DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module 3

Solving Problems

A neutron of mass 1.675×10^{-27} Kg is moving with a kinetic energy 10 keV. Calculate the De-Broglie wavelength associated with it.

Given data

Mass of the neutron $= 1.675 \times 10^{-27}$ kg

Kinetic energy $= 10$ keV $= 10 \times 10^{3}$ eV

$$= 10 \times 10^{3} \times 1.6 \times 10^{-19} \text{ J}$$

Planck's constant $h = 6.625 \times 10^{-34}$ Js

Solution:

We know that $\lambda = \dfrac{h}{\sqrt{2mE}}$

Substituting the given values, we have

$$= \frac{6.625 \times 10^{-34}}{\sqrt{2 \times 1.675 \times 10^{-27} \times 10 \times 10^{3} \times 1.6 \times 10^{-19}}}$$

$$= \frac{6.625 \times 10^{-34}}{\sqrt{5.36 \times 10^{-42}}}$$

$$\boxed{\lambda = 2.862 \times 10^{-13}\ \text{m}}$$

An electron at rest is accelerated through a potential of 5000 V. Calculate de-Broglie wavelength of matter wave associated with it.

Given data

Accelerating potential (V) = 5000 V

Solution

We know that $\lambda = \dfrac{h}{\sqrt{2meV}}$

$$\lambda = \frac{12.26}{\sqrt{V}} \times 10^{-10} \text{ m}$$

Substituting the given values, we have

$$\lambda = \frac{12.26 \times 10^{-10}}{\sqrt{5000}}$$

$$\lambda = \frac{12.26 \times 10^{-10}}{70.71}$$

$$\lambda = \mathbf{0.173 \times 10^{-10}\ m}$$

$$\boxed{\lambda = 0.173\ \text{Å}}$$

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Calculate de- Broglie's wavelength associated with a proton moving with a velocity equal to one-thirtieth of velocity of light.

Given data

Velocity of the proton $v = \frac{1}{30} \times$ velocity of light

$$= \frac{1}{30} \times 3 \times 10^{8} \text{ ms}^{-1}$$

$$= 1 \times 10^{7} \text{ ms}^{-1}$$

Mass of the proton $m = 1.67 \times 10^{-27}$ kg

Planck's constant $h = 6.625 \times 10^{-34}$ J s

Solution

We know that de - Broglie wavelength

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

Substituting the given values, we have

$$\lambda = \frac{6.625 \times 10^{-34}}{1.67 \times 10^{-27} \times 1 \times 10^{7}}$$

$$\boxed{\lambda = 3.97 \times 10^{-14} \text{ m}}$$

If the momentum of two particles are in the ratio 1: 0.25, compare their de-Broglie wavelengths.

de - Broglie wavelengths associated with two particles of momentum in the ratio 1 : 0.25 are λ_1 and λ_2

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

$$\lambda_1 = \frac{h}{p_1}, \qquad \lambda_2 = \frac{h}{p_2}$$

$$\lambda_1 : \lambda_2$$

$$\frac{h}{p_1} : \frac{h}{p_2}$$

$$\frac{1}{1} : \frac{1}{0.25}$$

$$1 : 4$$

de - Broglie wavelengths are in the ratio

$$\boxed{1 : 4}$$

Calculate the de- Broglie's wavelength of an electron having a velocity of 10^6 m/sec.

Given data

Velocity of the electron $(v) = 10^6 \text{ ms}^{-1}$

Mass of the electron $(m) = 9.1 \times 10^{-31}$ kg

Planck's constant $(h) = 6.625 \times 10^{-34}$ Js

Solution

We know that de - Broglie's wavelength $\lambda = \frac{h}{mv}$

Substituting the given values, we have

$$\lambda = \frac{6.625 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{6}}$$

$$\lambda = 7.28 \times 10^{-10} \text{ m}$$

$$\boxed{\lambda = 7.28 \text{ Å}}$$

Calculate the de- Broglie's wavelength associated with an electron which travels with a velocity 500 Kms^{-1}

Given data

Velocity of the electron

$$(v) = 500 \text{ km / sec} = 500 \times 10^{3} \text{ m s}^{-1}$$

Planck's constant $(h) = 6.625 \times 10^{-34}$ Js

Mass of the electron $(m) = 9.1 \times 10^{-31}$ kg

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

Substituting the given values, we have

$$\lambda = \frac{6.625 \times 10^{-34}}{9.1 \times 10^{-31} \times 500 \times 10^{3}}$$

$$\lambda = 0.00145 \times 10^{-6}$$

$$\lambda = 14.5 \times 10^{-10}\ \text{m}$$

$$\boxed{\lambda = 14.5\ \text{Å}}$$

Calculate the minimum energy which an electron can possess in an infinitely deep potential well of width 4 nm.

Given data

Width of potential well $(a) = 4 \text{ nm} = 4 \times 10^{-9}$ m

For minimum energy, $n = 1$

Mass of the electron $(m) = 9.1 \times 10^{-31}$ kg

Planck's constant $(h) = 6.625 \times 10^{-34}$ Js

Solution:

We know that $$E_n = \frac{n^2 h^2}{8ma^2}$$

Substituting the given values, we have

$$E_1 = \frac{1^2 \times (6.625 \times 10^{-34})^2}{8 \times 9.11 \times 10^{-31} \times (4 \times 10^{-9})^2}$$

$$E_1 = 3.764 \times 10^{-21}\ \mathrm{J}$$

$$E_1 = \frac{3.764 \times 10^{-21}}{1.6 \times 10^{-19}}\ \mathrm{eV} \quad [\because 1\ \mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}]$$

$$\boxed{E_1 = 0.024\ \mathrm{eV}}$$