REVISION SHEETS

PHYSICS

Units and Measurements

- The **SI system :** It is the international system of units. At present internationally accepted for measurement. In this system there are seven fundamental and two supplementary quantities and their corresponding units are:

Quantity	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		
1. Plane angle	radian	rad
2. Solid angle	steradian	sr

- Dimensions : These are the powers to which the fundamental units are raised to get the unit of a physical quantity.
- Uses of dimensions
  (i) To check the correctness of a physical relation.
  (ii) To derive relationship between different physical quantities.
  (iii) To convert one system of unit into another.

$$n_1u_1 = n_2u_2$$

$$n_1[M_1^aL_1^bT_1^c] = n_2[M_2^aL_2^bT_2^c]$$

- Significant figures : In any measurement, the reliable digits plus the first uncertain digit are known as significant figures.
- Error : It is the difference between the measured value and true value of a physical quantity or the uncertainty in the measurements.
- Absolute error : The magnitude of the difference between the true value and the measured value is called absolute error.

$$\Delta a_1 = \bar{\mathbf{a}} - a_1,\ \Delta a_2 = \bar{\mathbf{a}} - a_2,\ \Delta a_n = \bar{\mathbf{a}} - a_n$$

Mean absolute error

$$\Delta\bar{\mathbf{a}} = \frac{|\Delta a_1| + |\Delta a_2| + ... + |\Delta a_n|}{n} = \frac{1}{n}\sum_{i=1}^{n}|\Delta a_i|$$

- Relative error : It is the ratio of the mean absolute error to its true value or relative error $= \frac{\Delta\bar{\mathbf{a}}}{\bar{\mathbf{a}}}$
- Percentage error : It is the relative error in per cent.

$$\text{Percentage error} = \left(\frac{\Delta\bar{a}}{a_{mean}}\right)\times 100\%$$

Motion in a Straight Line

- Average speed, $V_{av} = \frac{s_1 + s_2 + s_3}{t_1 + t_2 + t_3}$
- Average acceleration, $a_{av} = \frac{a_1t_1 + a_2t_2}{t_1 + t_2}$
- The area under the velocity-time curve is equal to the displacement and slope gives acceleration.
- If a body falls freely, the distance covered by it in each subsequent second starting from first second will be in the ratio 1 : 3 : 5 : 7 etc.
- If a body is thrown vertically up with an initial velocity u, it takes u/g second to reach maximum height and u/g second to return, if air resistance is negligible.
- If air resistance acting on a body is considered, the time taken by the body to reach maximum height is less than the time to fall back the same height.
- For a particle having zero initial velocity if $s \propto t^{\alpha}$, where $\alpha > 2$, then particle's acceleration increases with time.
- For a particle having zero initial velocity if $s \propto t^{\alpha}$, where $\alpha < 0$, then particle's acceleration decreases with time.
- Kinematic equations :
  $v = u + a_t(t)$; $v^2 = u^2 + 2a_t(s)$

$$S = ut + \frac{1}{2}a_t(t)^2;\ S_n = u + \frac{a}{2}(2n-1)$$

applicable only when $|\vec{a}_t| = a_t$ is constant.
a_t = magnitude of tangential acceleration, S = distance

- If acceleration is variable use calculus approach.
- Relative velocity : $\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$

Motion in a Plane

- If T is the time of flight, h maximum height, R horizontal range of a projectile, α its angle of projection, then the relations among these quantities.

$$h = \frac{gT^2}{8} \quad .....(1);\quad gT^2 = 2R\tan\alpha \quad .....(2);$$

$$R\tan\alpha = 4h \quad .....(3)$$

- $T = \frac{2u\sin\theta}{g}; h = \frac{u^2\sin^2\theta}{2g}$

$$R = \frac{u^2\sin 2\theta}{g};\ R_{max} = \frac{u^2}{g} \text{ when } \theta = 45°$$

- For a given initial velocity, to get the same horizontal range, there are two angles of projection α and $90° - \alpha$.
- The equation to the parabola traced by a body projected horizontally from the top of a tower of height y, with a velocity u is $y = gx^2/2u^2$, where x is the horizontal distance covered by it from the foot of the tower.
- Equation of trajectory is $y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$, which is parabola.
- Equation of trajectory of an oblique projectile in terms of range (R) is $y = x\tan\theta\left(1 - \frac{x}{R}\right)$
- Maximum height is equal to n times the range when the projectile is launched at an angle $\theta = \tan^{-1}(4n)$.
- In a uniform circular motion, velocity and acceleration are constants only in magnitude. Their directions change.
- In a uniform circular motion, the kinetic energy of the body is a constant. $W = 0, \vec{a} \neq 0, \vec{P} \neq$ constant, $\vec{L}$=constant
- Centripetal acceleration, $a_r = \omega^2 r = \frac{v^2}{r} = \omega v$ (always applicable) $\vec{a}_r = \vec{\omega} \times \vec{v}$

Laws of Motion

- Newton's first law of motion or law of inertia : It is resistance to change.
- Newton's second law : $\vec{F} = m\vec{a}, \ \vec{F} = d\vec{p}/dt$
- Impulse : $\Delta\vec{p} = \vec{F}\Delta t, \ p_2 - p_1 = \int_1^2 F\,dt$
- Newton's third law : $\vec{F}_{12} = -\vec{F}_{21}$
- Frictional force $f_s \leq (f_s)_{max} = \mu_s R; \quad f_k = \mu_k R$
- Circular motion with variable speed. For complete circles, the string must be taut in the highest position, $u^2 \geq 5ga$.
  Circular motion ceases at the instant when the string becomes slack, i.e., when T = 0, range of values of u for which the string does go slack is $\sqrt{2ga} < u < \sqrt{5ga}$.
- Conical pendulum : $\omega = \sqrt{g/h}$ where h is height of a point of suspension from the centre of circular motion.
- The acceleration of a lift
  $a = \frac{\text{actual weight} - \text{apparent weight}}{\text{mass}}$
  If 'a' is positive lift is moving down, and if it is negative the lift is moving up.
- On a banked road, the maximum permissible speed
  $V_{max} = \left(R_g \frac{u_s + \tan\theta}{1 - u_s\tan\theta}\right)^{1/2}$

Work, Energy and Power

- Work done $W = FS\cos\theta$
- Relation between kinetic energy E and momentum, $P = \sqrt{2mE}$
  K.E. = $^1/_2 mV^2$; P.E. = mgh
- If a body moves with constant power, its velocity (v) is related to distance travelled (x) by the formula $v \propto x^{3/2}$.
- Power $P = \frac{W}{t} = F.V$
- Work due to kinetic force of friction between two contact surfaces is always negative. It depends on relative displacement between contact surfaces. $W_{FK} = -F_K(S_{rel})$.
- $\Sigma W = \Sigma \Delta K$, $\Sigma W \Rightarrow$ total work due to all kinds of forces, $\Sigma \Delta K \Rightarrow$ total change in kinetic energy.
- $\Sigma W_{conservative} = -\Sigma \Delta U$; $\Sigma W_{conservative} \Rightarrow$ Total work due to all kinds of conservative forces.
  $\Sigma\Delta u \Rightarrow$ Total change in all kinds of potential energy.
- Coefficient of restitution $e = \frac{\text{velocity of separation}}{\text{velocity of approach}}$
- The total momentum of a system of particles is a constant in the absence of external forces.

System of Particles & Rotatioal Motion

- The centre of mass of a system of particles is defined as the point whose position vector is $R = \frac{\sum m_i r_i}{M}$
- The angular momentum of a system of n particles about the origin is $L = \sum_{i=1}^{n} r_i \times p_i$; $L = mvr = I\omega$
- The torque or moment of force on a system of n particles about the origin is $\tau = \sum_i r_i \times F_i$
- The moment of inertia of a rigid body about an axis is defined by the formula $I = \sum m_i r_i^2$
- The kinetic energy of rotation is $K = \frac{1}{2} I\omega^2$
- The theorem of parallel axes : $I_z' = I_z + Ma^2$
  Theorem of perpendicular axes : $I_z = I_x + I_y$
- A rigid body is in mechanical equilibrium if
  (a) It is translational equilibrium i.e., the total external force on it is zero : $\Sigma F_i = 0$.
  (b) It is rotational equilibrium i.e., the total external torque on it is zero : $\Sigma \tau_i = \Sigma r_i \times F_i = 0$.

Gravitation

- Newton's universal law of gravitation

  Gravitational force $F = \frac{Gm_1m_2}{r^2}$

  $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$
- The acceleration due to gravity.
  (a) at a height h above the Earth's surface

  $g(h) = \frac{GM_E}{(R_E + h)^2} = g\left(1 - \frac{2h}{R_E}\right)$ for $h << R_E$

  $g(h) = g(0)\left(1 - \frac{2h}{R_E}\right)$ where $g(0) = \frac{GM_E}{R_E^2}$

  (b) at depth d below the Earth's surface is

  $g(d) = \frac{GM_E}{R_E^2}\left(1 - \frac{d}{R_E}\right) = g(0)\left(1 - \frac{d}{R_E}\right)$
- Gravitational potential $V_g = -\frac{GM}{r}$
- Intensity of gravitational field $I = \frac{GM}{r^2}$
- The gravitational potential energy

  $V = -\frac{Gm_1m_2}{r} + \text{constant}$
- The escape speed from the surface of the Earth is $v_e = \sqrt{\frac{2GM_E}{R_E}} = \sqrt{2gR_E}$ and has a value of 11.2 km s^{-1}.
- Orbital velocity, $v_{orbi} = \sqrt{\frac{GM_E}{R_E}} = \sqrt{gR_E}$
- Kepler's 3rd law of planetary motion.

  $T^2 \propto a^3$; $\frac{T_1^2}{T_2^2} = \frac{a_1^3}{a_2^3}$

Mechanical Properties of Solids

- Hooke's law : stress $\propto$ strain
- Young's modulus of elasticity $Y = \frac{F\Delta\ell}{A\ell}$
- Compressibility $= \frac{1}{\text{Bulk modulus}}$
- If S is the stress and Y is Young's modulus, the energy density of the wire E is equal to $S^2/2Y$.
- Thermal stress = $\frac{F}{A} = Y\alpha\Delta\theta$

Mechanical Properties of Fluids

- Pascal's law : A change in pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and the walls of the containing vessel. Pressure exerted by a liquid column P = hρg
- Bernoulli's principle $P + \rho v^2/2 + \rho gh = \text{constant}$
- Surface tension is a force per unit length (or surface energy per unit area) acting in the plane of interface.
- Stokes' law states that the viscous drag force F on a sphere of radius a moving with velocity v through a fluid of viscosity η $F = -6\pi\eta av$.
- Terminal velocity $V_T = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$
- The surface tension of a liquid is zero at boiling point. The surface tension is zero at critical temperature.
- If a drop of water of radius R is broken into n identical drops, the work done in the process is $4\pi R^2S(n^{1/3} - 1)$ and fall in temperature $\Delta q = \frac{3T}{J}\sqrt{\frac{1}{r} - \frac{1}{R}}$
- Two capillary tubes each of radius r are joined in parallel. The rate of flow is Q. If they are replaced by single capillary tube of radius R for the same rate of flow, then $R = 2^{1/4}\, r$.
- Ascent of a liquid column in a capillary tube

  $h = \frac{2s\cos\phi}{r\rho g}$
- Coefficient of viscosity, $n = -\frac{F}{A\left(\frac{dv}{dx}\right)}$
- Velocity of efflux $V = \sqrt{2gh}$

Thermal Properties of Matter

- Relation between different temperature scales :

  $\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$
- The coefficient of linear expansion (α_ℓ), superficial (β) and volume expansion (α_v) are defined by the relations :

  $\frac{\Delta\ell}{\ell} = \alpha_\ell\Delta T$; $\frac{\Delta A}{A} = \beta\Delta T$; $\frac{\Delta V}{V} = \alpha_V\Delta T$

  $\alpha_v = 3\alpha_\ell$; $\beta = 2\alpha_\ell$
- In conduction, heat is transferred between neighbouring parts of a body through molecular collisions, without any flow of matter. The rate of flow of heat $H = KA\frac{T_C - T_D}{L}$, where K is the thermal conductivity of the material of the bar.
- Convection involves flow of matter within a fluid due to unequal temperatures of its parts.
- Radiation is the transmission of heat as electromagnetic waves.
- Heat required to change the temperature of the substance, $Q = mc\Delta\theta$
  c = specific heat of the substance
- Heat absorbed or released during state change Q = mL
  L = latent heat of the substance
- Mayer's formula $c_p - c_v = R$

Thermodynamics

- First law of thermodynamics: $\Delta Q = \Delta U + \Delta W$, where ΔQ is the heat supplied to the system, ΔW is the work done by the system and ΔU is the change in internal energy of the system.
- In an isothermal expansion of an ideal gas from volume V_1 to V_2 at temperature T the heat absorbed (Q) equals the work done (W) by the gas, each given by
$$Q = W = nRT \ln\left(\frac{V_2}{V_1}\right)$$
- In an adiabatic process of an ideal gas $PV^{\gamma} = TV^{\gamma-1}$ $= \frac{T^{\gamma}}{P^{\gamma-1}} =$ constant, where $\gamma = \frac{C_p}{C_v}$.
- Work done by an ideal gas in an adiabatic change of state from (P_1, V_1, T_1) to (P_2, V_2, T_2) is $W = \frac{nR(T_1 - T_2)}{\gamma - 1}$
- **Second law of thermodynamics:** No engine operating between two temperatures can have efficiency greater than that of the Carnot engine.
- Entropy or disorder $S = \frac{\delta Q}{T}$

Kinetic Theory

- Ideal gas equation PV = nRT
- Kinetic theory of an ideal gas gives the relation $P = \frac{1}{3}nm\bar{v}^2$, Combined with the ideal gas equation it yields a kinetic interpretation of temperature.
$$\frac{1}{2}nm\bar{v}^2 = \frac{3}{2}k_BT,\ v_{rms} = (\bar{v}^2)^{1/2} = \sqrt{\frac{3k_BT}{m}}$$
- The law of equipartition of energy is stated thus: the energy for each degree of freedom in thermal equilibrium is 1/2 (k_BT)
- The translational kinetic energy $E = \frac{3}{2}k_BNT$. This leads to a relation $PV = \frac{2}{3}E$.
- Degree of freedom : Number of directions in which it can move freely.
- Root mean square (rms) velocity of the gas
$$C = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{\rho}}$$
- Most probable speed $V_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{m}}$
- Mean free path $\lambda = \frac{KT}{\sqrt{2}\pi d^2 P}$

Oscillations

- Displacement in SHM : Y = a sin ωt or, y = a cos ωt
- The particle velocity and acceleration during SHM as functions of time are given by, v (t) = – ωA sin (ω + ϕ) (velocity), a (t) = – ω^2A cos (ωt + ϕ) = – ω^2x (t) (acceleration) Velocity amplitude $v_m = \omega A$ and acceleration amplitude $a_m = \omega^2 A$.
- A particle of mass m oscillating under the influence of a Hooke's law restoring force given by F = – k x exhibits simple harmonic motion with $\omega = \sqrt{\frac{k}{m}}$ (angular frequency),
$T = 2\pi\sqrt{\frac{m}{k}}$ (period)
Such a system is also called a linear oscillator.
- Time period for conical pendulum $T = 2\pi\sqrt{\left(\frac{\ell\cos\theta}{g}\right)}$ where θ angle between string & vertical.
- Energy of the particle $E = k + u = \frac{1}{2}m\omega^2A^2$

Waves

- The displacement in a sinusoidal wave y (x, t) = a sin (kx – ωt + ϕ) where ϕ is the phase constant or phase angle.
- Equation of plane progressive wave : $= a\sin 2\pi\left(\frac{t}{T} - \frac{x}{V}\right)$
- Equation of stationary wave : $Y = 2a\sin\frac{2\pi t}{T}\cos\frac{2\pi x}{\lambda}$
- The speed of a transverse wave on a stretched string $v = \sqrt{T/\mu}$.
- Sound waves are longitudinal mechanical waves that can travel through solids, liquids, or gases. The speed v of sound wave in a fluid having bulk modulus B and density μ is $v = \sqrt{B/\rho}$.
- The speed of longitudinal waves in a metallic bar is $v = \sqrt{Y/\rho}$
For gases, since B = γ P, the speed of sound is $v = \sqrt{\gamma P/\rho}$
- The interference of two identical waves moving in opposite directions produces standing waves. For a string with fixed ends, standing wave y (x, t) = [2a sin kx] cos ωt
- The separation between two consecutive nodes or antinodes is λ/2.
- A stretched string of length L fixed at both the ends vibrates with frequencies $f = \frac{1}{2}\frac{v}{2L}$.
The oscillation mode with lowest frequency is called the fundamental mode or the first harmonic.

- A pipe of length L with one end closed and other end open (such as air columns) vibrates with frequencies given by $f = \left(n + \frac{1}{2}\right)\frac{v}{2L}$, n = 0, 1, 2, 3, ... The lowest frequency given by v/4L is the fundamental mode or the first harmonic.

  Open organ pipe $n_1 : n_2 : n_3$ ..... 1, 2, 3....., $n = \frac{V}{2l}$

- Beats arise when two waves having slightly different frequencies, f_1 and f_2 and comparable amplitudes, are superposed. The beat frequency $f_{beat} = f_1 - f_2$

Electrostatics

- Coulomb's Law : $\vec{F}_{21}$ = force on q_2 due to $q_1 = \frac{k(q_1q_2)}{r_{21}^2}\hat{r}_{21}$

  where $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ Nm^2\ C^{-2}$

- Electric field due to a point charge q has a magnitude $|q|/4\pi\varepsilon_0 r^2$

- Field of an electric dipole in its equatorial plane

  $$E = \frac{-\vec{p}}{4\pi\varepsilon_0}\frac{1}{(a^2 + r^2)^{3/2}} \cong \frac{-\vec{p}}{4\pi\varepsilon_0 r^3}, \qquad \text{for } r >> a$$

  Dipole electric field on the axis at a distance r from the centre:

  $$\vec{E} = \frac{2\vec{p}r}{4\pi\varepsilon_0(r^2 - a^2)^2} \cong \frac{2\vec{p}}{4\pi\varepsilon_0 r^3} \text{ for } r >> a$$

  Dipole moment $\vec{p} = q2a$

- In a uniform electric field $\vec{E}$, a dipole experiences a torque $\vec{\tau}$ given by $\vec{\tau} = \vec{p} \times \vec{E}$ but experiences no net force.

  The flux $\Delta\phi$ of electric field $\vec{E}$ through a small area element $\Delta\vec{S}$ is given by $\Delta\phi = \vec{E}.\Delta\vec{S}$

- Gauss's law: The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed i.e., Q

- Thin infinitely long straight wire of uniform linear charge density λ : $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{n}$

- Infinite thin plane sheet of uniform surface charge density σ

  $$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$$

- Thin spherical shell of uniform surface charge density σ :

  $$\vec{E} = \frac{\sigma}{4\pi\varepsilon_0 r^2}\hat{r} \qquad (r \geq R)\ ;\ \vec{E} = 0 \quad (r < R)$$

- Electric Potential : $V(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$.

- An equipotential surface is a surface over which potential has a constant value.

- Potential energy of two charges q_1, q_2 at $\vec{r}_1, \vec{r}_2$ is given by $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$, where r_{12} is distance between q_1 and q_2.

- Capacitance C = Q/V, where Q = charge and V = potential difference

- For a parallel plate capacitor (with vacuum between the plates), $C = \varepsilon_0\frac{A}{d}$.

- The energy U stored in a capacitor of capacitance C, with charge Q and voltage V is $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

- For capacitors in the series combination,

  $$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$$

  In the parallel combination, $C_{eq} = C_1 + C_2 + C_3 + ...$
  where C_1, C_2, C_3... are individual capacitances.

Current Electricity

- Electric current, $I = \frac{q}{t}$

- Current density j gives the amount of charge flowing per second per unit area normal to the flow, $\vec{J} = nqv_d$

- Mobility, $\mu = \frac{V_d}{E}$ and $V_d = \frac{I}{Ane}$

- Resistance $R = \rho\frac{\ell}{A}$, ρ = resistivity of the material

- Equation $\vec{E} = \rho\vec{J}$ another statement of Ohm's law,
  ρ= resistivity of the material.

- Ohm's law $I \propto V$ or $V = RI$

- (a) Total resistance R of n resistors connected in series $R = R_1 + R_2 + ... + R_n$
  (b) Total resistance R of n resistors connected in parallel

  $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}.$$

- Kirchhoff's Rules – (a) Junction rule: At any junction of circuit elements, the sum of currents entering the junction must equal the sum of currents leaving it.
  (b) Loop rule: The algebraic sum of changes in potential around any closed loop must be zero.
- The Wheatstone bridge is an arrangement of four resistances R_1, R_2, R_3, R_4. The null-point condition is given by $\frac{R_1}{R_2} = \frac{R_3}{R_4}$
- According 'to Joule's Heating law, $H = I^2Rt$

Magnetism

- The total force on a charge q moving with velocity v i.e., Lorentz force. $\vec{F} = q(\vec{v} \times \vec{B} + \vec{E})$.
- A straight conductor of length ℓ and carrying a steady current I experiences a force $\vec{F}$ in a uniform external magnetic field $\vec{B}$, $\vec{F} = I\vec{\ell} \times \vec{B}$, the direction of ℓ is given by the direction of the current.
- Biot-Savart law $d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{\ell} \times \vec{r}}{r^3}$.
- The magnitude of the magnetic field due to a circular coil of radius R carrying a current I at an axial distance x from the centre is $B = \frac{\mu_0 IR^2}{2(x^2 + R^2)^{3/2}}$.
- The magnitude of the field B inside a long solenoid carrying a current I is : $B = \mu_0 nI$. For a toroid one obtains, $B = \frac{\mu_0 NI}{2\pi r}$.
- Ampere's Circuital Law : $\oint_C \vec{B}.d\vec{\ell} = \mu_0 I$, where I refers to the current passing through S.
- Force between two long parallel wires $F = \frac{\mu_0 I_1 I_2}{2\pi a}$ Nm^{-1}.
  The force is attractive if currents are in the same direction and repulsive currents are in the opposite direction.
- For current carrying coil $\vec{M} = NI\vec{A}$; torque = $\vec{\tau} = \vec{M} \times \vec{B}$
- Conversion of (i) galvanometer into ammeter, $S = \left(\frac{I_g}{I - I_g}\right) G$

  (ii) galvanometer into voltmeter, $S = \frac{V}{I_g} - G$
- The magnetic intensity, $\vec{H} = \frac{\vec{B}_0}{\mu_0}$.
- The magnetisation $\vec{M}$ of the material is its dipole moment per unit volume. The magnetic field B in the material is, $\vec{B} = \mu_0(\vec{H} + \vec{M})$
- For a linear material $\vec{M} = \chi\vec{H}$. So that $\vec{B} = \mu\vec{H}$ and χ is called the magnetic susceptibility of the material.
  $\mu = \mu_0\mu_r$; $\mu_r = 1 + \chi$.

Electromagnetic Induction

- The magnetic flux
  $\phi_B = \vec{B}.\vec{A} = BA\cos\theta$, where θ is the angle between $\vec{B}$ & $\vec{A}$.
- Faraday's laws of induction : $\varepsilon = -N\frac{d\phi_B}{dt}$
- Lenz's law states that the polarity of the induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.
- The induced emf (motional emf) across ends of a rod $\varepsilon = B\ell v$
- The self-induced emf is given by, $\varepsilon = -L\frac{dI}{dt}$
  L is the self-inductance of the coil.
  $L = \frac{\mu_0 N^2 A}{\ell}$
- A changing current in a coil (coil 2) can induce an emf in a nearby coil (coil 1).
  $\varepsilon_1 = -M_{12}\frac{dI_2}{dt}$, M_{12} = mutual inductance of coil 1 w.r.t coil 2.
  $M = \frac{\mu_0 N_1 N_2 A}{\ell}$

Alternating Current

- For an alternating current $i = i_m \sin \omega t$ passing through a resistor R, the average power loss P (averaged over a cycle) due to joule heating is $(1/2)i^2_m R$.
  E.m.f, $E = E_0 \sin \omega t$
- Root mean square (rms) current $I = \frac{i_m}{\sqrt{2}} = 0.707\, i_m$.
  $E_{rms} = \frac{E_0}{\sqrt{2}}$

- The average power loss over a complete cycle $P = V I \cos\phi$. The term $\cos\phi$ is called the power factor.
- An ac voltage $v = v_m \sin\omega t$ applied to a pure inductor L, drives a current in the inductor $i = i_m \sin(\omega t - \pi/2)$, where $i_m = v_m/X_L$. $X_L = \omega L$ is called inductive reactance.
- An ac voltage $v = v_m \sin\omega t$ applied to a capacitor drives a current in the capacitor: $i = i_m \sin(\omega t + \pi/2)$. Here,

  $i_m = \frac{v_m}{X_C}$, $X_C = \frac{1}{\omega C}$ is called capacitive reactance.

- Impedance $z = \sqrt{R^2 + (x_L - x_C)^2}$
- Transformation ratio, $K = \frac{N_S}{N_P} = \frac{E_S}{E_P} = \frac{I_P}{I_S}$
- Step up transformer : $N_S > N_P$; $E_S > E_P$; $I_P > I_S$
- Step down transformer $N_P > N_S$; $E_P > E_S$ and $I_P < I_S$

Ray Optics

- Reflection is governed by the equation $\angle i = \angle r$ and refraction by the Snell's law, sini/sinr = n, where the incident ray, reflected ray, refracted ray and normal lie in the same plane.
- Mirror equation: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

  Magnification $M = \frac{V}{u} = \frac{I}{O}$

- Prism Formula $n_{21} = \frac{n_2}{n_1} = \frac{\sin[(A + D_m)/2)]}{\sin(A/2)}$, where D_m is the angle of minimum deviation.
- Dispersion is the splitting of light into its constituent colours. The deviation is maximum for violet and minimum for red.
- For refraction through a spherical interface (from medium 1 to 2 of refractive index n_1 and n_2, respectively)

  $\frac{n_2}{v} - \frac{n_1}{v} = \frac{n_2 - n_1}{R}$

- Refractive index of a medium $\mu = \frac{C}{V}$ ($C = 3 \times 10^8$ m/s)

  $r = \frac{1}{\sin C}$ (C = Critical angle)

- Condition for TIR : 1. Ray of light must travel from denser to rarer medium 2. Angle of incidence in denser medium > critical angle.
- Lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
- Lens maker's formula : $\frac{1}{f} = \frac{(n_2 - n_1)}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
- The power of a lens P = 1/f. The SI unit for power of a lens is dioptre (D): 1 D = 1 m^{-1}.
- If several thin lenses of focal length f_1, f_2, f_3,.. are in contact, the effective focal $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$
- The total power of a combination of several lenses $P = P_1 + P_2 + P_3 + ...$
- For compound microscope $M = \frac{V_0}{u_0}\left(1 + \frac{D}{f_e}\right)$

  when final image at D

  $M = \frac{V_0}{u_0} \cdot \frac{D}{f_e}$ when final image at infinity.

Wave Optics

- Wavefront **:** It is the locus of all the particles vibrating in the same phase.
- The resultant intensity of two waves of intensity $I_0/4$ of phase difference ϕ at any points $I = I_0 \cos^2\left[\frac{\phi}{2}\right]$,

  where I_0 is the maximum density.
- Intensity $I \propto (\text{amplitude})^2$
- Condition for dark band : $\delta = (2n - 1)\frac{\lambda}{2}$, for bright band :

  $\delta = m\lambda$

- Fringe width $\beta = \frac{D\lambda}{d}$
- A thin film of thickness t and refractive index μ appears dark by reflection when viewed at an angle of refraction *r* if $2\mu t \cos r = n\lambda$ (n = 1, 2, 3, etc.)
- A single slit of width a gives a diffraction pattern with a central maximum. The intensity falls to zero at angles of $\pm\frac{\lambda}{a}, \pm\frac{2\lambda}{a}$, etc.
- Amplitude of resultant wave $R = \sqrt{a^2 + b^2 + 2ab\cos\phi}$
- Intensity of wave $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$
- Brewster law : $\mu = \tan i_p$

Modern Physics

- Energy of a photon $E = h\nu = \frac{hc}{\lambda}$
- Momentum of a photon $P = \frac{h}{\lambda}$
- Einstein's photoelectric equation

$$\frac{1}{2}mv_{max}^2 = V_0 e = h\nu - \phi_0 = h(\nu - \nu_0)$$

- Mass defect,

$$\Delta M = (Z m_p + (A - Z)m_n) - M; \quad \Delta E_b = \Delta M c^2.$$

1 amu = 931 MeV

- $E_n = -\frac{Z^2}{n^2} \times 13.6eV$ (For hydrogen like atom)
- According to Bohr's atomic model, angular momentum for the electron revolving in stationary orbit, $mvr = nh/2\pi$
- Radius of the orbit of electron $r = \frac{n^2h^2}{4\pi^2 mkze^2}$
- Radius of the nucleus $R = R_o A^{1/3}$
- Pure semiconductors are called 'intrinsic semiconductors'. The presence of charge carriers (electrons and holes) number of electrons (n_e) is equal to the number of holes (n_h).
- The number of charge carriers can be changed by 'doping' of a suitable impurity in pure semiconductors known as extrinsic semiconductors (n-type and p-type).
- In n-type semiconductors, $n_e >> n_h$ while in p-type semiconductors $n_h >> n_e$.
- n-type semiconducting Si or Ge is obtained by doping with pentavalent atoms (donors) like As, Sb, P, etc., while p-type Si or Ge can be obtained by doping with trivalent atom (acceptors) like B, Al, In etc.
- In forward bias (n-side is connected to negative terminal of the battery and p-side is connected to the positive), the barrier is decreased while the barrier increases in reverse bias.
- Diodes can be used for rectifying an ac voltage (restricting the ac voltage to one direction).
- Zener diode is one such special purpose diode. In reverse bias, after a certain voltage, the current suddenly increases (breakdown voltage) in a Zener diode. This property has been used to obtain voltage regulation.
- The important digital circuits performing special logic operations are called logic gates. These are: OR, AND, NOT, NAND, and NOR gates. NAND gate is the combination of NOT and AND gate. NOR gate is the combination of NOT and OR gate.

Experimental Skills in Physics

Least Count and Zero Error

The magnitude of the smallest measurment that can be measured by an instrument accurately is called its **least count (L.C.)**.

The difference between one main scale division (M.S.D.) and one vernier scale division is called least count.

i.e. *L.C. = 1 M.S.D. – 1 V.S.D.*

Zero Error

If there is no object between the jaws (i.e., jaws are in contact), the vernier should give zero reading. But due to some extra material on jaws, even if there is no object between the jaws, it gives some excess reading. This excess reading is called zero error.

Zero correction : Zero correction is invert of zero error.

Zero correction = – (Zero error)

Actual reading = observed reading – excess reading (zero error)

= observed reading + zero correction

EXPERIMENT 1

Aim : ***To measure the internal and external diameter and depth of a vessel using a vernier callpers.***

Theory : If with the body between the jaws, the zero of vernier scale lies ahead of N^{th} division of main scale, then main scale reading (M.S.R.) = N

If with division of vernier scale coincides with any division of main scale, then vernier scale reading (V.S.R.)

$= n \times (L.C.)$ (L.C. is least count of vernier callipers)

$= n \times (V.C.)$ (V.C. is vernier constant of vernier callipers)

And total reading, *T.R. = M.S.R. + V.S.R. = N + n × (V.C.)*

Precautions :

- Make the motion of vernier scale on main scale very smooth (by oiling).
- Find the vernier constant and zero error carefully and record them properly.
- Grip the body between the jaws formerly but gently.
- Take atleast observation at three different places at right angles at each place.
- No parallax should be there.

EXPERIMENT 2

Aim : ***To determine thickness/diameter of thin sheet/wire using a Screw Guage.***

Theory : If with the wire between plane faces A and B, the edge of the cap lies ahead of Nth division of linear scale.

Then, linear scale reading (L.S.R.) = N

If nth division of circular scale lies over reference line, then circular scale reading (C.S.R.) = n × L.C. (L.C. is least count of screw gauge)

Total reading, *T.R. = L.S.R. + C.S.R. = N + n × (L.C.)*

First calculate the pitch of screw guage.

$$Pitch = \frac{Distance\ moved\ by\ screw}{Number\ of\ rotations}$$

Note the total number of divisions on the circular scale, then

$$\text{Least count (L.C.)} = \frac{\text{Pitch}}{\text{Total number of division on the circular scale}}$$

To find **zero error,** screw up until the gap between jaws is just closed and ratchet arrangement gives a click. If zero division of the circular scale coincides with the refrence line, then there is no zero error, if reference line may be x divisions towards positive side of zero, then zero error is + x × L.C. and if negative side then zero error is – x × L.C.

Precautions :

- Always rotate the screw by the ratchet and not by the cap.
- The screw should move freely without friction.
- Note the zero correction properly (with sign).
- Avoid back-lash error of the screw by moving it in the same direction for same set of observations.
- Measure the diameter into two perpendicular directions at each place.
- Avoid parallax error.

EXPERIMENT 3

Aim : ***To measure the mass of a given object by the principle of moments using a metre scale.***

Material Required : *A set of known masses, metre scale and an unknown mass.*

Theory : If m and M be the mass of the body and mass of the weight used and a_1 and a_2 be the distances of their loops from wedge. Then, power (mass) arm = a_1, weight arm = a_2

From principle of moments $mg\,a_1 = Mg\,a_2$

$$\text{or} \quad m = \frac{Ma_2}{a_1}, \text{ which can be calculated.}$$

Precautions :

- Use a broad and heavy wedge with sharp edge.
- Metre scale should have uniform mass distribution.
- Threads used for loops should be thin, light and strong.

EXPERIMENT 4

Aim : ***Determination of Young's modulus of elasticity of the material of a metallic wire.***

Material Required : Searle's apparatus with steel wire, screw gauge, metre rod and weight.

Theory : If a wire of length L and radius r be loaded by a weight Mg and if l be the increase in length, then,

$$\text{Normal stress} = \frac{\text{Mg}}{\pi r^2} \text{ and longitudinal strain } = \frac{l}{\text{L}}$$

$$\text{Hence, Young's modulus (Y)} = \frac{\text{Normal stress}}{\text{Longitudinal strain}}$$

$$\text{or} \quad \text{Y} = \frac{\text{Mg}/\pi r^2}{l/\text{L}} \quad \text{or} \quad Y = \frac{MgL}{\pi r^2 l}$$

Knowing L and r, and finding l for known Mg, Y can be calculated.

Mg = wt. suspended; L = original length of the wire; r = radius of the wire; l = change in length of wire

Precautions :

- The wires (both experimental and auxiliary) should be of same length, material and thickness.
- They must be supported from the same rigid support.
- Kinks should be removed from the experimental wire.
- Measure the diameter of the wire at different places and along two mutually perpendicular directions at every place.
- Add and remove weights gently and slowly.

EXPERIMENT 5

Aim : ***Calculation of surface tension of water by capillary rise and effect of detergents.***

Material Required : Tubes of different radii, a pointer, metallic plate, travelling microscope, open dish, thermometer etc.

Theory : Let the liquid rise upto a height h (as measured for the lower meniscus B) and let the meniscus ABC have hemispherical shape [Fig. (b)].

Then, volume of the liquid risen upto lower meniscus = $\pi r^2 h$

Volume of liquid in meniscus above B.

= Volume of cylinder of radius r – Volume of hemisphere of radius r

$$= \pi r^2 . r - \frac{2}{3}\pi r^3 = \frac{1}{3}\pi r^3$$

Total volume of the liquid risen

$$= \pi r^2 h + \frac{1}{3}\pi r^3 = \pi r^2 \left[h + \frac{r}{3} \right]$$

Precautions :

- Capillary tube and water should be free from grease.
- The tube should be set properly.
- Vertical microscope should be moved in lower direction only to avoid back-lash error.
- Keep a note of the temperature of water.
- Measure the internal diameter of the capillary tube in two mutually perpendicular directions.

EXPERIMENT 6

Aim : ***Calculation of co-efficient of viscosity of a given viscous liquid by measuring terminal velocity of a given spherical body.***

Material Required : A beaker or jar, screw gauge, viscous liquid. steel ball, glycerine and paper clip.

Theory : We know that the terminal velocity

$$v = \frac{2r^2}{9\eta}(\rho - \sigma); \quad \text{or,} \quad \eta = \frac{2r^2(\rho - \sigma)g}{9v}$$

where, r = radius of spherical body, ρ = density of solid, σ = density of liquid, v = terminal velocity, η = coefficient of viscosity.

Precautions :

- Liquid should be transparent to watch the motion of the ball.
- Ball should be perfectly spherical.
- Note the velocity only once it becomes constant.

EXPERIMENT 7

Aim : ***Determination of specific heat capacity of a given (a) solid (b) liquid by method of mixtures.***

Material Required : A calorimeter, a metal piece, water, thermometer, balance, burner etc.

Theory : Firstly measure the mass of metal piece heated upto temperature T_1. Now drop metal piece into known mass of water in copper calorimeter whose initial temperature is T_2 ($T_2 < T_1$). After strirring sometime the temperature of mixture becomes T. The specific heat of water is known i.e., in M.K.S. system 4200 J/kg°C. So, according to the principle of calorimetery,

Heat lost by metal piece = Heat gained by water

$$m_1c_1(T_1 - T) = m_2c_2(T - T_2)$$

$$\text{so, } c_1 = \frac{m_2c_2(T - T_2)}{m_1(T_1 - T)}$$

Precautions :

- Take the reading of thermometer carefully.
- Stirring should remain continuous,

EXPERIMENT 8

Aim : ***To determine the speed of sound in air at room temperature using a resonance tube.***

Principle : The resonance tube works on the phenomenon of resonance of air column.

Theory : Let l_1 and l_2 be the length of the air column for the first and the second resonance respectively with a tuning fork of frequency ν then, $\lambda = 2(l_2 - l_1)$

From relation, $v = \nu\lambda$

$\Rightarrow v = \nu\, 2(l_2 - l_1)$ [Putting the value of λ]

$\Rightarrow v = 2\nu(l_2 - l_1)$, which can be calculated.

If *t* be the temperature of the air in air column of the resonance tube Then from formula,

$$\frac{v}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273 + t}{273}} \quad \text{or} \quad v_0 = v\sqrt{\frac{273}{273 + t}}$$

Precautions :

- Keep the resonance tube vertical and pinch cock tight.
- Vibrate the tuning fork gently by a rubber pad.
- Prongs should be vibrated in a vertical plane above the mouth (end) of the metallic tube and it should not touch it.
- Note the reading for water level falling and rising using a set square.
- While measuring the air temperature, thermometer bulb should not touch water or sites of the resonance tube.

EXPERIMENT 9

Aim : ***To determine the resistance and resistivity of the material of a given wire using metre bridge.***

Material Required : A meter bridge, wire whose resistivity is to be measure, battery, etc.

Theory :

(i) For Resistance : Let AB = ℓ cm, then BC = (100 – ℓ)

As the metre bridge wire AC has uniform material density and area of cross-section.

$$\frac{P}{Q} = \frac{R}{X} \text{ or } X = \frac{Q}{P}R \text{ or } \boxed{X = \frac{(100 - \ell)}{\ell}.R}$$

So knowing R and ℓ, unknown resistance X can be determined.

(ii) For Specific Resistance : From resistance formula

$$X = \rho\frac{L}{A} \text{ or } \rho = \frac{XA}{L}$$

For a wire of radius r or diameter D = 2r

$$A = \pi r^2 = \frac{\pi D^2}{4} \text{ Hence, } \boxed{\rho = \frac{X\pi D^2}{4L}}$$

Precautions :

- The connections should be neat, clean and tight.
- Move the jockey gently over the bridge wire and do not rub it.
- Introduce a high resistance box in series or a low resistance shunt in parallel with the galvanometer to save the sensitive galvanometer from high current.
- When taking the observation, close the box or open the shunt.
- The plug in the key should be inserted only when the observations are to be taken.
- Keep the null point between 40 cm and 60 cm.
- Use set square to note null point to avoid parallax error.
- Measure the diameter of the wire in two mutually perpendicular directions at one place.
- The wire should not make a loop.

EXPERIMENT 10

Aim : ***To determine the resistance of a given wire using Ohm's law.***

Material Required : Ammeter, voltmeter, rheostat, battery and wire whose resistance is to be determined.

Theory : If V is the potential difference between the two ends of a conductor and I be the current flowing through it, then

$$V \propto I \text{ or } V = IR$$

where R is the resistance of the conductor.

Precautions :

- The connections should be neat, clean and tight.
- Use thick copper wires for the connections after removing the insulations near their ends by sand paper.
- The range of the ammeter and voltmeter should be proper.
- Use a low resistance rheostat.
- The unknown resistance should not be too low (much lower than the internal resistance of the battery).
- The key should be inserted only while taking observations to avoid heating of resistance (otherwise its resistance will increase).

EXPERIMENT 11

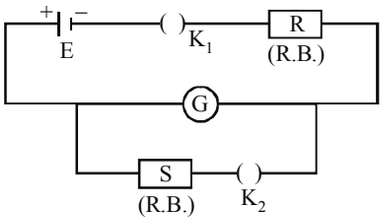
Aim : ***To determine the resistance and figure of merit of a galvanometer by half deflection method.***

Material Required : Resistance box, galvanometer, battery etc.

Theory :

When K_1 is closed and K_2 is open, the current I_g through the galvanometer

$$I_g = \frac{E}{R+G} = k\theta \quad [E = \text{e.m.f. of the cell}]$$



When K_2 is closed, current through the galvanometer,

$$I'_g = \frac{ES}{R(G+S)+GS} = \frac{k\theta}{2}$$

$$\therefore \quad G = \frac{RS}{R-S}$$

Figure of merit (k) can be calculated by the relation,

$$I_g = k\,\theta \Rightarrow k = \frac{E}{(R+G)}$$

Where θ is the deflection of the galvanometer when current through it is I_g.

Precautions :

- The e.m.f. of cell or battery should be constant.
- The ammeter used for verification should preferably be of same range, as the range of conversion.
- Initially a high resistance from the resistance box should be introduced in the circuit (otherwise for small resistance an excess current will flow and damage the galvanometer or ammeter).
- Measure the diameter of the shunt resistance wire (neither too small nor too large in length) accurately.

EXPERIMENT 12(i)

Aim : ***To determine the focal length of a concave mirror.***

Material Required : Concave mirror, object needle, metre scale etc.

Theory : Let an object needle be at a distance 'u' from the mirror. Position of image is found by removing the parallax between the image of the object needle and the image needle.

Let 'v' be the distance of the image from the mirror. Then the focal length of the mirror 'f' is calculated from the relation $f = \frac{uv}{u+v}$

EXPERIMENT 12(ii)

Aim : ***To find the focal length of convex mirror using convex lens.***

Material Required : Convex mirror, convex lens, metre scale.

Theory : Focal length $f = \frac{r}{2}$ or, $r = 2f$

EXPERIMENT 12(iii)

Aim : ***To find the focal length of a convex lens by plotting u versus v graph and $\frac{1}{u}$ versus $\frac{1}{v}$ graph.***

Material Required : Convex lens, image needle and metre scale.

Theory :

The focal length is calculated by the relation $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Precautions :

- Principal axis of the mirror should be horizontal and parallel to the central line of the optical bench.
- The uprights should be vertical.
- Tip to tip parallax should be removed between the needle and image of the needle.
- To locate the position of the image the eye should be at least 30 cm away from the needle.
- Tips of the object and image needles should lie at the same height as that of pole of the concave mirror.
- Index correction for u and v should be applied.

(For experiment iii)

- Tips of the object and image needles should lie at the same height as the centre of the lens.
- Parallax should be removed from tip to tip by keeping eye at a distance atleast 30 cm away from the needle.
- The object needle should be placed at such a distance that only real, inverted image of it is formed.
- Index correction for u and v should be applied.

EXPERIMENT 13

Aim : ***Using parallax method, to plot a graph of angle of deviation vs angle of incidence for a triangular prism.***

Material Required : A prism, a protactor, drawing board, drawing pins.

Theory : The refractive index of the material be calculated by the formula.

$$\mu = \frac{\left(\frac{\sin(A+D_m)}{2}\right)}{\sin\frac{A}{2}}$$

where, A = angle of prism

D_m = angle of minimum deviation

Precautions :

- A sharp pointed pencil should be used for drawing boundary of the prism and for making the pin pricks.
- The angle of incidence should lie between 30º–60º.
- The pins should be fixed vertical.

- The distance between the two pins should not be less than 10 cm.
- Arrow heads should be marked to represent the incident and emergent rays.
- The same angle of prism should be used for all the observations.

EXPERIMENT 14

Aim : ***To determine the refractive index of a glass slab using a travelling microscope.***

Material Required : Travelling microscope, ink, white paper and glass slab.

Theory : Refractive index of glass $\mu = \frac{Real\ depth}{Apparent\ depth}$

Precautions :

- In microscope, the parallax should be properly removed.
- The microscope should be moved in upper direction only to avoid back lash error.

EXPERIMENT 15

Aim : ***To draw the characteristic curves of a p-n junction diode in forward and reverse bias.***

Material Required : PN junction diode, milliammeter, micro-ammeter, voltmeter, potentiometer and battery.

Theory :

Forward-bias Pn junction. It produces forward current. With increase in bias voltage the forward current increases slowly in the beginning and then rapidly. At about 2.4 V, the current increases suddenly. The bias is at once made zero to avoid damage to the diode.

Reverse-bias Pn junction. In the beginning no appreciable reverse current flows. At about 5V a feeble current starts flowing. With increase in bias voltage, the current slowly increases. At about 25 V the reverse current increases suddenly. Again the bias is made zero to avoid damage.

Precautions :

- All connections should be neat, clean and tight.
- Key should be used in circuit and opened when the circuit is not being used.
- Forward-bias voltage beyond breakdown should not be applied.
- Reverse-bias voltage beyond breakdown should not be applied.

EXPERIMENT 16

Aim : ***To draw the characteristic curves of a Zener diode and finding reverse breakdown voltage.***

Material Required : Zener diode, battery microammeter and voltmeter.

Theory :

Zener diode a semiconductor diode, in which the n-type and the p-type sections are heavily doped, i.e., they have more percentage of impurity atoms. This heavy doping results in a low value of reverse breakdown voltage (BV_R). This value can be controlled during manufacture.

The reverse breakdown voltage of Zener diode, is called Zener current (I_Z).

Precautions :

- All connection should be neat, clean and tight.
- Key should be used in circuit and opened when the circuit is not being used.

EXPERIMENT 17

Aim : ***To identify diode, LED, transistor, IC, resistor, capacitor from mixed collection of such items.***

Description :

(i) **Diode :** Diodes are two terminal devices. A diode is a device that has a very high resistance when connected in reverse bias i.e. the p-side is connected to negative side of the battery and n-side to positive of the battery. But it has a very low resistance when connected in forward bias i.e. p-side is connected to positive and n-side to negative of a battery.

Semiconductor diodes are designed by two letters followed by a serial number. The first letter indicates the material : A is used for material with a band gap of 0.6 eV to 1.0 eV such as germanium. B is used for material with a band gap of 1.0 eV to 1.3 eV, such as silicon. The second letter indicates the main application : A signifies **detection diode**. B denotes a variable **capacitance diode**, E. for **tunnel diode**, Y for **rectifying diode** and Z denotes **zener diode**. The serial number specify the diodes with particular values of power rating, peak reverse voltage, maximum **current** rating etc. For example, BY127 and BZ148 respectively denote a **silicon rectifier diode** and a **silicon zener diode**.

(ii) **LED (light emitting diode) :** It is a p-n junction diode, operates in forward bias and emits light. It's negative leg is longer than the positive.

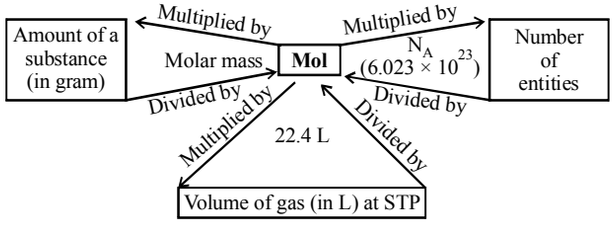
(iii) **Resistor:** They are 2 terminal devices. When it is connected in a d.c. circuit, it shows a constant current. It shows continuity both in direct and reverse connectors.

(iv) **Capacitor :** Capacitors are two terminal devices. When it is connected to a battery, electric charge immediately flows into the capacitor until it is full. This takes fraction of a second. With a multimeter it shows a full scale deflection indicating small resistance initially which becomes infinite in a fraction of a second.

CHEMISTRY

PHYSICAL CHEMISTRY

Some Basic Concepts of Chemistry



- Molecular mass $= \dfrac{\text{Average relative mass of one molecule}}{\frac{1}{12} \times \text{mass of C-12 atom}}$
- Molecular mass = 2 × VD
- Molecular formula = $(\text{Empirical formula})_n$

Atomic Structure

- Energy of electron in species with one electron.

$$E_n = \frac{-2\pi^2 me^4 Z^2}{n^2 h^2}$$

For energy in SI system, $E_n = \dfrac{-2\pi^2 me^4 Z^2}{n^2 h^2 (4\pi\varepsilon_0)^2}$

$$E_n = \frac{-1312 Z^2}{n^2} \text{ kJ mol}^{-1}$$

$$mvr = \frac{nh}{2\pi}$$

- $r = \dfrac{n^2 h^2}{4\pi^2 mZe^2} = 0.529 \left(\dfrac{n^2}{Z}\right)$ Å
- Total energy of electron in the n^{th} shell

$$= \text{K.E.} + \text{P.E.} = kZ\frac{e^2}{2r_n} + \left(-\frac{kZe^2}{r_n}\right) = -\frac{kZe^2}{2r_n}$$

- $\bar{\upsilon} = \dfrac{1}{\lambda} = RZ^2\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$, $[R = 1.0968 \times 10^7 \text{ m}^{-1}]$

$$E = h\nu = \frac{hc}{\lambda}, \quad \lambda = \frac{h}{\sqrt{2m \times \text{K.E.}}}$$

- Heisenberg's Uncertainty Principle $(\Delta x)(\Delta p) \geq h/4\pi$
- Nodes $(n - 1)$ = total nodes, ℓ = angular nodes, $(n - \ell - 1)$ = Radial nodes

Chemical Bonding

- (i) % ionic character $= \dfrac{\text{Actual dipole moment}}{\text{Calculated dipole moment}} \times 100$

  (ii) Dipole moment is helpful in predicting geometry and polarity of molecule.
- **Fajan's Rule :** Following factors are helpful in increasing covalent character in ionic compounds
  - (i) Small cation
  - (ii) Big anion
  - (iii) High charge on cation/anion
  - (iv) Cation having pseudo inert gas configuration ($ns^2p^6d^{10}$) e.g. Cu^+, Ag^+, Zn^{2+}, Cd^{2+}
- **M.O. theory :**

  (i) Bond order = $\frac{1}{2}(N_b - N_a)$

  (ii) Higher the bond order, higher is the bond dissociation energy, greater is the stability, shorter is the bond length.
- Formal charge (F.C.) on an atom in a Lewis structure
  = [total number of valence electrons in the free atoms]
  – [total number of non-bonding (lone pair) electrons]
  $-\dfrac{1}{2}$[total number of bonding (shared) electrons]
- **Relative bond strength :** $sp^3d^2 > dsp^2 > sp^3 > sp^2 > sp > p\text{-}p$ (Co-axial) > s - p > s - s > p - p (Co-lateral)
- **VSEPR theory**
  - (i) (LP-LP) repulsion > (LP-BP) > (BP-BP)
  - (ii) $NH_3 \rightarrow$ Bond Angle 107° 45' because (LP-BP) repulsion > (BP-BP) $H_2O \rightarrow$ 104° 27' because (LP-LP) repulsion > (LP-BP) > (BP-BP)
- **Hybridisation :**

$$= \frac{1}{2}\begin{pmatrix} \text{number of valence electrons of central atom} \\ + \text{number of monovalent atoms attached to it} \\ + \text{negative charge if any} - \text{positive charge if any} \end{pmatrix}$$

Chemical Equilibrium

- $K_p = K_c (RT)^{\Delta n_g}$ where $\Delta n_g = n_P - n_R$
- Free Energy Change (ΔG)
  (a) If $\Delta G = 0$ then reversible reaction would be in equilibrium, $K_c = 0$
  (b) If ΔG = (+) ve then equilibrium will be displaced in backward direction; $K_c < 1$
  (c) If ΔG = (–) ve then equilibrium will shift in forward direction; $K_c > 1$
- (a) K_c unit $\rightarrow (mol/lit)^{\Delta n}$,
  (b) K_p unit $\rightarrow (atm)^{\Delta n}$
- **Reaction Quotient and Equilibrium Constant**
  Consider the following reversible reaction $A + B \rightleftharpoons C + D$

  $\therefore \quad Q_c = \frac{[C][D]}{[A][B]}$

  Case I : If $Q_c < K_c$ then : [Reactants] > [Products]
  then the system is not at equilibrium
  Case II : If $Q_c = K_c$ then : The system is at equilibrium.
  Case III : If $Q_c > K_c$ then : [Products] > [Reactants]
  The system is not at equilibrium.
- A relationship between the equilibrium constant K_C, reaction quotient and Gibb's energy.
  $\Delta G = \Delta G° + RT \ln Q$
  At equilibrium $\Delta G = 0$ and $Q = K$ then $\Delta G° = -RT \ln K_c$
  $\therefore \quad \Delta G° = -RT \ln K_p$
- Le-Chatelier's principle
  (i) Increase of reactant conc. (Shift reaction forward)
  (ii) Decrease of reactant conc. (Shift reaction backward)
  (iii) Increase of pressure (from more moles to less moles)
  (iv) Decrease of pressure (from less moles to more moles)
  (v) For exothermic reaction decrease in temp. (Shift forward)
  (vi) For endothermic increase in temp. (Shift backward)

Ionic Equilibrium

- (i) Lewis Acid (e^- pair acceptor) $\rightarrow CO_2, BF_3, AlCl_3, ZnCl_2$, normal cation
  (ii) Lewis Base (e^- pair donor) $\rightarrow NH_3$, ROH, ROR, H_2O, RNH_2, normal anions
- Dissociation of Weak Acid and Weak Base
  (i) Weak Acid, $K_a = Cx^2/(1-x)$ or $K_a = Cx^2$; $x << 1$
  (ii) Weak Base, $K_b = Cx^2/(1-x)$ or $K_b = Cx^2$; $x << 1$
- Buffer solution {Henderson equation} :
  (i) Acidic, $pH = pK_a + \log \{Salt/Acid\}$.
  For maximum buffer action $pH = pK_a$
  Range of buffer $pH = pK_a \pm 1$
  (ii) Alkaline $\rightarrow pOH = pK_b + \log \{Salt/Base\}$ for max. buffer action $pH = 14 - pK_b$
  Range $pH = 14 - pK_b \pm 1$
- Relation between ionisation constant (K_i) and degree of ionisation(α) : – $K_i = \frac{\alpha^2}{(1-\alpha)V} = \frac{\alpha^2 C}{(1-\alpha)}$ = (Ostwald's dilution law)
  It is applicable to weak electrolytes for which $\alpha << 1$ then

  $\alpha = \sqrt{K_i V} = \sqrt{\frac{K_i}{C}}$ or $V \uparrow C \downarrow \alpha \uparrow$
- **Common ion effect :** By addition of X mole/L of a common ion, to a weak acid (or weak base) α becomes equal to $\frac{K_a}{X}\left(\text{or } \frac{K_b}{X}\right)$ [where α = degree of dissociation]
- (i) If solubility product > ionic product then the solution is unsaturated and more of the substance can be dissolved in it.
  (ii) If ionic product > solubility product the solution is super saturated (principle of precipitation).
- Salt of weak acid and strong base :

  $pH = 0.5 (pK_w + pK_a + \log c)$; $h = \sqrt{\frac{K_h}{c}}$; $K_h = \frac{K_w}{K_a}$

  (h = degree of hydrolysis)
  Salt of weak base and strong acid :

  $pH = 0.5 (pK_w - pK_b - \log c)$; $h = \sqrt{\frac{K_w}{K_b \times c}}$

  Salt of weak acid and weak base :

  $pH = 0.5 (pK_w + pK_a - pK_b)$; $h = \sqrt{\frac{K_w}{K_a \times K_b}}$

Redox Reactions

- Oxidant itself is reduced (gives O_2)
  Or Oxidant $\longrightarrow$ e^- (s) Acceptor
  Reductant itself is oxidised (gives H_2)
  Or reductant $\longrightarrow$ e^- (s) Donor
- (i) Strength of acid $\propto$ O.N
  (ii) Strength of base $\propto$ 1/ O.N
- (i) Electrochemical Series:- Li, K, Ba, Sr, Ca, Na, Mg, Al, Mn, Zn, Cr, Fe, Cd, Co, Ni, Sn, Pb, H_2, Cu, Ag, Pt, Au.
  (ii) As we move from top to bottom in this series
  (a) Standard Reduction Potential ↑
  (b) Standard Oxidation Potential
  (c) Reducing Capacity ↓
  (d) IP ↑
  (e) Reactivity ↓

Thermodynamics

- First Law of Thermodynamics : $\Delta E = Q + W$
  Expression for pressure volume work $W = -P\Delta V$

Maximum work in a reversible expansion :

$$W = -2.303n\,RT \log \frac{V_2}{V_1} = -2.303\,nRT \log \frac{P_1}{P_2}$$

$W_{rev} \geq W_{irr}$

- $q_v = C_v\Delta T = \Delta U$, $q_p = C_p\Delta T = \Delta H$

Enthapy changes during phase transformation

(i) Enthalpy of Fusion
(ii) Heat of Vapourisation
(iii) Heat of Sublimation

- **Enthalpy :** $\Delta H = \Delta E + P\Delta V = \Delta E + \Delta n_g RT$
- **Entropy(s) :** Measure of disorder or randomness

$\Delta S = \Sigma S_p - \Sigma S_R$

$$\Delta S = \frac{q_{rev}}{T} = 2.303\,nR \log \frac{V_2}{V_1} = 2.303\,n\,R \log \frac{P_1}{P_2}$$

- Free energy change : $\Delta G = \Delta H - T\Delta S$, $\Delta G^o = -nFE^o_{cell}$
  $-\Delta G = W(maximum) - P\Delta V$, $\Delta G_{system} = -T\Delta S_{total}$

ΔH	ΔS	ΔG	Reaction characteristics
–	+	Always negative	Reaction is spontaneous at all temperature.
+	–	Always positive	Reaction is nonspontaneous at all temperature
–	–	Negative at low temperature but positive at high temperature	Spontaneous at low temp. & non spontaneous at high temperature
+	+	Positive at low temp. but negative at high temperature	Non spontaneous at low temp. & spontaneous at high temp.

INORGANIC CHEMISTRY

Periodic Table

- General electronic configuration (of outer orbits)

s-block ns^{1-2}
p-block ns^2np^{1-6}
d-block $(n-1)d^{1-10}\ ns^{1-2}$
f-block $(n-2)f^{1-14}s^2p^6d^{10}$
$(n-1)s^2p^6d^{0\text{ or }1}\ ns^2$

	Property	Pr (L To R)	Gr (T to B)
(i)	Atomic radius	↓	↑
(ii)	Ionisation potential	↑	↓
(iii)	Electron affinity	↑	↓
(iv)	Electronegativity	↑	↓
(v)	Metallic character or electropositive character	↓	↑
(vi)	Alkaline character of hydroxides	↓	
(vii)	Acidic character	↑	↓
(viii)	Reducing property	↓	↑
(ix)	Oxidising property	↑	↓
(x)	Non metallic character	↑	↓

- $IP \propto \frac{1}{\text{Metallic character}} \propto \frac{1}{\text{Reducing character}}$
- $EA \propto \frac{1}{\text{size}} \propto$ nuclear charge.

Second electron affinity is always negative.
Electron affinity of chlorine is greater than fluorine (small atomic size).

- The first element of a group has similar properties with the second element of the next group. This is called diagonal relationship. The diagonal relationship disappears after IV group.

Boron Family

- Stability of +3 oxidation state : B > Al > Ga > In > Tl
- Stability of +1 oxidation state : Ga < In < Tl
- Basic nature of the oxides and hydroxides : B < Al < Ga < In < Tl
- Relative strength of Lewis acid : $BF_3 < BCl_3 < BBr_3 < BI_3$
- **Ionisation energy : B > Al < Ga > In < Tl**
- **Electronegativity :** Electronegativity first decreases from B to Al and then increases marginally.

Carbon Family

- Reactivity : C < Si < Ge < Sn < Pb
- Metallic character : C < Si < Ge < Sn < Pb
- Acidic character of the oxides :
  $CO_2 > SiO_2 > GeO_2 > SnO_2 > PbO_2$
  Weaker acidic (amphoteric)
- Reducing nature of hydrides
  $CH_4 < SiH_4 < GeH_4 < SnH_4 < PbH_4$
- Thermal stability of tetrahalides
  $CCl_4 > SiCl_4 > GeCl_4 > SnCl_4 > PbCl_4$
- Oxidising character of M^{+4} species
  $GeCl_4 < SnCl_4 < PbCl_4$
- Ease of hydrolysis of tetrahalides
  $SiCl_4 < GeCl_4 < SnCl_4 < PbCl_4$

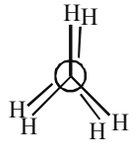
ORGANIC CHEMISTRY

General Organic Chemistry

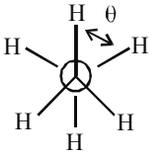
- The order of decreasing electronegativity of hybrid orbitals is $sp > sp^2 > sp^3$.
- Conformational isomers are those isomers which arise due to rotation around a single bond.
- A meso compound is optically inactive, even though it has asymmetric centres (due to internal compensation of rotation of plane polarised light)
- An equimolar mixture of enantiomers is called racemic mixture, which is optically inactive.
- Reaction intermediates and reagents :
  Homolytic fission $\rightarrow$ Free radicals
  Heterolytic fission $\rightarrow$ Ions (Carbonium ions, carbanions etc.)
- Nucleophiles – Electron rich
  Two types : (i) Anions (ii) Neutral molecules with lone pair of electrons (Lewis bases)
  Electrophiles : Electron deficient.
  Two types : (i) Cations (ii) Neutral molecules with vacant orbitals (Lewis acids).
- Inductive effect is due to σ electron displacement along a chain and is permanent effect.
- +I (inductive effect) increases basicity, – I effect increases acidity of compounds.
- Resonance is a phenomenon in which two or more structures can be written for the same compound but none of them actually exists.

Alkanes

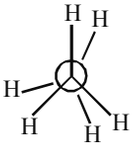
- Pyrolytic cracking is a process in which alkane decomposes to a mixture of smaller hydrocarbons, when it is heated strongly, in the absence of oxygen.
- Ethane can exist in an infinite number of conformations. They are



Eclipsed



$\theta = 60°$ Staggered



$\theta < 60° > 0$ Skew

Alkenes

- In dehydration and dehydrohalogenation the preferential order for removal of hydrogen is $3° > 2° > 1°$ (Saytzeff's rule).
- The lower the ΔH_h (heat of hydrogenation) the more stable the alkene is.
- Alkenes undergo anti-Markonikov addition only with HBr in the presence of peroxides.

Alkynes

- Alkynes add water molecule in presence of mercuric sulphate and dil. H_2SO_4 and form carbonyl compounds.
- Terminal alkynes have acidic H-atoms, so they form metal alkynides with Na, ammonical cuprous chloride solution and ammoniacal silver nitrate solution.
- Alkynes are acidic because of H-atoms which are attached to sp 'C' atom which has more electronegativity and 's' character than sp^2 and sp^3 'C' atoms.

Arenes

- All o and p-directing groups are ring activating groups (except – X)
  They are : $-OH, -NH_2, -X, -R, -OR$, etc.
- All m-directing groups are ring deactivating groups.

  They are : $-CHO, -COOH, -NO_2, -CN, -\overset{+}{N}R_3$, etc.

PHYSICAL CHEMISTRY

Chemical Kinetics

- **Unit of rate constant :** $k = mol^{1-n}\ lit^{n-1}\ sec^{-1}$
- **Order of reaction** It can be fraction, zero or any whole number.
- **Molecularity of reaction** is always a whole number. It is never more than three. It cannot be zero.
- **First Order Reactions :**

$$k = \frac{2.303}{t}\log_{10}\frac{a}{(a-x)}\ \&$$

$$t_{1/12} = \frac{0.693}{k}\ [A]_t = [A]_0 e^{-kt}$$

- **Second Order Reactions :** When concentration of A and B taking same. $k_2 = \frac{1}{t}\left(\frac{x}{a(a-x)}\right)$

When concentration of A and B are taking different -

$$k_2 = \frac{2.303}{t(a-b)}\log\frac{b(a-x)}{a(b-x)}$$

- **Zero Order Reaction :** $x = kt$ and $t_{1/2} = \frac{a}{2k}$

The rate of reaction is independent of the concentration of the reacting substance.

- Time of n^{th} fraction of first order process,

$$t_{1/n} = \frac{2\cdot303}{k}\log\left(\frac{1}{1-\frac{1}{n}}\right)$$

- Amount of substance left after 'n' half lives $= \frac{[A]_o}{2^n}$
- **Arrhenius equation :** $k = Ae^{-E_a/RT}$, slope $= \frac{-E_a}{2.303R}$

and Temperature Coefficient $\log\left(\frac{k_2}{k_1}\right) = \frac{E_a}{2.303R}\left(\frac{T_2-T_1}{T_1T_2}\right)$

- It has been found that for a chemical reaction with rise in temperature by 10 °C, the rate constant gets nearly doubled.

$$k = PZ_{AB}e^{-E_a/RT}$$

Electrochemistry

- Degree of dissociation : $\alpha = \frac{\lambda_{eq}}{\lambda^0_{eq}}$
- Specific conductance

$$\kappa = \frac{1}{\rho} = \frac{\ell}{R.a} = G \times \frac{\ell}{a} = G \times \text{cell constant } (G^*);$$

$$\Lambda_m = \frac{\kappa \times 1000}{M},\ \Lambda_{eq} = \frac{\kappa \times 1000}{N}$$

- Kohlrausch's law : $\Lambda^0_m = x\lambda^0_A + y\lambda^0_B$
- Nernst Equation $E = E^o - \frac{0.0591}{n}\log_{10}\frac{[Products]}{[Reactants]}$

$$\&\ E^o_{Cell} = E^o_{right} + E^o_{left}\ \&\ K_{eq.} = \text{antilog}\left[\frac{nE^o}{0.0591}\right]$$

$$\Delta G = -nFE_{cell}\ \&\ \Delta G^o = -nFE^o\,cell = -2.303\ RT\log K_c$$

- Calculation of pH of an electrolyte by using a calomel electrode : $pH = \frac{E_{cell} - 0.2415}{0.0591}$
- Thermodynamic efficiency of fuel cell is 95%.

Solutions

- $P = K_H \cdot x$
- Normality (N) $= \frac{\text{number of equivalents}}{\text{volume of the solution in litres}}$
- Molarity (M) $= \frac{\text{number of moles}}{\text{volume of the solution in litres}}$
- Raoult's law

$$P = p_A + p_B = p^\circ_A X_A + p^\circ_B X_B$$

- **Characteristics of an ideal solution:**

(i) $\Delta_{sol}V = 0$ (ii) $\Delta_{sol}H = 0$

- Relative lowering of vapour pressure $= \frac{P^o_A - P_A}{P^o_A}$

$$\frac{P^o_A - P_A}{P^o_A} = X_B = \frac{n_B}{n_A + n_B}$$

- Colligative $\propto$ Number of particles/ ions/ moles of solute properties
- Depression of freezing point, $\Delta T_f = K_f m$

- Elevation in boiling point with relative lowering of vapour pressure $\Delta T_b = \frac{1000K_b}{M_1}\left(\frac{p^o - p}{p^o}\right)$ (M_1 = mol. wt. of solvent)
- Osmotic pressure (P) with depression in freezing point ΔT_f

$$P = \Delta T_f \times \frac{dRT}{1000K_f}$$

- Relation between Osmotic pressure and other colligative properties:

(i) $\pi = \left(\frac{p_A^o - p_A}{p_A^o}\right) \times \frac{dRT}{M_B}$ Relative lowering of vapour pressure

(ii) $\pi = \Delta T_b \times \frac{dRT}{1000K_b}$ Elevation in boiling point

(iii) $\pi = \Delta T_f \times \frac{dRT}{1000K_f}$ Depression in freezing point

- $i = \frac{\text{Normal molar mass}}{\text{Observed molar mass}} = \frac{\text{Observed colligative property}}{\text{Normal colligative property}}$
- Degree of association $a = (1 - i)\frac{n}{n-1}$

& degree of dissociation $(\alpha) = \frac{i-1}{n-1}$

INORGANIC CHEMISTRY

Nitrogen Family

- Acidic strength of trioxides : $N_2O_3 > P_2O_3 > As_2O_3$
- Acidic strength of pentoxides
  $N_2O_5 > P_2O_5 > As_2O_5 > Sb_2O_5 > Bi_2O_5$
- Acidic strength of oxides of nitrogen
  $N_2O < NO < N_2O_3 < N_2O_4 < N_2O_5$
- Basic nature, bond angle, thermal stability and dipole moment of hydrides $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$
- Stability of trihalides of nitrogen : $NF_3 > NCl_3 > NBr_3$
- Lewis base strength : $NF_3 < NCl_3 > NBr_3 < NI_3$
- Ease of hydrolysis of trichlorides
  $NCl_3 > PCl_3 > AsCl_3 > SbCl_3 > BiCl_3$
- Lewis acid strength of trihalides of P, As and Sb
  $PCl_3 > AsCl_3 > SbCl_3$
- Lewis acid strength among phosphorus trihalides
  $PF_3 > PCl_3 > PBr_3 > PI_3$
- Nitrogen displays a great tendency to form $p\pi - p\pi$ multiple bonds with itself as well as with carbon and oxygen.
- The basic strength of the hydrides
  $NH_3 > PH_3 > AsH_3 > SbH_3$
- The thermal stability of the hydrides decreases as the atomic size increases.

Oxygen Family

- Melting and boiling point of hydrides :
  $H_2O > H_2Te > H_2Se > H_2S$
- Volatility of hydrides: $H_2O < H_2Te < H_2Se < H_2S$
- Reducing nature of hydrides : $H_2S < H_2Se < H_2Te$
- Covalent character of hydrides : $H_2O < H_2S < H_2Se < H_2Te$
- The acidic character of oxides (elements in the same oxidation state) $SO_2 > SeO_2 > TeO_2 > PoO_2$; $SO_3 > SeO_3 > TeO_3$
- Acidic character of oxide of a particular element (e.g. S)
  $SO < SO_2 < SO_3$; $SO_2 > TeO_2 > SeO_2 > PoO_2$

Halogen Family

- Bond energy of halogens : $Cl_2 > Br_2 > F_2 > I_2$
- Solubility of halogen in water : $F_2 > Cl_2 > Br_2 > I_2$
- Oxidising power : $F_2 > Cl_2 > Br_2 > I_2$
- Enthalpy of hydration of X^- ion : $F^- > Cl^- > Br^- > I^-$
- Reactivity of halogens : F > Cl > Br > I
- Ionic character of M - X bond in halides
  M – F > M – Cl > M – Br > M – I
- Reducing character of X^- ion : $I^- > Br^- > Cl^- > F^-$
- Acidic strength of halogen acids : HI > HBr > HCl > HF
- Conjugate base strength of halogen acids: $I^- < Br^- < Cl^- < F^-$
- Reducing property of hydrogen halides : HF < HCl < HBr < HI
- Oxidising power of oxides of chlorine
  $Cl_2O > ClO_2 > Cl_2O_6 > Cl_2O_7$

Transition Elements (d- and f-Block Elements)

- The element with exceptional configuration are
  $Cr^{24}[Ar]\ 3d^5 4s^1$, $Cu^{29}[Ar]\ 3d^{10}4s^1$
  $Mo^{42}[Kr]\ 4d^5 5s^1$, $Pd^{46}[Kr]\ 4d^{10}5s^0$ $Ag^{47}[Kr]\ 4d^{10}5s^1$, $Pt^{78}[Xe]\ 4f^{14}5d^{10}6s^0$
- **Inner Transition Elements**
  (i) **Electronic Configuration -** $[Xe]4f^{0-14}5d^{0-1}6s^2$
  (ii) **Magnetic properties -** Magnetic moment is given by the formula $\mu = \sqrt{4S(S+1)+L(L+1)}$ where L = Orbital quantum number, S = Spin quantum number

Coordination Compounds

- Coordination number is the number of the nearest atoms or groups in the coordination sphere.
- Ligand is a Lewis base donor of electrons that bonds to a central metal atom in a coordination compound.
- Paramagnetic substance is one that is attracted to the magnetic field, this results on account of unpaired electrons present in the atom/molecule/ion.
- Factors affecting stability of complex
  (i) Greater the charge on the central metal ion, greater is the stability.
  (ii) Greater the ability of the ligand to donate electron pair (basic strength) greater is the stability.
  (iii) Formation of chelate rings increases the stability.
- Isomerism in coordination compounds :
  (i) Structural Isomerism (ii) Ionization Isomerism
  (iii) Hydration Isomerism (iv) Linkage Isomerism
  (v) Polymerisation Isomerism (vi) Valence Isomerism
  (vii) Coordination Position Isomerism
  (viii) Stereo Isomerism
  (a) *Geometrical Isomerism*
  (1) *Square planar complexes of the type* MA_2X_2 ; $MABX_2$; MABXY
  (2) Octahedral of the type : MA_4XY, MA_4X_2 MA_3X_3 $MA_2X_2Y_2$. $M(AA)_2X_2$ and M(ABCDEF).
  (b) *Optical isomerism* :
  Shown by the compounds that are mirror images and cannot be superimposed on one another.

ORGANIC CHEMISTRY

Halogen Compounds

- The order of reactivity is
  (i) RI > RBr > RCl > RF
  (ii) Allyl halide > Alkyl halide > Vinyl halide
  (iii) Alkyl halide > Aryl halide
- **S_N1 reaction :** Mainly 3° alkyl halides undergo this reaction and form racemic mixture. S_N1 is favoured by polar solvent and low concentration of nucleophile.
- **S_N2 reaction :** Mainly 1° alkyl halides undergo this substitution. Walden inversion takes place. S_N2 reaction is preferred by non-polar solvents and high concentration of nucleophile.
- **Reaction with metals:**

(*i*) $\underset{\text{Alkyl halides}}{R-X} + Mg \xrightarrow{\text{Dry ether}} \underset{\text{Grignard reagent}}{R-Mg-X}$

(*ii*) **Wurtz reaction:**

$$R\text{-}X + 2Na + X\text{-}R \xrightarrow{\text{Dry ether}} \underset{\text{Alkane}}{R-R} + 2Na^+X^-$$

Alcohols

- Alkenes are converted to alcohol in different ways as follows

Reagent	Types of addition
dil H_2SO_4	Markovnikov
B_2H_6 and H_2O_2, OH^-	Anti-Markovnikov
Oxymercuration demercuration	– Markovnikov

- Oxidation of
  1° alcohol ⟶ aldehyde (with same no. of C atom) ⟶ carboxylic acid (with same no. of C atom)
  2° alcohol ⟶ ketone (with same no. of C atom) ⟶ carboxylic acid (with less no. of C atom)
  3° alcohol ⟶ ketone (with less no. of C atom) ⟶ carboxylic acid (with less no. of C atom)

Phenols

- Phenol $\xrightarrow{CHCl_3/OH^\ominus}$ Phenolic aldehyde (Reimer-Tieman reaction)

- Phenol $\xrightarrow[\Delta]{CO_2}$ Phenolic carboxylic acid (Kolbe's reaction)
- Acidity of phenols
  (i) Increases by electron withdrawing substituents like
  $-NO_2, -CN, -CHO, -COOH, -X, -\overset{+}{N}R_3$
  (ii) decreases by electron releasing substituents like
  $-R, -OH, -NH_2, -NR_2, -OR$

Ethers

- $2ROH \xrightarrow[250^oC]{Al_2O_3} R-O-R + H_2O$
- $RONa + X-R' \longrightarrow ROR' + NaX$
  (Williamson's synthesis)
- $ROR + H_2O \xrightarrow[\Delta]{dil.\ H_2SO_4} 2ROH$

Carbonyl Compounds

- Formation of alcohols using RMgX
  (a) Formaldehyde + RMgX $\xrightarrow{Hydrolysis}$ 1° alcohol
  (b) Aldehyde + RMgX $\xrightarrow{Hydrolysis}$ 2° alcohol (other than HCHO)
  (c) Ketone + RMgX $\xrightarrow{Hydrolysis}$ 3° alcohol
- Cannizzaro reaction (Disproportionation)
  Aldehyde $\xrightarrow[alkali]{Hot\ conc.}$ Alcohol + Salt of acid
  (no α H-atom)
- Aldol condensation :
  Carbonyl compound + dil. alkali $\longrightarrow$ β-hydroxy carbonyl compound
  (with α H-atom)
- The relative reactivities of different acid derivatives towards nucleophilic acyl substitution reaction follow the order:

$$\underset{\text{Acid chloride}}{R-\overset{O}{\overset{\|}{C}}-Cl} > \underset{\text{Anhydride}}{R-\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{C}}-R'} > \underset{\text{Ester}}{R-\overset{O}{\overset{\|}{C}}-OR'} > \underset{\text{Amide}}{R-\overset{O}{\overset{\|}{C}}-NH_2}$$

Carboxylic Acids

- The rate of esterfication decreases when alcohol, acid or both have branched substituents.
- Ortho effect : All ortho substituted benzoic acids (irrespective of type of substituent) are stronger than benzoic acid.

Nitrogen Compounds

- Order of basicity :
  ($R = -CH_3$ or $-C_2H_5$) $2° > 1° > 3° > NH_3$
- Hoffmann degradation
  Amides $\xrightarrow{Br_2/KOH}$ 1° amine
- The basicity of amines is (i) decreased by electron with drawing groups (ii) increased by electron releasing groups
- Reduction of nitrobenzene in different media gives different products

Medium	Product
Acidic	Aniline
Basic	Azoxy, Azo and finally hydrazobenzene
Neutral	Phenyl hydroxylamine

Biomolecules

- Carbohydrates are polyhydroxy aldehydes or ketones.
- Monosaccharides are simple sugars, containing three to nine carbon atoms.

Identification Tests

- Unsaturated compound (Bayer's reagent)
  Decolourising the reagent
- Alcohols (Ceric ammonium nitrate solution)
  Red colouration
- Phenols (Neutral $FeCl_3$ solution)
  Violet/deep blue colouration
- Aldehydes and ketones (2, 4-D.N.P.)
  Orange precipitate
- Acids ($NaHCO_3$ solution)
  Brisk effervescence (CO_2 is evolved)
- 1° amine ($CHCl_3 + KOH$)
  Foul smell (isocyanide)
- 2° amine ($NaNO_2 + HCl$)
  Yellow oily liquid (Nitrosoamine)

Characteristic Reactions

Homologous series	Type of reactions
(i) Alkanes	Substitution Mostly free radical
(ii) Alkenes and alkynes	Electrophillic addition
(iii) Arenes	Electrophillic substitution
(iv) Alkyl halides	Nucleophillic substitution
(v) Aldehyde and ketones	Nucleophillic addition

- Tests to differentiate :

1°, 2° and 3° alcohols	(i) Lucas test (ii) Victor meyer's test
1°, 2° and 3° amines	Hinsberg test
1°, 2° and 3° nitro compounds	Test with HNO_2 and KOH
Aryl halides and alkyl halides	Test with $AgNO_3$ solution
Aldehydes and ketones	Tollen's test/Fehling's test
Aromatic aldehydes and Aliphatic aldehydes	Fehling's test

PRACTICAL CHEMISTRY

Detection of Extra Elements (N, S, Halogens) in Organic Compounds

Lassaigne's test: Common for N, S and X (halogens)

Lassaigne's filtrate or sodium extract is prepared by fusing the organic compound with Na in ignition tube. Fused mass is dissolved in water, boiled and filtered. The filtrate is sodium extract which contains

$Na + C + N \rightarrow$ NaCN sodium cyanide

$2Na + S \rightarrow Na_2S$ Sodium sulphide

$Na + X \rightarrow$ NaX (Sodium halide)

$Na + C + N + S \rightarrow$ NaCNS (Sodium Sulphocyanide)

Test for nitrogen : Sod. extract + freshly prepared $FeSO_4$ solution + $FeCl_3$ solution + dil. $H_2SO_4 \rightarrow$ green or blue colouration or sometimes blood red colour

$2NaCN + FeSO_4 \rightarrow Fe(CN)_2 + Na_2SO_4$

$4NaCN + Fe(CN)_2 \rightarrow Na_4[Fe(CN)_6]$

$3Na_4[Fe(CN)_6] + 4FeCl_3 \rightarrow Fe_4[Fe(CN)_6]_3 + 12NaCl$

ferric ferrocyanide (prussian blue)

$FeCl_3 + 3NaCNS \rightarrow Fe(CNS)_3 + 3NaCl$

Ferric sulphocyanide (Blood red)

($NH_2.NH_2$ and diazo compounds do not give this test, diazo compounds are decomposed to give N_2 and $NH_2.NH_2$ does not contain C)

Test for sulphur :

$Na_2S + Na_2[Fe(CN)_5NO] \rightarrow Na_4[Fe(CN)_5NOS]$

Sodium nitropruside — Purple coloured complex

$Na_2S + (CH_3COO)_2Pb \rightarrow PbS + 2CH_3COONa$

black ppt.

Test for halogens :

Sod. extract + Conc. HNO_3 + $AgNO_3$ Solution

1. If white precipitate soluble in $NH_4OH \rightarrow Cl^-$ present

$NaCl + AgNO_3 \rightarrow AgCl\downarrow + NaNO_3$

$AgCl + 2NH_4OH \rightarrow [Ag(NH_3)_2]Cl + 2H_2O$

Soluble Complex

2. If light yellow precipitate sparingly soluble in $NH_4OH \rightarrow Br^-$ present

$NaBr + AgNO_3 \rightarrow AgBr\downarrow + NaNO_3$

$AgBr + 2NH_4OH \rightarrow [Ag(NH_3)_2]Br + 2H_2O$

Sparingly Soluble Complex

3. If yellow precipitate insoluble in $NH_4OH \rightarrow I^-$ present

$NaI + AgNO_3 \rightarrow AgI\downarrow + NaNO_3$

$AgI + NH_4OH \rightarrow$ No Complex

(i) Function of Conc. HNO_3 : It decomposes NaCN and Na_2S to avoid their interference

$NaCN + HNO_3 \rightarrow NaNO_3 + HCN\uparrow$

$Na_2S + 2HNO_3 \rightarrow 2NaNO_3 + H_2S\uparrow$

$NaCN + AgNO_3 \rightarrow AgCN\downarrow + NaNO_3$

white ppt.

$Na_2S + 2AgNO_3 \rightarrow Ag_2S + 2NaNO_3$

Black ppt.

(ii) Layer test for bromine and iodine :

Sod. extract + dil. HNO_3 + $CHCl_3$ or CCl_4 or CS_2

$+ Cl_2$ water $\xrightarrow{\text{Shake}}$ Brown layer Br

$\rightarrow$ Violet layer I

$2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$

Br_2 + Solvent – Brown layer

$2NaI + Cl_2 \rightarrow 2NaCl + I_2$

I_2 + Solvent – Violet layer

(iii) Beilstein's test:

Organic compounds containing halogens when heated over Cu wire loop, give blue or green colour flame due to formation of volatile copper halides.

(Not reliable since thiourea, urea, pyridine and organic acids also give this test)

Detection of Functional Groups in Organic Compounds

Alcoholic group (–OH)

Ceric ammonium nitrate lest

Treat 2 drops of the organic substance with 0.5 c.c. of ceric ammonium nitrate solution and dilute with 2 c.c. of water. A red colour indicates alcoholic group

$2ROH + (NH_4)_2Ce(NO_3)_6 \rightarrow$

$Ce(NO_3)_4R(OH)_2 + 2NH_4NO_3$

Distinction between 1°, 2° and 3° alcohol :

2 ml of organic compound + 8 ml of Lucas reagent and shake. Separation of an insoluble layer at once –3° alcohol

Appearance of cloudiness within 4-5 minutes –2° alcohol solution remains clear –1° alcohol.

◈ **Phenolic group (–OH)**

Ferric Chloride Test

2 c.c. of aqs. or alcoholic solution + 2 drops of ferric chloride → deep colour change shows the presence of phenols.

◈ **Aldehydic group (–CHO)**

Schiff's reagent

5-6 drops or 0.1 g of O.S. + 2c.c. Schiff's reagent

→ Shake and wait for 1-2 minutes → Deep red or violet colour

- **Tollen's reagent.**

  5-6 drops or 0.1 g of O.S. + 2 c.c. Tollen's reagent

  → warm and allow to stand the contents for 2-3 minutes

  → Formation of silver mirror or grey ppt.

$$2Ag(NH_3)_2\,OH + RCHO \rightarrow$$

$$2Ag + RCOONH_4 + 3NH_3 + H_2O$$

- **Fehling solution :**

  5-6 drops or 0.1 g of O.S. + 5 c.c. Fehling solution

  → boil → Red ppt.

$$2CuO + RCHO \rightarrow Cu_2O + RCOOH \text{ Red ppt}$$

Note : Aromatic aldehydes do not respond to this test.

- **Benedict's solution :**

  0.1 g of O.S. + 2-3 c.c. of Benedict's solution

  → Boil → Appearance of red yellow ppt.

◈ **Ketonic group** $\left(\begin{matrix}R\\R\end{matrix}\!>\!C=O\right)$ **:**

2, 4–Dinitro phenyl hydrazine test :

1–2 drops or 0.1g of O.S. + 2c.c. of reagent

— Shake vigrously and heat if necessary– A yellow or orange ppt.

◈ **Carboxylic group (–COOH) :**

Sodium bicarbonate test

Small amount of O.S. + 3 c.c. of saturated solution of sodium bicarbonate-Brisk effervescence

$$RCOOH + NaHCO_3 \rightarrow RCOONa + H_2O + CO_2 \uparrow$$

◈ **Amino group (–NH_2, primary)**

1. **Carbylamine test :**

   2 drops of O.S. + 2 drops of $CHCl_3$ + 2c.c. of alcoholic caustic potash → Intolerable offensive odour

$$RNH_2 + CHCl_3 + 3KOH \rightarrow \underset{\text{Carbylamine}}{RNC\uparrow} + 3KCl + 3H_2O$$

   Aromatic or aliphatic 1° amines give this test

2. **Nitrous acid test**

$$0.2\text{ g of O.S.} + 10\text{ c.c. of } HCl \xrightarrow[\text{(ii) Cool}]{\text{(i) Heat}} \text{Add 10\%}$$

aqs $NaNO_2$ → Brisk effervescence (aliphatic 1° amine)

$$RNH_2 + HNO_2 \rightarrow ROH + H_2O + N_2\uparrow$$

A yellow oily layer is formed $\left(2^\circ \text{amine}\right)$

$$R_2NH + HONO \rightarrow \underset{\substack{\text{Nitrosamine}\\\text{(yellow oil)}}}{R_2N \rightarrow NO} + H_2O$$

No visible change $\left(3^\circ \text{amine}\right)$

$$R_3N + HONO \rightarrow \underset{\text{Trialkyl ammonium nitrate}}{R_3N^+HONO^-}$$

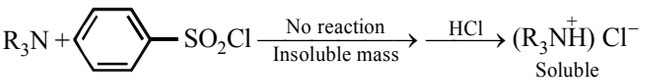
3. **Distinguishing test for 1°, 2° and 3° amines**

Hinsberg's Test :

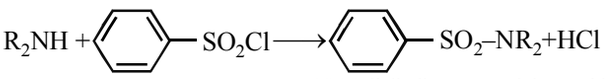
0.5 ml of O.S. + 2 ml of 25% NaOH + 1 ml of benzene sulphonyl chloride. Shake and Cool.

→ If ppt is obtained add 2 ml of conc HCl

(i) Precipitate dissolves in conc HCl → 3° amine

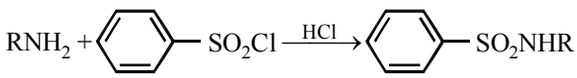


(ii) Precipitals does not dissolve in conc. HCl → 2° amine

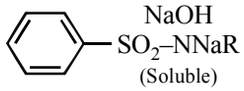


N, N-dialkylbenzene sulphonamide
(Insoluble in NaOH)

Clear solution. On addition of conc HCl, insoluble mass is formed → 1° amine



N-alkyl benezene Sulphonamide
HCl ↑ (Insoluble)
↓
NaOH



(Soluble)

Chemical Principles Involved in Qualitative Salt Analysis

◈ **Physical appearance -** It gives valuable information about certain salts eg

Salts	PbO_2, Bi_2S_3	are dark brown
Salts of	Mn^{2+}	are light pink
	Co^{2+}	are pink
Salts of	Fe^{2+}, Ni^{2+} and Cr^{3+}	are green
Salts of	Fe^{3+}	are Yellow
Salt	Fe_2O_3	Redish brown
Salts	HgO, HgI_2, Pb_3O_4	are Red
Salt	CuO	Black

Gas evolated on heating

Gas evolved	Possible compound
CO burns with blue flame	Oxalate $(COO)_2Ca \rightarrow CaO + CO + CO_2$
CO_2 turns lime water milky	Carbonate (except carbonate of alkali metals)
NH_3 white fumes with HCl	Ammonium salts $(NH_4)_2SO_4 \rightarrow NH_4HSO_4 + NH_3$
SO_2 smell of burning sulpher turns $K_2Cr_2O_7$ Soln green	Sulphites $CaSO_3 \rightarrow CaO + SO_2$
H_2S Smell of rotten eggs	Sulphides $Na_2S + 2H_2O \rightarrow 2NaOH + H_2S$
Br_2 Reddish brown	Bromide $2CdBr_2 + O_2 \rightarrow 2CdO + 2Br_2$
I_2 Violet vapours	Iodide $2ZnI_2 + O_2 \rightarrow 2ZnO + I_2$
NO_2 reddish brown	Nitrate (except Ba and alkali metals)

Flame tests - Salt + 1–2 drops of Conc HCl $\rightarrow$ Heat in a non luminous (oxidising) Bunsen flame using platinum wire.

Element	Colour (to naked eye)	Colour (through cobalt glass)
Sodium	Golden yellow	Nil
Potassium	Lilac	Crimson
Calcium	Brick red	Light green
Strontium	Crimson	crimson
Barium	Apple green	green
Copper	Bluish green	–
Tin	Greyish blue	–
Antimony	Greyish green	–
Manganese	Green	–
Boron	Bright green	–
AS, Bi, Hg, Pb	Bluish white	–
Li	Caramine red	–

Borax Bead Test

Borax is heated on a loop of Pt. wire when colourless glassy bead of sodium metaborate and boric anhydride is formed

$Na_2B_4O_7 . 10H_2O \rightarrow Na_2B_4O_7 \longrightarrow 2NaBO_2 + B_2O_3$

Coloured salts are then heated on the glassy bead when coloured metaborate is formed in the oxidising flame

$CuSO_4 + B_2O_3 \longrightarrow \underset{\text{Copper metaborate (blue)}}{Cu(BO_2)_2} + SO_3$

In reducing flame we have $2Cu(BO_2)_2 + C \longrightarrow 2CuBO_2 + B_2O_3 + CO$

$2Cu(BO_2)_2 + 2C \longrightarrow 2Cu + 2B_2O_3 + 2CO$

Hence different clolour appear in differnt flames

Metal	Colour in Oxidising flame		Colour in Reducing - flame	
	Hot	Cold	Hot	Cold
Copper	Green	Blue	Colourles	Brown red
Iron	Brown yellow	Pale yellow	Bottle green	Bottle green
Chromium	Green	Green	Green	Green
Cobalt	Blue	Blue	Blue	Blue
Manganese	Violet	Amethyst Red	Grey	Grey
Nickel	Violet	Brown	Grey	Grey

Identification of acid radicals

Type I: The radicals decomposed by dil . H_2SO_4 or dil HCl

$CO_3^{2-} \rightarrow CO_2$
$SO_3^{2-} \rightarrow SO_2$
$S^{2-} \rightarrow H_2S$
$NO_2^- \rightarrow NO_2 + NO$
$CH_3COO^- \rightarrow CH_3COOH$
} gas evolved

Type II: The radicals decomposed by Conc H_2SO_4

$Cl^- \rightarrow HCl$
$Br^- \rightarrow HBr + Br_2$
$I^- \rightarrow HI + I_2$
$NO_3^- \rightarrow NO_2$
$C_2O_4^{--} \rightarrow CO + CO_2$
$F^- \rightarrow HF$
} gas liberated

Separation of metallic ions into groups

Group	Group reagent	Ions	Composition and colour of the precipitate	
1.	Dilute HCl	Ag^+	AgCl white	Insoluble in cold dil HCl
		Pb^{2+}	$PbCl_2$ white	
		Hg_2^{2+}	Hg_2Cl_2 white	
2A.	H_2S in presence of dil HCl	Hg^{2+}	HgS Black	Soluble in yellow ammonium sulphide
		Pb^{2+}	PbS Black	
		Bi^{3+}	Bi_2S_3 Black	
		Cu^{2+}	CuS Black	
		Cd^{2+}	CdS yellow	
2B		AS^{3+}	AS_2s_3 yellow	
		Sb^{3+}	Sb_2S_3 orange	
		Sn^{2+}	SnS brown	
		Sn	SnS_2 yellow	
3.	NH_4OH in presence of NH_4Cl	Fe^{3+}	$Fe(OH)_3$ reddish brown	
		Al^{3+}	$Al(OH)_3$ white	
		Cr^{3+}	$Cr(OH)_3$ green	
4.	H_2S in presence of NH_4OH	Ni^{2+}	NiS Black	
		Co^{2+}	CoS Black	
		Zn^{2+}	ZnS Greyish white	
		Mn^{2+}	MnS Buff	
5.	$(NH_4)_2CO_3$ in presence of NH_4OH	Ba^{2+}	$BaCO_3$ white	
		Sr^{2+}	$SrCO_3$ white	
		Ca^{2+}	$CaCO_3$ white	
6.	Na_2HPO_4	Mg^{2+}	$Mg(NH_4)PO_4$ white	
	NaOH	NH_4^+	NH_3 gas is given out	
		Na^+	Flame and other tests	
		K^+		

BIOLOGY

The Living World & Taxonomy

- Nomenclature – It is the process of giving scientific names (not vernacular or local names) to the organisms.
- Systematics – This includes the identification, nomenclature and classification of organisms based on various parameters.
- In **bionomial nomenclature** each scientific name has 2-components,
  i. Generic name (Genus),
  ii. Specific name/epithet (Species)
- Various levels of classification are –
  Kingdom → Phylum (animals)/ Division (plants) → Class → Order → Family → Genus → Species.
  - Species is the basic unit of classification.

Table: Organisms with their Taxonomic Categories

Common Name	Biological Name	Genus	Family	Order	Class	Phylum/Division
Man	*Homo sapiens*	*Homo*	Hominidae	Primata	Mammalia	Chordata
Housefly	*Musca domestica*	*Musca*	Muscidae	Diptera	Insecta	Arthropoda
Mango	*Mangifera indica*	*Mangifera*	Anacardiaceae	Sapindales	Dicotyledonae	Angiospermae
Wheat	*Triticum aestivum*	*Triticum*	Poaceae	Poales	Monocotyledonae	Angiospermae

Biological Classification

- **Artificial system of Classification** - All taxonomists, from Aristotle to Linnaeus, classified organisms on the basis of external observable (morphological) characters like floral structure (number of stamens), root modification, leaf venation etc. In this system, no weightage was given to natural and phylogenetic relationship.
- **Natural System of Classification** - It uses more number of characters and is based upon natural affinities using homology and comparative study. Bentham - Hooker used this system of classification for angiosperms.
- **Phylogenetic Classification (Cladistics)** - This system of classification is based upon evolutionary relationship and uses morphological characters, origin and evolution of the different organisms.
- Characteristics of five kingdom system was proposed by R.H. Whittaker (1969). Accordingly, a separate kingdom has been created for Fungi. Thus, these are – Monera, Protista, Fungi, Plantae and Animalia.

Characters	Five Kingdoms				
	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Non-cellulosic (Polysaccharide + Amino acid)	Present in some	Present with chitin	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic/parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

- Bacteria are prokaryotes. They lack nucleus and other cell organelles of complex cells and have prokaryotic ribosome (70 S). Like plants, they possess cell wall.
- The cyanobacteria are the largest and most diverse group of photosynthetic bacteria, *e.g.*, *Nostoc*. Heterocyst is specialised to perform nitrogen fixation.

- Mycoplasma are the smallest known aerobic prokaryotes without cell wall.
- Kingdom protista to include all unicellular eukaryotic microorganisms. E.g. Euglenoids are photosynthetic in the presence of sunlight, when deprived of sunlight they behave like heterotrophs by predating on other smaller organisms.
- Fungi are achlorophyllous, heterotrophic, gametophytic, haploid, multicellular, eukaryotic nucleated, spore producing thallophytes which are surrounded by cell wall of chitin (fungus cellulose). Study of fungi is called Mycology.
- Viruses are obligate parasites, *i.e.*, can live inside living host only. They have either RNA or DNA. Bacterial viruses or bacteriophages (viruses that infect the bacteria) are usually double stranded DNA viruses.
- Viroids contain only very low molecular weight RNA and protein coat cause persistent infections, *i.e.*, never recovered.
- In lichens, there are 2 components; *i.e.*, algal partner called phycobiont and fungal partner called mycobiont.

Plant and Animal Kingdoms

- Bryophytes are terrestrial plants but they require water for dehiscence of antheridia, liberation and swimming of antherozoids, fertilization of egg, opening of archegonial neck and entry of sperms into the archegonium. Because of such peculiar habitat they have been most appropriately called the **amphibians of the plant kingdom**.

Table : Divisions of Algae and their Main Characteristics

Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyll a, b	Green algae	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Chlorophyll a, c, fucoxanthin	Brown algae	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Chlorophyll a, d, phycoerythrin	Red algae	Floridean starch	Cellulose, pectin and poly sulphate esters	Absent	Fresh water (some), brackish water, salt water (most)

- Evolutionarily, Pteridophytes are the first terrestrial plants to possess vascular tissues – xylem and phloem. So known as vascular cryptogams. They are flowerless and seedless plants.
- Gymnosperms are plants which bear naked seeds *i.e.*, the ovules and the seeds that develop from these ovules after fertilization are not enclosed in fruit wall. In most gymnosperms, secondary growth occurs and annual rings are distinct. The xylem is without vessels (except in *Gnetales*) and phloem lacks companion cells.
- **Animalia** – They are eukaryotic, multicellular and heterotrophic organisms that do not have cell wall. On the basis of extent and type of body design, they are classified as–
  - (i) Porifera – E.g. *Spongilla*, *Sycon*.
  - (ii) Coelenterata – E.g. Jelly fish, Sea anemone
  - (iii) Platyhelminthes – E.g. *Planaria*.
  - (iv) Annelida – E.g. Earthworms.
  - (v) Arthropoda – E.g. Prawns.
  - (vi) Mollusca – E.g. Snails.
  - (vii) Echinodermata – E.g. Starfish.
- **Vertebrates are divided into 5 classes :**
  - (i) Pisces – Include fishes which are aquatic, E.g. Shark, Rohu.
  - (ii) Amphibia – Animals are found both in water and on land, E.g. Toads, Frogs, Salamander.
  - (iii) Reptilia – They are cold blooded animals with scales and breathe through lungs. E.g. Snakes, Turtles, Crocodiles etc.
  - (iv) Aves – They have feathers and forelimbs are modified for flight. E.g. Pigeon, Sparrow, Ostrich.
  - (v) Mammalia – They are warm blooded animals with 4 – chambered heart. They have mammary glands for milk production.

Morphology of Flowering Plants

- A typical root can be differentiated into five distinct regions namely region of root cap, meristematic region, region of elongation, region of root hair and mature region.
- Roots are divided into two types:
  - (i) Tap root : It forms lateral branches or secondary roots which are further branched to form tertiary roots.
  - (ii) Adventitious roots : These roots develop from any part of the plant instead of radicle.
- Shoot system is an aerial system, usually above the soil and originates from the plumule. It consists of stem, branches, leaves, flowers, fruits and seeds.
- The various types of underground modifications of stem are: Rhizome : *Zingiber* (ginger). Corm : Saffron (*Crocus*) Tuber : *Solanum tuberosum* (potato). Bulb : (onion)

- An inflorescence is the mode of arrangement of flowers on peduncle or mother axis.
  The main axis of *racemose* inflorescence has indefinite growth because there is no terminal flower. In cymose, the growth of the main axis is definite because the growing point of peduncle is used up in the formation of a flower.
- **Symbols For Floral Formula**

Br	Bracteate
⊕	Actinomorphic
% or †	Zygomorphic
♂	Staminate (male)
♀	Pistillate (female)
K	Calyx
C	Corolla
P	Perianth
A	Androecium
G	Gynoecium
$G_{(\bar{2})}$	Bicarpellary, syncarpous, inferior
$G_{(\underline{2})}$	Bicarpellary, syncarpous, superior

- **Families - floral formula**

Malvaceae	$\oplus ♂♀ Epi_{3\to\infty}\overset{\frown}{K}_{(5)}C_{(5)}A_{\infty}G_{(5-\infty)}$
Brassicaceae	$\oplus ♂♀ K_{2+2}C_{\times 4}A_{2+4}G_{(\underline{2})}$
Graminae	$\oplus ♂♀ \overset{\frown}{P}_{3+3}A_{3+3}\underline{G}_{(3)}$
Fabaceae	$\% K_{(5)}C_{1+2+(2)}A_{(9)+1}G_{1}$

Plant Tissues

- A group of structurally similar or dissimilar cells that perform a common function and have a common origin is called a tissue.
- Cells which are capable of active cell division are called meristematic cells.
- On the basis of position, the meristematic tissues can be divided into the following three types:
  - Apical meristem
  - Intercalary meristem
  - Lateral meristem
- Intercalary meristem is present at the base of internodes, *e.g,* in grasses (Gramineae) or at the base of leaves, *e.g*., in *Pinus* or at the base of nodes, *e.g*., mint or Mentha (Labiatae).

Simple Permanent Tissue

1. Parenchyma : It helps in storage of food, conduction of substances, provides turgidity to softer parts of plants.
2. Collenchyma : It is living mechanical tissue, found beneath the epidermis (*i.e*., hypodermis) of herbaceous dicot stem.
3. Sclerenchyma : These are dead, mechanical tissue and act as skeleton in plants.

Complex Permanent Tissues

1. Xylem is mainly responsible for conduction of water and minerals from the roots to the top of plants (unidirectional). It also provides mechanical support to the plant. Xylem is made of 4 types of cells i.e., tracheids, tracheae (vessels), xylem fibres and xylem parenchyma.
2. Phloem mainly carries food. It is a complex tissue made up of 4 kinds of cells in angiosperms. These are -sieve elements, companion cells, phloem fibres, phloem parenchyma.

Animal Tissues

- **Epithelial tissue** – It forms protective covering in the animal body, covers organs and separates different body systems. Different types of epithelial tissues on the basis of functions are–
  (i) Simple squamous epithelium – Oesophagus, lining of mouth are made of it.
  (ii) Stratified squamous epithelium– In the skin epithelial cells are arranged in many layers to prevent wear and tear.
  (iii) Columnar epithelium – It is present in the inner lining of intestine, pillar like tall cells.
  (iv) Cuboidal epithelium – It forms lining of kidney tubules and ducts of salivary glands.
  (v) Glandular epithelium– In glands.
- **Connective Tissue** – The cells are loosely packed and embedded in intercellular matrix.
  (i) Areolar tissue – It fills space inside organs, helps in repair of tissues.
  (ii) Adipose tissue – It is fat storing, found below the skin and between internal organs.
  (iii) Bone – Bone cells lie embedded in hard matrix composed of calcium and phosphorus.
  (iv) Ligament – connects two bones.
  (v) Tendons – connect muscles to bones.
  (vi) Cartilage – It is present in nose, ear, trachea, larynx.
  (vii) Blood – It is a fluid connective tissue. Fluid matrix is called plasma that contains red blood cells (RBCs), white blood cells (WBCs) and platelets unit.
- **Muscular tissue** – It consists of elongated cells called muscle fibres. They are responsible for movement in our body. The three types of muscles are –
  (i) Striated muscles – E.g. muscles of hands and legs.
  (ii) Smooth muscles – E.g. muscles found in iris of eye, ureters, bronchi of lungs, alimentary canal.
  (iii) Cardiac muscles – E.g.the muscles of heart.
- **Nervous tissue** – They are found in brain, spinal cord and nerves. They transmit the stimulus. A neuron consists of a cell body with a nucleus and cytoplasm. It has a long part called axon and many short, branched parts called dendrites. Many nerve fibres together form a nerve.

Cell : The Unit of Life

- Cell theory was proposed by Schleiden and Schwann.
- All living organisms (animals, plants and microbes) are made up of cells and cell products *i.e*., cell is the structural unit of life.
- S.J.Singer and G. Nicolson in 1972 proposed the most accepted model of membrane structure only after the advent of electron microscope in 1950. According to this model, the lipid bilayer is a semifluid in which the proteins are dispersed to give mosaic appearance to the whole membrane.

- Plasmodesmata are characteristic of multicellular plants that enables the solutes to move considerable distances through the pits without crossing differentially permeable membranes.
- Endoplasmic reticulum is also called as 'endoskeleton of the cell' or 'endomembranous system of the cell'. The endoplasmic reticulum is bounded by a single unit membrane. Smooth or agranular ER : They do not have attached ribosomes on their surface. The SER is well developed in those cells which are actively concerned with the synthesis and secretion of steroid hormone.
  Rough or granular ER : They bear ribosomes on their surface. The cells which are active in protein synthesis have RER in abundance.
- Golgi apparatus or Golgi complex is a stack of flattened, membrane bound, parallely arranged organelles that occur in the association of endoplasmic reticulum in the cytoplasmic matrix. It principally performs the function of packaging materials to be delivered either to the intra-cellular targets or secreted outside the cell.
- Lysosomes are originated by Golgi complex and contain many hydrolytic enzymes (amylases, lipases, proteases, carbohydrases) optically active at the acidic pH. They are popularly called "suicide bags".
- The vacuole is bound by a single membrane called tonoplast. It contains many dissolved solutes such as organic acids, soluble carbohydrates, soluble nitrogenous compounds as nitrates, enzymes, tannins, chlorides, phosphates, amino acids, alkaloids and anthocyanin pigments.
- Cilia and flagella are contractile filamentous or hair-like outgrowths of the cytoplasm, which help in cell movement, excretion, secretion and transportation.
- Centrosome is an organelle usually containing two cylindrical structures called centrioles. Centrioles duplicate before cell division so that dividing cell has a pair of centrioles at each pole.
- Peroxisomes are the smallest membrane bound cell organelles. These organelles were named peroxisomes because these are the sites of formation of hydrogen peroxide (H_2O_2).
- A typical nucleus consists of four structures: nuclear membrane, nucleoplasm, chromatin and the nucleolus.
- Nucleolus is site of active ribosomal RNA synthesis.
- In interphasic nucleus, the genetic material (DNA) is seen as the thread like structure called chromatin or chromatin fibres. During cell divisions (mitosis and meiosis), chromatin fibres become condensed to form thick structures called chromosomes.
- Based on the position of the centromere, the chromosomes can be classified into four types :
  - metacentric (middle centromere)
  - sub-metacentric (centromere nearer to one end of the chromosome)
  - acrocentric (centromere situated close to its end)
  - telocentric (terminal centromere).
- Plastids are found in plants and few protists (*Euglena*). They may be colourless (leucoplastids) or coloured (chromoplastids and chloroplasts). Each chloroplast has two parts *i.e.*, grana and stroma.
- Stroma : It is the enzymatic part of chloroplast. Stroma contains proteins, DNA, ribosomes and fewer amounts of enzymes. Dark reaction of photosynthesis occurs in this fraction.
- Grana : In chloroplast, several membranes are arranged in the form of stacks of coins. These thylakoids are stacked one above the other to form grana. Due to presence of chlorophyll in granum lamella, the light reaction of photosynthesis takes place in granum.
- Mitochondria are referred as "powerhouse" of the cell as they produce 95% of ATP. This energy is produced during the break down of food molecules which involve glycolysis, oxidative decarboxylation and oxidative phosphorylation (Kreb's cycle and respiratory chain).
- PPLO stands for Pleuro Pneumonia like Organisms
- Glycocalayx differs in the composition and thickness among different bacteria.
- Bacterial flagellum is composed of three parts-filaments, hook and basal body.
- Gas vacuoles are found in blue green and purple as well as green photosynthetic bacteria.
- The non-polar tail of saturated hydrocarbons is protected from the aqueous environment.
- Balbiani rings are sites of RNA and protein synthesis.
- Materials to be packed in the form of vesicles from the ER fuse with the Cis face of the golgi apparatus and move towards the maturing face.
- In *Amoeba*, the contractile vacuole is important for excretion.
- The chromoplasts fat soluble carotenoid pigments such as carotene, xanthophylls and other present.
- Flagella are comparatively longer and responsible for cell movement.
- Microfilaments are involved in cytoplasmic streaming and amoeboid movements.
- Each of the peripheral fibril is a triplet.
- The central part of the proximal region of the centriole is also proteinaceous and is called the 'hub' which is connected with tubules of the peripheral triplets by radial spoke which is made of protein.
- Some chromosomes have non-staining secondary constrictions at a constant location and this gives the appearance of a small fragment called the satellite.
- Nucleoplasm is a site of the active ribosomal RNA synthesis.

Biomolecules

- Lactose - It is milk sugar.
- Sucrose – It is non-reducing sugar as it does not have free aldehyde or ketose groups.
- Glycogen - It is present in animals (also called animal starch). It is a branched chain compd. and has about 30 ±-glucose units.
- Starch - It is present in plants. The natural starch contains a mixture of amylose (10-20%) and amylopectin (80-90%).

- Cellulose - It is a fibrous polysaccharide and forms cell wall in plants.

Some secondary metabolites have ecological importance

Pigments	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose

- Proteins contain C, H, O, N. Some contain S (Sulphur) and P (Phosphorus) also. The structural unit of protein is amino acid. In **primary structure,** only Peptide bonds are present between amino acids. The first (or left) amino acid is called N-terminal ($-NH_2$) amino acid, and the last (or right) amino acid is called C-terminal (–COOH gp.) amino acid. In **secondary structure**, besides peptide bonds, Hydrogen bonds are also present in polypeptide chain. Such proteins may have helical or pleated structures. The **tertiary structure** may result from further folding and coiling, and may be stablized by S-S (disulphide) bond, hydrophobic bonds and ionic bonds. In **quaternary structure**, more than one polypeptide chains are involved to form a large multiunit protein. e.g. Haemoglobin.

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT-4	Enables glucose transport into cells

- All amino acids contain atleast 1-Amino group and 1-carboxylic group.

$$H_2N-\underset{H}{\overset{R}{\underset{|}{\overset{|}{C_{\alpha}}}}}-COOH$$

- The nucleic acid on hydrolysis yields 1–Pentose Sugar, 2-types of heterocyclic nitrogenous bases (Purines and Pyrimidines) and phosphoric acid.

Nucleic Acid	Purines	Pyrimidines
DNA	Adenine and Guanine	Cytosine and Thymine
RNA	Adenine and Guanine	Cytosine and Uracil

- ATP (Adenosine Triphosphate) is also a nucleotide. It contains 1-Adenine base, 1-Ribose sugar and 3-phosphate bonds. It is energy-rich compound, and is also called as 'energy currency'.
- Erwin Chargaff reported that net amount of adenine was equal to thymine (A = T) and amount of guanine was equal to cytosine (G ≡ C). This means that total number of purines is equal to the total number of pyrimidines (A + G = T + C).
- **Double Helical Structure of DNA :** To explain base equivalence (A / T, G / C) and other properties of DNA, Watson and Crick (1953), based on X-ray diffraction studies, proposed double helical structure of DNA. The two strands of helix are anti-parallel, means 5' → 3' Phosphodiester bonds (Sugar-phosphate groups) are oriented in opposite direction in 2-strands, there are 2 hydrogen bonds (A = T) and in between C & G there are 3 hydrogen bonds (C ≡ G). The enzymes are tertiary proteins. The energy required for a chemical reaction to proceed is called Activation energy. Higher is the affinity of an enzyme for a substrate the lower is its K_m value, *i.e.* K_m value $\propto \frac{1}{\text{affinity}}$
- The co-factor can be inorganic or organic in nature. The organic factor, if permanently attached to the enzymes, is called prosthetic group and if temporarily attached (only during reaction), is called co-enzyme. Most of the co-enzymes are derivatives of vitamin B & C.

Cell Cycle and Cell Division

- The interphase is the longest phase of the mitotic cycle, lasts more than 95% of the duration of cell cycle. It has three sub-phases: G_1, S and G_2 which occurs in this order followed by M phase.
- **Mitosis :** It is also called as equational division as the number of chromosomes in the parent and progeny cells is the same. So mitosis involves increase in number of cells without any change in genetic constitution. It is usually divided into several stages or phases, viz. prophase, metaphase, anaphase, telophase and cytokinesis.
- **Meiosis :** It ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. Thus, meiosis is required to run the reproductive cycle of eukaryotes.
- **Significance of Meiosis** : Meiosis is the mechanism by which conservation of specific chromosome number of each species is achieved across generations in sexually reproducing organisms, even though the process, per se, paradoxically, results in reduction of chromosome number by half.
  It also increases the genetic variability in the population of organisms from one generation to the next. Variations are very important for the process of evolution.

Plant and Animal Physiology

- Photosynthesis is the process by which autotrophic chlorophyll containing organisms manufacture their own energy sources (simple sugars) from intracellular chemical reaction of carbon dioxide and water in presence of sunlight and chlorophyll.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

- Respiration is a complex process which includes breathing i.e. exchange of O_2 and CO_2 and oxidation of food to release energy.
  (a) Aerobic Respiration

$$\text{Glucose} \xrightarrow[\text{(in cytoplasm)}]{\text{Glycolysis}} \text{Pyruvic acid}$$

$$\xrightarrow[\text{(in mitochondria)}]{\text{Oxygen (Krebs cycle)}} 6CO_2 + H_2O + 38ATP$$

(b) Anaerobic Respiration

$$\xrightarrow[\text{(in cytoplasm)}]{\text{Glycolysis}} \text{Pyruvic acid}$$

$$\xrightarrow[\text{Yeast fermentation}]{\text{in absence of } O_2} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2 + 2ATP$$

- In human beings, respiratory pigment is haemoglobin which remains present in RBC. CO_2 is more soluble in water than oxygen and hence is mostly transported in the dissolved form in blood. Due to difference in concentration of gases, exchange takes place between tissues and blood capillaries.
- **Transportation** is a process in which substances are absorbed in one part and move to the other parts of the body.
- Arteries are thick-walled and transport blood from heart to the various parts of the body. Veins are thin walled and carry blood from various organs to the heart. Heart is situated in the thoracic cavity between two lungs. Heart is made up of cardiac muscles which works continuously. Human heart has four chambers i.e. two auricles and two ventricles. Normal heart rate is 72/minute.
- The removal of unwanted waste materials from the body is called **excretion**. Excretory system of human beings consists of a pair of kidneys, a pair of ureters, urinary bladder, urethra.
- Improper functioning of the kidneys may lead to accumulation of water in the body called oedema.
- An artificial kidney is a device to remove nitrogenous waste products from the blood through dialysis.
- Oxygen is waste product of photosynthesis in plants. Many waste products are stored as resins and gums in plants.

Human Brain :

- Brain is inside the cavity called cranium. It is filled with cerebrospinal fluid. It is divided into three parts –
  (a) Fore brain (Cerebrum) is the main thinking part of the brain. All our thoughts, sensations, actions and movements are controlled by the cerebrum.
  (b) Midbrain consist of nerve cells, connects forebrain to the hind brain. It has reflex centres for eye movement and hearing response.
  (c) Hind brain (Cerebellum) is the second largest part of brain. The surface is of grey matter while deeper part is of white matter. Cerebellum maintains posture, regulates muscle tone.
- Medulla oblongata controls involuntary movement, acts as reflex centre for vomiting, coughing, sneezing, swallowing etc.

Hormones

- **Growth hormones** are the natural growth substances which are produced in any part of the plant.
  (i) Auxins : It stimulates growth, phototropism, geotropism 2, 4 - D is used to avoid pre-harvest fruit in oranges, apples, used as weedicide.
  (ii) Gibberellins : These can increase the height of plant, can induce parthenocarpy, stimulate flowering.
  (iii) Cytokinins : Promote cell division, inhibit or delay ageing, organ formation.
  (iv) Ethylene : It's a gaseous plant hormone, used in artificial ripening of fruits, promote ageing in plants, breaks dormancy of several organs.
  (v) Abscisic Acid (ABA) : Also known as stress hormone. It is a growth inhibitor, inhibits the process of flowering, seed development.

- **Hormones in Animals :**

(i) Hypothalamus : The hypothalamic hormones are also called releasing hormones : TSH, ACTH, FSH, LH.
(ii) Pituitary gland : It has two lobes anterior (adenohypophysis) and posterior (neurohypophysis).
  (a) Anterior lobe : Secretes TSH (Thyroid Stimulating hormone), ACTH (Adrenocorticotrophic hormone), GH (Growth hormone), FSH (Follicle stimulating hormone), LH (Luteinizing hormone), Prolactin.
  (b) Intermediate lobe : Production of melanin pigment.
  (c) Posterior lobe :
    (A) Oxytocin : Released during child birth, during breast feeding.
    (B) Vasopressin : It's an antidiuretic hormone which controls the secretion of urine by kidney.
(iii) Pineal : It secretes biogenic amine hormone called melatonin. It inhibits ovarian growth and ovulation.
(iv) Thyroid : Thyroxine promotes the growth of body tissues. Calcitonin lowers blood calcium level.
(v) Parathyroid : It increases blood calcium level from bone to blood.
(vi) Pancreas : It is exocrine as well as endocrine. The endocrine part is called islets of Langerhans. It consists of α and β cells. β cells secrete hormone insulin which regulates blood sugar level. Excess of glucose starts appearing in urine and the disease is called diabetes.

Reproduction in Plants

- The innermost wall layer is the tapetum. It nourishes the developing pollen grains. Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus.
- No enzyme that degrades sporopollenin is so far known. Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent.
- Pollen grains are well preserved as fossils because of the presence of sporopollenin. The exine exhibits a fascinating array of patterns and designs.
- Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements.
- In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months.
- Pollen grains of a large number of species store for years in liquid nitrogen (–196°C). Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.
- The body of the ovule fuses with funicle in the region called hilum. Thus, hilum represents the junction between ovule and funicle.

- Megasporogenesis : The process of formation of megaspores from the megaspore mother cell is called megasporogenesis. Ovules generally differentiate a single megaspore mother cell (MMC) in the micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus. The MMC undergoes meiotic division.
- Female gametophyte : In a majority of flowering plants, one of the megaspores is functional while the other three degenerate. Only the functional megaspore develops into the female gametophyte (embryo sac).
- The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid. Three cells are at the chalazal end and are called the antipodals. The large central cell, as mentioned earlier, has two polar nuclei. Thus, a typical angiosperm embryo sac, at maturity, though 8-nucleate is 7-celled.
- Cleistogamous flowers produce assured seed-set even in the absence of pollinators.
- Geitonogamy – Transfer of pollen grains from the anther to the stigma of another flower of the same plant. Although geitonogamy is functionally cross-pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grains come from the same plant.
- Xenogamy – Transfer of pollen grains from anther to the stigma of a different plant. This is the only type of pollination which during pollination brings genetically different types of pollen grains to the stigma.
- Wind pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence; a familiar example is the corn cob – the tassels you see are nothing but the stigma and style which wave in the wind to trap pollen grains. Wind-pollination is quite common in grasses.
- Not all aquatic plants use water for pollination. In a majority of aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants.
- In *Vallisneria*, the female flower reach the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water.
- Pollen grains in many such species are long, ribbon like and they are carried passively inside the water; some of them reach the stigma and achieve pollination.
- In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering.
- Among the animals, insects, particularly bees are the dominant biotic pollinating agents.
- Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar.
- Nectar and pollen grains are the usual floral rewards.
- In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy). This condition prevents both autogamy and geitonogamy.
- The compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
- Filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.
- Since two types of fusions, syngamy and triple fusion take place in an embryo sac the phenomenon is termed double fertilisation, an event unique to flowering plants.
- Mature seeds may be non-albuminous or ex-albuminous. Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development (e.g., pea, groundnut).
- Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent. This residual, persistent nucellus is the perisperm.
- In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as apple, strawberry, cashew, etc., the thalamus also contributes to fruit formation. Such fruits are called false fruits.
- Although seeds, in general are the products of fertilisation, a few flowering plants such as some species of Asteraceae and grasses, have evolved a special mechanism, to produce seeds without fertilisation, called apomixis.

Reproduction in Human Beings

- The sex organ in males are testes and ova in females.
- Male reproductive organ consist of a pair of testes, vas deferens, a pair of epididymis, a pair of ejaculatory duct, urethra, pairs of accessory gland. Leydig cells secrete male sex hormone i.e., testosterone which is concerned with the production of male sexual characters.
- Female reproductive part consist of a pair of ovaries, a pair of fallopian tube, uterus, vagina, external genitalia, mammary glands and accessory glands.
- If sperms are present, fertilization of ovum takes place in the upper end of the fallopian tube.
- Fertilization process occurs in fallopian tube. In this process, zygote is formed. Umbilical cord is produced which is attached to foetus. During this process, two hormones are produced which are estrogen and progesterone. Progesterone stops mensturation and prevents ovulation.
- Structure analogous to the placenta in mammals is chorion.
- Capacitation refers to changes in the sperm before fertilisation.
- Placenta and umbilical cord are rich source of stem cells. These cells can be stored and preserved through placenta banking.
- The mature oocytes adhere to wall of follicle through a stalk, cumulus oophorus formed by granulosa cells.

Heredity and Evolution

- **Mendel's laws of inheritance**

The first study of inheritance was done by Gregor Mendel on garden pea (*Pisum sativum*). He used a number of contrasting characters like round / wrinkled seeds, tall/ short plants, white/ violet flowers and so on.

- Law of Dominance : Out of a pair of allelomorphic characters one is dominant (expressed) and the other is recessive/ unexpressed. The benefit of this law is that recessive (harmful) characters are not expressed in hybrid and can exist for several generations.
- Law of Segregation : The factors for each character segregate during gametogenesis. As a result, each gamete receives only one factor for each character and hence is always pure.
- Law of Independent Assortment : The two factors of each trait assort at random and independent of the factors of other trait at the time of meiosis and get randomly as well as independently arranged in the offspring.
- Chromosome movement during meiosis had been worked out. Walter Sutton and Theodore Boveri noted that the behaviour of chromosomes was parallel to the behaviour of genes and used chromosome movement to explain Mendel's laws.
- This sex linked recessive disease, which shows its transmission from unaffected carrier female to some of the male progeny has been widely studied.
- This is an autosome linked recessive trait that can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous).
- In Thalassemia, production of globin chain is affected while in Thalassemia, production of globin chain is affected. Thalassemia is controlled by two closely linked genes HBA1 and HBA2 on chromosome 16 of each parent and it is observed due to mutation or deletion of one or more of the four genes.
- While Thalassemia is controlled by a single gene HBB on chromosome 11 of each parent and occurs due to mutation of one or both the genes.
- Thalassemia differs from sickle-cell anaemia in that the former is a quantitative problem of synthesising too few globin molecules while the latter is a qualitative problem of synthesising an incorrectly functioning globin.
- Down's Syndrome: The cause of this genetic disorder is the presence of an additional copy of the chromosome number 21 (trisomy of 21).

Sex Determination

- All human chromosomes are not paired. 22 pairs are called autosomes. Women have a perfect pair of sex chromosomes XX. But men have a mismatched pair XY.
- Grasshopper is an example of XO type of sex determination in which the males have only one X-chromosome besides the autosomes, whereas females have a pair of X-chromosomes.
- The genetic makeup of the sperm determines the sex of the child.

Evolution

It is the sequence of gradual changes which takes place in the primitive organisms over millions of years in which new species are produced.

The evidences of evolution are :

(i) Homologous organs : The organs which have same fundamental structure but different functions.

(ii) Analogous organs : The organs which have similar functions but are different in their structural detail and origin. E.g. wings of insect and wings of bird.

(iii) Fossils : Fossils are the remains of the past and the study of fossils is known as paleontology.

Charles Robert Darwin (1809-1882) explained the evolutionary principle in his famous book "The origin of species". The theory proposed by him is popularly known as theory of natural selection.

Speciation

The process by which new species develop from the existing species is known as speciation.

(i) Geographical isolation of a population caused by various types of barriers (such as mountain ranges, rivers and sea).

(ii) Genetic drift caused by drastic changes in the frequencies of particular genes is by chance alone.

(iii) Variations caused in individuals due to natural selection.

Gene migration / Gene flow
Genetic drift
Mutation
Genetic recombination
Natural Selection

- If the same change occurs by chance, it is called genetic drift.
- The original drifted population becomes founders and the effect is called founder effect.
- Natural selection can lead to stabilisation (in which more individuals acquire mean character value), directional change (more individuals acquire value other than the mean character value) or disruption (more individuals acquire peripheral character value at both ends of the distribution curve).
- About 15 mya, primates called *Dryopithecus* and *Ramapithecus* were existing.
- Some of the bones among the bones discovered were different. This creature was called the first human-like being the hominid and was called *Homo habilis*. The brain capacities were between 650-800cc. They probably did not eat meat.
- The Neanderthal man with a brain size of 1400cc lived in near east and central Asia between 1,00,000-40,000 years back.

Principles of Inheritance and Variaton

- Incomplete dominance is the phenomenon where the dominant allele does not completely express itself. Example, In *Mirabilis jalapa* (four O' clock).
- In codominance, both the alleles of a gene are equally dominant, thus both the characters appear side by side in the F_1 hybrids. F_1 generation resembles both the parents. E.g., ABO blood group in humans.
- Linkage is the phenomenon in which certain genes staying together inherit through generations without any change or separation. This is due to their location on the same chromosomes.
- The rearrangement of linked genes due to crossing over is known as recombination.

- The phenomenon that results in alteration of DNA sequence and consequently results in change of genotype and phenotype of an organism is called mutation.
  Mutagens are various chemical and physical factors that induce mutations, e.g., UV radiations, carcinogenic chemicals like nicotine, nitric oxide (NO).

Molecular Basis of Inheritance

- Formation of a new DNA strand from an old DNA is called DNA replication or DNA duplication.
- Process of copying genetic information from DNA to RNA is called transcription.
- Transfer of genetic information from a polymer of nucleotides to a polymer of amino acids is called translation. This is accomplished with the help of genetic code which is a row of three consecutive nucleotides – coding for 20 amino acids.

Summary of enzymes involved in DNA replication process

Protein	Role
Helicase	Unwinds the double helix
Primase	Synthesis RNA primers
Single strand binding protein	Stabilises single stranded regions
DNA gyrase	Relieves torque or strain
DNA polymerase III	Synthesis DNA (5' ? 3')
DNA polymerase I	Erases primer and fill gaps
DNA ligase	Joins the ends of DNA segment

Health and Diseases

- **AIDS :** Acquired Immuno Deficiency Syndrome, was first recognized in USA in 1981. It is caused by HIV (Human immunodeficiency virus), a retro virus having 2-strands of single stranded RNA (ssRNA), with reverse transcriptase enzyme.
- **Vaccination :** It is the inoculation/injection of weak or attenuated antigens, or a toxin, or a protein, into the body. The introduction of antigens stimulates the production of antibodies and memory cells, which protect the body against that antigen/disease.
- The study of cancer is called 'Oncology'. Cancer is the unregulated and uncontrolled proliferation of cells, or the breakdown of regulatory mechanism that governs normal cell division.
- Immunity is the resistance against pathogens, foreign materials and cancer etc. It is of 2-types.
  (a) Innate Immunity : This immunity is by birth, and develops by virtue of genes.
  (b) Acquired Immunity : It can be acquired before birth (from mother through placenta) or after birth. There is an antigen-antibody reaction in this type of immunity.

Antigens : 'Antigen' is an acronym for antibody generating material.
Antibodies : These are pure proteins (β-globulins). Since they participate in the immune system, they are also known as immunoglobulins (Ig).
Drugs : Drugs are chemicals that alter the functioning of the body.
(i) Sedatives and tranquilizers - *eg*. Barbiturates (used in sleeping pills), Valium,
(ii) Opiate narcotics (opioids) - *eg*. Opium, Morphine, Pathedine and Heroin etc.

Biotechnology

- Biotechnology is the application of techniques using live organisms to get desired product of human welfare. It includes recombinant DNA, gene cloning, gene therapy.
- rDNA technology is hybridization of DNA from different sources to achieve desired genotype and phenotype in an organism.
- Restriction endonucleases can break DNA at specific sites. They are appropriately called molecular scissors or biological scissors.
- Vectors are cloning vehicles required to transfer DNA of interest from one organism to another.
- Plasmids are extra-chromosomal, circular, double stranded autonomously replicating DNA sequence in a bacterial cell.
- *Bt* cotton is the first genetically modified crop of the country.
- It was learnt by scientists, during 1950s, that whole plants could be regenerated from explants, i.e., any part of a plant taken out and grown in a test tube, under sterile conditions in special nutrient media. This capacity to generate a whole plant from any cell/explant is called totipotency.
- In mammals, including humans, insulin is synthesised as a pro-hormone (like a pro-enzyme, the pro-hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the C peptide.
- In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.
- Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.
- Gene therapy is a technique that modifies a person's genes to treat or cure disease.
- The first clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency. This enzyme is crucial for the immune system to function.
- ADA deficiency in children can be cured by bone marrow transplantation; and enzyme replacement therapy, in which functional ADA is given to the patient by injection.
- ADA results into Dysfunction of immune system.
- Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible. Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno-sorbent Assay (ELISA) are some of the techniques that serve the purpose of early diagnosis.

- PCR is now used to detect HIV in suspected AIDS patients. It is being used to detect mutations in genes in suspected cancer patients too.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridise to its complementary DNA in a clone of cells followed by detection using autoradiography. The clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene.
- ELISA is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesised against the pathogen.

Organisms and Populations

- Population is a group of individuals of a particular species, which can potentially interbreed and live in a well defined geographical area, and also share or compete for similar resources.
- **Birth** or **Natality rate** – It is the number of births per thousand in a population per year.
- **Death** or **Mortality rate** – It is the number of deaths occurring in a population of one thousand per year.
- The growth of population with time shows specific and predictable patterns. The 2 common patterns are
  - **Exponential growth**

$$\frac{dN}{dt} = (b - d) \times N$$

If (b – d) = r, then $\mathbf{\frac{dN}{dt} = rN}$

Here 'r' is called 'Intrinsic rate of natural increase' or Biotic potential (maximum capacity of reproduction), which indicates the impact of biotic and abiotic factors in population growth.

  - **Logistic growth**

$$\mathbf{\frac{dN}{dt} = rN\left(\frac{K - N}{K}\right)}$$

K = Nature's carrying capacity in that habitat

(K – N)/ K or 1– N/ K = environmental resistance

- **Population Interactions**

S. No.	Name of interaction	Species A	Species B
1	**Parasitism**	+	–
2	**Commensalism**	+	**0**
3	**Mutualism**	+	+
4	**Predation**	+	–
5	**Competition**	–	–
6	**Amensalism**	–	**0**

Ecosystem

- Ecosystem is the functional unit of nature where living organisms interact with each other and with their environment.
- Productivity refers to the rate of biomass production i.e. the rate at which sunlight is captured by producers for the synthesis of energy rich organic compounds.
- Primary productivity is the amount of biomass produced per unit area over a time period by plants during photosynthesis.
- Gross primary productivity (GPP) – It is the rate of production of biomass or accumulation of energy by green plants per unit area per unit time. GPP depends on the chlorophyll content.
- Net primary productivity = Gross primary productivity – Respiration losses. (or GPP–R = NPP)
- Secondary productivity is defined as the rate of formation of new organic matter by consumers.
- Detritivores (e.g., earthworm) break down detritus into smaller particles. This process is called fragmentation.
- *Pheretima* nourishment desire from decaying fallen leaves and soil organic matter.
- In a particular climatic condition, decomposition rate is slower if detritus is rich in lignin and chitin, and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.
- Food chain is the sequence of different organisms which are arranged in a way that energy of food components is passed from one type of organism to other organisms such that the organisms of one order or trophic level are the food of the organisms of next order or trophic level.
- Food web refers to a group of inter- related food chains in a particular community.

Biodiversity and Conservation

- Biodiversity means diversity or heterogeneity at all levels of biological organization, *i.e.*, from macromolecules of the cells to the biomass.
  The important levels of biodiversity are
  (i) Genetic diversity,
  (ii) Species diversity
  (iii) Ecological diversity
- Some extreme estimates range from 20 to 50 million, but a more conservative and scientifically sound estimate made by Robeat May places the global diversity at about 7 million.
- **Biosphere reserves** – They represent natural biomes which contain unique biological communities.
- **National Parks** – They are reserved for the betterment of wild life, (both fauna and flora).
- **Sanctuaries** – In sanctuaries protection is given to fauna only. Activities like harvesting of timber, collection of forest products and private ownership rights are permitted so long as they do not interfere with the well being of the animals.

The Modifications of Root.

Roots of plants are very important for anchorage and absorption of water and nutrients from soil. In certain plants, roots perform additional functions such as storage organs of photosynthates. Roots are also modified to provide additional support to weak stems or to trees that are massive.

(a) For storage of food

- In some plants roots are modified for storing reserve food materials. These **modified roots** usually are swollen and assume different forms such as spindle shaped, e.g., radish; top shaped, e.g., beet, turnip; cone-like, e.g., carrot; indefinite shape, e.g., sweet potatoes.
- *Dahlia, Asparagus, Portulaca* are some other examples of plants with modified roots for food storage.

(b) For mechanical support

- Roots are modified to provide mechanical support as seen in **banyan** tree that has roots growing vertically/obliquely downwards (prop roots); sugarcane/maize in which roots arise from the **nodes** in cluster at the base of the stem (stilt roots) and betel/black pepper in which nodes and **internodes** bear roots that help in climbing.

(c) For gaseous exchange

- Pneumatophores or breathing roots that are present in plants growing in **mangroves** or swamps with saline water for exchange of gases. They are erect peg like structures with numerous pores through which air circulates e.g., *Rhizophora mangle*.

(d) Nodulated roots

- There are numerous swollen nodules on fine branches of roots of the pea and other **leguminous** plants. These nodules are formed due to **symbiotic association** of Rhizobium (bacterium) that live inside the root cortical cells of the roots. They are involved in fixation of nitrogen. An active nodule is pink in colour.

The modifications of stem.

The stem which provides support to all the aerial parts of the plant that is present in the central axis of the plants. Besides, in some plants these also help in perennation, vegetative propagation, food storage, photosynthesis etc. through various modifications.

(a) For vegetative propagation

- Plants besides reproducing sexually also propagate through vegetative parts. For this purpose, stems may be modified into **runner** (*Cyanodon dactylon, Oxalis*).
- Runners are a type of slender prostrate branches that arise from axillary buds; stolon (e.g., mint, strawberry) which is a slender lateral branch arising from the base of stem grows upward and then down to develop new daughter plants; Offset that has a single long horizontal internode growing upto some distance and producing a tuft of leaves above and cluster of roots below at the apex (*Eichhornia, Pistia*).
- **Sucker**, that arises from underground part of stem, grows obliquely and gives rise to a new shoot. (*Chrysanthemum, Banana, Pineapple*).

(b) For storage of food

- Stems get modified into **underground structures** for storage of food as seen in potato (tuber), ginger (rhizome), *zaminkand* garlic (bulb), yam (corm).
- The presence of an **eye** (node) in potato, distinct nodes with internodes and scaly leaves in ginger/yam, a cluster of roots at the base of the reduced stem in garlic/ onion. All of these indicate that underground plant parts are modified stem.

(c) For support

- **Tendrils** provide support to plants that are modifications of stem, e.g., *Vitis*, passion flower, *Bignonia* etc.

(d) For protection

- There are some modified stem that provides protection such as thorns that are hard, pointed structures each representing a branch that arises from the axil of leaf.
- **Thorns** are found in plants like *Duranta*, Pomegranate, *Acacia*, *Bougainvillea, Citrus*, etc.

(e) For photosynthesis

- Stems are also modified into phylloclade, that facilitate photosynthesis.
- Phylloclades are flattened/cylindrical stem or branches of unlimited growth (*Cactus*).

The modifications of leaf.

Leaf is an important organ of the plant. It is a lateral appendage that is borne at **nodes of stem** and is associated with photosynthesis, gaseous exchange and transpiration. Leaves of many plant species are also modified to perform some other special functions. These modifications may be with respect to mechanical support, protection, reducing transpirational rate or to trap insects.

(a) For storage of food

- Like stems and roots, **leaves** are also modified to store reserve food in plants as in the fleshy leaves of garlic, onion.

(b) For mechanical support

- Leaves are modified into long, slender, thread like spirally coiled structures called **tendrils** to provide support and help in climbing, in plants like sweet pea, lentil etc.

(c) For protection

- Leaves are modified into sharp, pointed structures or spines to act as defensive mechanism against excessive grazing and to check transpiration, e.g., *Cactus*, *Argemone*.

(d) For trapping insects

- Leaves are modified to **capture insects** and digest them in pitcher plant (*Nepenthes*) and as bladder in bladderwort (*Utricularia*).

Different types of inflorescences.

Angiosperms are flowering plants in which the flowers are borne either singly or in clusters. Flowers borne singly are solitary, and those borne in clusters together on a common stalk or peduncle that form an inflorescence. It is the reproductive shoot composed of a number of shoots of limited growth (dwarf shoots) termed flowers. Pedicel is the stalk of a flower.

On the basis of development of flowers on the peduncle the **inflorescences** are categorized into two types:-

(i) Racemose (Indefinite or indeterminate)

(ii) Cymose (definite or determinate)

Racemose Inflorescence

- In racemose the unbranched main axis bearing stalked (pedicellate) flowers as in mustard, radish, *Crotalaria* is simple raceme.
- Fleshy peduncle covered by long showy bract with spike inflorescence as in banana and *Colocasia* is called spadix.
- In corymb inflorescence, that is a relatively shorter and broader raceme, the pedicel of lower flowers are longer than the upper ones and all the flowers reach the same level. e.g., *Cassia auriculata*, *Gynandropsis*, candy tuft.
- An inflorescence with extremely reduced main axis bearing a cluster of pedicellate flowers with more or less equal stalk is referred to as umbel, e.g., coriander, *Allium cepa* (onion).
- In Head or Capitulum type, sessile flowers are borne in a dense cluster in a common receptacle, which is the flattened main axis e.g., sunflower. When the main axis is branched then the inflorescence is termed as compound.
- A panicle as seen in mango and drumstick is a compound raceme.
- There can be compound **spadix**, e.g., palm, compound umbel, e.g., coriander, compound corymb, e.g., candy tuft.

Cymose Inflorescence

- There are mainly three types inflorescence in of cymose viz. monochasial cyme, dichasial cyme, polychasial cyme.
- In monochasial cyme a single flower arises in the axil of a leaf of an ordinary shoot or the **peduncle** ends in a single flower, e.g. *Hibiscus rosa sinensis* (shoe flower).
- Dichasial cyme made up of only three flowers, out of which the central one is the oldest and the two lateral ones arising in the axils of bracts below the older flower are youngest, e.g., *Jasminum*.
- The main axis ends in a flower with more than two branches arising from the peduncle below the terminal flower in polychasial cyme., e.g., *Calotropis*.

Anatomy of stem and root of monocots and dicots.

The study of internal organ of a living body is known as **anatomy**. Tissue is a group of cells that perform a common function that may be simple tissue or complex tissue. The tissues may be temporary (eg.,meristematic) or permanent (e.g., sclerenchyma, parenchyma, collenchyma).

Anatomy of the Shoot

The central ascending part of the plant axis is known the **shoot**. It develops from the plumule of the embryo. The shoot bears lateral appendages known as leaves.

The anatomical feature of stem are:

(a) Epidermis:

- Epidermis is the outermost layer of cells that are generally parenchymatous rectangular in shape. Multi-cellular **trichomes** or epidermal hairs, (no epidermal hairs in monocots) are generally present. The epidermis has an outer layer of cuticle made up of waxy material.

(b) Hypodermis:

- It is is a multilayered that is located just below the epidermis. The hypodermis is generally collenchymatous in dicots and sclerenchymatous in monocots.

(c) Cortex and pith:

- They are well defined in cases of dicots whereas in monocots only ground tissue is present. In dicots well defined endodermis and pericycle below the cortex are present. In monocots the endodermis is found around each vascular bundle.
- Distinction into **cortex**, **pericycle**, and **pith** is not seen. Vascular bundles are present in the ground tissue.

(d) Vascular bundle:

- Each vascular bundle is made up of xylem, phloem, cambium (absent in case of monocots) and associated parenchyma tissue.
- The vascular bundles are **conjoint** and **collateral**. They are open (i.e., cambium present between xylem and phloem) in dicot stems and thus show the secondary growth.
- Cambium is absent in monocot stems and therefore there is no secondary growth with a few exception.
- The vascular bundles are arranged in a **ring** in dicots whereas they are **scattered** in ground tissue in monocots.
- Each vascular bundle is surrounded by a sclerenchymatous bundle sheath. The vascular bundles are usually of equal size in dicots whereas in monocots they are of unequal size. In monocot stem the bundles near the periphery or closer to epidermis are smaller in size and the bundles nearer to the center are larger in size.
- The protoxylem is endarch, i.e., towards the centre. The phloem is made up of sieve tubes, companion cells and phloem parenchyma.
- In dicot stems, in between the xylem and phloem of the vascular bundle a procambium strip of **2-3 cells** thickness (fascicular cambium) is present.

- The secondary growth (formation of secondary phloem and secondary xylem) is due to the activity of cambium.

(e) Pith

- In dicot stem the central region of the stem is known pith (medulla).
- The pith is made up of thin walled parenchymatous cell with intercellular spaces.
- The pith is well developed in dicot stem whereas in monocots it is absent

Anatomy of the Root

- The most distinguishing anatomical characters of the root are following:

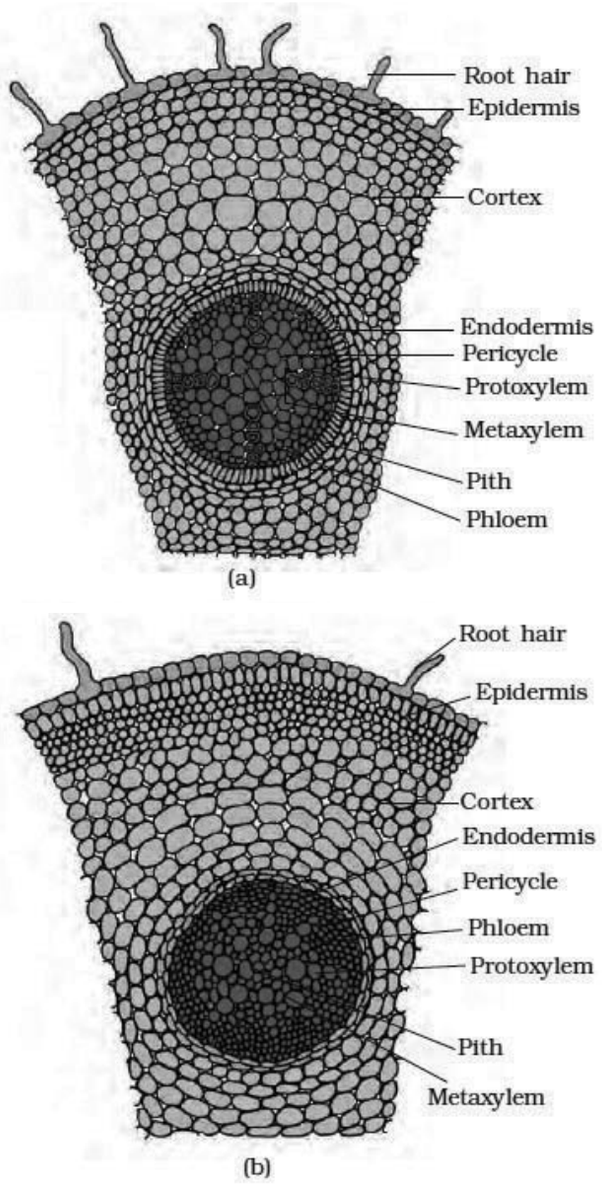


Fig.: T.S. of root : (a) Dicot root (Primary) (b) Monocot root

(a) Epidermis:

- It is the outer most layer of thin walled parenchymatous cells with many unicellular root hairs. It does not have **stomata** and cuticle.

(b) Cortex:

- It is multilayered and well developed and cells are thin walled, **parenchymatous** and may have leucoplasts.
- The intercellular spaces are well developed.
- Collenchyma is absent.
- The inner most layer of the **cortex** is called endodermis. The endodermis is a definite ring like layer consisting of barrel shaped cells compactly arranged without any intercellular spaces.
- Casparian thickenings that are present in the form of strips are present on the radial and inner walls of the endodermal cells.

(c) Pericycle:

- The outer most layer of the **stele** (vascular tissue) is known as pericycle.
- It is single layered and is made up of compactly arranged thin walled parenchymatous cells with no intercellular spaces.
- The pericycle cells alternate with the endodermal cells suggesting that these two layers differ in their origin.
- The endodermis is originated from periblem initials of the apical meristem, whereas the pericycle is derived from the pleurome initials.

(d) Vascular system:

- Bounded by the endodermal and pericycle layers, vascular system is made up of xylem, phloem and the associated parenchyma tissue known as conjunctive tissue.
- The vascular bundles are arranged in a ring.
- The bundles are radial and there are equal number of separate bundles of xylem and phloem.
- The number of xylem and phloem bundles varies from two to six (diarch, triarch, tetrarch, pentarch, and hexarch) in dicots and more than six, i.e., **polyarch** in monocots.
- The xylem made up of protoxylem that lies towards periphery and metaxylem which lies towards the centre or pith. Such type of arrangement of xylem is known as exarch (protoxylem is exarch in root and endarch in shoot). The protoxylem consists of annular and spiral vessels with narrow lumen (in cross section) and the **metaxylem** made up of reticulate and pitted vessels with broad lumen.
- The phloem made up of of sieve tubes, companion cells and phloem parenchyma. The parenchyma present in between the xylem and phloem bundles is named as conjunctive tissue.

(e) Pith:

- It occupies the central area and may be large, small or even, absent.
- Generally in dicot roots the pith is small or absent.
- Total obliteration of pith occurs sometimes when metaxylem elements grow and meet in the centre. In monocot roots pith is large in size.

The morphology of flowers

The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicel, called thalamus or receptacle. These are calyx, corolla, androecium and gynoecium. Calyx and corolla are accessory organs, while androecium and gynoecium are reproductive organs. In some flowers like lily, the calyx and corolla are not distinct and are termed as perianth. When a flower has both androecium and gynoecium, it is **bisexual**. A flower having either only stamens or only carpels is unisexual.

- In symmetry, the flower may be **actinomorphic** (radial symmetry) or **zygomorphic** (bilateral symmetry)
- A flower can be divided into two equal radial halves in any radial plane passing through the centre, it is said to be actinomorphic, e.g., mustard, datura, chilli.
- It can be divided into two similar halves only in one particular vertical plane, it is zygomorphic, e.g., pea, gulmohur, bean, *Cassia*
- A flower is asymmetric (irregular) if it cannot be divided into two similar halves by any vertical plane passing through the centre, as in canna
- A flower may be trimerous, tetramerous or pentamerous when the floral appendages are in multiple of 3, 4 or 5, respectively
- Flowers with bracts-reduced leaf found at the base of the pedicel - are called **bracteate** and those without bracts, **ebracteate**.
- Based on the position of calyx, corolla and androecium in respect of the ovary on thalamus, the flowers are described as hypogynous, perigynous and epigynous
- In the hypogynous flower the gynoecium occupies the highest position while the other parts are situated below it.
- The ovary in such flowers is said to be superior, e.g., mustard, china rose and brinjal.
- If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called **perigynous**.
- The ovary is said to be half inferior, e.g., plum, rose, peach.
- In epigynous flowers, the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary the ovary is said to be inferior as in flowers of guava and cucumber, and the ray florets of sunflower.

The anatomy of plant tissues.

Tissue is a group of cells performing a common function. Tissue may be simple (parenchyma, collenchyma and sclerenchyma) i.e., containing only one type of cells or complex (xylem, phloem) that is containing more than one type of cells. The tissues are also classified into meristematic or permanent tissues. Cells of different types of tissues differ in their structure, shape, size, function and wall composition.

The cells of parenchyma, collenchyma, or sclerenchyma are shown as following:

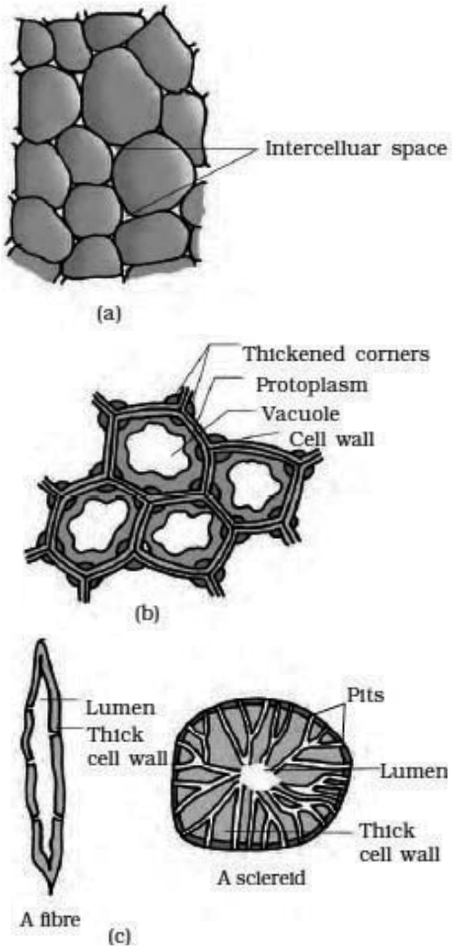


Fig.: Simple tissues : (a) Parenchyma (b) Collenchyma (c) Sclerenchyma

- Parenchyma cells containing chloroplast are chlorenchyma which could be a tissue with loosely arranged cells (spongy) or compactly arranged columnar cells (palisade). If large intercellular spaces are present between the cells, the tissue is known **as aerenchyma**. Parenchyma tissue that forms the outer covering of root, stem or leaves is known as as epidermis or protective tissue.

Parenchyma	Collenchyma	Sclerenchyma
Cells are thin walled. Only primary wall present	Thick primary wall at the corners.	Thick walled
Cells loosely arranged	Cells compactly arranged	Cells compactly arranged.
Cells are living, nucleus present	Cells living, nucleus seen	Cells dead, devoid of cellular contents.
Spherical, polygonal, oval, rectangular or rod shaped.	Shapes are variable.	Elongated

Many intercellular spaces.	Intercellular spaces absent	Intercellular spaces absent
Cells vacuolated	Vacuoles absent	Vacuoles absent

The human skeleton.

Human skeleton in adults is made up of of 206 bones. It is classified into two categories.
(i) Axial- The axial skeleton made up of the bones of the **skull**, vertebral column, sternum and ribs.
(ii) Appendicular skeleton- The appendicular skeleton made up of the bones of the **limbs** along with their girdles.

(a) Human Skull

- It is consist of two sets of bones that are known as crania and facial.
- Occipital, parietal, frontal, temporal, sphenoid and ethmoid bones are Cranial bones.
- On the basis of their location in the body, the cranial bones have strong bone case for eyes that is known as orbit.

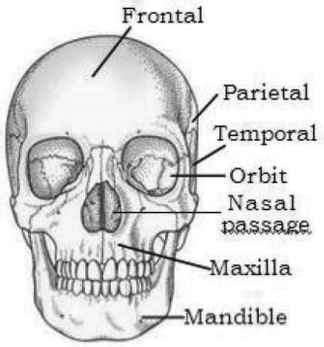


Fig.: Human Skull

- The front part (i.e., face) of the skull is made up of Cranial bones.
- **Hyoid** is a U-shaped bone that is present at the base of the buccal cavity.
- A nasal passage that is formed by nasal bones is present just below the orbit.
- The upper jaw is made up of maxilla and pre-maxilla bones , and the lower jaw is made up of mandible bone. These bones also form the face. Teeth are embedded in special sockets. Teeth are not bones.
- There are distinct sutures that are present in zig-zag fashion are located at the junctions of the frontal with the two parietals, as well as between the two parietals.
- The occipital bone has a very big foramen at its posterior base, the foramen magnum, through which the brain is continued posteriorly as a spinal cord.
- The skull is dicondylic, that is, it has two occipital condyles to articulate with the first cervical vertebra.

(b) Vertebral Column

- It is formed by 26 serially arranged units called vertebrae (singular: vertebra).
- Each vertebra has a central hollow portion called **neural canal** through which the spinal cord passes. The first vertebra is the atlas and it articulates with the occipital condyles of skull.
- Vertebral column is differentiated into cervical (7), thoracic (12), lumbar (5), sacral (1 which is fused), and caudal or coccygeal (1 which is fused).
- A typical vertebra has a — (i) centrum, the modified notochord (ii) two laterally projecting transverse process
- A neural canal passes through the spinal cord
- A mid dorsal neural spine formed by the union of neural arch.
- Depending upon their location in the body, secondary modifications are seen in the length of transverse process and the length of neural spine.
- The two neighbouring vertebrae articulate with each other through their anterior and posterior zygapophyses. Intervertebral discs are present between the centra of two neighbouring vertebrae.


Fig.: Vertebral column

- The vertebral column protects the spinal cord, supports the head.

(c) Rib Cage and Sternum

- Branchial basket is made up of Sternum. It has 7 (seven) notches for articulation with ribs. It has hexagonal disc at the top called **manubrium**. Lower end has a reduced bone known as xiphoid process.

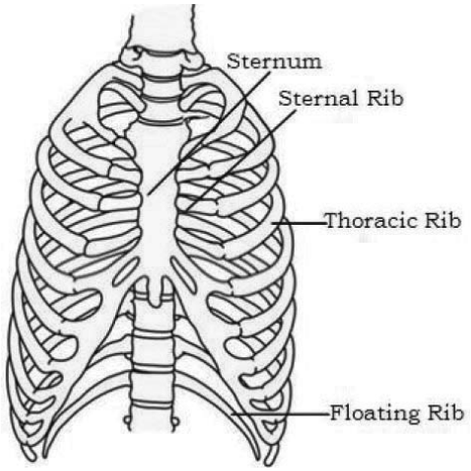


Fig.: Rib cage and sternum

- Ribs can be classified into two classes: the thoracic ribs, and the sternal ribs. The thoracic ribs articulate with the thoracic vertebrae, and the sternal ribs do so with the sternum. Some (7) of the thoracic ribs are attached to the sternal ribs with the help of ligaments, enabling the increase and decrease in volume of the thoracic chamber during respiration.
- There are 12 (twelve) pairs of ribs. Each rib is a thin flat bone and is carried ventrally from the vertebral column. It has a head articulating with the centrum, and tubercle articulating with transverse process of vertebrae.
- 7 (seven) pairs of thoracic ribs are attached to the sternal ribs.

- Last 5 (five) pairs of thoracic ribs do not articulate with sternal ribs, and are known as **false ribs**.
- The last 2 pairs (11^{th} and 12^{th}) of false ribs are free and are known as floating ribs.

(d) Pectoral Girdle

- Pectoral girdle is formed of two halves.
- Each half of pectoral girdle consists of a **scapula** and a **clavicle**.

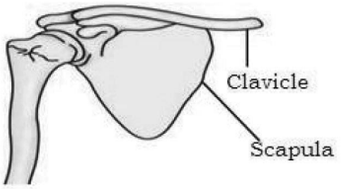


Fig.: Pectoral Girdle

- Scapula is a large triangular flat bone with a slightly elevated ridge known as spine. The spine projects as a flat, expanded process known as the **acromion**.
- The clavicle is a type of long slender bone with two curvatures. The clavicle articulates with the acromion.
- Below the acromion is a depression known as the glenoid cavity, which articulates the head of the humerus to form the shoulder joint.

(e) Pelvic Girdle

- It consists of two halves.
- Each half is formed by the fusion of three bones - ilium, ischium and pubis.

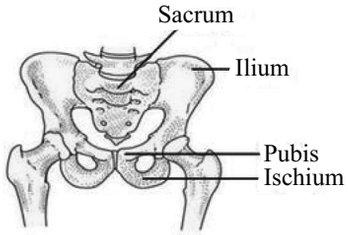


Fig.: Pelvic Girdle

- At the point of fusion of the above bones is a cavity called acetabulum to which the thigh bone articulates.
- The two halves of the pelvic girdle meet ventrally to form the pubic symphysis.

(f) Bones of the Hand or Fore Limb

- Fore limb is made up of bones that is made up of humerus, radius and ulna, carpals, metacarpals and phalanges.

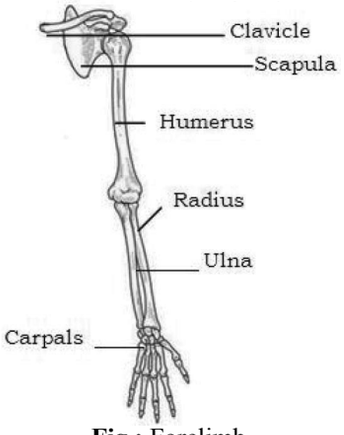


Fig.: Forelimb

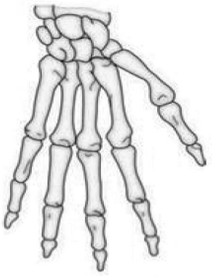


Fig.: Carpals, Metacarpals and Phalanges

- **Humerus** is a straight bone that has a long shaft, and forms the upper arm. The head of the humerus fits into the glenoid cavity of the pectoral girdle. It has a crest at its proximal end in the form of deltoid ridge for the attachment of arm muscles. The distal end has a foramen and a trochlear process, that constitute elbow joint with radius and ulna.
- Radius-ulna made up of 2 (two) separate bones of the forearm known as radius and ulna. Ulna is more developed and has olecranon process at its proximal end, which forms elbow joint with humerus.
- Carpals consist of 8 (eight) small bones that are arranged in two rows. It forms the wrist.
- Metacarpals are made up of 5 (five) long bones that form the palm of hand.
- Phalanges consist of 2 (two) in the thumb and, 3 (three) bones in the remaining four fingers, thus totalling 14 (fourteen) bones.

(g) Bones of the Leg or Hind Limb

- Hind limb is made up of femur, tibia and fibula, patella (knee cap) tarsals, metatarsals, phalanges.
- The femur is the longest bone. The head of femur fits into the **acetabulum** of the pelvic girdle. The proximal end has trochanters for attachment of thigh muscles. The distal end contains two condyles, that articulate with triangular shaped patella and proximal part of tibia to form knee on the ventral side.

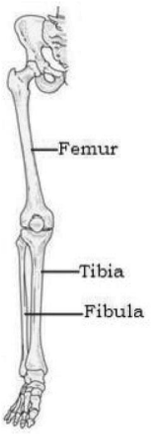


Fig.: Hind limb

- Tibia-fibula made up of two separate bones known as **tibia** and **fibula** and is present in the shank region of leg. Tibia is more developed than fibula. Its proximal end articulates with femur and patella and constitutes knee.
- There are 7 (seven) tarsal bones, that are arranged in two rows to form the ankle. The largest bone of these is **calcareous** which form heel.
- Metatarsals made up of 5 (five) bones and form foot.
- Phalanges made up of 2 (two) bones in big toe and three bones in each of the remaining toes thus totaling 14 (fourteen) bones.

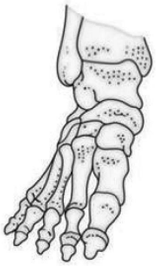


Fig.: Tarsals