CONTENTS

Description	Page Number
1. Elecrotstatics and Capacitance	03
2. Current Electricity	12
3. Magnetic Effects of Current	15
4. Magnetic Properties of Current	18
5. Electromagnetic Induction	20
6. Alternating Current	22
7. Light	26
8. Modern Physics	35
9. Some Study Tips	43

ELECTROSTATICS & CAPACITANCE

ELECTROSTATICS

1. Coulomb's Law

(a) $F_m = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1q_2}{r^2}$, K = Dielectric constant or relative permittivity of the medium

(b) $F_m = \frac{F_0}{K}$ [F_0 – Force between point charges placed in vacuum]

(c) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(d) $\frac{F_e}{F_g} = 2.4 \times 10^{39}$ [For electron–proton pair]

$= 1.2 \times 10^{36}$ (For proton–proton pair)

2. Electric field

(a) $\vec{E} = \frac{\vec{F}}{q_0}$

(b) Electric field due to a point charge: (i) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}.\hat{r}$ (if charge q is placed at the origin)

(ii) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q(\vec{r}-\vec{r}_0)}{|\vec{r}-\vec{r}_0|^3}$ (if charge q is placed at some point having position vector $\vec{r}_0$)

(c) $[E] = [M^1L^1T^{-3}A^{-1}]$

3. Electric field on the axis of a uniformly charged ring

(a) $E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{qx}{\left(R^2+x^2\right)^{3/2}}$ (R = radius of the ring)

(b) $E_{centre} = 0$

4. Electric dipole

(a) dipole moment $p = q(2\ell)$ (where 2ℓ = length of the dipole)

(b) $E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{\left[r^2-\ell^2\right]^2}$ (r = distance of axial point w.r.t. centre of dipole)

$\cong \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$ (if $r >> \ell$)

(c) $E_{equat.} = \frac{1}{4\pi\varepsilon_0}\frac{p}{\left[r^2+\ell^2\right]^{3/2}} \approx \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$ (if $r >> \ell$)

(d) $(E_{axial}/E_{equat.}) = 2/1$

(e) Dipole field at an arbitrary point (r, θ)

(i) $E_r = \frac{1}{4\pi\varepsilon_0}\frac{2p\cos\theta}{r^3}$; (ii) $E_\theta = \frac{1}{4\pi\varepsilon_0}\frac{p\sin\theta}{r^3}$

(iii) $E = \sqrt{E_r^2+E_\theta^2} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}\sqrt{1+3\cos^2\theta}$

(f) Dipole field component at (x, y, z) point

(i) $E_x = \frac{1}{4\pi\varepsilon_0}\frac{3xz\,p}{r^s}$; (ii) $E_y = \frac{1}{4\pi\varepsilon_0}\frac{3yz\,p}{r^5}$;

(iii) $E_z = \dfrac{1}{4\pi\varepsilon_0}\dfrac{p\left(3z^2 - r^2\right)}{r^5}$

(g) Torque on a dipole : (i) $\vec{\tau} = \vec{p} \times \vec{E}$; (ii) $\tau = pE \sin\theta$

(h) Potential energy of a dipole: (i) $U = -\vec{p}\cdot\vec{E} = -pE\cos\theta$

(ii) Work done in rotating a dipole from angle θ_1 to angle θ_2

$W = U_2 - U_1 = pE(\cos\theta_1 - \cos\theta_2)$

5. Electric flux

(a) $d\phi = \vec{E}\cdot d\vec{S}$

(b) $\phi \int \vec{E}\cdot d\vec{S} = EA\cos\theta$ (If electric field is constant over the whole surface)

(c) Unit of ϕ = (Nm^2/Coulomb) = J.m/Couplomb

(d) $[\phi] = [M^1L^3T^{-3}A^{-1}]$

6. Gauss's Law: $\oint \vec{E}\cdot d\vec{S} = \dfrac{q}{\varepsilon_0}$

7. Electric field due to various systems of charges

(a) Isolated Charge:

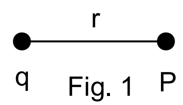


Fig. 1

$E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$

(b) Electric dipole:

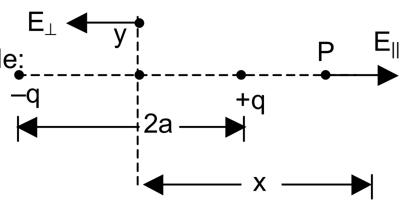


Fig. 2

(i) $\vec{E}_{\parallel} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{2\vec{p}}{x^3}$

(ii) $\vec{E}_{\perp} = -\dfrac{1}{4\pi\varepsilon_0}\dfrac{\vec{p}}{y^3}$

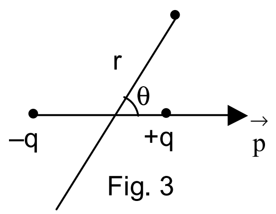


Fig. 3

(iii) $E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{p}{r^3}\sqrt{1 + 3\cos^2\theta}$

(c) A ring of charge:

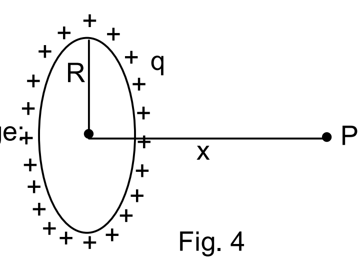


Fig. 4

$E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{qx}{\left(R^2 + x^2\right)^{3/2}}$

(d) A disc of charge:

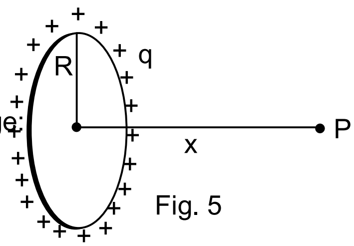


Fig. 5

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$$

(e) Infinite sheet of charge:

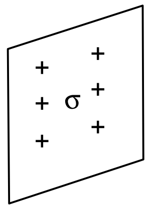


Fig. 6

$$E = \frac{\sigma}{2\varepsilon_0}$$

(f) Infinitely long line of charge:

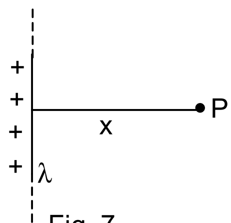


Fig. 7

$$E = \frac{\lambda}{2\pi\varepsilon_0 x}$$

(g) Finite line of charge:

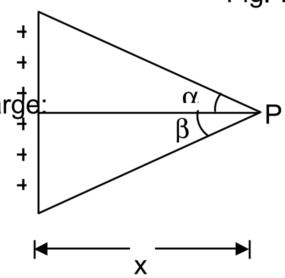


Fig. 8

$$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 x}\ (\sin\alpha + \sin\beta)$$

$$E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0}\ (\cos\alpha + \cos\beta)$$

(h) Charged spherical shell:

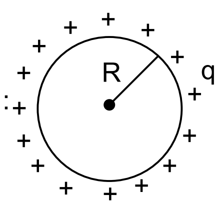


Fig. 9

(i) Inside: $0 \le r \le R$

$E = 0$

(ii) Outside: $r \ge R$

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

(i) Solid sphere of charge:

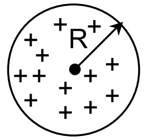


Fig. 10

(i) Inside: $0 \le r \le r$

$E = \rho r/3\varepsilon_0$

(ii) Outside : $r \ge R$

$$E = \frac{\rho R}{3\varepsilon_0}\left(\frac{R}{r}\right)^2$$

8. **Force on a charged conductor: The force per unit area or electric pressure**

$$P_{elec.} = \frac{dF}{dA} = \frac{\sigma^2}{2\varepsilon_0}$$

9. **Charged soap bubble:** (a) $P_{in} - P_{out}$ **=** $\frac{4T}{r} - \frac{\sigma^2}{2\varepsilon_0}$

(b) If air pressure inside and outside are assumed equal then: $P_{in} = P_{out}$ and $\frac{4T}{r} = \frac{\sigma^2}{2\varepsilon_0}$

or $r = \frac{8\varepsilon_0 T}{\sigma^2}$ or $T = \frac{\sigma^2 r}{8\varepsilon_0}$ or $\sigma = \sqrt{(8\varepsilon_0 T/r)}$ or $Q = 8\pi r\sqrt{(2\varepsilon_0 rT)}$

or $r = [Q^2/128\pi^2\varepsilon_0 T]^{1/3}$

10. **Electric potential:**

(a) $V = (W/q)$

(b) Unit of V = Volt

(c) $[V] = [ML^2T^{-3}A^{-1}]$

(d) $\vec{E} = -\vec{\nabla} V$

(e) Potential due to a point charge, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

(f) Potential due to a group of charges, $V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3}\right]$

(g) Potential due to a dipole:

(i) Axial point, $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$; (ii) equatorial point, V = 0;

(iii) $V(r, \theta) = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{\rho^2}$

(h) Potential due to a charged spherical shell

(i) outside: $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ (ii) surface: $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$;

(iii) inside : $V = V_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$

(i) Potential due to a charged spherical conductor is the same as that due to a charged spherical shell.

(j) Potential due to a uniformly charged nonconducting sphere

(i) outside: $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$; (ii) surface: $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$

(iii) inside: $V = \frac{1}{4\pi\varepsilon_0}\frac{q(3R^2 - r^2)}{2R^3}$; (iv) centre: $V = \frac{3}{2} x \frac{1}{4\pi\varepsilon_0}\frac{q}{R} = 1.5\ V_{surface}$

(k) Common potential (Two spheres joined by thin wire)

(i) common potential $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 + Q_2}{r_1 + r_2}\right)$

(ii) $q_1 = \frac{r_1(Q_1 + Q_2)}{(r_1 + r_2)} = \frac{r_1 Q}{r_1 + r_2}$; $q_2 = \frac{r_2 Q}{r_1 + r_2}$

(iii) $\frac{q_1}{q_2}=\frac{r_1}{r_2}$ or $\frac{\sigma_1}{\sigma_2}=\frac{r_2}{r_1}$

11. Potential energy

(a) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}=q_1V_1$ (For a system of two charges)

(b) $U=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}+\frac{1}{4\pi\varepsilon_0}\frac{q_1q_3}{r_{13}}+\frac{1}{4\pi\varepsilon_0}\frac{q_2q_3}{r_{23}}$ (For a system of three charges)

(c) $U=-\vec{p}\cdot\vec{E}$ (For an electric dipole)

12. If n drops coalesce to form one drop, then

(a) $Q = nq$; (b) $R=n^{1/3}r$; (c) $V = n^{2/3}V_{small}$;
(d) $\sigma = n^{1/3}\sigma_{small}$ (e) $E=n^{1/3}E_{small}$

13. Energy density of electrostatic field: $u=\frac{1}{2}\varepsilon_0E^2$

CAPACITANCE

14. Capacitance:

(a) $C = (q/V)$
(b) Unit of C = farad (F)
(c) Dimensions of C = $[M^{-1}L^{-2}T^4A^2]$

15. Energy stored in a charged capacitor

(a) $U=\frac{1}{2}CV^2$; (b) $U=\frac{1}{2}QV$; (c) $U=\frac{1}{2}\frac{Q^2}{C}$

16. Energy density: (a) $u = \frac{1}{2}\varepsilon_0E^2$; (b) $u = \frac{1}{2}\frac{\sigma^2}{\varepsilon_0}$

17. Force of attraction between plates of a charged capacitor

(a) $F=\frac{1}{2}\varepsilon_0E^2A$; (b) $F = \frac{\sigma^2A}{2\varepsilon_0}$; (c) $F=\frac{Q^2}{2\varepsilon_0A}$

18. Capacitance formulae

(a) Sphere: (i) $C_{air} = 4\pi\varepsilon_0R$; (ii) $C_{med} = K(4\pi\varepsilon_0R)$

(b) Spherical capacitor: (i) $C_{air} = \frac{4\pi\varepsilon_0r_ar_b}{r_b-r_a}$; (ii) $C_{med} = \frac{4\pi\varepsilon_0Kr_ar_b}{(r_b-r_a)}$

(c) Parallel plate capacitor: (i) $C_{air} = \frac{\varepsilon_0A}{d}$; (ii) $C_{med} = \frac{K\varepsilon_0A}{d}$

(d) Cylindrical capacitor: (i) $C_{air} = \frac{2\pi\varepsilon_0\ell}{\log_e(r_b/r_a)}$; (ii) $C_{med} = \frac{2\pi K\varepsilon_0\ell}{\log_e(r_b/r_a)}$

(e) Two long parallel wires: $C=\frac{\varepsilon_0\ell}{\log_e(d/a)}$ where d is the separation between wires and a radius of each wire (d>>a)

19. Series Combination of Capacitors

(a) $q_1 = q_2 = q_3 = q$ (Charge remains same)

(b) $V_1 = \frac{q}{C_1}, V_2=\frac{q}{C_2}, V_3=\frac{q}{C_3}$ (Potential difference is different)

(c) $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

(d) For two capacitors in series: $C = C_1C_2/(C_1 + C_2)$

(e) Energy stored: $U = U_1 + U_2 + U_3$

20. Parallel Combination of Capacitors

(a) $V_1 = V_2 = V_3 = V$ (Potential difference remains same)

(b) $q_1 = C_1V$, $q_2 = C_2V$, $q_3 = C_3V$ (Charges are different)

(c) $C = C_1 + C_2 + C_3$

(d) $U = U_1 + U_2 + U_3$

21. Effect of dielectric

(a) Field inside dielectric, $E_d = E_0/K$

(b) Polarization charges on surface of dielectric:

(i) $Q_p = Q\left(1-\frac{1}{K}\right)$; (ii) $\sigma_p = \frac{Q_p}{A} = \sigma\left(1-\frac{1}{K}\right)$

(c) Polarization vector: (i) $|\vec{P}| = Q_p/A$; (ii) $|\vec{P}| = \varepsilon_0\chi E_d$

22. Capacitance formulae with dielectric

(a) $C - \frac{\varepsilon_0 A}{d - t\left(1-\frac{1}{K}\right)} = \frac{K\,\varepsilon_0 A}{K\,d - t\,(K-1)}$ (For a dielectric slab of thickness t)

(b) $C = \frac{\varepsilon_0 A}{d-t}$ (For a metallic slab of thickness t)

(c) $C = \frac{\varepsilon_0 A}{d}\left(\frac{K_1 + K_2}{2}\right)$

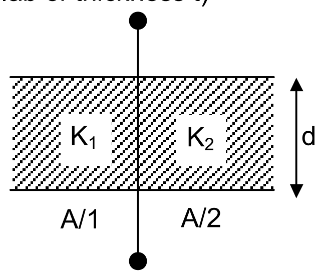


Fig. 11

(d) $C = \frac{2\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1 + K_2}\right)$

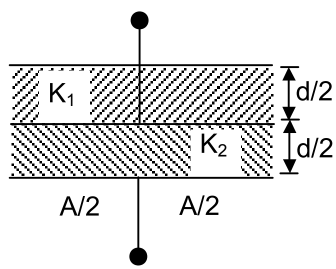
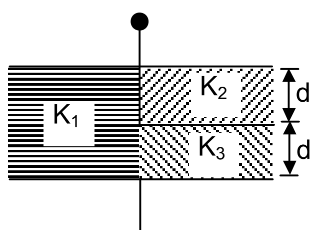


Fig. 12

(e) $C = \frac{\varepsilon_0 A}{4\,d}\left(K_1 + \frac{2K_2\,K_3}{K_2 + K_3}\right)$



(f) For n plates with alternate plates connected: $C = (n-1)\,\varepsilon_0 A/d$

(g) $$C = \frac{\varepsilon_0 A}{\left(\frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3}\right)}$$

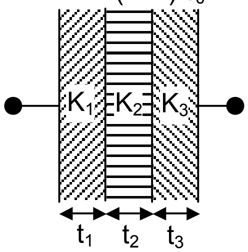


Fig. 14

23. Spherical capacitor with inner sphere grounded

(a) $$C = \frac{4\pi\varepsilon_0 r_1 r_2}{(r_2 - r_1)} + 4\pi\varepsilon_0 r_2$$

(b) Charge on inner sphere = $-q_1$, while charge on outer sphere = $+q_2$

(c) Magnitude of charge on inner sphere: $q_1 = \left(\frac{r_1}{r_2}\right) q_2$

24. Insertion of dielectric slab

(a) Battery remains connected when slab is introduced
(i) $V' = V$; (ii) $C' = KC$; (iii) $Q' = KQ$; (iv) $E' = E$; (v) $U' = KU$

(b) Battery is disconnected after charging the capacitor and slab is introduced
(i) $Q' = Q$; (ii) $C' = KC$; (iii) $E' = E/K$; (iv) $V' = V/K$; (v) $U' = U/K$

25. Charge transfer, Common potential and energy loss when two capacitors are connected

(a) Common potential: $V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{q_1 + q_2}{C_1 + C_2}$

(b) Charge transfer: $\Delta q = \frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)$

(c) Energy loss: $\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$

26. Charging and discharging of a capacitor

(a) Charging: (i) $q = q_0(1 - e^{-t/RC})$; (ii) $V = V_0(1 - e^{-t/RC})$; (iii) $I = I_0 e^{-t/RC}$;
(iv) $I_0 = V_0/R$

(b) Discharge: (i) $q = q_0 e^{-t/RC}$; (ii) $V = V_0 e^{-t/RC}$; (iii) $I = -I_0 e^{-t/RC}$
(b) Time constant: $\tau = RC$

Whether you think you can…

…or you think you can't…

…either ways you are right!

CURRENT ELECTRICITY

1. Electric Current

(a) $I = (q/t)$; (b) $I = (dq/dt)$; (c) $I = (ne/t)$; (d) $q = \int I dT$

2. Ohm's law, Resistivity and Conductivity

(a) $V = IR$; (b) $R = \rho(\ell/A)$; (c) $\sigma = (1/\rho)$ (d) $v_d = (eE\tau/m)$; (e) $I = neAv_d$;

(f) $R = \left(\frac{m}{ne^2\tau}\right)\left(\frac{\ell}{A}\right)$; (g) $\rho = \frac{m}{ne^2\tau}$; (h) $\sigma = \frac{ne^2\tau}{m}$

3. Current density

(a) $J = (I/A)$; (b) $J = nev_d$; (c) $J = \sigma E$; (d) $\mu = (v_d/E)$; (e) $\sigma = ne\mu$

4. Temperature Coefficient of Resistance

(a) $R = R_0[1 + \alpha(T-T_0)]$; (b) $\alpha = \frac{R - R_0}{R_0(T - T_0)}$; (c) $\rho = \rho_0 [1+\alpha(T-T_0)]$;

(d) $\alpha = \frac{\rho - \rho_0}{\rho_0(T - T_0)}$

5. Cell: (a) $E = \frac{W}{Q}$; **(b)** $I = \frac{E}{r + R}$; **(c)** $V = E - Ir$ **(where V = IR)**

6. Series Combination of Resistances

(a) $R = R_1 + R_2 + R_3$; (b) $V = V_1 + V_2 + V_3$;

(c) $I = \text{constant} = I_1 = I_2 = I_3$; (d) $V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$

7. Parallel Combination of resistances

(a) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$;

(b) $I = I_1 + I_2 + I_3$;

(c) $V = \text{constant} = V_1 = V_2 = V_3$;

(d) $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$

(e) For a parallel combination of two resistances:

(i) $R = \frac{R_1R_2}{R_1 + R_2}$; (ii) $I_1 = \frac{R_2}{R_1 + R_2} I$; (iii) $I_2 = \frac{R_1}{R_1 + R_2} I$

8. Heating effect of current

(a) $W = VI\,t$;

(b) $P = VI$;

(c) $P = I^2R = V^2/R$;

(d) $H = I^2 Rt$ Joule = $\frac{I^2Rt}{J}$ Calorie

9. Electric bulb: (a) Resistance of filament $R = V^2/P$;

(b) Maximum current that can be allowed to pass through bulb, $I_{max} = (P/V)$

10. Total Power Consumed

(a) Parallel combination: $P = P_1 + P_2 + P_3$

(b) Series combination: $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3}$

11. Effect of stretching a resistance wire

$$\frac{R_2}{R_1}=\frac{\ell_1}{\ell_2}\times\frac{A_1}{A_2}=\left(\frac{\ell_2}{\ell_1}\right)^2=\left(\frac{A_1}{A_2}\right)^2=\left(\frac{r_1}{r_2}\right)^4 \qquad [\because\ \ell_1A_1=\ell_2A_2]$$

12. Cells in series: $I=\dfrac{nE}{nr+R}=\dfrac{E}{R}$ (if n r <<R)

13. Cells in parallel: $I=\dfrac{E}{(r/n)+R}=\dfrac{E}{R}$ (if r << R)

$=\dfrac{nE}{r}$ (if r >>R)

14. Mixed Combination (m rows with each containing n cells in series)

(a) $I=\dfrac{nE}{(nr/m)+R}=\dfrac{m\,n\,E}{nr+m\,R}$;

(b) I is maximum when n r = m R ;

(c) $I_{max}=\dfrac{m\,n\,E}{2\sqrt{m\,n\,r\,R}}$

15. Chemical effect of current:

(a) Faraday's first law of electrolysis: m = Zq = ZIt

(b) Faraday's second law of electrolysis:

(i) $m \propto W$ (W = ECE) or m/W = constant (where W = atomic weight/valency)

(ii) As $\dfrac{m_1}{m_2}=\dfrac{Z_1}{Z_2}$ and $\dfrac{m_1}{m_2}=\dfrac{W_1}{W_2}$; so $\dfrac{Z_1}{Z_2}=\dfrac{W_1}{W_2}$

(c) Faraday : 1 Faraday = 96,500 Coulomb

(d) $\dfrac{W}{Z}=F=$ Faraday's constant

16. Thermo e.m.f. : $e=\alpha\theta+\dfrac{\beta\theta^2}{2}$ (where $\theta=\theta_H=\theta_C$)

17. Neutral temperature: $\theta_N=-\left(\dfrac{\alpha}{\beta}\right)$ $\left[\left(\dfrac{de}{d\theta}\right)_{\theta_N}=0\right]$

18. Temperature of inversion: $\theta_N=\dfrac{\theta_1+\theta_C}{2}$ $[\because \theta_I-\theta_N=\theta_N-\theta_C]$

19. Thermoelectric power or Seebeck Coefficient: $S=\dfrac{de}{d\theta}=\alpha+\beta\theta$

20. Peltier effect:

(i) Heat absorbed per second at a junction when a current I flows = πI (where π = Peltier coefficient)

(ii) Peltier coefficient, $\pi=S\theta_H$

21. Thomson Coefficient:

(i) Heat absorbed/ sec = $I\int_{\theta_X}^{\theta_H}\sigma d\theta$

(ii) Thomson coefficient, $\sigma = \dfrac{\Delta Q/\text{time}}{I\,\Delta\theta}$

MAGNETIC EFFECTS OF CURRENT

22. Biot–Savart law : $dB = \frac{\mu_0}{4\pi}\frac{I\,d\ell \sin\theta}{r^2}$

23. Field due to a long straight wire: $B = \frac{\mu_0 I}{2\pi r}$

24. Field due to a circular coil:

(a) at centre: $B = \frac{\mu_0 N I}{2a}$;

(b) at an axial point: $B = \frac{\mu_0 N I a^2}{2\left(a^2 + x^2\right)^{3/2}}$

(c) on axis when x >> a : $B = \frac{\mu_0\ N I a^2}{2x^3}$

(d) point of inflexion: It occurs at $x = a/2$

Field at the point of inflexion: $B = \left(\frac{4\mu_0 N I}{5\sqrt{5}\ a}\right) = 0.716\ B_{centre}$

25. Magnetic moment of circular coil: (a) M = NIA ; (b) Field: $B = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$

26. Field due to an arc of current:

(a) $B = (\mu_0 I\ell/4\pi R^2)$;

(b) $B = (\mu_0 I\theta/4\pi R)$

(c) At the centre of a semicircular coil: $B = (\mu_0 I/4R)$

27. Field due to finite length of wire: $B = \frac{\mu_0 I}{4\pi a}(\sin\phi_1 + \sin\phi_2)$

28. Field at the centre of a square loop: $B = \left(\frac{2\sqrt{2}\,\mu_0 I}{\pi\ell}\right)$

29. Ampere's law: (a) $\oint \vec{B}.d\vec{\ell} = \mu_0 I$; (b) $\oint \vec{H}.d\vec{\ell} = 1$

30. Field due to a current in cylindrical rod:

(a) outside: $B = (\mu_0 I/2\pi r)$; (b) surface: $B = (\mu_0 I/2\pi R)$; (c) inside: $B = \frac{\mu_0 I r}{2\pi R^2}$

31. Field due to a current carrying solenoid:

(a) inside: $B = \mu_0 n I$; (b) at one end : $B = (\mu_0 n I/2)$

(c) at an axial point: $B = \frac{\mu_0 n I}{2}(\cos\alpha_2 - \cos\alpha_1)$

32. Field due to a toroid: (a) inside: $B = \mu_0 nI - \mu_0 NI/2\pi R$; (b) outside: B = 0

33. Force on electric current: $\vec{F} = \vec{H} \times \vec{B}$

34. Force between two parallel conductors: $\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi d}$

35. Comparison of magnetic and electric forces between two moving charges: $(F_{magnetic}/F_{electric}) = (v^2/c^2)$

36. Force on a current loop in a magnetic field: $\vec{F} = 0$ (any shape)

37. Torque on a current loop in a magnetic field: $\vec{\tau} = \vec{M} \times \vec{B}$ or τ M B sin θ

38. Moving coil galvanometer:

(a) τ – N I A B ;

(b) τ =Kθ ;

(c) $I = \left(\frac{K}{N\,AB}\right)\theta$;

(d) Current sensitivity = (θ/I) = (NaB/K) ; (e) Voltage sensitivity = (θ/V) = (θ/IR) = (NAB/KR)

39. Ammeter:

(a) Shunt resistance S = ($I_g G / I - I_g$);

(b) Length of shunt wire, $\ell = S\,\pi r^2/\rho$;

(c) Effective resistance of ammeter, R_A = GS/(G+S);

(d) For an ideal ammeter, R_A = 0

40. Voltmeter:

(a) High resistance in series, $R = \left(\frac{V}{I_g} - G\right)$;

(b) For converted Voltmeter, R_V = R + G;

(c) For an ideal Voltmeter, $R_V = \infty$

41. Force on a moving charge:

(a) $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$; (b) F = q v B sin θ

42. Path of a moving charge in a magnetic field

(a) When $\vec{v}$ is $\perp$ to $\vec{B}$:

(i) path = circular; (ii) r = (mv/qB) ; (iii) ν = (qB/2πm);
(iv) T = (2πm/qB) ; (v) ω = qB/m)

(b) When angle between $\vec{v}$ and $\vec{B}$ is θ:

(i) path=helical ; (ii) r = ($mv_\perp$/qB) = (mv sin θ/qB);

(iii) ν = (qB/2πm); (iv) $T = \frac{2\pi m}{q\,B}$; (v) ω = (qB/m);

(vi) pitch p = 2πr/tan θ (where tan θ = ($v_\perp/v_\parallel$)

43. Cyclotron:

(i) T = (2πm/qB) ;

(ii) ν = (qB/2πm) ;

(iii) ω = (θB/m) ;

(iv) radius of particle acquiring energy E, r = [$\sqrt{(2mE)}$/qB];

(v) velocity of particle at radius r, v = qBr/m;

(vi) the maximum kinetic energy (with upper limit of radius = R)

$$K_{max} = \frac{1}{2}\frac{q^2B^2R^2}{m}$$

44. Magnetic field produced by a moving charge:

(a) $\vec{B} = \frac{\mu_0}{4\pi} \frac{q\,(\vec{v} \times \vec{r})}{r^3}$;

(b) $B = \frac{\mu_0}{4\pi} \frac{q\,v \sin\theta}{r^2}$

MAGNETIC PROPERTIES OF CURRENT

45. Magnetic field:

(a) $B = \frac{F_{max}}{q\,v}$; (b) $B = \frac{1}{I}\left(\frac{dF}{d\ell}\right)_{max}$

46. Atomic magnetic moments:

(a) $\mu_L = -\frac{eL}{2m}$; (b) $\mu_S = -\frac{eS}{m}$;

(c) $\mu_J = -g\frac{eJ}{2m}$; (d) $\mu_B = \frac{e\,h}{4\,\pi\,m}$ = 0.927×10^{-23} J/T

47. Intensity of magnetization: $I = (M/V)$

48. Magnetizing field:

(a) $H = \frac{B}{\mu_0} - I$;

(b) For vacuum, $H = \frac{B}{\mu_0}$;

(c) For medium, $h = B/\mu$;

(d) $H = nI$ (solenoid);

(e) $H = I/2\pi r$ (straight wire);

(f) $H = \frac{I\,d\ell \sin\theta}{r^2}$ (Biot-Savart law) ;

(g) $\oint \vec{H}.d\vec{\ell} = I_{free}$

49. Magnetic susceptibility: $\chi = (I/H)$

50. Magnetic permeability:

(a) $\mu = (B/H)$; (b) $\mu_r = (\mu/\mu_0)$; (c) $\mu_r = (B/B_0)$

51. Other relations:

(a) $\mu = \mu_0 (1+\chi)$; (b) $\mu_r = 1 + \chi$ or $\chi = \mu_r - 1$;

(c) $B = B_0 (1+\chi)$: (d) $B = \mu_0 (H + I)$

52. Pole strength: $m = F/B$

53. Magnetic moment of dipole : $M = m \times 2\ell$

54. Field due to a pole: $B = \frac{\mu_0}{4\pi}\left(\frac{m}{r^2}\right)$

55. Field due to a bar magnet:

(a) Axial point: $B = \frac{\mu_0}{4\pi}\frac{2\,Mr}{(r^2 - \ell^2)^2} = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$ (if $r >> \ell$)

(b) Equatorial point: $B = \frac{\mu_0}{4\pi}\frac{M}{(r^2 + \ell^2)^{3/2}} = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)$

(c) At arbitrary point: $B = \frac{\mu_0}{4\pi}\frac{M}{r^3}\sqrt{1 + 3\cos^2\theta}$

56. Force and torque on a dipole in uniform magnetic field

(a) $\vec{F} = 0$; (b) $\vec{\tau} = \vec{M} \times \vec{B}$; (c) τ MB sin θ

57. Potential energy of a dipole in magnetic field: $U = -\vec{M}.\vec{B} = -MB\cos\theta$

58. Tangent galvanometer:

(a) $B = B_H \tan\theta$;

(b) $I = K \tan\theta$, where $K = \dfrac{2r B_H}{\mu_0 n}$

59. Vibration magnetometer: $T = 2\pi\sqrt{\dfrac{I}{M B_H}}$

Nothing will happen

until

you generate the will to

make it happen!

The most powerful weapon on earth is

human soul on fire!

ELECTROMAGNETIC INDUCTION

60. Magnetic flux:

(a) $d\phi = \vec{B}.d\vec{A} = BdA\cos\theta$; (b) $\phi = \int \vec{B}.d\vec{A}$;

(c) $\phi = BA\cos\theta$; (d) $\oint \vec{B}.d\vec{S} = 0$; (e) $\overline{V}.\vec{B} = 0$

61. Faraday's laws of e.m. induction:

(a) Induced e.m.f., $e = -(d\phi/dt)$;

(b) Induced current, $I = \frac{e}{R} = -\frac{1}{R}\frac{d\phi}{dt}$;

(c) Induced charge, $q = (\phi_1 - \phi_2)/R$

62. Motion of a conducting rod:

(a) $\vec{F} = -e(\vec{v} \times \vec{B})$;

(b) Induced e.m.f., e = B/v

(c) For a rod rotating with angular frequency ω or rotating disc, induced e.m.f.,

$e = \frac{1}{2}B\ell^2\omega = B\pi f\ell^2 = Baf$

63. Motion of conducting loop in a magnetic field:

(a) Induced e.m.f. $e = B\ell v$; (b) Induced current, $I = (e/R) = (B\ell v/R)$

(c) $F = I\ell B = B^2\ell^2 v/R$; (d) $P = Fv = I\ell Bv = B^2\ell^2v^2R$;

(e) $H = I^2R = (B^2\ell^2v^2/R)$;

(f) In non uniform magnetic field, $e = (B_1 - B_2)\ell v$ and $I = (B_1 - B_2)\ell v/R$

64. Rotating loop:

(a) $\phi = NAB\cos\omega t = \phi_0\cos\omega t$, with $\phi_0 = NAB$;

(b) $e = e_0\sin\omega t$, where $e_0 = NaB\omega$; (c) $I = (e_0\sin\omega t/R) = I_0\sin\omega t$, with $I_0 = e_0/R$

65. Induced electric field: Induced e.m.f. = $\int \vec{E}.d\vec{\ell}$

66. Self Inductance:

(a) $L = \phi/I$;

(b) $e = -(LdI/dt)$;

(c) $L = \mu_0N^2A/\ell = \mu_0n^2A\ell$ (For a solenoid with air core);

(d) $L = \mu_r\mu_0N^2A/\ell$ (For a solenoid with a material core);

(e) $L = \mu_0N^2\pi R/2$ (For a plane circular coil)

67. Mutual inductance:

(a) $M = (\phi_2/I_1)$; (b) $e_2 = -M(dI_1/dt)$; (c) $M = \mu_0N_sN_p A/\ell p$

68. Series and parallel combination

(a) $L = L_1 + L_2$ (if inductors are kept far apart and joined in series)

(b) $L = L_1 + L_2 \pm 2M$ (if inductors are connected in series and they have mutual inductance M)

(c) $L = \frac{L_1L_2}{L_1 + L_2}$ or $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$

(if two inductors are connected in parallel and are kept for apart)

(d) $M = K\sqrt{(L_1 L_2)}$

(if two coils of self inductances, L_1 and L_2 are over each other)

69. Energy stored in an inductor:

(a) $U = \frac{1}{2}LI^2$; (b) $u_B = (B^2/2\mu_0)$

70. Growth and decay of current in LR circuit

(a) $I = I_0 (1 - e^{-t/\tau})$ (for growth), where $\tau = L/R$

(b) $I = I_0 e^{-t/\tau}$ (for decay), where $\tau = L/R$

The heights by great men reached and kept…
…were not attained by sudden flight,

but they, while their companions slept…
…were toiling upwards in the night.

ALTERNATING CURRENT

71. A.C. Currrent and e.m.f. :

(a) $I = I_0 \sin(\omega t \pm \phi)$;

(b) $e = e_0 \sin(\omega t \pm \phi)$;

(c) $< I > = 0$, $< I >_{1/2} = \frac{2I_0}{\pi} = 0.637\ I_0$;

(d) $< I^2 > I_0^2 / 2$;

(e) $I_{rms} = (I0/\sqrt{2}) = 0.707\ I_0$;

(f) form factor = $\pi/2\sqrt{2}$

72. A.C. response of R, L, C and their series combinations

(a) Resistance only:

- (i) $e = e_0 \sin \omega t$;
- (ii) $I = I_0 \sin \omega t$;
- (iii) phase difference $\phi = 0$;
- (iv) $e_0 = I_0 R$;
- (v) $e_{rms} = I_{rms} R$

(b) Inductance only:

- (i) $e = e_0 \sin \omega t$;
- (ii) $I = I_0 \sin(\omega t - \pi/2)$;
- (iii) current lags the voltage or voltage leads the current by a phase $\pi/2$; (iv) $e_0 = I_0 X_L$;
- (iv) $e_{rms} = I_{rms} X_L$; (vi) $X_L = \omega L$

(c) Capacitance only:

- (i) $e = e_0 \sin \omega t$;
- (ii) $I = I_0 \sin(\omega t + \pi/2)$;
- (iii) current leads the voltage or voltage lags the current by a phase $\pi/2$; (iv) $e_0 = I_0 X_C$;
- (v) $e_{rms} = I_{rms} X_C$;
- (vi) $X_C = (1/\omega C)$

(d) Series LR circuit:

- (i) $e = e_0 \sin \omega t$;
- (ii) $I = I_0 \sin(\omega t + \phi)$;
- (iii) the current lags the voltage or voltage leads the current by a phase $\phi = \tan^{-1}(X_L/R)$;
- (iv) $\cos \phi = (R/Z)$ and $\sin \theta = (XL/Z)$;
- (v) Impedance, $Z = \sqrt{[R^2 + (\omega L)^2]}$;
- (vi) $e_0 = I_0 Z$;
- (vii) $e_{rms} = I_{rms} Z$

(e) Series RC circuit:

- (i) $e = e_0 \sin \omega t$;
- (ii) $I = I_0 \sin(\omega t + \phi)$;
- (iii) The current leads the voltage or voltage lags behind the current by a phase $\phi = \tan^{-1}(X_C/R)$
- (iv) $\cos \phi = (R/Z)$;
- (v) Impedance, $Z = \sqrt{[R^2 + (1+\omega C)^2)]}$;
- (vi) $e_0 = I_0 Z$;
- (vii) $e_{rms} = I_{rms} Z$

(f) Series LCR circuit:

(i) $e = e_0 \sin \omega t$;
(ii) $I = I_0 \sin (\omega t - \phi)$;
(iii) $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$, ϕ is positive for $X_L > X_C$, ϕ is negative for $X_L < X_C$;
(iv) current lags and circuit is inductive if $X_L < X_C$;
(v) current leads and circuit is capacitive if $X_L < X_C$; (vi) $e_0 = I_0 Z$;
(vi) Impedance, $Z = \sqrt{[R^2 + (X_L - X_C)^2]}$;
(viii) $\cos \phi = (R/Z)$ and $\sin \phi = \left(\frac{X_L - X_C}{Z}\right)$

73. Resonance

(a) Resonance frequency, $f_r = \left(\frac{1}{2\pi\sqrt{LC}}\right)$

(b) At resonance, $X_L = X_C$, $\phi = 0$, $Z = R$ (minimum), $\cos \phi = 1$, $\sin \phi = 0$ and current is maximum ($= E_0/R$)

74. Half power frequencies

(a) lower, $f_1 = f_r - \frac{R}{4\pi L}$ or $\omega_1 = \omega_r - \frac{R}{2L}$

(b) upper, $f_2 = f_r + \frac{R}{4\pi L}$ or $\omega_2 = \omega_r + \frac{R}{2L}$

75. Band width: $\Delta f = \frac{R}{2\pi L}$ or $\Delta\omega = \frac{R}{L}$

76. Quality factor

(a) $Q = \frac{\omega_r}{\Delta\omega} = \frac{\omega_r L}{R}$;

(b) As $\omega_r = \frac{1}{\sqrt{LC}}$, hence $Q \alpha \sqrt{L}$, $Q \alpha \frac{1}{R}$ and $Q \alpha \frac{1}{\sqrt{C}}$;

(c) $Q = \frac{1}{\omega_r CR}$;

(d) $Q = \frac{(X_L)_{res}}{R}$ or $\frac{(X_C)_{res}}{R}$;

(e) $Q = \left(\frac{f_r}{\Delta f}\right)$ or $\Delta f = \frac{f_r}{Q}$

77. At resonance, peak voltages are

(a) $(V_L)_{res} = e_0 Q$; (b) $(V_C)_{res} = e_0 Q$; (c) $(V_R)_{res} = e_0$

78. Conductance, susceptance and admittance

(a) Conductance, $G = (1/R)$;
(b) Susceptance, $S = (1/X)$;
(c) $S_L = (1/X_L)$ and $S_C = (1/X_C) = \omega C$;
(d) admittance $Y = (1/Z)$;
(e) Impedance add in series while admittance add in parallel

79. Power in AC circuits

(a) $P_{av} = \frac{1}{2} E_0 I_0 \cos \phi = E_{rms} I_{rms} \cos \phi$;

(b) Power factor, $\cos \phi = \frac{\text{Real power}}{\text{Virtual power}} = \frac{P_{av}}{E_{rms} I_{rms}}$

(c) $\cos\phi = (R/Z)$

(d) (i) R only : $\phi = 0$, $\cos\phi = 1$, $P_{av} = I^2_{rms} R = \frac{e^2_{rms}}{R}$

(ii) C only : $\phi = -90^0 = -\pi/2$, $\cos\phi = 0$, $P_{av} = 0$

(iii) L only : $\phi = 90^0 = \pi/2$, $\cos\phi = 0$, $P_{av} = 0$

(iv) Series RL or RC: $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$ or $\phi = \tan^{-1}\left(\frac{X_C}{R}\right)$

$P_{av} = E_{rms} I_{rms} \cos\phi = \frac{E^2_{rms} R}{Z^2} = I^2_{rms} R$

(iv) Series LCR: $\phi = \tan^{-1} \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$, $P_{AV} = \frac{E^2_{rms} R}{Z^2} = I^2{}_{rms} R,$

At resonance, $\phi = 0$, $\cos\phi = 1$ and $P_{av} = I^2{}_{rms} R = E^2{}_{rms}/R$

80. Parallel LCR circuit

(a) $\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$;

(b) $Y = \sqrt{G^2 + (S_L - S_C)^2}$;

(c) $I_0 = E_0 Y$;

(d) $\tan\phi = \frac{S_L - S_C}{G}$;

(e) $\omega_r = \frac{1}{\sqrt{LC}}$ or $\omega_r = \sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)}$;

(f) in parallel resonance circuit, impedance is maximum, admittance is minimum and current is minimum.

81. Transformer:

(a) $C_p = N_p\left(\frac{d\phi}{dt}\right)$ and $e_s = N_s\left(\frac{d\phi}{dt}\right)$

(b) $\left(\frac{e_p}{e_s}\right) = \left(\frac{N_p}{N_s}\right)$

(c) $\because$ $e_p I_p = e_s I_s$, so $\left(\frac{I_s}{I_p}\right) = \left(\frac{e_p}{e_s}\right) = \left(\frac{N_p}{N_s}\right)$

(d) Step down: $e_s < e_p$, $N_s < N_p$ and $I_s > I_p$

(e) Step up : $e_s > e_p$, $N_s > N_p$ and $I_s < I_p$

(f) Efficiency, $\eta = \left(\frac{e_s I_s}{e_p I_p}\right)$

82. AC generator: $e = e_0 \sin(2\pi f t)$, (where $e_0 = NBA\omega$)

83. DC motor:

(a) $I = \left(\frac{E - e}{R}\right)$

(b) $IE = Ie = I^2R$

(c) efficiency, $\eta\left(\frac{e}{E}\right) = \frac{\text{Back emf}}{\text{Applied emf}}$

LIGHT

1. Intensity of light

(a) Spherical wave front: (i) $I = \frac{P}{4\pi r^2}$, (ii) amplitude $\propto \frac{1}{r}$

(b) Cylindrical wave front: (i) $I \propto \frac{1}{r}$, (ii) amplitude $\propto \frac{1}{\sqrt{r}}$

(c) Plane wave front: (i) $I \propto r_0$, (i) $A \propto r_0$ (i.e. I and A are both constants)

2. **Law of reflection**: Angle of incidence (i) = Angle of reflection (r)

3. **Law of reflection**: Snell's law: $\eta = \frac{\sin i}{\sin r}$

4. Other relations

(a) $2\eta_1 = \frac{v_1}{v_2}$ and $\eta = \frac{c}{v}$

(b) $\lambda_{medium} = \frac{\lambda_{air}}{\eta}$ or $v_{medium} = \frac{v_{air}}{\eta}$ $(\because \nu_{medium} = \nu_{air})$

(c) $\eta_1 \sin i = \eta_2 \sin r$

5. Electromagnetic nature of light

(a) The magnitude of $\vec{E}$ and $\vec{B}$ are related in vacuum by: $B = \frac{E}{C}$

(b) $\vec{E}$ and $\vec{B}$ are such that $\vec{E} \times \vec{B}$ is always in the direction of propagation of wave

(c) $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and $v = \frac{1}{\sqrt{\mu\varepsilon}}$

(d) Refractive index, $\eta = \sqrt{(\mu_r \varepsilon_r)}$ $(\mu_r = \mu/\mu_0$ and $\varepsilon_r = \varepsilon/\varepsilon_0)$
For non–magnetic material, $\mu_r \approx 1$ and $\eta = \sqrt{(\varepsilon_r)}$

(e) The *EM* wave propagating in the positive x–direction may be represented by:
$E_y = E_0 \sin(kx - \omega t)$ and $B_z = B_0 \sin(kx - \omega t)$

6. Energy transmitted by an electromagnetic wave

(a) Energy density of electromagnetic wave is: $u = u_e + u_m = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$

(b) As for *EM* wave, $B = \frac{E}{C}$ and $\frac{1}{c} = \sqrt{(\mu_0 \varepsilon_0)}$, hence

$$u = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2\mu_0}\frac{E^2}{c^2} = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\varepsilon_0 E^2 = \varepsilon_0 E^2$$

(c) Time averaged value of energy density is: $\bar{u} = \frac{1}{2}\varepsilon_0 E_0^{\,2}$

7. Intensity of an electromagnetic wave

(a) In a medium: $I = \left(\frac{1}{2}\varepsilon_0 E_0^2\right) v$

(b) In free space: $I = \left(\frac{1}{2}\varepsilon_0 E_0^2\right) c$

8. Pointing vector

(a) $\vec{S} = \vec{E} \times \vec{H} = \frac{1}{\mu_0}(\vec{E} \times \vec{B}) = c^2\varepsilon_0 (\vec{E} \times \vec{B})$

(b) $S = c\varepsilon_0 E^2 = \sqrt{(\varepsilon_0/\mu_0)}E^2$

(c) $I = \bar{S}$ and $\bar{S} = c\bar{u}$

(d) Impedance of free space, $Z = \sqrt{(\mu_0/\varepsilon_0)} \cong 377$ ohm

9. Pressure of EM Radiation

(a) Change in momentum (normal incidence)

$$\Delta p = \frac{U}{c} = \frac{\bar{S}\, A\Delta t}{c} \quad \text{(absorber)}$$

$$\Delta p = \frac{2U}{c} = \frac{\bar{S}\, A\Delta t}{c} \quad \text{(reflector)}$$

(b) Pressure (normal incidence)

$$P = \frac{\bar{S}}{c} = \bar{u} \qquad \text{(absorber)}$$

$$P = \frac{2\bar{S}}{c} = 2\bar{u} \qquad \text{(reflector)}$$

(c) Pressure for diffused radiation

$$P = \frac{1}{3}\frac{\bar{S}}{c} = \frac{1}{3}\bar{u} \qquad \text{(absorber)}$$

$$P = \frac{2}{3}\frac{\bar{S}}{c} = \frac{2}{3}\bar{u} \qquad \text{(reflector)}$$

10. **Quantum theory of light**:

(a) Energy of photon, $E = h\nu = hc/\lambda$

(b) Momentum, $p = \frac{E}{c} = \frac{h}{\lambda}$

(c) Rest mass of photon = 0

(d) Mass equivalent of energy, $m = (E/c^2)$

11. **Inclined mirrors**: number of images

(a) When 360^0 is exactly divisible by θ^0 and $360^0/\theta^0$ is an even integer then the number of images formed is

$$n = \frac{360}{\theta} - 1 \text{ (whatever may be location of the object)}$$

(b) When 360^0 is exactly divisible by θ^0 and $360/\theta)$ is an odd integer, then the number of images formed is

$$n = \frac{360}{\theta} - 1 \text{ (for symmetrical placement)}$$

$$= \frac{360}{\theta} \qquad \text{(for unsymmetrical placement)}$$

(c) When 360^0 is not exactly divisible by θ, then the number of images formed is
= integer value of n (where $n = 360/\theta$)

12. Reflection amplitude and intensity

(a) When a ray of light is incident (with angle of incidence $i \approx 0$) from a medium 1 of refractive index η_1 to the plane surface of medium 2 of refractive index η_2, then reflection amplitude is

$$R = \frac{\eta_1 - \eta_2}{\eta_1 + \eta_2}$$

(b) The ratio of the reflected intensity and the incident intensity is: $\frac{I_r}{I_i} = \left(\frac{\eta_1 - \eta_2}{\eta_1 + \eta_2}\right)^2$.

13. Refraction of light

(a) $\eta = \frac{\sin i}{\sin r}$; (b) ${}^1\eta_2 = \frac{\sin \theta_1}{\sin \theta_2}$;

(c) ${}^1\eta_2 = \frac{1}{2\eta_1}$; (d) Cauchy's relation: $\eta = A + \frac{B}{\lambda^2}$

14. Parallel slab

(a) Angle of incidence, i = Angle of emergence, e

(b) Lateral shift = [t sin (i – r)/cos r]

15. **Composite block**: $\eta_1 \sin \theta_1 = \eta_2 \sin \theta_2 = \eta_3 \sin \theta_3 =$ constant

16. Apparent depth

(a) $a = \frac{R}{\eta} = \frac{t}{\eta}$ (where R = Real depth)

(b) If there is an ink spot at the bottom of a glass slab, if appears to be raised by a distance
$x = t - a = t - \frac{t}{\eta} = t\left(1 - \frac{1}{\eta}\right)$, where t is the thickness of the glass slab

(c) If a beaker is filled with immissible transparent liquids of refractive indices η_1, η_2, η_3 and individual depths t_1, t_2, t_3 respectively, then the apparent depth of the beaker is:
$$a = \frac{t_1}{\eta_1} + \frac{t_2}{\eta_2} + \frac{t_3}{\eta_3}$$

17. **Total internal reflection: Critical angle i_C is given by**: $\sin i_C = \frac{1}{\eta}$

18. **For a luminous body at a depth d inside a liquid**: Radius of bright circular patch at the surface
$r = d \tan i_C = \frac{d}{\sqrt{\eta^2 - 1}}$

19. **For optical fibre**: $\sin i \le \sqrt{\left[(n_2/n_1)^2 - 1\right]}$

20. **Prism**:

(a) $i + e = A + \delta$

(b) $r_1 + r_2 = A$;

(c) At minimum deviation: i = e and $r_1 = r_2$. Hence, $\eta = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

(d) For small angle prism: $\delta = (\eta - 1) A$

21. **Dispersion**:

(a) $\delta_{red} < \delta_{violet}$ because $\eta_{red} < \eta_{violet}$

(b) Angular dispersion: $\theta = \delta_V - \delta_R = (\eta_V - \eta_R)A$

(c) Dispersive power: $\omega = \dfrac{\delta_V - \delta_R}{\delta_Y} = \dfrac{\eta_V - \eta_R}{\eta_Y - 1} = \dfrac{\eta_B - \eta_R}{\eta_Y - 1}$ (In practice)

(d) Dispersion without deviation: (i) $\delta_C + \delta_F = 0$ or $\dfrac{A_F}{A_C} = -\dfrac{(\eta_C - 1)}{(\eta_F - 1)}$

(ii) Also, angular dispersion, $\theta = A_C(\eta_C - 1)(\omega_C - \omega_F)$

(e) Deviation without dispersion: (i) $\theta_C + \theta_F = 0$ or, $\dfrac{A_F}{A_C} = -\dfrac{\eta_{CV} - \eta_{CR}}{\eta_{FV} - \eta_{FR}}$

(ii) Also, $\dfrac{\omega_F}{\omega_C} = -\dfrac{\delta_{CY}}{\delta_{FY}}$

22. **Principle of superposition**: $y = y_1 + y_2$

23. Superposition of waves of equal frequency and constant phase difference

(a) Resultant wave amplitude, $a = \sqrt{(a_1^2 + a_2^2 + 2a_1a_2 \cos\phi)}$

(b) Resultant wave intensity, $I = I_1 + I_2 + 2\sqrt{(I_1I_2)} \cos\phi$

(c) If $a_1 = a_2 = a_0$, and $I_1 = I_2 = I_0$, then $a = 2a_0 \cos(\phi/2)$ and $I = 4I_0 \cos^2(\phi/2)$

24. Constructive interference

(a) conditions: $\phi = 2n\pi \equiv 0, 2\pi, 4\pi, 6\pi, \ldots$

or, $\Delta = n\lambda \equiv 0, \lambda, 2\lambda, 3\lambda, \ldots$

(b) $a_{max} = a_1 + a_2$

(c) $I_{max} \propto (a_1 + a_2)^2$

(d) $I_{max} = I_1 + I_2 + 2\sqrt{(I_1I_2)} = (\sqrt{I_1} + \sqrt{I_2})^2$

(e) $I_{max} = 4I_0$; If $I_1 = I_2 = I_0$

25. Destructive interference

(a) conditions: $\phi = (2n - 1)\pi \equiv \pi, 3\pi, 5\pi, \ldots$ or, $\Delta = (2n-1)\dfrac{\lambda}{2} = \dfrac{\lambda}{2}, \dfrac{3\lambda}{2}, \dfrac{5\lambda}{2}, \ldots$

(b) $a_{min} = a_1 - a_2$

(c) $I_{min} \propto (a_1 - a_2)^2$

(d) $I_{min} = I_1 + I_2 - 2\sqrt{(I_1I_2)} = (\sqrt{I_1} - \sqrt{I_2})^2$

(e) $I_{min} = 0$ if $I_1 - I_2 = I_0$

26. Young's double slit experiment

(a) Phase difference, $\phi = \dfrac{2\pi}{\lambda}(S_2P - S_1P) = \dfrac{2\pi}{\lambda}$ x path difference

(b) $A = 2a_0 \cos(\phi/2)$ and $I \; 4I_0 \cos^2(\phi/2)$

(c) Position of nth fringe on the screen:

(i) for bright fringe, $x_n = \dfrac{nD\lambda}{d}$

(ii) for dark fringe, $x_n = \dfrac{(2n-1)D\lambda}{2d}$

27. **Fringe width**:

(a) Linear fringe width, $\beta = \dfrac{D\lambda}{d}$

(b) Angular fringe width, $\alpha = \frac{\lambda}{d}$

(c) $\beta_{liquid} = \frac{\beta_{air}}{{}^{air}\eta_{liquid}}$ or $\lambda_{liquid} = \frac{\lambda_{air}}{{}^{air}\eta_{liquid}}$

(d) $\beta_{water} = \frac{3}{4}\beta_{air}$

28. **When a thin shit is introduced in the path of one of the interfering waves**:
(a) $(\eta - 1)\, t = n\lambda$
(b) Shift of the central fringe = $\frac{(\eta - 1)\, t\, \beta}{\lambda}$

29. **Fringe visibility**: $V = \frac{I_{max} - I_{min}}{I_{max} - I_{min}}$

30. **Frensel's biprism**:
(a) $d = 2a(\eta - 1)\,\alpha$; (b) $d = \sqrt{(d_1 d_2)}$
(c) $\beta = (D\lambda/d)$; (d) $d_{liquid} < d_{air}$, for example, $d_{water} = d_{air}/4$
(e) $\beta_{liquid} > \beta_{air}$; $\beta_{liquid} = \beta_{air}\left(\frac{\eta_g - 1}{\eta_g - \eta t}\right)$

31. **Newton's rings**:
(a) Diameter of nth dark fringe, $D_n = \sqrt{(4n\lambda R)}$
(b) $\lambda = \frac{D_{n+p}^2 - D_n^2}{4\, pR}$ and $\eta = \frac{D_{n+p}^2 - D_n^2}{D'^2_{n+p} - D'^2_n}$

32. **Thin films**: For reflected light

$2\eta t \cos r = n\lambda$ (Dark fringe)
$2\eta t \cos r = (n - \frac{1}{2})\lambda$ (Bright fringe)

33. **Diffraction**:
(a) $a \sin\theta = n\lambda$ (a = width of slit)
(b) Half angular width of central maxima, $\theta = \sin^{-1}(\lambda/a)$
(c) Intensity distribution of the screen $I = I_0\left(\frac{\sin\phi}{\phi}\right)^2$

where, $\phi = \frac{\pi a\, y}{\lambda D}$ and I_0 = Intensity at central point of screen
(d) Limit of resolution of telescope: $\theta = \frac{1.22\,\lambda}{a}$
(e) Resolving power of telescope = $\frac{1}{\theta} = \frac{a}{1.22\lambda}$

34. **Spherical mirrors**:
(a) Focal length: $f = (R/2)$
(b) Mirror formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$
(c) Newton's formula: $f^2 = xy$ (x and y are the distances of the object and image from the principal focus respectively)

(d) Linear magnification: $m = \frac{I}{o} = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$

(e) Longitudinal magnification: $m = -\frac{v^2}{u^2}$

35. **Spherical lenses**:

(c) A single spherical surface:

(i) $\frac{\eta_2}{v} - \frac{\eta_1}{u} = \frac{(\eta_2 - \eta_1)}{R}$ [For an object placed in a medium of refractive index η_1]

(ii) $\frac{\eta_1}{v} - \frac{\eta_2}{u} = \frac{(\eta_1 - \eta_2)}{R}$ [For an object placed in a medium of refractive index η_2]

(iii) First principal focus: $f_1 = \frac{R}{(\eta - 1)}$ where $\eta = \eta_2/\eta_1$

(iv) Second principal focus: $f_2 = \frac{\eta R}{(\eta - 1)}$

(v) Magnification: $m = \frac{v/\eta_2}{u/\eta_1}$

(d) Lens Maker's formula:

(i) $\frac{1}{f} = \left(\frac{\eta_2}{\eta_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ or, $\frac{\eta_1}{v} - \frac{\eta_1}{u} = (\eta_2 - \eta_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

[When medium is same on both sides of the lens]

(ii) $\frac{\eta_3}{v} - \frac{\eta_1}{u} = \left(\frac{\eta_2 - \eta_1}{R_1}\right) + \left(\frac{\eta_3 - \eta_2}{R_2}\right)$

[When different medium exist on two sides of the lens]

(e) Biconvex or biconcave lens of the same radii for two surfaces: $\frac{1}{f} = \frac{2(\eta - 1)}{R}$

(f) Linear magnification: $m = \frac{I}{O} = \frac{v}{u} = \frac{f-v}{f} = \frac{f}{f+u}$

(g) Power of lens: $P = \frac{1}{f}$

(h) Lenses in contact:

(i) $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$; (ii) $P = P_1 + P_2$

(iii) For lenses separated by a distance d = $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

(i) Achromatic lens combinations: Condition of achromatism, $\frac{\omega}{f_y} = -\frac{\omega'}{f'_y}$

36. **Silvering at one surface**:

(a) $\frac{1}{F} = \frac{1}{f_\ell} + \frac{1}{f_m} + \frac{1}{f_\ell} = \frac{2}{f_\ell} = \frac{2(\eta - 1)}{R}$

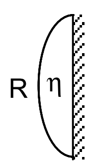


Fig. 1

(b) $\frac{1}{F}=\frac{2}{f_\ell}+\frac{1}{f_m}=2\left[\frac{(\eta-1)}{R}\right]+\frac{2}{R}=\frac{2n}{R}$

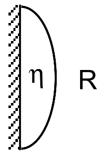


Fig. 2

(c) $\frac{1}{F}=\frac{2}{f_\ell}+\frac{1}{f_m}=2(\eta-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)+\frac{2}{R_2}$

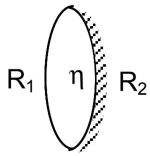


Fig. 3

37. Optical Instruments

(a) Astronomical Telescope:

(i) For normal adjustment: m = $\frac{f_0}{f_e}$

(ii) For near–point adjustment: m = $\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$

(b) Simple Microscope:

(i) For normal adjustment: m = $\frac{D}{f}$

(ii) For near–point adjustment = m = 1+$\frac{D}{f}$

(c) Compound Microscope:

(i) For normal adjustment: m = $\frac{v_0}{u_0}\left[\frac{D}{f_e}\right]$

(ii) For near–point adjustment: m = $\frac{v_0}{u_0}\left[1+\frac{D}{f_e}\right]$

I do not ask to walk smooth paths, nor bear an easy load.
I pray for strength and fortitude to climb rock-strewn road.
Give me such courage I can scale the hardest peaks alone,
And transform every stumbling block into a stepping-stone.

– Gail Brook Burkett

MODERN PHYSICS
CATHODE RAYS AND POSITIVE RAYS

1. Cathode rays

(a) Thomson identified cathode rays as an electron beam.

(b) Specific charge q/m as measured by Thomson is: $(q/m) = 1.759 \times 10^{11}$ Coulomb/Kg

2. Positive rays

(a) Positive rays were discovered by Goldstein.

(b) (q/m) for positive rays is much less than that of electrons.

3. Motion of charge particle through electric field (Field $\perp$ to initial velocity)

(a) The path is parabolic: $y = (qE/2mu^2)x^2$

(b) The time spent in the electric field: $t = (L/u)$

(c) The y–component of velocity acquired: $v_y = (qEL/mu)$

(d) The angle at which particle emerges out $\tan\theta = qEL/mu^2$

(e) The displacement in y-direction, when the particle emerges out of the field: $y_1=(qEL^2/2mu^2)$

(f) The displacement on the screen = $Y = (qELD/mu^2)$

4. Motion of charged particle through magnetic field (Field $\perp$ to initial velocity)

(a) The path is circular with radius: $r = (mu/qB)$

(b) Momentum of the particle: $p = qBr$

(c) The deflection on the screen: $X = (qBLD/mu)$

5. Mass spectrographs

(a) Thomson's mass spectrograph

- (i) Traces on the screen are parabolic in nature
- (ii) Inner parabola corresponding to heavy M white outer parabola to light M.
- (iii) The upper portion of parabola is due to small v ions, while lower portion is due to high v ions.
- (iv) Only $v = \infty$ ions can reach vertex of parabola.
- (v) Equation of parabola: $X^2 = (B^2LD/E)\,(q/M)\,Y = K\,(q/M)\,Y$

(b) Brain bridge mass spectrograph

- (i) Velocity selector: $v = (E/B)$
- (ii) Other relations: $r = (Mv/qB') = (ME/qBB')$ (whre B' is the magnetic field in dome);
  $d = 2r$; $(d_2 - d_1) \propto (M_2 – M_1)$; $M_1 : M_2 = d_1 : d_2$ [where d_1 and d_2 are the distances of traces 1 and 2 from the slit S_2 of velocity selector].

PHOTOELECTRIC EFFECT

6. **Threshold frequency**: $v_0 = \frac{\text{Work function}}{h} = \frac{W}{h}$

7. **Threshold wavelength**: $\lambda_0 = \frac{c}{v_0} = \frac{hc}{hv_0} = \frac{hc}{W}$

(To calculate λ_0, use hc = 1240 (eV) (nm) = 1.24 x 10^{-6} eV) (m)

8. Maximum kinetic energy of emitted photoelectrons

(a) $K_{max} = \frac{1}{2} mv^2_{max} = eV_0$

(b) $K_{max} = hv - W = h(v - v_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

9. **Slope of (V_0 v) graph** = $\frac{h}{e}$

10. Energy, momentum and mass of a photon

(a) Rest mass of photon = 0 (b) $E = hv = \frac{hc}{\lambda}$

(c) $p = \frac{E}{c} = \frac{h}{\lambda}$ (d) $m = \frac{E}{c^2} = \frac{h}{c\lambda}$

11. **Number of photons**:

(a) number of photons per sec per m^2, $n_p = \frac{\text{Intensity}\left(\text{Watt/m}^2\right)}{h\,v}$

(b) number of photons incident per second, $n_p = \frac{\text{Power}\left(\text{Watt}\right)}{hv}$

(c) number of electrons emitted per second = (efficiency of surface) x number of photons incident per second.

12. **Compton wavelength**:

(a) $\lambda_c = \frac{h}{m_0 C}$ =2.426 pm

(b) Change in wavelenth, $(\lambda' - \lambda) = \lambda_c (1 - \cos\phi)$

ATOMIC STRUCTURE

13. Rutherford's α–particle scattering

(a) $N(\theta) \propto \text{cosec}^4 (\theta/2)$

(b) Impact parameter, $b = \frac{(Ze^2)\cot(\theta/2)}{(4\pi\varepsilon_0)E}$, (where $E = \frac{1}{2}mu^2$ = KE of the α–particle)

14. **Distance of closest approach**: $r_0 = \frac{2Ze^2}{(4\pi\varepsilon_0)E}$ (where $E = \frac{1}{2}mu^2$ = KE of the α–particle)

15. Bohr's atomic model

(a) $L = mvr = \frac{nh}{2\pi}$

(b) $h\nu = E_i = E_f = \frac{hc}{\lambda}$

(c) Radius of nth orbit:

(i) $r_n \propto \frac{n^2}{Z}$, (ii) $r_n = \frac{n^2}{Z}\left(\frac{h^2}{4\pi^2 m ke^2}\right)$

(iii) Bohr's radius: $a_0 = (h^2/4\pi^2 mke^2) = 0.529$ Å

(iv) Ratio of radii: $r_1 : r_2 : r_3 = 1 : 4 : 9$; $r_N : {}^{r}He^{+} : {}^{r}Li^{++} = 1 : \frac{1}{2} : \frac{1}{3} = 6 : 3 : 1$

(d) Velcotiy of electron in nth orbit:

(i) $v_n = \frac{Z}{n}\left(\frac{c}{137}\right) = \frac{Z}{n}\alpha c$ (where $\alpha = \frac{2\pi Ke^2}{ch} = \frac{1}{137}$ = fine structures constant)

(ii) $v_1 : v_2 ; v_3 = 1 : \frac{1}{2} : \frac{1}{3} = 6 : 3 : 2$

(iii) v_1 = velocity of electron is 1st orbit of H–atom = (c/137)

(e) Total energy of electron:

(i) Potential energy, $U = -(kZe^2/r)$

(ii) $K = \frac{1}{2}mv^2 = (kZe^2/2r)$

(iii) $E = K + U = -(kZe^2/2r) = (U/2) = -K$

(iv) $K = -(U/2)$ or $U = 2K = 2E$

(v) $E_n = -\frac{13.6 Z^2}{n^2}$ eV $= -\frac{Z^2}{n^2}\left(\frac{2\pi^2 m k^2 e^4}{h^2}\right) = -\frac{2.18 \times 10^{-18} Z^2}{n^2}$ J

(f) Ionization energy $= -E_1 = +(13.6Z^2)$eV

(i) For H–atom, I.E. = 13.6 eV

(ii) For He^+ – ion, I.E = 54.4 eV

(iii) For Li^{++}–ion, I.E. = 122.4 eV

(g) Ionization potential:

(i) For H–atom, I.P. = 13.6 V

(ii) For He^+ ion, I.P. = 54.42

(h) Series formula (wave number $\bar{\nu} = 1/\lambda$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad \text{where } R = \frac{2\pi^2\, m\, k^2 e^4}{c\, h^3} = 1.097 \times 10^7\ m^{-1}$$

(i) Series formula for H–atom

(i) Lyman series: $\frac{1}{\lambda} = R\left(1 - \frac{1}{n^2}\right), n = 2, 3, 4, ...\infty$

(ii) Balmer series: $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right), n = 3, 4, 5....\infty$

(iii) Paschen series: $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right), n = 4, 5, 6....\infty$

(iv) Brackett series: $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$, n = 5, 6, 7....$\infty$

(v) P–fund series: $\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right), n = 6, 7, 8 ....\infty$

(j) Series limits (λ_{min})

(i) Lyman: λ_{min} = 912 Å

(ii) Balmer: λ_{min} = 3645 Å

(iii) Paschen: λ_{min} = 8201 Å

16. **Number of emission lines from excited state n** = n(n–1)/2

17. Time period of revolution

(a) $T_n \propto (n^3/Z^2)$; (b) $T_1 = 1.5 \times 10^{-16}$ sec ; (c) $T_1 : T_2 : T_3 = 1 : 8 : 27$

18. Frequency of revolution

(a) $v_n \propto (Z^2/n^3)$; (b) $v_1 = 6.6 \times 10^{15}$ Hz ; (c) $v_1 : v_2 : v_3 = 1 : \frac{1}{8} : \frac{1}{27}$

19. Current due to orbital motion

(a) $I_n \propto (Z^2/n^3)$; (b) I_1 = 1 mA

20. Magnetic field at nucleus due to orbital motion of electron

(a) $B_n \propto (Z^3/n^5)$; (b) B_1 = 12.5 Tesla

21. **Magnetic moment**:

(a) $M_n = (eL/2m) = (nhe/4\pi m)$;

(b) $M_1 = (eh/4\pi m) = \mu_B$ = Bohr Magneton = 9.27×10^{-24} Am^2

22. **Magnitude of angular momentum**: $L = \sqrt{[\ell(\ell+1)]}\,(h/2\pi)$

23. Angle of angular momentum vector from z–axis

(a) $\cos\theta = [m_\ell / \sqrt{\{\ell(\ell+1)\}}]$; (b) the least angle is for $m\ell = \ell$ i.e. $\cos\theta_{min} = [\ell/\sqrt{\{\ell(\ell+1)\}}]$

24. Magnitude of spin angular momentum

$S = \sqrt{[s(s+1)]}\,(h/2\pi) = \frac{\sqrt{3}}{2}(h/2\pi)$

X–RAYS

25. **Continuous X–rays**:

(a) $v_{max} = (eV/h)$; (b) $\lambda_{min} = (hc/eV) = (12400/V)$ Å

26. **Characterictic X–rays**:

(a) $\lambda_{K\alpha} < \lambda_{L\alpha} < \lambda_{M\alpha}$; (b) $v_{K\alpha} > v_{L\alpha} > v_{M\alpha}$

27. **Frequency of K_α line** : $v(K_\alpha) = \frac{3cR}{4}(Z-1)^2 = 2.47 \times 10^{15}(Z-1)^2$

28. **Wavelength of K_α line**: $\lambda(K_\alpha) = [4/3R(Z-1)^2] = [1216/(Z-1)^2]$Å

29. **Energy of K_α X–ray photon**: $E(K_\alpha) = 10.2\,(Z-1)^2$ eV

30. **Mosley's law**:

(a) $v = a\,(Z-b)^2$, where $a = (3cR/4) = 2.47 \times 10^5$ Hz

(b) For K_α line, $b = 1$; (c) $\sqrt{v} \propto Z$

31. **Bragg's law**: $2d \sin\theta = n\lambda$

32. **Absorption formula**: $I = I_0\, e^{-\mu x}$

33. **Half–value thickness**: $x_{1/2} = (0.693/\mu)$

MATTER WAVES

34. **For photons**:

(a) $E = hv = (hc/\lambda)$;

(b) $p = (hv/c) = (E/c) = (h/\lambda)$;

(c) $m = (E/c^2) = (hv/c^2) = h/c\lambda$

(d) rest mass = 0, charge = 0, spin = 1 $(h/2\pi)$

35. **Matter waves**:

(a) de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$ $\quad [\because E = \frac{1}{2}mv^2 = qV]$

(b) (i) For electron $\lambda_e = \frac{12.27}{\sqrt{V}}$ Å

(ii) For proton, $\lambda_p = \frac{0.286}{\sqrt{V}}$ Å

(iii) For alpha particle $\lambda_\alpha = \frac{0.101}{\sqrt{V}}$ Å

(c) For particle at temperature T : $\lambda = \frac{h}{\sqrt{3mKT}}$ $\quad \left(E = \frac{3}{2}kT\right)$

(i) For neutron or proton: $\lambda = (25.2/\sqrt{T})$ Å [if $E = (3/2)$ kT, average energy]

but $\lambda = \frac{30.8}{\sqrt{T}}$ Å [if E = kT, most probable energy]

(d) The wavelength of electron accelerated by potential difference of V volts is: $\lambda_e = \frac{12.27}{\sqrt{v}}$ Å

Hence, accelerating potential required for obtaining de Broglie wavelength for as electron is:

$$V = \frac{150.6}{\lambda_e^2}\text{ volt}$$

(e) Condition for obtaining stable orbit: $2\pi r_n = n\lambda$

(f) The phase velocity of a de Broglie wave of wavelength λ and frequency v is

$$v_p = v\lambda = \frac{E}{h} \times \frac{h}{mv} = \frac{mc^2}{h} \times \frac{h}{mv} = \frac{c^2}{v} \text{ i.e. } v_p > c.$$

(g) Group velocity, $v_g = (d\omega/dk)$. It is found that group velocity is equal to particle velocity i.e., $v_g = v$

RADIOACTIVITY

36. **Decay law**: (a) $(dN/dt) = -\lambda N$; (b) $N = N_0 e^{-\lambda t}$; (c) $(N/N_0) = (1/2)^{t/T}$

37. **Half life and decay constant**:
(a) $\lambda = -\frac{(dN/dt)}{N}$; (b) $\lambda T = \log_e 2$ or $T = (0.693/\lambda)$ or $\lambda = (0.693/T)$

38. **Mean life**:
(a) $\tau = (1/\lambda)$ or $\lambda = (1/\tau)$; (b) $T = 0.693\tau$ or $\tau = 1.443\, T$

39. **Activity**:
(a) $R = |dN/dt|$; (b) $R = \lambda N$; (c) $R = R_0 e^{-\lambda t}$; (d) $(R/R_0) = (1/2)^{t/T}$;
(e) 1 Becquerel = 1 dps ; (f) 1 curie = 1 ci = 3.7×10^{10} dps;
(g) 1 Rutherford = 1Rd = 10^6 Rd = 10^6 dps

40. **Decay of active mass**:
(a) $m = m_0 e^{-\lambda t}$; (b) $(m/m_0) = (1/2)^{t/T}$; (c) $N = \frac{6.023 \times 10^{23} \times m}{A}$

41. **Radioactive equilibrium**: $N_A \lambda_A = N_B \lambda_B$

42. **Decay constant for two channels**: (a) $\lambda = \lambda_1 + \lambda_2$; (b) $T = \frac{T_1 T_2}{T_1 + T_2}$

43. **Gamma intensity absorption**: (a) $I = I_0 e^{-\mu x}$; (b) Half value thickness, $x_{1/2} = (0.693/\mu)$

NUCLEAR PHYSICS

44. **Atomic mass unit**: (a) 1 amu = 1.66×10^{-27} kg ; (b) 1 amu $\equiv$ 1u $\equiv$ 931.5 MeV

45. Properties of nucleus
(a) Radius: $R = R_0 A^{1/3}$ where R_0 = 1.2 fermi
(b) Volume: $V \propto A$ $\left[\because V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A\right]$
(c) Density: $\rho = 2.4 \times 10^{17}$ Kg/m^3 (ρ is independent of A)

46. **Mass defect**: $\Delta M = Zm_p + (A-Z)\, m_n - M$

47. **Packing fraction**: $f = \Delta/A$ = mass excess per nucleon [$\Delta = -\Delta M$ = mass excess]
48. **Binding energy**: $\Delta E = BE = (\Delta M)c^2$

49. **Binding energy per ncuelon**:
(a) BEN = (BE/A);
(b) BEN for Helium = 7.1 MeV/nucleon
(c) BEN for Deuterium = 1.1 MeV/nucleon

ELECTRONICS

50. Richarson equation
(a) $J = AT^2 e^{-W/KT}$ where $A = 60 \times 10^4$ A/K^{2}m^2
(b) $J = AT^2 e^{11600\, W/T}$ [$\therefore$ K = Boltzmann's constant = 1.38×10^{-23} J/K = 8.62×10^{-5} eV/K
Hence, 1/K = 11600 kelvin/eV]
(c) $I = AT^2 S e^{-W/KT}$

51. **Child's law**: $I_p = KV_p^{3/2}$ [K = constant of proportionality]

52. Diode resistance

(a) Static plate resistance: (i) $R_p = (V_p/I_p)$; (ii) $R_p \propto V_p^{-1/2}$ (iii) $R_p \propto I_p^{-1/3}$

(b) Dynamic plate resistance: (i) $r_p = (\Delta V_p/\Delta I_p)$; (ii) $r_p \propto v_p^{-1/2}$; (iii) $r_p \propto I_p^{-1/3}$.

53. **Triode Constants**:

(a) $r_p = \left(\frac{\Delta V_p}{\Delta I_p}\right)_{V_g = \text{constant}}$; (b) $g_m = \left(\frac{\Delta I_p}{\Delta V_g}\right)_{V_p = \text{constant}}$;

(c) $\mu = \left(\frac{\Delta V_p}{\Delta V_g}\right)_{I_p = \text{consant}}$; (d) $\mu = r_p \times g_m$; (e) $r_p \propto I_p^{-1/3}$; (f) $g_m \propto I_p^{1/3}$

54. **Plate current equation**: $I_p = K\left(V_g + \frac{V_p}{\mu}\right)^{3/2}$

55. **Cut off voltage**: $V_g = -(V_p/\mu)$

56. **Triode as an amplifier**:

(a) $I_p = (\mu V_g/R_L + r_p)$; (b) $A = (\mu R_L/R_L + r_p)$

(c) $A_{max} = \mu$; (d) $\mu = A\left(1 + \frac{r_p}{R_L}\right)$; (e) $A = \mu/2$ if $R_L = r_p$

57. Conductivity of semi conductors

(a) Intrinsic: (i) $\sigma = e(n_e\mu_e + n_h\mu_h)$; (ii) $\sigma = \sigma_0 e^{-E_g/2KT}$

(b) Extrinsic: (i) n–type : $\sigma = en_e\mu_e$; (ii) p–type : $\sigma = en_h\mu_h$

58. **Transistor**:

(a) $I_E = I_C + I_B$ ($I_B << I_E$, $I_B << I_C$)

(b) Current gains: (i) $\alpha = \frac{I_C}{I_E}$, $\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}$

(ii) $\beta = \frac{I_C}{I_B}$, $\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}$

(c) Relation between α and β: $\alpha = \frac{\beta}{1+\beta}$ or $\beta = \frac{\alpha}{1-\alpha}$

STUDY TIPS

- **Combination of Subjects**

  Study a combination of subjects during a day i. e. after studying 2–3 hrs of mathematics shift to any theoretical subject for 2 horrs. When we study a subject like math, a particular part of the brain is working more than rest of the brain. When we shift to a theoretical subject, practically the other part of the brain would become active and the part studying maths will go for rest.

- **Revision**

  Always refresh your memory by revising the matter learned. At the end of the day you must revise whatever you've learnt during that day (or revise the previous days work before starting studies the next day). On an average brain is able to retain the newly learned information 80% only for 12 hours, after that the forgetting cycle begins. After this revision, now the brain is able to hold the matter for 7 days. So next revision should be after 7 days (sundays could be kept for just revision). This ways you will get rid of the problem of forgetting what you study and save a lot of time in restudying that topic.

- **Use All Your Senses**

  Whatever you read, try to convert that into picture and visualize it. *Our eye memory is many times stronger than our ear memory* since the nerves connecting brain to eye are many times stronger than nerves connecting brain to ear. So instead of trying to mug up by repeating it loudly try to see it while reapeating (loudly or in your mind). This is applicable in theoritical subjects. Try to use all your senses while learning a subject matter. On an average we remember 25% of what we read, 35% of what we hear, 50% of what we say, 75% of what we see, 95% of what we read, hear, say and see.

- **Breathing and Relaxation**

  Take special care of your breathing. Deep breaths are very important for relaxing your mind and hence in your concentration. Pranayam can do wonders to your concentration, relaxation and sharpening your mined (by supplying oxygen to it). Aerobic exercises like skipping, jogging, swimming and cycling are also very helpful.

The most powerful weapon on earth is

human soul on fire!

Never say Quit!

When things go wrong, as they sometimes will,
When the road you are trudging seems all uphill.

When the funds are low and debts are high,
And you want to smile, but you have to sigh.

When care is pressing, you're down a bit.
Rest if you must, but never quit.

Life is queer, with its twists and turns,
As every one of us, sometimes learns.

And many a fellow turns about,
When he might have won, if he had stuck it out.

Stick to your task, though the pace seems slow,
You may succeed with just another blow.

Often the goal is nearer than,
It seems to a faint and faltering man.

Often the struggler has given up.
When he might have captured the victor's cup.

And he learned too late, when the night slipped down,
How close he was to the golden crown.

Success is failure turned inside out,
The silver tints of the clouds of doubt.

And you never can tell how close you are,
It may be near when it seems afar.

So stick to the fight when you are hardest hit,
It's when things seem worst, that you must never quit!

Edwin Markham

Put Forth Your Best…
And You've Already Won!

The contest last for just moments,
though the training's taken years.
It was'nt the winning alone
that was worth the work and tears.

The applause will be forgotten,
the prize will be misplaced.
But the long hours of practise
will never be a waste.

For in trying to win, you build a skill.
You learn that winning depends on will.

You never grow by how much you win,
you only grow by how much you put in.

So any new challenge you've just begun,
Put forth your best and you've already won!

You can…
if you think
you can!

If you think you are beaten, you are;
If you think that you dare not, you don't;
If you'd like to win, but think you can't,
It's almost certain you won't.
If you think you'll lose, you've lost,
For out in the world you find,
Success begins with a fellow's will,
It's all in the state of mind.

Often many a race is lost,
Before even a step is run,
And many a coward fails,
Before even his work's begun.
Think big, and your deeds will grow
Think small, and you'll fall behind.
Think that you can, and you will,
It's all in the state of mind.

If you think you're outclassed, you are;
You've got to think high to rise;
You've got to be sure of yourself,
Befoe you can ever win a prize.
Life's battles don't always go,
To the stronger or faster man,
BUT SOONER OR LATER THE MAN WHO WINS,
IS THE ONE WHO THINKS HE CAN.

–**Edwin Markham**