Wave Optics

Here are six numerical problems involving frequency, wavelength, and the velocity of light:

Problem 1

Given: The speed of light in vacuum $c = 3.0 \times 10^8 \, \text{m/s}$ and the wavelength $\lambda = 500 \, \text{nm}$.
Find: The frequency of light, f.

Solution:

$$f = \frac{c}{\lambda}$$

Convert wavelength to meters: $500 \, \text{nm} = 500 \times 10^{-9} \, \text{m}$.

$$f = \frac{3.0 \times 10^8}{500 \times 10^{-9}} = 6.0 \times 10^{14} \, \text{Hz}$$

Problem 2

Given: A wave has a frequency of $f = 4.5 \times 10^{14} \, \text{Hz}$ in a medium where the speed of light is $v = 2.25 \times 10^8 \, \text{m/s}$.
Find: The wavelength λ of the wave.

Solution:

$$\lambda = \frac{v}{f} = \frac{2.25 \times 10^8}{4.5 \times 10^{14}} = 5.0 \times 10^{-7} \, \text{m or } 500 \, \text{nm}$$

Problem 3

Given: The wavelength of red light is $\lambda = 650 \, \text{nm}$ and its frequency is $f = 4.6 \times 10^{14} \, \text{Hz}$.
Verify: Calculate the speed of light v and verify if it matches the expected value $3.0 \times 10^8 \, \text{m/s}$.

Solution: Convert wavelength to meters: $650 \, \text{nm} = 650 \times 10^{-9} \, \text{m}$.

$$v = f\lambda = (4.6 \times 10^{14}) \times (650 \times 10^{-9}) = 2.99 \times 10^8 \, \text{m/s}$$

So, $v \approx 3.0 \times 10^8 \, \text{m/s}$, verifying the expected value.

Problem 4

Given: The speed of light in water is $v = 2.25 \times 10^8\,\mathrm{m/s}$. Calculate the frequency of blue light ($\lambda = 450\,\mathrm{nm}$) in water.

Solution: Convert wavelength to meters: $450\,\mathrm{nm} = 450 \times 10^{-9}\,\mathrm{m}$.

$$f = \frac{v}{\lambda} = \frac{2.25 \times 10^8}{450 \times 10^{-9}} = 5.0 \times 10^{14}\,\mathrm{Hz}$$

Problem 5

Given: A green light wave has a frequency of $f = 5.5 \times 10^{14}\,\mathrm{Hz}$.
Find: Its wavelength λ in air, where the speed of light $c = 3.0 \times 10^8\,\mathrm{m/s}$.

Solution:

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{5.5 \times 10^{14}} = 5.45 \times 10^{-7}\,\mathrm{m} \text{ or } 545\,\mathrm{nm}$$

Problem 6

Given: A radio wave has a wavelength of $1500\,\mathrm{m}$ and travels at the speed of light in air, $c = 3.0 \times 10^8\,\mathrm{m/s}$.
Find: The frequency f of the radio wave.

Solution:

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{1500} = 2.0 \times 10^5\,\mathrm{Hz} \text{ or } 200\,\mathrm{kHz}$$
