11. DUAL NATURE OF RADIATION AND MATTER

Single Page Simple Synopsis

This chapter **Dual Nature of Radiation and Matter** refers to the concept that energy (like light) and matter (like electrons) exhibit both wave-like and particle-like properties depending on the situation. This phenomenon is known as wave-particle duality.

1. Dual Nature of Radiation (Wave to Particle)

Classical physics considered light purely as a continuous wave (explaining interference and diffraction). However, the Photoelectric Effect proved that light also behaves like a stream of discrete, tiny particles.

Photons: Light is composed of energy packets called photons. Each photon carries an energy given by $E = h\nu$. Here h is Planck's constant and ν is the frequency of light.

Photoelectric Emission: When photons of sufficient frequency strike a metal surface, they knock out free electrons.

Work Function (ϕ_0): It is the minimum energy required to liberate an electron from a metal .

2. Dual Nature of Matter (Particle to Wave):

If waves (like light) can behave as particles, de Broglie hypothesized that moving particles (like electrons and protons) should also exhibit wave-like properties.

De Broglie Wavelength: The wavelength (λ) of a moving particle is inversely proportional to its momentum (p).**Formula:** $\lambda = h / p = h / mv$ Here m is mass, and v is velocity.

Matter Waves: Every moving particle is associated with a wave called **matter wave.** Unlike electromagnetic waves, they do not require a medium to travel but their wavelength is typically too small to be observed in everyday life.

- Radiation acts as a wave when it travels through space (interference / diffraction).
- Radiation acts as a particle when it interacts with matter (photoelectric effect).
- Matter acts as a particle when it has mass and collides with objects.
- Matter acts as a wave when it is moving and shows interference-like behavior

Real Life Examples

- **Solar panels, cells,** automatic doors & burglar alarms, X-Ray Imaging, Electron Microscope, digital cameras- Images sensors, night vision goggles.

IMP. IPE POINTS

1. The minimum energy required by an electron to escape from the surface of a metal is called **work function (ϕ_0)** of the metal. It is maximum for Platinum and minimum for Caesium.

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2. When the surface of a metal is illuminated by light of suitable frequency, electrons are emitted from the surface of the metal. This phenomenon is called **'photoelectric effect'.**

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3. **Photocurrent** depends on
   i) intensity of incident light
   ii) potential applied between the two electrodes
   iii) nature of the photo-metal

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4. The negative potential that should be given to collector to stop the photoelectrons is called **stopping potential** ($-V_0$).

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5. **Stopping potential** is a measure of maximum kinetic energy of photoelectron.

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6. **Stopping potential (or) K_{max}** does not depend on the intensity of incident light.

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7. Stopping potential or K_{max} depends on frequency of incident light and nature of the photo-metal.

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8. Relation between maximum kinetic energy of photoelectron and stopping potential is

$$K_{max} = eV_0 \Rightarrow \frac{1}{2}mv_{max}^2 = eV_0$$

9. If the frequency of incident light is less than a particular frequency called **threshold frequency** (ν_0), photoelectrons will not be emitted, no matter how large the intensity may be.

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10. **Threshold frequency** is constant for a given photo-metal.

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11. **Energy of photon** is

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

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12. Relation between work function and threshold frequency(ν_0) is $\phi_0 = h\nu_0$

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13. Einstein's photoelectric equation is
$K_{max} = h\nu - \phi_0$ (or) $K_{max} = h\nu - h\nu_0$
(or) $\frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)$

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14. Radiation has dual nature
i.e, wave nature and particle nature.

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15. **de Broglie wavelength** of matter waves is $\lambda = \frac{h}{p}$

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16. Heisenberg's uncertainty principle is

$$\Delta x \Delta p = \hbar \text{ where } \hbar = \frac{h}{2\pi}$$

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17. Davisson and Germer's experiment verified de-Broglie hypothesis.