Problems

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

Solution: Data given Accelerating potential V= 120 V

To find the de-Broglie wavelength of electron λ=?

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

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

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

$$\lambda = 1.12\ \text{Å}$$

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= $\frac{120\times10^{3}}{60\times60} m/s$

$v = 33.333 m/s$

To find the de-Broglie wavelength of electron λ=?

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

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

$$\boldsymbol{\lambda = \frac{6.626\times10^{-34}}{0.3\times33.33} = 6.626\times10^{-35} m}$$

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

Solution: Data given

Particle mass m= **0.5MeV $/c^2$** $= \frac{0.5\times10^{6}\times1.602\times10^{-1}}{(3\times10^{8})^{2}}$ **J**

m $=8.9\times10^{-31}$kg

Kinetic energy E= 100eV= $100 \times 1.602 \times 10^{-1}\ J = 1.602 \times 10^{-17}$J

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

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

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

λ =1.2408×10^{-10}m

λ =1.2408 Å

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= 400gm= 0.4kg

Speed/velocity of the ball= 90km/hr= $\frac{90\times10^3}{60\times60}\,m/s$

$v = 25m/s$

To find the de-Broglie wavelength of electron λ=?

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

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

$$\boldsymbol{\lambda = \frac{6.626\times10^{-34}}{0.4\times25} = 6.626\times10^{-35}m}$$

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*

$v = 0.01 \times 3 \times 10^8 = 3{\times}10^6\, m/s$

To find wavelength of electrons

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

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

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

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

$$\boldsymbol{\lambda = 2.427\ \text{Å}}$$

6. A particle of mass 0.65MeV/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

Particle mass m= **0.65MeV /c^2** $= \frac{0.65\times10^6\times1.602\times10^{-19}}{(3\times10^8)^2}$ **J**

m $=1.157\times10^{-30}$kg

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

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

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

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

$\boldsymbol{\lambda}$ **=1.2167×10^{-10}m**

$\boldsymbol{\lambda}$ **=1.2167 Å**

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

group velocity is same as particle velocity then we can write

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

$$v_{group} = \frac{h}{m\,\lambda} = \frac{6.626\times10^{-34}}{1.157\times10^{-30}\times1.2167\times10^{-10}}$$

$$v_{group} = 4.706\times10^{6}\,\text{m/s}$$

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

$$v_g\, v_p = c^2 \qquad v_{phase} = \frac{(3\times10^8)^2}{4.706\times10^6} \qquad v_{phase} = 1.912\times10^{10}\,m/s$$

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

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 $\lambda = 0.2nm$

To find energy of photon and electron

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

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

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

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

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

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= 1.675×10^{-2} kg

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

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

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

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 1.675 \times 10^{-27} \times 8.6508 \times 10^{-18}}}$$

$\lambda = 3.892\times10^{-12}$m

$\lambda = 3.892\times10^{-2}$ Å

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 λ=**20** Å

To find Accelerating potential V= ?

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

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

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

$$V = \sqrt{0.6135}$$

V = 0.783 V