



Dual Nature of Radiation and Matter

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NEET: 1-2 Qs (~4-8 marks)

Boards: 4-6 marks



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Light is also a particle (photon) and matter is also a wave: the photoelectric effect proves the photon, de Broglie waves prove matter waves – both confirmed by experiment.

1. Photoelectric Effect & Its Laws

Light above a threshold frequency ejects electrons instantly – a result classical wave theory could not explain.

$$\phi_0 = h\nu_0 = \frac{hc}{\lambda_0}$$

work function & threshold

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

energy unit

MUST KNOW Below threshold frequency ν_0 NO emission occurs, however intense the light.

MUST KNOW Above ν_0 , photocurrent (number of electrons) $\propto$ intensity; emission is instantaneous ($\sim 10^{-9}$ s, no time lag).

- Work function ϕ_0 is a property of the metal/surface, never of the light.

2. Einstein's Equation & Stopping Potential

One photon gives all its energy to one electron: part pays the escape fee ϕ_0 , the rest is kinetic energy.

$$h\nu = \phi_0 + K_{\text{max}}$$

energy conservation

$$K_{\text{max}} = h\nu - \phi_0 = h(\nu - \nu_0)$$

max KE of electron

$$eV_0 = h\nu - \phi_0 \text{ (stopping potential)}$$

V_0 stops fastest electron

$$E \text{ (eV)} = 1240 / \lambda \text{ (nm)}$$

photon-energy shortcut

MUST KNOW V_0 vs ν is a straight line of slope h/e – the SAME for every metal; only the intercept changes.

MUST KNOW K_{max} vs ν is a straight line of slope h (Planck's constant), x-intercept ν_0 .

- Won Einstein the 1921 Nobel Prize – the most tested idea of the chapter.

3. Effect of Intensity vs Frequency

Intensity controls how MANY electrons; frequency controls how FAST (energetic) they are.

$$\text{Intensity} = (\text{photons/s}) \times h\nu$$

brightness = more photons

$$\text{Saturation current} \propto \text{intensity}$$

at fixed frequency

MUST KNOW Increasing intensity raises saturation current but NOT V_0 or K_{max} .

MUST KNOW Increasing frequency raises V_0 and K_{max} but NOT the saturation current.

- A brighter beam of the same colour has more photons, not more energetic ones.

4. Particle Nature of Light: The Photon

Radiation travels as discrete quanta (photons), each carrying fixed energy and momentum.

$$E = h\nu = \frac{hc}{\lambda}$$

$h = 6.63 \times 10^{-34} \text{ J-s}$

$$p = \frac{h}{\lambda} = \frac{E}{c}$$

momentum (rest mass = 0)

$$N = P / (h\nu)$$

photons per second from power P

MUST KNOW Photon energy depends only on frequency, not on intensity.

- Photons are massless (zero rest mass) yet carry momentum $p = h/\lambda$ and travel at c .

5. de Broglie Matter Waves & Davisson-Germer

Every moving particle has a wave nature with wavelength set by its momentum – confirmed by electron diffraction.

$$\text{de Broglie } \lambda = \frac{h}{p} = \frac{h}{mv}$$

matter wave

$$\lambda = \frac{h}{\sqrt{2mK}}$$

in terms of kinetic energy K

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

charge q accelerated by V

$$\lambda = 12.27 / \sqrt{V} \text{ \AA for electrons}$$

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

MUST KNOW λ is inversely proportional to momentum; for equal K, the LIGHTER particle has the LARGER λ .

- Everyday objects have λ far too small to detect; only light particles (electrons) show wave effects.

MUST KNOW Davisson-Germer (electron diffraction by a nickel crystal) confirmed matter waves.

Intensity vs Frequency: What Changes

Quantity	↑ Intensity (ν fixed)	↑ Frequency (I fixed)
Saturation current	Increases	Unchanged
Stopping potential V_0	Unchanged	Increases
Max KE / speed	Unchanged	Increases
Threshold ν_0, ϕ_0	Unchanged	Unchanged

Graph Slopes to Memorise

Graph	Slope	X-intercept
K_{max} vs ν	h	ν_0
V_0 vs ν	h/e (universal)	ν_0

Mnemonic - Intensity sets the NUMBER of photoelectrons (current); frequency sets their ENERGY (K_{max} , V_0).

Intensity = how MANY, Frequency = how FAST

Common traps

- Very intense light below threshold gives ZERO current - piling on weak photons never helps.
- Photon energy depends only on frequency; doubling intensity only doubles the NUMBER of photons, not their energy.
- Slope of V_0 vs ν is h/e and is the SAME for all metals; only the intercept (work function) differs.
- In $\lambda = h/\sqrt{2mK}$, don't drop the square root: if K becomes $4K$, λ becomes HALF, not one-fourth.
- The $\lambda = 12.27/\sqrt{V}$ Å shortcut is for ELECTRONS only - not protons or alpha particles.

Most asked in NEET »

Below-threshold $\rightarrow$ zero current

$K_{\text{max}} = h\nu - \phi_0$ & stopping potential

Threshold/cut-off wavelength $\lambda_0 = hc/\phi_0$

V_0 vs ν slope = h/e

Photons per second $N = P\lambda/hc$

de Broglie $\lambda = 12.27/\sqrt{V}$ Å

Davisson-Germer confirms matter waves

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