Chapter Eleven

DUAL NATURE OF RADIATION AND MATTER

MCQ I

11.1 A particle is dropped from a height H. The de Broglie wavelength of the particle as a function of height is proportional to

(a) H
(b) $H^{1/2}$
(c) H^0
(b) $H^{-1/2}$

11.2 The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nucleus with 1 MeV energy is nearly

(a) 1.2 nm
(b) 1.2×10^{-3} nm
(c) 1.2×10^{-6} nm
(d) 1.2×10^{1} nm

11.3 Consider a beam of electrons (each electron with energy E_0) incident on a metal surface kept in an evacuated chamber. Then

(a) no electrons will be emitted as only photons can emit electrons.
(b) electrons can be emitted but all with an energy, E_0.
(c) electrons can be emitted with any energy, with a maximum of $E_0 - \phi$ (ϕ is the work function).
(d) electrons can be emitted with any energy, with a maximum of E_0.

11.4 Consider Fig. 11.7 in the NCERT text book of physics for Class XII. Suppose the voltage applied to A is increased. The diffracted beam will have the maximum at a value of θ that

(a) will be larger than the earlier value.
(b) will be the same as the earlier value.
(c) will be less than the earlier value.
(d) will depend on the target.

11.5 A proton, a neutron, an electron and an α-particle have same energy. Then their de Broglie wavelengths compare as

(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$
(b) $\lambda_\alpha < \lambda_p = \lambda_n > \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$
(d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

11.6 An electron is moving with an initial velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$ and is in a magnetic field $\mathbf{B} = B_0\hat{\mathbf{j}}$. Then it's de Broglie wavelength

(a) remains constant.
(b) increases with time.
(c) decreases with time.
(d) increases and decreases periodically.

11.7 An electron (mass m) with an initial velocity $\mathbf{v} = v_0\hat{\mathbf{i}} (v_0 > 0)$ is in an electric field $\mathbf{E} = -E_0\hat{\mathbf{i}} (E_0 = \text{constant} > 0)$. It's de Broglie wavelength at time t is given by

(a) $\dfrac{\lambda_0}{\left(1 + \dfrac{eE_0}{m}\dfrac{t}{v_0}\right)}$

(b) $\lambda_0 \left(1 + \dfrac{eE_0 t}{m v_0}\right)$

(c) λ_0
(d) $\lambda_0 t$.

11.8 An electron (mass m) with an initial velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$ is in an electric field $\mathbf{E} = E_0\hat{\mathbf{j}}$. If $\lambda_0 = h/mv_0$, it's de Breoglie wavelength at time t is given by

(a) λ_0

(b) $\lambda_0\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}$

(c) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}}$

(d) $\frac{\lambda_0}{\left(1+\frac{e^2E_0^2t^2}{m^2v_0^2}\right)}$

MCQ II

11.9 Relativistic corrections become neccssary when the expression for the kinetic energy $\frac{1}{2}mv^2$, becomes comparable with mc^2, where m is the mass of the particle. At what de Broglie wavelength will relativistic corrections become important for an electron?

(a) λ =10nm
(b) λ =10^{-1}nm
(c) λ =10^{-4}nm
(d) λ =10^{-6}nm

11.10 Two particles A_1 and A_2 of masses m_1, m_2 ($m_1 > m_2$) have the same de Broglie wavelength. Then

(a) their momenta are the same.
(b) their energies are the same.
(c) energy of A_1 is less than the energy of A_2.
(d) energy of A_1 is more than the energy of A_2.

11.11 The de Broglie wavelength of a photon is twice the de Broglie wavelength of an electron. The speed of the electron is $v_e = \frac{c}{100}$. Then

(a) $\frac{E_e}{E_p} = 10^{-4}$

(b) $\frac{E_e}{E_p} = 10^{-2}$

(c) $\frac{p_e}{m_e c} = 10^{-2}$

(d) $\frac{p_e}{m_e c} = 10^{-4}$.

11.12 Photons absorbed in matter are converted to heat. A source emitting n photon/sec of frequency ν is used to convert 1kg of ice at 0°C to water at 0°C. Then, the time T taken for the conversion

(a) decreases with increasing n, with ν fixed.

(b) decreases with n fixed, ν increasing

(c) remains constant with n and ν changing such that $n\nu$ = constant.

(d) increases when the product $n\nu$ increases.

11.13 A particle moves in a closed orbit around the origin, due to a force which is directed towards the origin. The de Broglie wavelength of the particle varies cyclically between two values λ_1, λ_2 with $\lambda_1 > \lambda_2$. Which of the following statement are true?

(a) The particle could be moving in a circular orbit with origin as centre

(b) The particle could be moving in an elliptic orbit with origin as its focus.

(c) When the de Broglie wave length is λ_1, the particle is nearer the origin than when its value is λ_2.

(d) When the de Broglic wavelength is λ_2, the particle is nearer the origin than when its value is λ_1.

VSA

11.14 A proton and an α-particle are accelerated, using the same potential difference. How are the deBroglie wavelengths λ_p and λ_a related to each other?

11.15 (i) In the explanation of photo electric effect, we asssume one photon of frequency ν collides with an electron and transfers its energy. This leads to the equation for the maximum energy E_{max} of the emitted electron as

$$E_{max} = h\nu - \phi_0$$

where ϕ_0 is the work function of the metal. If an electron absorbs 2 photons (each of frequency ν) what will be the maximum energy for the emitted electron?

(ii) Why is this fact (two photon absorption) not taken into consideration in our discussion of the stopping potential?

11.16 There are materials which absorb photons of shorter wavelength and emit photons of longer wavelength. Can there be stable substances which absorb photons of larger wavelength and emit light of shorter wavelength.

11.17 Do all the electrons that absorb a photon come out as photoelectrons?

11.18 There are two sources of light, each emitting with a power of 100 W. One emits X-rays of wavelength 1nm and the other visible light at 500 nm. Find the ratio of number of photons of X-rays to the photons of visible light of the given wavelength?

SA

11.19 Consider Fig.11.1 for photoemission.

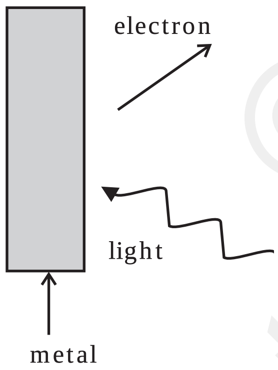

Fig. 11.1

How would you reconcile with momentum-conservation? Note light (photons) have momentum in a different direction than the emitted electrons.

11.20 Consider a metal exposed to light of wavelength 600 nm. The maximum energy of the electron doubles when light of wavelength 400 snm is used. Find the work function in eV.

11.21 Assuming an electron is confined to a 1nm wide region , find the uncertainty in momentum using Heisenberg Uncertainty principle (Ref Eq 11.12 of NCERT Textbook). You can assume the uncertainty in position Δx as 1nm. Assuming $p \approx \Delta p$, find the energy of the electron in electron volts.

11.22 Two monochromatic beams A and B of equal intensity I, hit a screen. The number of photons hitting the screen by beam A is twice that by beam B. Then what inference can you make about their frequencies?

11.23 Two particles A and B of de Broglie wavelengths λ_1 and λ_2 combine to form a particle C. The process conserves momentum. Find the de Broglie wavelength of the particle C. (The motion is one dimensional).

11.24 A neutron beam of energy E scatters from atoms on a surface with a spacing $d = 0.1$nm. The first maximum of intensity in the reflected beam occurs at $\theta = 30°$. What is the kinetic energy E of the beam in eV?

LA

11.25 Consider a thin target (10^{-2}m square, 10^{-3}m thickness) of sodium, which produces a photocurrent of 100μA when a light of intensity 100W/m^2 (λ = 660nm) falls on it. Find the probability that a photoelectron is produced when a photons strikes a sodium atom. [Take density of Na = 0.97 kg/m^3].

11.26 Consider an electron in front of metallic surface at a distance d (treated as an infinite plane surface). Assume the force of attraction

by the plate is given as $\frac{1}{4}\frac{q^2}{4\pi\varepsilon_0 d^2}$

Calculate work in taking the charge to an infinite distance from the plate. Taking $d = 0.1$nm, find the work done in electron volts. [Such a force law is not valid for $d < 0.1$nm].

11.27 A student performs an experiment on photoelectric effect, using two materials A and B. A plot of V_{stop} vs ν is given in Fig. 11.2.

(i) Which material A or B has a higher work function?

(ii) Given the electric charge of an electron = 1.6×10^{-19}C, find the value of h obtained from the experiment for both A and B.

Comment on whether it is consistent with Einstein's theory:

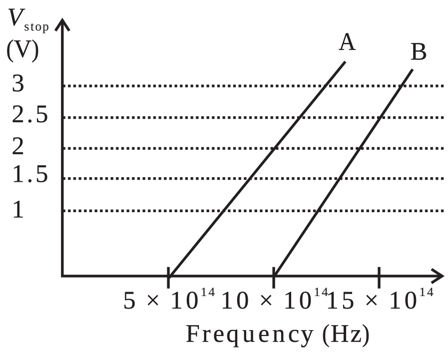

Fig. 11.2

11.28 A particle A with a mass m_A is moving with a velocity v and hits a particle B (mass m_B) at rest (one dimensional motion). Find the change in the de Broglic wavelength of the particle A. Treat the collision as elastic.

11.29 Consider a 20 W bulb emitting light of wavelength 5000 $\mathring{A}$ and shining on a metal surface kept at a distance 2m. Assume that the metal surface has work function of 2 eV and that each atom on the metal surface can be treated as a circular disk of radius 1.5 $\mathring{A}$.

(i) Estimate no. of photons emitted by the bulb per second. [Assume no other losses]

(ii) Will there be photoelectric emission?

(iii) How much time would be required by the atomc disk to receive energy equal to work function (2 eV)?

(iv) How many photons would atomic disk receive within time duration calculated in (iii) above?

(v) Can you explain how photoelectric effect was observed instantaneously?

[Hint: Time calculated in part (iii) is from classical consideration and you may further take the target of surface area say 1cm^2 and estimate what would happen?]