ENTRI

Particle properties of waves

Part:3

Problems on Blackbody and Photoelectric Effect

1. If wavelength of maximum intensity of radiations emitted by the sun and the moon are 0.5×10^{-6} m and 10^{-4}m respectively, the ratio of their temperatures is

(a) $1/100$
(b) $1/200$
(c) 100
(d) 200

Solution :(d) 200

As we know λ_m**T= Constant**

Sun
λ_s= Wavelength of Sun
T_s= Temperature of Sun
$\lambda_s T_s$= Constant — (a)
λ_s=0.5×10^{-6}

Moon
λ_m= Wavelength of moon
T_m= Temperature of moon
$\lambda_m T_m$= Constant — (b)
λ_m=10^{-4}m

From (a) and (b) $\lambda_s T_s = \lambda_m T_m$

$$\frac{T_s}{T_m} = \frac{\lambda_m}{\lambda_s}$$

$$= \frac{10^{-4}}{0.5\times10^{-6}}$$

$$\frac{T_s}{T_m} = 200$$

2. If the mean wavelength of light radiated by a 100 W lamp is 5000Å, then the number of photons radiated per second are

(a) 3×10^{23}
(b) 2.5×10^{22}
(c) 2.5×10^{20}
(d) 5×10^{17}

Solution :2.5×10^{20}

Given, P=100W

$\lambda = 5000\times10^{-10}$m

Since $\mathbf{P} = \frac{E}{t}$

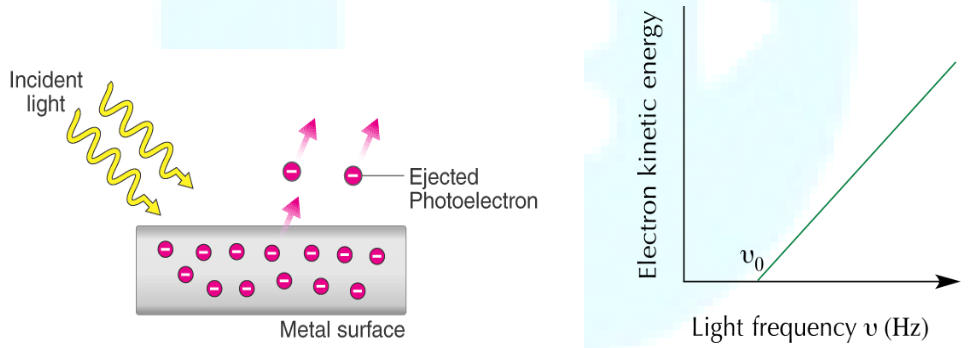
We know E= nhν $= \frac{nhc}{\lambda t}$ { c=νλ}

$$\frac{n}{t} = \frac{P\lambda}{hc} = \frac{1000\times5000\times10^{10}}{6.626\times10^{-34}\times3\times10^{8}}$$

$$\frac{n}{t} = 2.5\times10^{20}$$

Photoelectric Effect

- Direct confirmation for the energy quantization of light.
- 1887 Hertz discovered the photoelectric effect.
- Cannot be explained within the context of purely classical picture of radiation.
- Einstein succeeded in 1905 in giving theoretical explanation.



(a) **(b)**

Figure 1.1 (a) Photoelectric effect; When a metal is irradiated with light, electrons may get emitted. (b) Kinetic energy K of the electron leaving the metal surface when irradiated with a light of frequency ν ; when $\nu < \nu_0$ no electron is ejected from the metal regardless of the intensity of radiation.

Properties of Photoelectric Effect

- If the frequency of the incident radiation is smaller than the metal's threshold frequency, no electron can be emitted regardless of the radiation's intensity.
- Threshold frequency depends on the properties of the metal.

- No matter how low the intensity of the incident radiation, electrons will be ejected instantly the moment the frequency of the radiation exceeds the threshold frequency ν_0
- At any frequency above the threshold frequency ν, the number of electrons ejected increases with the intensity of the light but does not depend on light's frequency.
- The kinetic energy of the ejected electrons depends on the frequency but not on the intensity of the beam; the kinetic energy of the ejected electrons increases linearly with the incident frequency.

Why classical Physics failed?

- The dependence of the effect on the threshold frequency
- According to classical physics, any (continuous) amount of energy can be exchanged with matter. Also the intensity of an electromagnetic wave is proportional to the square of its amplitude, any frequency with sufficient intensity can supply the necessary energy to free the electron from the metal.
- When we use a weak light source, according to classical physics, an electron would keep absorbing energy until it gained a sufficient amount; then it would leave the metal.
- If this argument is to hold, then for a very weak radiation, the P.E effect would not take place for a long time, possibly hours, until an electron gradually accumulated the necessary amount of energy
- This conclusion, however, disagrees utterly with experimental observation. Experiments were conducted with a light source that are so weak it would have taken several hours for an electron to accumulate the energy needed for its ejection, and yet some electrons were observed to leave the metal instantly.
- An increase in intensity (brightness) alone can in no way dislodge electrons from the metal. But by increasing the frequency of the incident radiation beyond a certain threshold, even at very weak intensity, the emission of electrons starts immediately. These experimental facts indicate that the concept of gradual accumulation or continuous absorption, of energy by the electron, as predicted by classical physics, is indeed erroneous.