🌟 DUAL NATURE OF RADIATION & MATTER – CLASS 12 STUDY GUIDE

(Fun, colorful, exam-smart, and easy to memorize!)

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1. THEORY IN SIMPLE WORDS – WITH VISUALS & ANALOGIES

1.1 What is Dual Nature?

- Light & matter show **both wave and particle behavior**.
- **Analogy:**
  - Imagine a superhero who can fly like a wave but also punch like a particle → dual nature!
- This chapter studies **wave nature of particles** and **particle nature of light**.

1.2 Photoelectric Effect (Light as Particle)

- Light = stream of **photons** (energy packets)
- When light falls on a metal, electrons are ejected → **photoelectrons**

Key Observations:

1. No electrons below threshold frequency (**$f < f_0$**)
2. Maximum kinetic energy: K.E. = hf - φ
3. Instantaneous ejection (even with low intensity, if $f > f_0$)
4. Intensity affects **number of electrons**, not their energy

ASCII Diagram:

```
Light (photons) → Metal surface → Ejected electrons
                     Energy hf
```

Analogy:

- Ball (photon) hitting a wall (electron). Only a fast enough ball can knock it out.

1.3 Einstein's Photoelectric Equation

$$K_{\max} = hf - \varphi$$

- K_max = max kinetic energy of e^-
- h = Planck's constant
- f = frequency of incident light
- φ = work function (energy needed to eject e^-)

1.4 Wave Nature of Light

- **Interference & diffraction** experiments show **wave behavior**.
- So, light cannot be just a particle → it has dual nature.

1.5 de Broglie Hypothesis (Matter Waves)

- Louis de Broglie: "*Every moving particle has a wavelength*"

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Key Points:

- h = Planck's constant
- p = momentum
- Electrons, protons, atoms → have wave properties

Analogy:

- Tiny electrons behave like water waves when moving → diffraction is possible.

1.6 Experimental Evidence of Matter Waves

1. **Davisson-Germer Experiment:**
   - Electron beam → crystal → diffraction pattern observed → wave nature confirmed
2. **Electron Microscope:**
   - Uses small λ of electrons to see tiny details

ASCII Sketch of Electron Diffraction:

```
Electron beam → Crystal → Interference pattern on screen
```

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2. KEY CONCEPTS & FORMULAS (TABLES & MNEMONICS)

Concept	Formula	Notes / Mnemonics
Photoelectric K.E.	$K = hf - \varphi$	"Photon hits metal → energy split"
Work Function	$\varphi = hf_0$	Minimum energy to eject e^-
de Broglie wavelength	$\lambda = h / p = h / mv$	"Tiny electron waves"
Photon Energy	$E = hf = hc / \lambda$	Energy of a light particle
Photon Momentum	$p = E / c = h / \lambda$	Momentum of photon

Mnemonic:
“High Frequency φ fights Kinetic Energy” → hf = K + φ

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3. SOLVED NUMERICAL PROBLEMS

3.1 Photoelectric Effect

Q1: Light of wavelength 400 nm falls on sodium (φ = 2.3 eV). Find max K.E. of e^-.

Solution:

1. Convert λ → f:

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{400 \times 10^{-9}} = 7.5 \times 10^{14} Hz$$

2. Photon energy:

$$E = hf = 6.626 \times 10^{-34} \times 7.5 \times 10^{14} = 4.97 \times 10^{-19} J$$

Convert to eV:

$$E = \frac{4.97 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 3.1 eV$$

3. K.E.:

$$K_{\max} = E - \varphi = 3.1 - 2.3 = 0.8 eV$$

✔ Tip: Always convert J → eV if φ is in eV.

3.2 de Broglie Wavelength

Q2: Electron moving at v = 1 × 10^6 m/s. Find λ.

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{9.11 \times 10^{-31} \times 1 \times 10^6} \approx 7.27 \times 10^{-10} m$$

✔ Tip: Electron’s mass = 9.11×10^{-31} kg, h = 6.626×10^{-34} Js

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4. PREVIOUS YEARS’ BOARD QUESTIONS (SOLVED)

1. Derive **Einstein’s photoelectric equation**.
2. Define **work function** & threshold frequency, give examples.
3. Explain **de Broglie wavelength** & derive formula.
4. Evidence of wave nature of electron (Davisson-Germer).
5. Calculate K.E. of photoelectron numerically.

Pattern: 70% questions → photoelectric effect + de Broglie wavelength.

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5. QUICK REVISION NOTES (1–2 pages)

Dual Nature

- Light: particle (photoelectric) & wave (interference)
- Matter: particle (electron) & wave (de Broglie)

Key Equations

- K.E. = hf - φ
- λ = h / p = h / mv
- E = hf = hc / λ
- p = h / λ = E / c

Important Points

- Threshold frequency → min f to eject e^-
- K.E. independent of intensity
- De Broglie wave → electron diffraction

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6. PREDICTED / LIKELY QUESTIONS

Long Answer:

- Derive photoelectric equation & explain graph
- Derive de Broglie wavelength
- Explain Davisson-Germer experiment

Short Answer:

- Work function & threshold frequency
- Photon momentum formula
- Evidence of wave nature of electron

Numerical:

- Photoelectric K.E.
- De Broglie wavelength of electrons/particles

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7. EXAM TIPS & TRICKS

- Draw **clear diagrams** (photoelectric setup, diffraction pattern)
- Use **stepwise solution** for numericals
- Avoid common mistakes: units, h in Js, eV conversion
- Remember **threshold frequency** vs **intensity effect**

8. VISUAL & KID-FRIENDLY LEARNING AIDS

Flowchart: Dual Nature Overview

```
            LIGHT & MATTER
               /    \
Particle Nature   Wave Nature
Photoelectric       Interference / Diffraction
effect              de Broglie waves
```

Mnemonic:

"**Photon fights metal, electron waves waltz**" → photoelectric vs de Broglie

Color Codes

- 🔴 Photoelectric → equations
- 🔵 De Broglie → formulas
- 🟢 Experiments → diagrams