Engineering Physics

(PHY1701)

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Contents

- Planck's concept (hypothesis) (AB 66-67)
- Compton Effect (AB 80-86),
- Particle properties of wave: Matter Waves (AB 104-114),
- Davisson Germer Experiment (AB 115-117),
- Heisenberg Uncertainty Principle (AB 119-128),
- Wave function (AB 182-184 & 190-195), &
- Schrödinger equation (time dependent & independent) (AB 187 -190 & 195-197).

❖ Concepts of Modern Physics, Arthur Beiser et al., Sixth Edition, Tata McGraw Hill (2013) (AB)

Problems

❶ **Calculate the average energy of an oscillator of frequency 5.6×10^{12} per second at T=330 K, treating it as 1. Classical oscillator 2. Planck's oscillator.**

- Average energy ε = KT = $1.380\times10^{-23}\times330 = 4.554\times10^{-21}$ J
- Average energy $\overline{E} = \dfrac{h\nu}{e^{h\nu/kT} - 1}$ = 2.94×10^{-21} J

Problems

❷ **X-rays with wavelength 1.0 Å are scattered from a metal block. The scattered radiation are viewed at 90^0 to the incident direction. Evaluate the Compton shift.**

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\Phi) \qquad \text{As, } \frac{h}{mc} = 2.426 \text{ pm}$$

$$\Delta\lambda = 2.426\, pm\ (1 - \cos 90^0)$$

$$\Delta\lambda = 2.426 \text{ pm} + 0$$

$$\Delta\lambda = 2.426\, pm$$

Problems

3 A beam of X-rays is scattered by a target. At 45^0 from the beam direction the scattered X-rays have a wavelength of 2.2 pm. What is the wavelength of X-rays in the direct beam?

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\Phi)$$ As, $\frac{h}{mc} = 2.426$ pm

$$\lambda = \lambda' - \frac{h}{mc}(1 - \cos\Phi)$$

$$\lambda = 2.2\, pm + 2.426\, pm\, (1 - \cos 45^0)$$

$$\lambda = 1.489\, pm$$

Problems

4 **Calculate the de Broglie wavelength associated with a proton moving with a velocity of 1/20th of velocity of light. Mass of proton = 1.67×10^{-27} kg.**

$$v = \frac{c}{20} = 1.5 \times 10^{7}\, m/sec$$

$$\lambda = \frac{h}{mv} = \frac{6.62\times10^{-24}}{1.67\times10^{-27}\times1.5\times10^{7}}$$

$$\lambda = 2.64\times10^{-14}\ \mathrm{m}$$

Problems

5 Calculate the de Broglie wavelength of an electron which has been accelerated from rest on application of potential of 400 volts.

$$\lambda = \frac{12.26}{\sqrt{V}} \text{ Å}$$

$$\lambda = \frac{12.26}{\sqrt{400}} \text{ Å}$$

$$\lambda = 0.613 \text{ Å}$$

6 Calculate the de Broglie wavelength associated with the following:

- A golf ball of 50 g moving with a velocity of 20m/sec

$$\lambda = \frac{h}{mv} = \frac{6.62\times10^{-34}}{0.05\ kg \times 20\ m/sec}$$

$$\lambda = 6.625\times10^{-34}\ \text{m}$$

- A proton moving with a velocity of 2200m/sec

$$\lambda = \frac{h}{mv} = \frac{6.62\times10^{-34}}{1.67\times10^{-27} kg \times 2200\ m/sec}$$

$$\lambda = 1.91\ \text{Å}$$

7 **Calculate the energy in electron volt of an electron wave $\lambda = 3\times10^{-12}$ m. Given, h=6.62×10^{-34} J.sec**

We know that,

$$E = \frac{h^2}{2m\lambda^2}$$

$$E = \frac{(6.62\times10^{-34})^2}{2\times9.1\times10^{-31}kg \times(3\times10^{-12})^2 m/sec}$$

$$= 0.26\ eV \times 10^{-13}\ \text{J}$$

$$= 0.166 \times 10^{+6}\ \text{eV}$$

Problems

8 **Energy of the particle at absolute temperature T is of the order of kT. Calculate the wavelength of thermal neutrons at 27°C. Given $h=6.62\times10^{-34}$ J.sec, $k=8.6\times10^{-5}$ eV deg^{-1}.**

We know that,

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

$$\lambda = \frac{6.62\times10^{-34}}{\sqrt{(2\times1.67\times10^{-27}kg\times1.376\times10^{-23}\times300)}}$$

$$= \mathbf{1.777}\text{Å}$$

Problems

9. A microscope using photons is employed to locate an electron in an atom to within a distance of 0.1 Å. What is the uncertainty in the momentum of the electron located in this way?

$$\Delta p = \frac{h}{\Delta x} = \frac{6.62\times10^{-34}\,J.sec}{(0.1\times10^{-10})m} = 6.63 \times 10^{-23}\,kg.m/sec$$

$$\Delta v = \frac{\Delta p}{m_0} = \frac{6.63\times10^{-23}\,kg-m/sec}{(9.1\times10^{-31})kg} = 7.28 \times 10^{7}\,m/sec$$

10 An electron is confined to a box of length 10^{-9} m. Calculate the minimum uncertainty in its velocity.

We know that, $\Delta \boldsymbol{x}.\Delta \boldsymbol{p}_x \approx$ h
If $\Delta \boldsymbol{x}$ is maximum, $\Delta \boldsymbol{p}_x$ must be minimum.
$(\Delta \boldsymbol{x})_{max} .(\Delta \boldsymbol{p}_x)_{min} \approx$ h
According to problem $(\Delta \boldsymbol{x})_{max}$ =$(10^{-9})\boldsymbol{m}$

$$(\Delta \boldsymbol{p})_{min} = \frac{\boldsymbol{h}}{(\Delta \boldsymbol{p})_{max}} = \frac{6.6\times 10^{-34}\, J.sec}{(10^{-9})m} = 6.6 \times 10^{-25}\, kg.m/s$$

$$(\Delta \boldsymbol{p}_x)_{min} = m(\Delta \boldsymbol{v}_x)_{min}$$

$$(\Delta \boldsymbol{v}_x)_{\mathrm{min}} = \frac{(\Delta \boldsymbol{p}_x)_{min}}{\boldsymbol{m}} = \frac{6.6\times 10^{-25}\, kg-m/sec}{(9.1\times 10^{-31})kg} = 7.3 \times 10^5\, m/s$$

Problems

⑪ **An electron has a speed of 3.5× 10^7 cm/sec accurated to 0.0098%. With what fundamental accuracy can we locate the position of electron. Mass of electron =9.11× 10^{-31} kg.**

The momentum mv of the electron is given by,

mv= $\mathbf{9.1} \times 10^{-31}$ × **3.5× 10^5 = 3.192× 10^{-25} kg. m/sec**

$$\Delta \boldsymbol{p} = \frac{\mathbf{0.0098}}{\mathbf{100}} \boldsymbol{mv} = (\mathbf{98} \times 10^{-6}) \times (\mathbf{3.192} \times 10^{-25})$$

$$(\Delta \boldsymbol{p} \Delta \boldsymbol{x}) = \frac{h}{2\pi}$$

$$(\Delta \boldsymbol{x})_{\min} = \frac{\boldsymbol{h}}{\mathbf{2}\boldsymbol{\pi}(\Delta \boldsymbol{p}_x)_{max}} = \frac{\mathbf{6.6} \times 10^{-34}}{2 \times 3.14 \times (\mathbf{98} \times 10^{-6})(\mathbf{3.192} \times 10^{-25})}$$

$$= 3.378 \times 10^{-6}\, \boldsymbol{m}$$

12 **Calculate the de=Broglie wavelength of a neutron whose energy is 12.MeV.**

Energy of the **= 12.8 MeV=12.8 $\times 10^6 \times 1.6 \times 10^{-19}$= 2.047×10^{-12} J**

$$\frac{1}{2}mv^2 = \mathbf{2.047\times10^{-12}\ J}$$

$$v = \sqrt{\frac{2\times \mathbf{2.047\times10^{-12}\ J}}{1.67\times\mathbf{10^{-12}}}} = \mathbf{4.952\times10^{7}\ m/s}$$

$$\lambda = \frac{h}{mv} = \frac{6.62\times10^{-34}}{1.67\times10^{-27}kg\times4.952\times10^{7}} = 0.00008017\text{Å}$$

Problems

13 Compare the uncertainties in the velocities of an electron and a proton confined to 1nm box. Their masses are 9.10×10^{-31} kg and 1.67×10^{-27} kg respectively

$$(\Delta v)_e = \frac{\Delta p}{m_e} \quad \textbf{\textit{and}} \quad (\Delta v)_p = \frac{\Delta p}{m_p}$$

$$\frac{(\Delta v)_e}{(\Delta v)_p} = \frac{m_p}{m_e} = \frac{1.67\times10^{-27}\,kg}{9.1\times10^{-31}\,kg}$$

$$= 1835$$