CHAPTER NO. 19(MODERN PHYSICS)

Question 19.1:- A particle called the pion lives on the average only about 2.6 x 10^{-8} s when at rest in the laboratory. It then changes into another form. How long would such a particle live when shooting through a space at 0.95 c?

Solution:- Lift time of pion at rest = t_o = 2.6 x 10^{-8} s

Speed of pion through space = v = 0.95 c

Life time of pion during motion = t

Special theory of relativity relation about time dilation is $t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$

v = 0.95 c

$\frac{v}{c} = 0.95$

$\frac{v^2}{c^2} = 0.90$

Put value of t_o and $\frac{v^2}{c^2}$ in the equation to find dilated life time of pion

$t = \frac{2.6 \, x \, 10^{-8}}{\sqrt{1-0.90}}$

$t = (2.6 \, x \, 10^{-8})/(0.32)$

<u>t = 8.3 x 10^{-8} s</u>

Question 19.2:- what is the mass of 70 Kg man in a space rocket travelling at 0.8 c from us as measured from earth?

Solution:- Rest mass of the person = m_o = 70 kg

Speed of the rocket = v = 0.8 c

Mass during motion = m

Special theory of relativity relation about mass variation is $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$

v = 0.8 c

$\frac{v}{c} = 0.8$

$\frac{v^2}{c^2} = 0.64$

Put value of m_o and $\frac{v^2}{c^2}$ in the equation to find mass of person

$m = \frac{70}{\sqrt{1-0.64}}$

$m = (70)/(0.6)$

<u>m = 116.7 kg</u>

Question 19.3:- Find the energy of photon in (a) Radio-wave of wavelength 100 m (b) Green light of wavelength 50 nm (c) X-ray with wavelength 0.2 nm.

Solution:- (a) Wavelength of radiowaves = λ = 100 m

$E = \frac{h\,c}{\lambda} = \frac{(6.63\,x\,10^{-34})\,(3\,x\,10^{8})}{100} = \frac{1.989\,x\,10^{-25}}{100}$ = 1.989 x 10^{-27} J

$E = \frac{1.989 \text{ x } 10^{-27}}{1.6 \text{ x } 10^{-19}}$ eV

<u>E = 1.24 x 10^{-8} eV</u>

(b) Wavelength of green light = λ = 550 nm = 550 x 10^{-9} m = 5.50 x 10^{-7} m

$E = \frac{h\,c}{\lambda} = \frac{(6.63\,x\,10^{-34})\,(3\,x\,10^{8})}{5.50\,x\,10^{-7}} = \frac{1.989\,x\,10^{-25}}{5.50\,x\,10^{-7}}$ = 3.62 x 10^{-19} J

$E = \frac{3.62 \text{ x } 10^{-19}}{1.6 \text{ x } 10^{-19}}$ eV

<u>E = 2.25 eV</u>

(c) Wavelength of x-ray = λ = 0.2 nm = 0.2 x 10^{-9} m = 2.0 x 10^{-10} m

$E = \frac{h\,c}{\lambda} = \frac{(6.63\,x\,10^{-34})\,(3\,x\,10^{8})}{2.0\,x\,10^{-10}} = \frac{1.989\,x\,10^{-25}}{2.0\,x\,10^{-10}}$ = 9.945 x 10^{-16} J

$E = \frac{9.945 \text{ x } 10^{-16}}{1.6 \text{ x } 10^{-19}}$ eV = 6.2 x 10^{3} eV

<u>E = 6200 eV</u>

Question 19.4:- Yellow light of 577 nm wavelength is incident on a cesium surface. The stopping value is found to be 0.25 V. Find (a) maximum K.E of photoelectrons (b) the work function of cesium.

Solution:- Wavelength of yellow light = λ = 577 nm = 577 x 10^{-9} m = 5.77 x 10^{-7} m

Stopping potential = V_o = 0.25 V

(a) Maximum kinetic energy of photoelectrons = $K.E._{max}$ = V_o e = (0.25) (1.6 x 10^{-19})

$K.E._{max}$ = 0.4 x 10^{-19} J

<u>$K.E._{max}$ = 4 x 10^{-20} J</u>

(b) Work function of metal = ϕ = E – $K.E._{max}$ = $\frac{h\,c}{\lambda}$ - $K.E._{max}$ = $\frac{(6.63\,x\,10^{-34})\,(3\,x\,10^{8})}{5.77\,x\,10^{-7}}$ – (4 x 10^{-20})

ϕ = (3.45 x 10^{-19}) – (4 x 10^{-20}) = 3.05 x 10^{-19} J

$\phi = \frac{3.05 \text{ x } 10^{-19}}{1.6 \text{ x } 10^{-19}}$ eV

<u>ϕ = 1.91 eV</u>

Question 19.5:- X-ray of wavelength 22 pm are scattered from a carbon target. The scattered radiation being viewed at 85° to the incident beam. What is Compton shift?

Solution:- Wavelength of x-rays = λ = 22 pm = 22 x 10^{-12} m

Angle of scattering = θ = 85^o

Compton shift = $\Delta\lambda = \frac{h}{m_o c}\,(1 - \cos\theta)$

$\Delta\lambda = \frac{(6.63\,x\,10^{-34})}{(9.1\,x\,10^{-31})(3\,x\,10^{8})}(1 - \cos 85^o)$ = (2.43 x 10^{-12}) (1 – 0.09)

$\Delta\lambda = 2.2 \times 10^{-12}$ m

<u>**$\Delta\lambda = 2.2$ pm**</u>

Question 19.6:- A 90 keV X-ray photon is fired at a carbon target and Compton scattering occurs. Find the wavelength of the incident photon and wavelength of the scattered photon for scattering angle (a) 30° (b) 60°.

Solution:- Energy of x-ray photon = E = 90 keV = 90×10^3 eV = $90 \times 10^3 \times 1.6 \times 10^{-19}$ J

$E = 1.44 \times 10^{-14}$ J

Wavelength of incident beam = λ

$E = \frac{h\,c}{\lambda}$

$\lambda = \frac{h\,c}{E} = \frac{(6.63 \times 10^{-34})\,(3 \times 10^{8})}{1.44 \times 10^{-14}} = \frac{1.989 \times 10^{-25}}{1.44 \times 10^{-14}} = 1.38 \times 10^{-11}$ m

<u>**$\lambda = 13.8$ pm**</u>

(a) Scattering angle = θ = 30°

Compton shift = $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_o c}\,(1 - \cos\theta)$

$\lambda' = \lambda + \frac{h}{m_o c}\,(1 - \cos\theta) = (13.8 \times 10^{-12}) + \frac{(6.63 \times 10^{-34})}{(9.1 \times 10^{-31})(3 \times 10^{8})}(1 - \cos 30^o)$

$\lambda' = (13.8 \times 10^{-12}) + [(2.43 \times 10^{-12})\,(1 - 0.866)]$

$\lambda' = (13.8 \times 10^{-12}) + (0.3 \times 10^{-12})$

$\lambda' = 14.1 \times 10^{-12}$ m

<u>**$\lambda' = 14.1$ pm**</u>

(a) Scattering angle = θ = 60°

Compton shift = $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_o c}\,(1 - \cos\theta)$

$\lambda' = \lambda + \frac{h}{m_o c}\,(1 - \cos\theta) = (13.8 \times 10^{-12}) + \frac{(6.63 \times 10^{-34})}{(9.1 \times 10^{-31})(3 \times 10^{8})}(1 - \cos 60^o)$

$\lambda' = (13.8 \times 10^{-12}) + [(2.43 \times 10^{-12})\,(1 - 0.5)]$

$\lambda' = (13.8 \times 10^{-12}) + (1.2 \times 10^{-12})$

$\lambda' = 15 \times 10^{-12}$ m

<u>**$\lambda' = 15$ pm**</u>

Question 19.7:- What is the maximum wavelength of the two photons produced when a positron annihilates an electron? The rest mass energy of each is 0.51 MeV.

Solution:- Minimum energy of γ-ray photon as a result of mass annihilation = E_{min} = 0.51 MeV

$E_{min} = 0.51 \times 10^6 \times 1.6 \times 10^{-19}$ J $= 0.816 \times 10^{-13}$ J

$E_{min} = 8.16 \times 10^{-14}$ J

$E_{min} = \frac{h\,c}{\lambda_{max}}$

$\lambda_{max} = \frac{h\,c}{E_{min}} = \frac{(6.63 \times 10^{-34})\,(3 \times 10^{8})}{8.16 \times 10^{-14}} = \frac{1.989 \times 10^{-25}}{8.16 \times 10^{-14}} = 0.244 \times 10^{-11}$ m

$\lambda_{max} = 2.44 \times 10^{-12}$ m

$\lambda_{max} = 2.44$ pm

Question 19.8:- Calculate the wavelength of (a) a 140 g ball moving at 40 m s^{-1} (b) a proton moving at the same speed (c) an electron moving at the same speed.

Solution:- (a) Mass of the ball = m = 140 g = 0.140 kg

Speed of the ball = v = 40 m s^{-1}

de Broglie wavelength = λ = h/mv = $(6.63 \times 10^{-34})/(0.140)\,(40)$

$\lambda = 1.18 \times 10^{-34}$ m

(b) Mass of the proton = m = 1.67×10^{-27} kg

Speed of the proton = v = 40 m s^{-1}

de Broglie wavelength = λ = h/mv = $(6.63 \times 10^{-34})/(1.67 \times 10^{-27})\,(40)$

$\lambda = 9.92 \times 10^{-9}$ m

λ = 9.92 nm

(c) Mass of the electron = m = 9.1×10^{-31} kg

Speed of the ball = v = 40 m s^{-1}

de Broglie wavelength = λ = h/mv = $(6.63 \times 10^{-34})/(9.1 \times 10^{-31})\,(40)$

$\lambda = 1.82 \times 10^{-5}$ m

Question 19.9:- What is the de Broglie wavelength of an electron whose kinetic energy is 120 eV?

Solution:- Kinetic energy of the electron = K.E. = 120 eV = $120 \times 1.6 \times 10^{-19}$ J

K.E. = 1.92×10^{-17} J

Mass of the electron = m = 9.1×10^{-31} kg

de Broglie wavelength = $\lambda = \frac{h}{\sqrt{2\,m\,K.E.}}$

$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2\,(9.1 \times 10^{-31})\,(1.92 \times 10^{-17})}} = (6.63 \times 10^{-34})/(5.91 \times 10^{-24})$

$\lambda = 1.12 \times 10^{-10}$ m

Question 19.10:- An electron is placed in a box about the size of an atom that is about 1.0×10^{-10} m. What is the velocity of electron?

Solution:- Mass of the electron = m = 9.1×10^{-31} kg

Size of the box = Δx = 1.0×10^{-10} m

Speed of the electron = Δv

According to uncertainty principle Δp Δx = h

(m Δv) (Δx) = h

$\Delta v = h/m\Delta x$

$\Delta v = (6.63 \times 10^{-34})/(9.1 \times 10^{-31})(1.0 \times 10^{-10})$

$\Delta v = 7.29 \times 10^{6}\ m\ s^{-1}$