Formulae of the Chapter

1. Displacement current, $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$

Also $I_d = \varepsilon_0 \frac{d}{dt}(EA) = \varepsilon_0 A \frac{dE}{dt}$

$= \varepsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right) = \frac{\varepsilon_0 A}{d}\frac{dV}{dt} = C\frac{dV}{dt}$

2. Modified Ampere's circuital law,

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 (I_c + I_d)$$

3. Wave velocity, $c = \nu\lambda$

4. Energy of photon, $E = h\nu = \frac{hc}{\lambda}$

5. Speed of e.m. wave in vacuum, $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

6. Speed of e.m. wave in a material medium,

$$c = \frac{1}{\sqrt{\mu\varepsilon}}$$

7. For a wave of frequency ν, wavelength λ, propagating along x-direction, the equations for electric and magnetic fields are

$$E_y = E_0 \sin(kx - \omega t) = E_0 \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$

$$B_z = B_0 \sin(kx - \omega t) = B_0 \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$

8. Amplitude ratio of electric and magnetic fields,

$$\frac{E_0}{B_0} = c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

9. Propagation constant, $k = \frac{2\pi}{\lambda} = \frac{\omega}{c}$

10. Average energy density of E-field,

$$u_E = \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{2}\varepsilon_0 E_{rms}^2$$

11. Average energy density of B-field,

$$u_B = \frac{1}{4\mu_0} B_0^2 = \frac{1}{2\mu_0} B_{rms}^2$$

12. Average energy density of e.m. wave,

$$u_{av} = \frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2\mu_0} B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \frac{B_{rms}^2}{\mu_0}$$

Or

$$u_{av} = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4\mu_0} B_0^2 = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2\mu_0} B_0^2$$

13. Momentum delivered by an e.m. wave

$$p = \frac{U}{c}$$

14. Intensity of a wave

$$= \frac{\text{Energy / time}}{\text{Area}} = \frac{\text{Power}}{\text{Area}}$$

or $\quad I = u_{av}\, c = \varepsilon_0 E_{rms}^2\, c$

Formulae of the Chapter

1. For any spherical mirror, $f = R/2$

2. Mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} = \frac{2}{R}$

3. Magnification produced by a spherical mirror, $m = \frac{h_2}{h_1} = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$

4. Refractive index $= \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$

   or $\mu = \frac{c}{v}$

5. $\mu = \frac{\text{Wavelength in vacuum}}{\text{Wavelength in medium}} = \frac{\lambda}{\lambda'}$

6. Snell's law, ${}^1\mu_2 = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$

   or $\mu_1 \sin i = \mu_2 \sin r$

7. Principle of reversibility, ${}^1\mu_2 = \frac{1}{{}^2\mu_1}$

8. ${}^1\mu_2 \times {}^2\mu_3 \times {}^3\mu_1 = 1$ or ${}^2\mu_3 = \frac{{}^1\mu_3}{{}^1\mu_2}$

9. Lateral shift of a ray through a rectangular slab,

$$x = \frac{t}{\cos r} \sin(i - r)$$

$$= t \sin i \left[1 - \frac{\cos i}{(\mu^2 - \sin^2 i)^{1/2}} \right]$$

10. $\mu = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{t}{\text{Apparent depth}}$

    Apparent depth $= \frac{t}{\mu}$

11. Apparent shift $= t\left(1 - \frac{1}{\mu}\right)$

12. Total apparent shift for compound media

$$= t_1\left(1 - \frac{1}{\mu_1}\right) + t_2\left(1 - \frac{1}{\mu_2}\right) + ...$$

13. Relation between μ and i_c, $\mu = \frac{1}{\sin i_c}$

14. For refraction through a spherical surface, from rarer to denser medium,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

15. For refraction through a spherical surface, from denser to rarer medium,

$$\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$$

16. Power of a surface,

$$P = \frac{\mu_2 - \mu_1}{R} = \frac{\mu - 1}{R} \quad \text{(For air)}$$

17. Focal length of any lens is given by the thin lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.

18. Magnification produced by a lens,

$$m = \frac{h_2}{h_1} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$$

19. Power of a lens, $P = \frac{1}{f\,(\text{m})} = \frac{100}{f\,(\text{cm})}$

20. $P = \frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

21. For a combination of lenses,

$$m = m_1 \times m_2 \times m_3 \times ...$$

22. For two lenses in contact, equivalent focal length F is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{or Power,} \quad P = P_1 + P_2$$

For n lenses in contact,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + ... + \frac{1}{f_n}$$

Power $P = P_1 + P_2 + ... + P_n$.

23. The equivalent focal length f of two lenses separated by distance d is given by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

or Power, $P = P_1 + P_2 - d \,.\, P_1 \,.\, P_2$

24. For refraction through a prism,

$$A + \delta = i + e \quad \text{and} \quad r + r' = A$$

25. In the condition of minimum deviation,

$$i = e, \; r = r', \; \delta = \delta_m; \quad \mu = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}$$

26. Deviation produced by a prism of small angle,

$$\delta = (\mu - 1) A$$

27. Angular dispersion

$$= \delta_V - \delta_R = (\mu_V - \mu_R) A$$

28. Dispersive power, $\omega = \dfrac{\delta_V - \delta_R}{\delta} = \dfrac{\mu_V - \mu_R}{\mu - 1}$

29. Mean deviation, $\delta = \dfrac{\delta_V + \delta_R}{2}$

30. Mean refractive index, $\mu = \dfrac{\mu_V + \mu_R}{2}$

31. *Simple Microscope.*

(i) When the final image is formed at the least distance of distinct vision, the magnifying power is $m = 1 + D/f$

(ii) When the final image is formed at infinity, the magnifying power is

$$m = \frac{D}{f}.$$

32. *Compound microwave.*

(i) Magnifying power, $m = m_o \times m_e$

(ii) When the final image is formed at the least distance of distinct vision,

$$m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right) = -\frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

(iii) When the final image is formed at infinity,

$$m = \frac{v_0}{u_0} \cdot \frac{D}{f_e} = -\frac{L}{f_0} \cdot \frac{D}{f_e}$$

33. *Astronomical telescope.* (i) In normal adjustment,

$$m = \frac{f_0}{f_e}$$

Distance between objective and eyepiece

$$= f_0 + f_e$$

(ii) When the final image is formed at the least distance of distinct vision,

$$m = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Distance between objective and eyepiece

$$= f_0 + u_e = f_0 + \frac{f_e D}{f_e + D}$$

34. *Reflecting telescope.* $m = \dfrac{f_0}{f_e} = \dfrac{R/2}{f_e}$

where f_0 = focal length of concave mirror,

f_e = focal length of eyepiece.

Chapter - 10

Formulae of the Chapter

For reflection and refraction of light waves :

1. Snell's law, $^1\mu_2 = \frac{\sin i}{\sin r}$

2. $\mu = \frac{c}{v} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$

3. Speed of light in vacuum, $c = \nu\lambda$

4. $\mu = \frac{\lambda}{\lambda'} = \frac{\text{Wavelength in vacuum}}{\text{Wavelength in medium}}$

5. Wavelength in medium, $\lambda' = \frac{\lambda}{\mu}$

6. Optical path (in vacuum)
$= \mu \times$ Path in medium

7. Frequency of light remains unchanged during its reflection or refraction.

For interference at Young's double slit :

8. Resultant amplitude,
$$a = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi}$$

9. Resultant intensity,
$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

10. When $I_1 = I_2 = I_0$,
$$I = 2I_0(1+\cos\phi) = 4I_0\cos^2\frac{\phi}{2}.$$

11. For a bright fringe, path difference, $p = n\lambda$

12. For a dark fringe,
$$p = (2n-1)\frac{\lambda}{2}, \quad n = 1, 2, 3, \ldots.$$

13. Distance of nth bright fringe from the centre of the screen,
$$x_n = n\frac{D\lambda}{d}, \quad n = 1, 2, 3, \ldots.$$

14. Distance of nth dark fringe from the centre of the screen,
$$x'_n = (2n-1)\frac{D\lambda}{2d}$$

15. Fringe width, $\beta = \frac{D\lambda}{d}$

16. Wavelength of light used, $\lambda = \frac{\beta d}{D}$

17. Ratio of slit widths, $\frac{\omega_1}{\omega_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$

18. Intensity at maxima, $I_{max} \propto (a_1 + a_2)^2$

19. Intensity at minima, $I_{min} \propto (a_1 - a_2)^2$

20. Intensity ratio at maxima and minima,
$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \left(\frac{r+1}{r-1}\right)^2$$
where $r = \frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}}$ = amplitude ratio of two waves.

For diffraction at a single slit :

21. Condition for nth minimum is
$$d\sin\theta = n\lambda \quad \text{where} \quad n = 1, 2, 3, \ldots$$

22. Condition of nth secondary maximum is
$$d\sin\theta = (2n+1)\frac{\lambda}{2}, \text{ where } n = 1, 2, 3, \ldots$$

23. Angular position or direction of nth minimum,
$$\theta_n = \frac{n\lambda}{d}$$

24. Distance of n th minimum from the centre of the screen,
$$x_n = \frac{nD\lambda}{d}$$

25. Angular position of nth secondary maximum,
$$\theta'_n = (2n+1)\frac{\lambda}{2d}$$

26. Distance of nth secondary maximum from the centre of the screen,
$$x'_n = (2n+1)\frac{D\lambda}{2d}$$

27. Width of central maximum, $\beta_0 = 2\beta = \frac{2D\lambda}{d}$

28. Angular spread of central maximum on either side, $\theta = \pm\frac{\lambda}{d}$

29. Total angular spread of central maximum,
$$2\theta = \frac{2\lambda}{d}$$

30. Fresnel distance, $D_F = \frac{d^2}{\lambda}$

31. Size of Fresnel zone, $d_F = \sqrt{\lambda D}$.

For resolving power of microscope and telescope :

32. Limit of resolution of a telescope,
$$d\theta = \frac{1.22\lambda}{D}$$

33. Resolving power of a telescope

$$= \frac{1}{d\theta} = \frac{D}{1.22\,\lambda}$$

where $D =$ diameter of the objective lens.

34. Limit of resolution of a microscope,

$$d = \frac{\lambda}{2\mu \sin \theta}$$

35. Resolving power of a microscope

$$= \frac{1}{d} = \frac{2\mu \sin \theta}{\lambda}$$

where $\theta =$ half angle of cone of light from the point object.

For polarisation of light waves :

36. Law of Malus, $I = I_0 \cos^2 \theta$

37. Brewster law,

$$\mu = \tan i_p$$

38. $i_p + r_p = 90°$

For Doppler effect of light* :

39. $\frac{\Delta \nu}{\nu} = \frac{\nu' - \nu}{\nu} = \pm \frac{v}{c}$

40. $\frac{\Delta \lambda}{\lambda} = \frac{\lambda' - \lambda}{\lambda} = \mp \frac{v}{c}$

Formulae of the Chapter

1. Energy of a photon, $E = h\nu = \dfrac{hc}{\lambda}$.
2. Number of photons emitted per second,
$$N = \frac{P}{E}$$
3. Momentum of photon, $p = mc = \dfrac{h\nu}{c} = \dfrac{h}{\lambda}$
4. Equivalent mass of a photon, $m = \dfrac{h\nu}{c^2}$
5. Work function, $W_0 = h\nu_0 = \dfrac{hc}{\lambda_0}$
6. Kinetic energy of photoelectrons is given by Einstein's photoelectric equation,
$$K_{max} = \frac{1}{2} mv_{max}^2 = h\nu - W_0$$
$$= h(\nu - \nu_0) = h\left[\frac{c}{\lambda} - \frac{c}{\lambda_0}\right]$$
7. If V_0 is the stopping potential, the maximum kinetic energy of the ejected photo electrons,
$$K = \frac{1}{2} mv_{max}^2 = eV_0$$
8. Intensity of radiation
$$= \frac{\text{Energy}}{\text{Area} \times \text{time}} = \frac{\text{Power}}{\text{Area}}$$
Incident power = Incident intensity × area
9. Kinetic energy,
$$K = \frac{1}{2} mv^2 = \frac{p^2}{2m}$$
$\therefore$ Momentum, $p = \sqrt{2mK}$
10. de-Brogile wavelength,
$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$$
11. de-Brogile wavelength of an electron beam accelerated through a potential difference of V volts is
$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{1.23}{\sqrt{V}} \text{ nm}$$
12. Bragg's equation for crystal diffraction is $2d \sin\theta = n\lambda$, n is order of the spectrum.

Formulae of the Chapter

CHAPTER - 12 ATOMS

1. K.E. of α-particle, $K = \frac{1}{2} mv^2 = \frac{1}{4\pi \varepsilon_0} \cdot \frac{2 Ze^2}{r_0}$

2. Distance of closest approach,

$$r_0 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2 Ze^2}{K} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4 Ze^2}{mv^2}$$

3. Impact parameter,

$$b = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2 \cot\frac{\theta}{2}}{K} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2 \cot\frac{\theta}{2}}{\frac{1}{2} mv^2}$$

4. $\frac{kZe^2}{r^2} = \frac{mv^2}{r}$

5. $L = mvr = \frac{nh}{2\pi}$

6. $h\nu = E_{n_2} - E_{n_1}$

7. $r_n = \frac{n^2 h^2}{4\pi^2 mk Ze^2}$

8. $v_n = \frac{2\pi ke^2}{nh} = \alpha \cdot \frac{c}{n}$,

where $\alpha = \frac{2\pi k e^2}{ch}$, is fine structure constant

9. K.E. $= \frac{k Ze^2}{2r}$

10. P.E. $= \frac{-kZe^2}{r}$

11. Total energy,

$$E_n = -\frac{2\pi^2 mk^2 Z^2 e^4}{n^2 h^2} = -\frac{Rhc}{n^2} = \frac{-13.6}{n^2} \text{ eV}$$

12. $E_n = -$K.E. or K.E. $= -E_n$;

P.E. $= -2$ K.E. $= 2E_n$

13. Frequency, $\nu = \frac{2\pi^2 mk^2 e^4}{h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

14. Wave number, $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

where $R = \frac{2\pi^2 mk^2 e^4}{ch^3}$, is Rydberg's constant

15. Ionisation potential $= -\frac{13.6 Z^2}{n^2}$ volt

16. $T_n = \frac{2\pi r_n}{v_n} = \frac{n^3 h^3}{4\pi^2 mk^2 Ze^4} = T_1 n^3$

CHAPTER-13 · NUCLEI

Formulae of the Chapter

1. Einstein's mass-energy equivalence, $E = mc^2$
2. 1 amu $= 1.66 \times 10^{-27}$ kg $= 931$ MeV
3. Nuclear radius, $R = R_0 A^{1/3}$,
   where $R_0 = 1.2 \times 10^{-15}$ m
4. $\rho_{nu} = \dfrac{\text{Nuclear mass}}{\text{Nuclear volume}} = \dfrac{m_{nu}}{\frac{4}{3}\pi R^3}$
5. Average atomic mass of an element
   = Weighted average of the masses of all isotopes.
6. Mass defect, $\Delta m = [Z\, m_p + (A - Z)\, m_n - m_N]$
7. B.E. $= (\Delta m)\, c^2$
8. B.E./nucleon $= \dfrac{\text{B.E.}}{A}$
9. Displacement laws for radioactive transformations are as follows :

   (i) α-decay :
   $${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

   (ii) β-decay :
   $${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \bar{\nu}$$

   (iii) γ-decay :
   $${}^{A}_{Z}X \longrightarrow {}^{A}_{Z}X + \gamma$$
   (Excited state) (Ground state)

10. Radioactive decay law :

    (i) $-\dfrac{dN}{dt} = \lambda N$ (ii) $N = N_0 e^{-\lambda t}$

    where λ = decay constant
11. Half life : $T_{1/2} = \dfrac{\log_e 2}{\lambda} = \dfrac{0.69}{\lambda}$
12. $N = N_0 \left(\dfrac{1}{2}\right)^n$, where $n = \dfrac{t}{T_{1/2}}$
13. Mean life,
    $$\tau = \frac{1}{\lambda} = \frac{T_{1/2}}{0.693} = 1.44\, T_{1/2}$$
    or $T_{1/2} = 0.693\, \tau$
14. Decay rate or activity of a substance :
    $$R = \left|\frac{dN}{dt}\right| = \lambda N = \lambda N_0 e^{-\lambda t}$$
15. Time required to reduce the radioacti substance,
    $$t = \frac{2.303}{\lambda} \log \frac{No}{N}$$
16. Decay constant,
    $$\lambda = \frac{2.303}{t} \log \frac{No}{N}$$

SEMICONDUCTOR DEVICES

Formulae of the Chapter

CHAPTER-14

1. In an intrinsic semiconductor, $n_e = n_h = n_i$
2. At equilibrium in any semiconductor,
$$n_e n_h = n_i^2$$
3. Minimum energy required to create a hole-electron pair,
$$E_g = h\nu_{min} = \frac{hc}{\lambda_{max}}$$
4. Mobility of a charge carrier, $\mu = \frac{v}{E}$
5. Electric current, $I = eA(n_e v_e + n_h v_h)$
6. Electrical conductivity,
$$\sigma = \frac{1}{\rho} = e(n_e \mu_e + n_h \mu_h)$$
7. Variation of conductivity with temperature,
$$\sigma = \sigma_0 \exp\left(-\frac{E_g}{2 k_B T}\right)$$
8. For any transistor, $I_E = I_C + I_B$
9. For a common base transistor amplifier,

(i) $\alpha_{dc} = \frac{I_C}{I_E}$ and $\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}$

(ii) $A_v = \alpha_{ac} \cdot \frac{R_o}{R_i} = A_i \cdot A_r$

(iii) $A_p = A_v \cdot A_i = \alpha_{ac}^2 \cdot \frac{R_o}{R_A}$

10. For a common emitter transistor amplifier,

(i) $\beta_{dc} = \frac{I_C}{I_B}$ and $\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}$

(ii) $A_v = A_i \cdot A_r = \beta_{ac} \cdot \frac{R_o}{R_i}$

(iii) $A_p = A_v \cdot A_i = \beta_{ac}^2 \cdot \frac{R_o}{R_i}$

(iv) $g_m = \frac{\Delta I_C}{\Delta V_{BE}}$

11. Relations between α and β are
$$\alpha = \frac{\beta}{1+\beta} \quad \text{and} \quad \beta = \frac{\alpha}{1-\alpha}$$
12. **OR gate.** It gives high output when either of the inputs is high, otherwise it gives low output. $Y = A + B$
13. **AND gate.** It gives high output when both the inputs are high, otherwise the input is low. $Y = A . B$
14. **NOT gate.** It gives high output when the input is low, and vice versa. $Y = \overline{A}$
15. **NAND gate.** It gives low output when both the inputs are high, otherwise the output is high. $Y = \overline{A . B}$
16. **NOR gate.** It gives high output when both the inputs are low, otherwise the output is low. $Y = A + B$