

Problems

1. Calculate the de-Broglie wavelength of an electron accelerated through a potential of 120 Volts

Solution: Data given Accelerating potential $V = 120 \text{ V}$

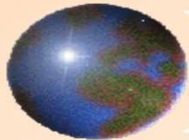
To find the de-Broglie wavelength of electron $\lambda = ?$

de-Broglie wavelength of electron for an accelerating electron is given by

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm} = \frac{12.27}{\sqrt{V}} \text{ \AA}$$

$$\lambda = \frac{12.27}{\sqrt{120}} \text{ \AA}$$

$$\lambda = 1.12 \text{ \AA}$$



2. Calculate the de-Broglie wavelength of a 0.3 kg cricket ball with a speed of 120km/hr

Solution: Data given

Mass of the cricket ball 0.3kg

Speed/velocity of the ball = 120km/hr = $\frac{120 \times 10^3}{60 \times 60} \text{ m/s}$

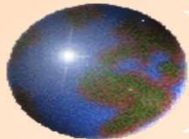
$v = 33.333 \text{ m/s}$

To find the de-Broglie wavelength of electron $\lambda = ?$

de-Broglie wavelength of cricket ball moving with a velocity of 120 km/hr is given by

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

$$\lambda = \frac{6.626 \times 10^{-34}}{0.3 \times 33.33} = 6.626 \times 10^{-35} \text{ m}$$



3. A particle of mass $0.5\text{MeV} / c^2$ has kinetic energy 100eV . Find its de-Broglie wavelength, where c is the velocity of light

Solution: Data given

$$\text{Particle mass } m = 0.5\text{MeV} / c^2 = \frac{0.5 \times 10^6 \times 1.602 \times 10^{-19}}{(3 \times 10^8)^2} \text{ J}$$

$$m = 8.9 \times 10^{-31} \text{ kg}$$

$$\text{Kinetic energy } E = 100\text{eV} = 100 \times 1.602 \times 10^{-19} \text{ J} = 1.602 \times 10^{-17} \text{ J}$$

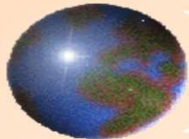
de-Broglie wavelength of electron when kinetic energy is given is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 8.9 \times 10^{-31} \times 1.602 \times 10^{-17}}}$$

$$\lambda = 1.2408 \times 10^{-10} \text{ m}$$

$$\lambda = 1.2408 \text{ \AA}$$



4. Calculate the de-Broglie wavelength associated with 400gm cricket ball with a speed of 90 Km/hr

Solution: Data given

Mass of the cricket ball $m = 400\text{gm} = 0.4\text{kg}$

Speed/velocity of the ball $= 90\text{km/hr} = \frac{90 \times 10^3}{60 \times 60} \text{ m/s}$

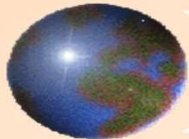
$v = 25\text{m/s}$

To find the de-Broglie wavelength of electron $\lambda = ?$

de-Broglie wavelength of cricket ball moving with a velocity of 90 km/hr is given by

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

$$\lambda = \frac{6.626 \times 10^{-34}}{0.4 \times 25} = 6.626 \times 10^{-35} \text{ m}$$



5. Calculate the wavelength associated with electrons whose speed is 0.01 part of the speed of light.

Solution: *Data given speed of electron = 0.01 part of c = 0.01 × c*
 $v = 0.01 \times 3 \times 10^8 = 3 \times 10^6 \text{ m/s}$

To find wavelength of electrons

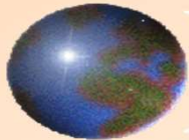
de-Broglie wavelength of electron with a speed of 0.01 part of “c”

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

$$\lambda = \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^6}$$

$$\lambda = 2.427 \times 10^{-10} \text{ m}$$

$$\lambda = 2.427 \text{ \AA}$$



6. A particle of mass $0.65\text{MeV}/c^2$ has a kinetic energy 80eV . Calculate the de-Broglie wavelength, group velocity and phase velocity of the de-Broglie wave

Solution: Data given

$$\text{Particle mass } m = 0.65\text{MeV}/c^2 = \frac{0.65 \times 10^6 \times 1.602 \times 10^{-19}}{(3 \times 10^8)^2} \text{ J}$$

$$m = 1.157 \times 10^{-30} \text{ kg}$$

$$\text{Kinetic energy } E = 80\text{eV} = 80 \times 1.602 \times 10^{-19} \text{ J} = 1.2816 \times 10^{-17} \text{ J}$$

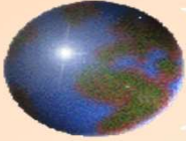
de-Broglie wavelength of electron when kinetic energy is given is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 1.157 \times 10^{-30} \times 1.2816 \times 10^{-17}}}$$

$$\lambda = 1.2167 \times 10^{-10} \text{ m}$$

$$\lambda = 1.2167 \text{ \AA}$$



Group velocity and phase velocity of the de-Broglie wave is

group velocity is same as particle velocity then we can write

$$v_g = \frac{d\omega}{dk} = v_{particle} \quad \lambda = \frac{h}{mv} \quad \text{Since } v_{group} = v_{particle}$$

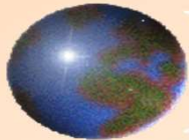
$$v_{group} = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34}}{1.157 \times 10^{-30} \times 1.2167 \times 10^{-10}}$$

$$v_{group} = 4.706 \times 10^6 \text{ m/s}$$

phase velocity can be relate with group velocity and velocity of light as

$$v_g v_p = c^2 \quad v_{phase} = \frac{(3 \times 10^8)^2}{4.706 \times 10^6} \quad v_{phase} = 1.912 \times 10^{10} \text{ m/s}$$

$$v_{phase} = \frac{c^2}{v_{group}}$$



7. Compare the energy of a photon with that of an electron when both are associated with Wavelength of 0.2 nm

Solution: Data given wavelength of electron $\lambda = 0.2 \text{ nm}$

To find energy of photon and electron

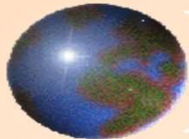
$$\text{Energy of the photon } E = h\gamma = h \frac{c}{\lambda} \quad E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.2 \times 10^{-9}}$$

$$E_{\text{photon}}(E_1) = 9.939 \times 10^{-16} \text{ J} = \frac{9.939 \times 10^{-16}}{1.602 \times 10^{-19}} \text{ eV} = 6.204 \times 10^3 \text{ eV}$$

de-Broglie wavelength of electron when kinetic energy is given is given by $\lambda = \frac{h}{\sqrt{2mE}}$ The energy of the neutron $E_{\text{electron}}(E_2)$ can be written as

$$E_{\text{electron}}(E_2) = \frac{h^2}{2m\lambda^2} = \frac{(6.626 \times 10^{-34})^2}{2 \times 9.1 \times 10^{-31} \times (0.2 \times 10^{-9})^2} = 6.031 \times 10^{-18} \text{ J} = 37.64 \text{ eV}$$

$$\frac{E_{\text{photon}}}{E_{\text{electron}}} = \frac{6.204 \times 10^3}{37.64} = 164.69$$



8. Calculate the de Broglie wavelength of a neutron moving with kinetic energy 54eV, given the mass of neutron= 1.675×10^{-27} kg.

Solution: Data given

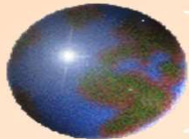
neutron mass $m = 1.675 \times 10^{-27}$ kg

Kinetic energy $E = 54\text{eV} = 54 \times 1.602 \times 10^{-19}\text{J} = 8.6508 \times 10^{-18}\text{J}$

de-Broglie wavelength of electron when kinetic energy is given is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 1.675 \times 10^{-27} \times 8.6508 \times 10^{-18}}} \quad \lambda = 3.892 \times 10^{-12} \text{ m}$$
$$\lambda = 3.892 \times 10^{-2} \text{ \AA}$$



9. Estimate the potential difference through which an electron is needed to be accelerated so that its de Broglie wavelength becomes equal to **20 Å**

Solution: Data given de-Broglie wavelength of electron $\lambda = \mathbf{20 \text{ Å}}$

To find Accelerating potential $V = ?$

de-Broglie wavelength of electron for an accelerating electron is given by

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm} = \frac{12.27}{\sqrt{V}} \text{ Å}$$

$$\sqrt{V} = \frac{12.27}{\lambda} = \frac{12.27}{20} = 0.6135$$

$$V = \sqrt{0.6135}$$

$$V = \mathbf{0.783 \text{ V}}$$