(i) In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.

(ii) Each photon has energy E (=$h\nu$) and momentum p (= $h\nu/c$), and speed c, the speed of light.

(iii) All photons of light of a particular frequency ν, or wavelength λ, have the same energy E (=$h\nu$ = hc/λ) and momentum p (= $h\nu/c = h/\lambda$), whatever the intensity of radiation may be. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons per second crossing a given area, with each photon having the same energy. Thus, photon energy is independent of intensity of radiation.

(iv) Photons are electrically neutral and are not deflected by electric and magnetic fields.

(v) In a photon-particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

EXAMPLE 11.1

Example 11.1 Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. (a) What is the energy of a photon in the light beam? (b) How many photons per second, on an average, are emitted by the source?

Solution

(a) Each photon has an energy

$E = h\nu = (6.63 \times 10^{-34}\ \text{J s})(6.0 \times 10^{14}\ \text{Hz})$

$= 3.98 \times 10^{-19}\ \text{J}$

(b) If N is the number of photons emitted by the source per second, the power P transmitted in the beam equals N times the energy per photon E, so that $P = NE$. Then

$$N = \frac{P}{E} = \frac{2.0 \times 10^{-3}\ \text{W}}{3.98 \times 10^{-19}\ \text{J}}$$

$= 5.0 \times 10^{15}$ photons per second.

$N = \frac{P}{E}$ where $E = h\nu$

EXAMPLE 11.2

Example 11.2 The work function of caesium is 2.14 eV. Find (a) the threshold frequency for caesium, and (b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potential of 0.60 V.

Solution

(a) For the cut-off or threshold frequency, the energy $h\nu_0$ of the incident radiation must be equal to work function ϕ_0, so that

$$\nu_0 = \frac{\phi_0}{h} = \frac{2.14\ \text{eV}}{6.63 \times 10^{-34}\ \text{J s}}$$

$$= \frac{2.14 \times 1.6 \times 10^{-19}\ \text{J}}{6.63 \times 10^{-34}\ \text{J s}} = 5.16 \times 10^{14}\ \text{Hz}$$

Thus, for frequencies less than this threshold frequency, no photoelectrons are ejected.

(b) Photocurrent reduces to zero, when maximum kinetic energy of the emitted photoelectrons equals the potential energy eV_0 by the retarding potential V_0. Einstein's Photoelectric equation is