Arts & Science 2D06

Quiz #6 2015 Feb 26 Name: Solutions

NB: Mark values are given in brackets [ ] beside each problem. Write all your answers on the quiz paper. No books or notes allowed. Time to write quiz: 50 minutes.

Wave function: $y = A\sin(kx - \omega t + \varphi)$ where $k = 2\pi/\lambda$

Two-slit interference: $\sin\theta = m\lambda/d$ and $\sin\theta = (m+1/2)\lambda/d$

Diffraction: $\sin\theta = m\lambda/a$

Photon energy: $E = hf$

$1\ MeV = 1.6 \times 10^{-13}$J

---

1. [3] Consider a single-slit diffraction experiment. If the light's wavelength is increased, what happens to the diffraction pattern?

→ (a) The central maximum broadens.
(b) The minima remain the same.
(c) Eventually a double-slit interference pattern appears.
(d) The central maximum narrows.
(e) The minima get closer together.

$\sin\theta = \frac{m\lambda}{a}$

$\lambda \uparrow \Rightarrow \sin\theta \uparrow$

$\Rightarrow \theta \uparrow$

∴ central max. broadens

2. [3] Two beams of light travel different paths and arrive at a point P. If the maximum destructive interference is to occur at this point P, what should be the phase difference between the two waves upon arrival?

(a) The phase difference between the two waves is $\pi/4$.
(b) The phase difference between the two waves is $\pi/2$.
→ (c) The phase difference between the two waves is π.
(d) The phase difference between the two waves is 2π.
(e) The two waves are in phase.

At P, if the two rays look like

One is shifted by $\frac{\lambda}{2}$ relative to the other.

$\frac{\lambda}{2} \rightarrow \pi$ phase shift

3. [5] Suppose a "gamma-ray" (i.e., a high-energy photon) has an energy of 1 MeV. What is the frequency associated with this photon? Also, calculate the photon's wavelength.

- frequency: $E_{photon} = hf$

$$f = \frac{1\ \text{MeV}\left(\frac{1.6\times10^{-13}\ \text{J}}{1\ \text{MeV}}\right)}{6.63\times10^{-34}\ \text{J}\cdot\text{s}}$$

$$\therefore \quad \underline{f = 2.4\times10^{20}\ \text{s}^{-1}}$$

- Wavelength: $E_{photon} = \frac{hc}{\lambda}$

$$\lambda = \frac{(6.63\times10^{-34})(3\times10^{8})}{1.6\times10^{-13}}$$

$$\therefore \quad \underline{\lambda = 1.24\times10^{-12}\ \text{m}}$$

4. [5] A wave has an amplitude of 20.0 cm and a wavelength of 3.00 m. Suppose we also know that the wave travels 60.0 m in 12.0 s. What is the frequency of this wave? What is its period?

$\lambda = 3\ m$

- Wave speed $V = \frac{60\ m}{12\ s} = 5\ m/s$

$\therefore$ frequency: $f = \frac{V}{\lambda} = \frac{5}{3} = 1.7\ s^{-1}$

Period: $T = \frac{1}{f} = 0.6\ s$

5. [4] In a two-slit experiment, the third bright fringe away from the central fringe is observed at an angle of 7.0 degrees. If the wavelength of the light is 490 nm, what is the distance between the two slits?

- 3rd bright fringe away from central fringe : $m = 3$, $\theta_3 = 7°$

interference max. : $\sin\theta = \frac{m\lambda}{d}$

$$\therefore \quad \sin 7° = \frac{3\,(490 \times 10^{-9}\,m)}{d}$$

$$d = \frac{1.47 \times 10^{-6}}{0.12}$$

$$d = 1.2 \times 10^{-5}\ m \quad (\text{or } 12\ \mu m)$$

20

[20] total marks