Dual Nature of Radiation and Matter Class 12 Formula Sheet

CBSE Class 12 Physics · NCERT · for boards, NEET and JEE revision

ChapterNotes

Big Idea: Dual Nature

Radiation ⇄ photons · Matter ⇄ waves

Wave nature shows in diffraction; particle nature in the photoelectric effect.

- Light = photons (particle) in the photoelectric effect
- Particles (electrons) act as waves (de Broglie)
- This 'duality' ties the whole chapter together

Work Function (ϕ_0)

$$1\ \text{eV} = 1.6 \times 10^{-19}\ \text{J}$$

ϕ_0 is a property of the metal only - not of the light shone on it.

- Caesium has a low $\phi_0 \approx 2.14$ eV, so it emits easily
- Four emission types: thermionic, field, photoelectric, secondary
- Don't confuse ϕ_0 with ionisation energy of an atom

Photons: Light in Packets

$$E = h\nu = hc/\lambda\ ;\ E(\text{eV}) = 1240/\lambda(\text{nm})$$

$h = 6.63 \times 10^{-34}$ J·s, $c = 3 \times 10^{8}$ m/s. Use λ in nm for the 1240 shortcut.

- Photon energy depends only on frequency, not intensity
- Brighter light of same colour = more photons, not bigger ones
- Photons are massless yet carry momentum $p = h/\lambda = E/c$

Photoelectric Effect

$$\nu \geq \nu_0 \text{ needed} \cdot \text{current} \propto \text{intensity}$$

Below threshold frequency ν_0, NO emission - however intense the light.

- Photocurrent (number of electrons) ∝ intensity
- Max KE depends on frequency, never on brightness
- Emission is instantaneous (~10^{-9} s), no time lag

Stopping Potential (V_0)

$$eV_0 = KE_{max}$$

V_0 vs ν graph is a straight line with universal slope h/e.

- Raising intensity lifts saturation current, not V_0
- Raising frequency raises V_0, not saturation current
- Slope h/e is the same for every metal; only intercept differs

Einstein's Photoelectric Equation

$$h\nu = \varphi_0 + KE_{max} \rightarrow KE_{max} = h(\nu - \nu_0)$$

Most-tested idea of the chapter; won Einstein the 1921 Nobel Prize.

- Threshold: $\phi_0 = h\nu_0 = hc/\lambda_0$
- With stopping potential: $eV_0 = h\nu - \phi_0$
- KE_{max} rises linearly with ν, slope exactly h

de Broglie Wavelength

$$\lambda = h/p = h/(m\nu) = h/\sqrt{(2mK)}$$

λ is inversely proportional to momentum - heavy/fast objects have tiny λ.

- Accelerated charge: $\lambda = h/\sqrt{(2mqV)}$
- Equal K → lighter particle has larger λ (note the √)
- Everyday objects have undetectably small λ

Electron λ & Davisson–Germer

$$\lambda = 1.227/\sqrt{V}\ \text{nm (V in volts)}$$

At 100 V, λ = 0.123 nm ≈ 1.23 Å - close to crystal atomic spacing.

- Shortcut is for electrons only, not protons or alphas
- Davisson–Germer: electron diffraction off a nickel crystal
- This confirmed matter waves and completes the dual nature

Quick revision

- Photoelectric effect: light → ejects electrons from metal; needs $\nu \geq \nu_0$
- Einstein: $KE_{max} = h\nu - \phi$; $V_0 = (h\nu - \phi)/e$
- Intensity ↑ → more electrons (photocurrent ↑), NOT more KE
- Frequency ↑ → more KE of electrons
- de Broglie: $\lambda = h/mv = h/p$; electron: $\lambda = 1.227/\sqrt{V}$ nm
- Davisson-Germer: confirmed electron waves by diffraction

Full chapter notes with solved examples and practice questions: https://chapternotes.in/cbse/class-12-physics/dual-nature-of-radiation-and-matter-class-12-notes/