King Saud University
College of Applied Studies
and Community Service
Department of Natural Sciences

Quantum Theory of Light

General Physics II
PHYS 111

Nouf Alkathran
nalkathran@ksu.edu.sa

Questions

- In the Compton experiment, the wavelength of the scattered light is________ the wavelength of the incident light.

(A) longer than

(B) the same as

(C) shorter than

Questions

- Suppose visible light of wavelength = 5 x 10 m is used to determine the position of an electron to within the wavelength of the light. What is the minimum uncertainty in the electron's speed?

We shall use the Heisenberg uncertainty relation

$$\Delta x \, \Delta p = \frac{h}{4\pi}.$$

With $p = mv$, and assuming negligible uncertainty in the mass of the electron, we find

$$\Delta v = \frac{h}{4\pi m \Delta x} = \frac{6.63 \times 10^{-34}\ \mathrm{J \cdot s}}{4\pi \cdot 9.11 \times 10^{-31}\ \mathrm{kg} \cdot 5 \times 10^{-7}\ \mathrm{m}} = 115.8 \frac{\mathrm{m}}{\mathrm{s}}.$$

Thus, the minimum uncertainty in the electron's speed is 115.8 m/s.

Questions

- (a)Calculate the wavelength in meters of an electron traveling at 1.24 x10^{7} m/s. The mass of an electron is 9.11x 10^{-28}g.

(a)

$$m = 9.11 \times 10^{-28}\ \text{g} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 9.11 \times 10^{-31}\ \text{kg}$$

Substituting into the de Broglie equation,

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\ \dfrac{\text{kg}\cdot\text{m}^2}{\text{s}}}{(9.11 \times 10^{-31}\ \text{kg})\left(1.24 \times 10^{7}\ \dfrac{\text{m}}{\text{s}}\right)} = \boxed{5.87 \times 10^{-11}\ \text{m}}$$

Questions

- A green line of wavelength 4.86×10^{-19} m is observed in the emission spectrum of hydrogen. Calculate the energy of one photon of this green light.

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ \mathrm{J \cdot s})(3.00 \times 10^{8}\ \mathrm{m/s})}{(4.86 \times 10^{-7}\ \mathrm{m})} = 4.09 \times 10^{-19}\ \mathrm{J/photon}$$

Questions

Planck's constant………….

A) remains unknown to this day.

B) is the inverse of Einstein's constant.

C) is used to find the quantum energy associated with a certain frequency of light.

D) is not really constant since it varies from one part of the universe to another.

Questions

- A light source of wavelength λ illuminates a metal and ejects photoelectrons with a maximum kinetic energy of 1.00 eV. A second light source with half the wavelength of the first ejects photoelectrons with a maximum kinetic energy of 4.00 eV. • Determine the work function of the metal.

$$\begin{aligned} K_1 &= \frac{hc}{\lambda_1} - \phi \\ K_2 &= \frac{hc}{\lambda_2} - \phi \end{aligned}$$

where $\lambda_2 = 0.5\,\lambda_1$, so

$$K_2 - 2K_1 = \phi$$

and therefore $\phi = 2\,\mathrm{eV}$ when $K_1 = 1\,\mathrm{eV}$ and $K_2 = 4\,\mathrm{eV}$.

<u>Questions</u>

Which statement is TRUE?

A) Light always behaves like a wave and electrons always behave like particles.

B) Light always behaves like a particle and electrons always behave like waves.

C) <u>Both light and electrons behave sometimes like waves and sometimes like particles.</u>

D) Light and electrons never behave like waves or particles.

Questions

How many Joules of energy are contained in a photon with $\lambda = 550$ nm?

- Use $f = c / \lambda$ to get the frequency:

  $f = (3.00 \times 10^{8}\ \text{m/s}) / (550 \times 10^{-9}\ \text{m}) = 5.4508 \times 10^{14}\ \text{s}^{-1}$.

- Now use $E = h\nu$ to get the energy:

  $E = (6.6260755 \times 10^{-34}\ \text{J s})\ (5.4508 \times 10^{14}\ \text{s}^{-1})$

  $= 3.612 \times 10^{-19}$ J.

Questions

What is the energy of a quantum of light with a frequency of 3.87×10^{19} Hz?

$$E = hf = (6.6260755 \times 10^{-34}\ \text{J s})\ (3.87 \times 10^{19}\ \text{s}^{-1})$$
$$= 2.56 \times 10^{-14}\text{J}$$