_1)$$

- **Isochoric Process:**
  V Constant ($\Delta V=0$)



$$W = 0$$



CYCLIC PROCESS:
Returns to initial state ($\Delta U_{cycle}=0$)

$\Delta U_{cycle}=0$
$Q_{net}=W_{net}$

Processes & Laws

- **Reversible Process**
  - quasi-static, path-dependent

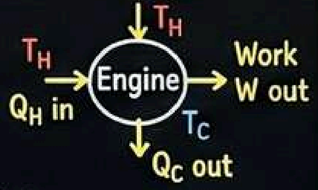
- **Irreversible Process**
  - fast, fast change

SECOND LAW OF THERMODYNAMICS:

Kelvin-Planck: no 100% efficient device

Clausius: no spontaneous cold-to-hot heat flow

Efficiency : $\eta = \frac{\text{Work}}{\text{Heat Input}}$



$$\eta_{Carnot} = 1 - \frac{T_C}{T_H}$$; T in Kelvin

CHAPTER-12: KINETIC THEORY OF GASES

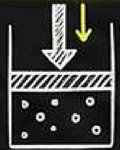
FORMULA SHEET

PERFECT GAS & WORK

Equation of state of a perfect gas

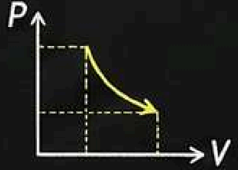
$PV = nRT = Nk_BT$ (State variables defined: P = Pressure, V = Volume, n = moles, N = molecules, T = Temperature, R = Molar Gas Constant, k_B = Boltzmann Constant)

Work done in compressing a gas



$dW = -P\,dV$ (for compression, dV < 0)

$W = \int_{V_1}^{V_2} P\,dV$ (general)

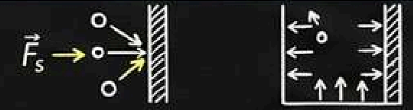


KINETIC THEORY OF GASES - ASSUMPTIONS

- Molecules are rigid spheres
- Elastic collisions
- Constant random motion
- Inter-molecular forces negligible

CONCEPT OF PRESSURE

$P = \frac{1}{3}\rho v_{rms}^2 = \frac{1}{3}\frac{mN}{V} v_{rms}^2$



(ρ = density, m = mass per molecule)

DEGREES OF FREEDOM, LAW OF EQUI-PARTITION OF ENERGY

Degrees of freedom (dof)

- Monoatomic (Example: He, Ar): dof = 3 (Translational)
- Diatomic (Example: H_2, N_2): dof = 5 (3 Translation + 2 Rotation) at normal T

Law of equi-partition of energy (STATEMENT ONLY)

- Energy of a gas molecule is distributed equally among all its degrees of freedom, with each dof having $\frac{1}{2}k_BT$ energy.

$U = N\frac{f}{2}k_BT = n\frac{f}{2}RT$ $\quad C_v = \frac{f}{2}R$ $\quad C_p = C_v + R =$ $\quad C_p = \frac{f+2}{2}R$

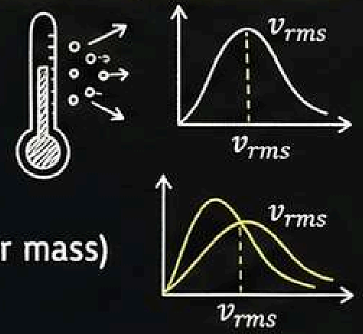
KINETIC INTERPRETATION OF TEMPERATURE; RMS SPEED

Average K.E. per molecule

$\langle E_{kin} \rangle = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_BT$

rms speed of gas molecules

$v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M}}$ (M = Molar mass)



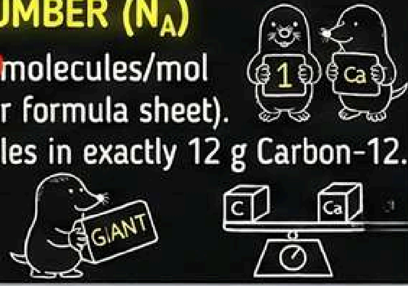
$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$

AVOGADRO'S NUMBER (N_A)

$N_A = 6.022\times10^{23}$ molecules/mol (standard value for formula sheet).

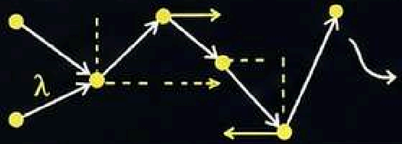
Defined as molecules in exactly 12 g Carbon-12.

$R = N_Ak_B$



CONCEPT OF MEAN FREE PATH

$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$ (d = molecule diameter, n = number density = N/V)



Chapter–13: Oscillations

(FORMULA SHEET)

PERIODIC MOTION

→ Motion that repeats itself at regular intervals.

* Time Period (T) : Time for one full cycle, unit: seconds
* Frequency (f/ν) : Cycles per second, unit: Hz

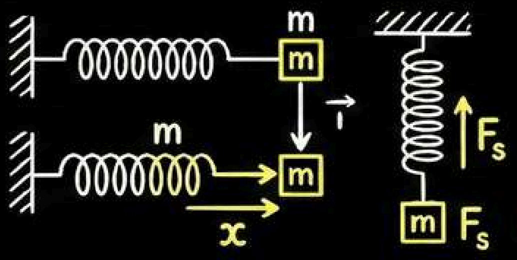
$T = \frac{1}{f}$ $\quad f = \frac{1}{T}$

* Angular Frequency (ω) $\quad \omega = 2\pi f = \frac{2\pi}{T}$

⇓

* Periodic Functions e.g., $y(t) = A\sin(\omega t + \phi)$

OSCILLATIONS OF A LOADED SPRING



$T = 2\pi\sqrt{\frac{m}{k}}$

$f = \left(\frac{1}{2\pi}\right)\sqrt{\frac{k}{m}}$

SIMPLE HARMONIC MOTION (S.H.M.)

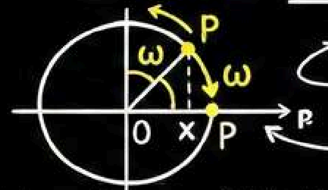
* Restoring Force ∝ –Displacement

$F \propto -x$ $\quad F = -kx$

Restoring Force, Force Constant

$a = \frac{F}{m} = -\frac{kx}{m} = -\omega^2 x$ $\quad \omega = \sqrt{\frac{k}{m}}$

Connection to Uniform Circular Motion



$x(t) = A\cos(\omega t + \phi)$

→ Amplitude A

→ Initial Phase ϕ

Equations of Motion

* Displacement (x)

$x(t) = A\cos(\omega t + \phi)$ → velocity

* Velocity (v)

$v(t) = -A\omega\sin(\omega t + \phi)$

$v_{max} = A\omega$

* Acceleration (a)

$a(t) = -A\omega^2\cos(\omega t + \phi)$

$a = -\omega^2 x$

$a_{max} = A\omega^2$

ENERGY IN S.H.M.

* Potential Energy (U)

$U = \frac{1}{2}kx^2 = \frac{1}{2}m\omega^2 x^2$

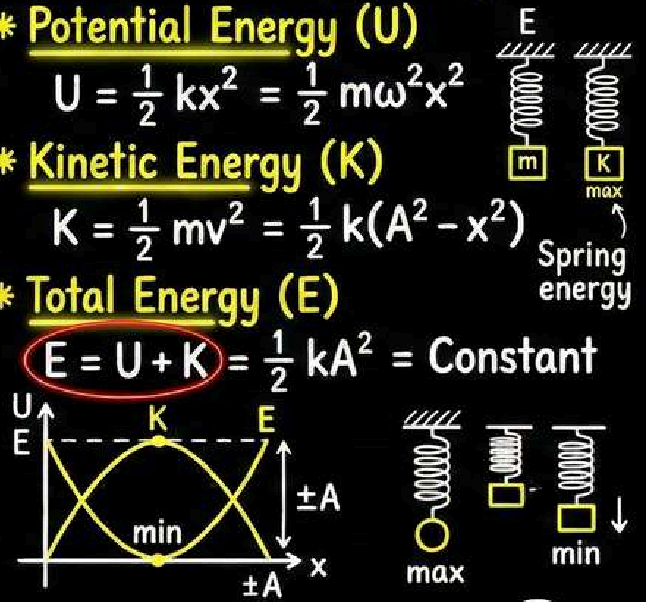
* Kinetic Energy (K)

$K = \frac{1}{2}mv^2 = \frac{1}{2}k(A^2 - x^2)$

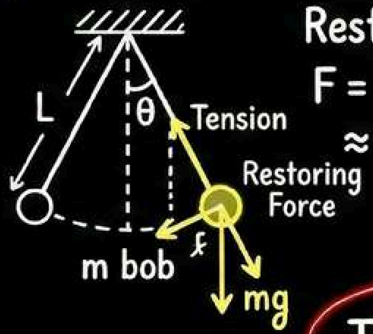
* Total Energy (E)

$E = U + K = \frac{1}{2}kA^2 = \text{Constant}$

Spring energy



SIMPLE PENDULUM



Restoring Force

$F = -mg\sin(\theta)$

$\approx -mg\theta$ (for small θ)

$k = \frac{mg}{L}$

$T = 2\pi\sqrt{\frac{L}{g}}$

* Small angles cann be note for small θ

Chapter–14: Waves (FORMULA SHEET)

Wave Motion & Progressive Waves

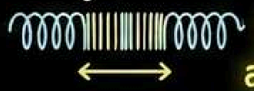
> **Wave Motion**

↳ Transverse wave

Parallel particles

↳ Perpendicular energy transfer

↳ Longitudinal wave



Parallel particles and energy transfer

> **Speed of Travelling Wave**

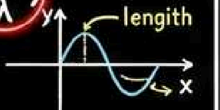
$v = f\lambda$ $\quad v = \dfrac{\omega}{k}$ $\quad v = \dfrac{1}{\sqrt{E/\rho}}$

E=elasticity
ρ=density

> **Progressive Wave Relation**

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

- A = Amplitude
- ω = Angular Frequency ($2\pi f$)
- k = Wave Number ($\frac{2\pi}{\lambda}$)
- ϕ = Initial Phase



Wave speed & Superposition

> String Speed

$$v = \sqrt{\frac{T}{\mu}}$$

T=Tension
μ=Linear Mass Density (m/L)

- Generic speed ideas

$$y = \frac{vT}{m/L} + \mu \cdots \text{speed}$$
speed

> **Principle of Superposition**

- Resultant displacement y is vector sum of individual displacements:

$$y = y_1 + y_2 + \ldots$$

Constructive interference
Destructive interference

Reflection & Standing Waves (Strings)

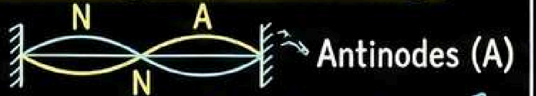
> **Reflection**

Fixed End / Free End

(pi phase change, inverts) $y_r = -A\sin(\omega t + kx)$

(0 phase change, not invert) $y_r = A\sin(\omega t + kx)$

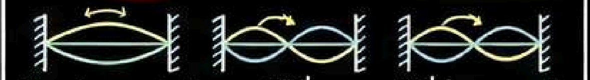
> **Standing Waves in Strings**



> **Strings fixed both ends**

- Conditions at Boundaries: Nodes at ends

$f_n = \dfrac{nv}{2L}$ $\quad \lambda = \dfrac{2L}{n}$ $\quad$ n=1,2,3... (all harmonics)



Fundamental $\quad$ 2nd $\quad$ 3rd harmonic

Standing Waves (Organ Pipes) & Beats

> **Organ Pipes**

- **Open Pipe** (Both ends open)

↳ Antinodes at ends

$$f_n = \frac{nv}{2L}$$

All Harmonics present

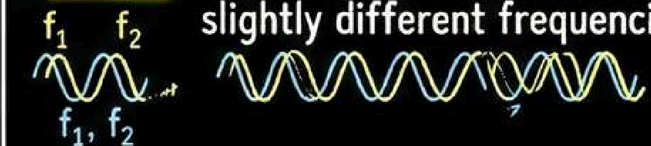
> **Closed Pipe** (One end closed)

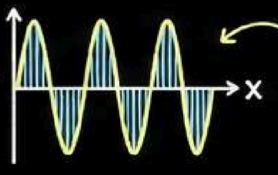
- Node closed end, Antinode open end

$f_n = \dfrac{(2n-1)v}{4L}$ $\quad \lambda = \dfrac{4L}{2n-1}$

- Odd Harmonics only present: $f_1, 3f_1, 5f_1 \ldots$

> **BEATS:** Superposition of waves with slightly different frequencies ⇒





Variation of sound intensity

> Beat frequency:

$$f_b = |f_1 - f_2|$$