Question #58653, Physics / Quantum Mechanics | completed

A particular x-ray photon has wavelength of 41.5pm. Calculate photon (a) energy, (b) frequency, (c) momentum.

Solution:

$\lambda = 41.5 \text{ pm} = 41.5 \cdot 10^{-12}\ m$

a) Relationship between wavelength of photons and its energy: $E = h\nu = h \cdot \frac{c}{\lambda}$,

where $c = 3 \cdot 10^8 \frac{m}{s}$ – is the speed of light and

$h = 6.626070040(81) \times 10^{-34} J \cdot s = 4.135667662(25) \times 10^{-15}\ eV \cdot s$ – Planck's constant

$$E = h \cdot \frac{c}{\lambda} = 4.136 \cdot 10^{-15}[\text{eV} \cdot s] \cdot \frac{3 \cdot 10^8[\text{m/s}]}{41.5 \cdot 10^{-12}[\text{m}]} = 29899\ [\text{eV}]$$

or in SI units:

$$E = h \cdot \frac{c}{\lambda} = 6.626 \cdot 10^{-34}[\text{J} \cdot s] \cdot \frac{3 \cdot 10^8[\text{m}/s]}{41.5 \cdot 10^{-12}[\text{m}]} = 4.79 \cdot 10^{-15}[\text{J}]$$

b) It is known the frequency of photon f can find from

$f = \frac{c}{\lambda} = \frac{3 \cdot 10^8[\text{m}/s]}{41.5 \cdot 10^{12}[\text{m}]} = 7.23 \cdot 10^{18}\ [\text{Hz}]$

or can find from a):

$$E = h \cdot \frac{c}{\lambda} = h \cdot f \Longrightarrow \quad f = \frac{E}{h} = \frac{4.79 \cdot 10^{-15}[\text{J}]}{6.626 \cdot 10^{-34}[\text{J} \cdot s]} = \frac{29899[\text{eV}]}{4.136 \cdot 10^{-15}[\text{eV} \cdot s]} = 7.23 \cdot [\text{Hz}]$$

c) We can calculate the momentum of the photon using the famous De Broglie wavelength formula:

$$\lambda = \frac{h}{p} \Longrightarrow p = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-34}\ [\text{J} \cdot s]}{41.5 \cdot 10^{-12}\ [m]} = 1.597 \cdot 10^{-23}[\text{kg} \cdot \text{m}/s]$$

Answer:

a) $E = h\frac{c}{\lambda} = 29899\ eV = 4.79 \cdot 10^{-15}\ J$

b) $f = \frac{c}{\lambda} = 7.23 \cdot 10^{18}\ \text{Hz}$

c) $p = \frac{h}{\lambda} = 1.597 \cdot 10^{-23}\text{kg} \cdot \text{m/s}$