EXERCISE 2.4

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Gr 10 Physical Sciences 3-in-1

QUESTION 1

The electromagnetic spectrum includes amongst others, radio waves, ultraviolet light, gamma rays, visible rays and x-rays.

1.1 List TWO common properties of all electromagnetic waves.

1.2 Briefly explain what is meant by the DUAL nature of electromagnetic radiation.

1.3 Briefly explain how electromagnetic radiation is propagated through space.

1.4 The frequency of a certain electromagnetic wave, is $5{,}5 \times 10^{14}$ Hz and the period of another electromagnetic wave is $3{,}5 \times 10^{-14}$ s. Calculate the wavelengths of the waves.

1.5 A certain radio program is broadcasted at a frequency of 120 MHz in the HF band and another program is broadcasted at a frequency of 60 kHz in the MF band. Calculate the corresponding wavelengths of the two waves.

1.6 Two waves have wavelengths of 3 cm and 6 μm respectively. Calculate the corresponding frequencies of the waves.

QUESTION 2

2.1 A photon associated with a certain electromagnetic wave has $1{,}66 \times 10^{-24}$ J of energy.

2.1.1 Define the term *photon*.

2.1.2 What is the speed at which this electromagnetic wave travels through space?

2.1.3 Calculate the wavelength of this electromagnetic wave in metres.

2.2 The wavelength of this electromagnetic wave was doubled.

2.2.1 What effect would this have on its penetrating ability? Write only INCREASE, DECREASE or REMAIN THE SAME.

2.2.2 Briefly explain your answer in QUESTION 2.2.1.

2.3 Blue light with a frequency of $6{,}6 \times 10^{14}$ Hz is incident on a metal surface.

2.3.1 How does the energy of a photon of the blue light compare to the energy of the photon mentioned in QUESTION 2.1. Will it be LESS, THE SAME or MORE? Motivate your answer at the hand of a calculation.

2.3.2. Calculate the energy that can be transferred by blue light that contains $1{,}37 \times 10^{17}$ photons.

QUESTION 3

3.1 Radio stations broadcast to listeners by means of electromagnetic radiations called radio waves. Listed below is information about TWO different radio stations:

Radio Station 1 – broadcasts at a frequency of 97,60 MHz

Radio Station 2 – has radiations of wavelength $1{,}50 \times 10^{13}$ *m*

3.1.1 Calculate the energy of a photon associated with Radio Station 1.

3.1.2 The owner of Radio Station 2 claims that his transmitter operates at a frequency of 2 MHz. Use a calculation to help explain why his claim is INCORRECT.

3.1.3 How will energy of a photon transmitted from Radio Station 2 be affected if its wavelength was decreased? Choose from INCREASES, DECREASES or REMAINS THE SAME.

3.1.4 Explain your answer in QUESTION 3.1.3

3.2 The Wi-Fi (Wireless Fidelity) has fast become a very necessary tool for electronic communication, learning and accessing social platforms. Electromagnetic waves are essential in wireless communication. Wi-Fi makes use of low frequency electromagnetic waves, i.e. 2,4 GHz and 5 GHz to send signals between devices and transmit data.

3.2.1 Name the type of electromagnetic waves used in Wi-Fi.

3.2.2 State ONE advantage that the type of radiation named in QUESTION 3.2.1 has for the use of Wi-Fi.

3.2.3 How will the **wavelength** of, and the **energy** transferred by the 2 GHz signal/wave compare to that of the 5 GHz signal?

3.2.4 Calculate the energy transferred by a Wi-Fi signal of 5 GHz.

EXERCISE ANSWERS

QUESTION 1

1.1 The different types of electromagnetic waves all travel at 3×10^8 m·s^{-1} through space.

Electromagnetic waves do not require a material medium to move between two points, but can move through space.

1.2 It means that electromagnetic radiation have both a wave and particle nature, Some properties of electromagnetic radiation can best be described by using a wave model and other properties can best be described by using a particle model.

1.3 Electromagnetic radiation is propagated through space at 3×10^8 m.s^{-1} by magnetic and electric fields that repeatedly regenerate each other.

1.4

(1)

$$c = f\lambda$$
$$\therefore 3 \times 10^8 = 5{,}5 \times 10^{14}\lambda$$
$$\therefore \lambda = \frac{3 \times 10^8}{5{,}5 \times 10^{14}}$$
$$= 5{,}45 \times 10^{-7}\text{ m}$$

$\boxed{f = 5{,}5 \times 10^{14}\text{ Hz}}$

(2)

$$f = \frac{1}{T}$$
$$\therefore c = \frac{1}{T}\lambda$$
$$\therefore 3 \times 10^8 = \frac{1}{3{,}5 \times 10^{-14}}\lambda$$
$$\therefore \lambda = (3 \times 10^8)(3{,}5 \times 10^{-14})$$
$$= 1{,}05 \times 10^{-5}\text{ m}$$

$\boxed{T = 3{,}5 \times 10^{-14}\text{ s}}$

1.5

(1)

$$c = f\lambda$$
$$\therefore 3 \times 10^8 = 1{,}2 \times 10^8\lambda$$
$$\therefore \lambda = \frac{3 \times 10^8}{1{,}2 \times 10^8}$$
$$= 2{,}5\text{ m}$$

$f = 120$ MHz
$= 120 \times 10^6$ Hz
$= 1{,}2 \times 10^8$ Hz

(2)

$$c = f\lambda$$
$$\therefore 3 \times 10^8 = 6 \times 10^4\lambda$$
$$\therefore \lambda = 0{,}5 \times 10^4$$
$$= 5\ 000\text{ m}$$

$f = 60$ kHz
$= 60 \times 10^3$ Hz
$= 6 \times 10^4$ Hz

1.6

(1)

$$c = f\lambda$$
$$\therefore 3 \times 10^8 = f(0{,}03)$$
$$\therefore f = \frac{3 \times 10^8}{3 \times 10^{-2}}$$
$$= 10^{10}\text{ Hz}$$

$\lambda = 3$ cm
$= 0{,}03$ m
$= 3 \times 10^{-2}$ m

(2)

$$c = f\lambda$$
$$\therefore 3 \times 10^8 = f(6 \times 10^{-6})$$
$$\therefore f = \frac{3 \times 10^8}{6 \times 10^{-6}}$$
$$= 5 \times 10^{13}\text{ Hz}$$

$\lambda = 6$ µm
$= 6 \times 10^{-6}$ m

QUESTION 2

2.1.1 A photon is the smallest indivisible quantity ('packet') of energy that light and other electromagnetic radiation consist of.

2.1.2 3×10^8 m·s^{-1}

2.1.3 $E = h\frac{c}{\lambda}$

$\boxed{E = 1{,}66 \times 10^{-24}\ J}$

$\therefore 1{,}66 \times 10^{-24} = \frac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{\lambda}$

$\therefore \lambda = \frac{1{,}989 \times 10^{-25}}{1{,}66 \times 10^{-24}}$

$\approx 0{,}20\ m$

2.2.1 decrease

2.2.2 The energy of the radiation is inversely proportional to the wavelength. If the wavelength is doubled, the energy of the photons will be halved and thus the penetration ability of the radiation will be less.

2.3.1 MORE

$E_{blue} = hf_{blue}$

$\boxed{f_{blue} = 6{,}6 \times 10^{14}\ Hz}$

$= 6{,}63 \times 10^{-34} \times 6{,}6 \times 10^{14}$

$= 4{,}3758 \times 10^{-19}\ J > 1{,}66 \times 10^{-24}\ J$

$\therefore$ the $E_{blue} > E_{photon\ 1}$

NOTE

Other options are to

1) calculate λ_{blue} with $\lambda = \frac{c}{f}$ and indicate that $\lambda_{blue} < \lambda_1$ ***OR***

2) calculate f_1 with $f = \frac{c}{\lambda}$ and indicate that $f_{blue} > f_1$

2.3.2 $E_{blue} = E_{photon} \times$ no. of photons

$= 4{,}38 \times 10^{-19} \times 1{,}37 \times 10^{17}$

$= 0{,}06\ J$

QUESTION 3

3.1.1 $E = hf$

$= 6{,}63 \times 10^{-34} \times 9{,}76 \times 10^{7}$

$= 6{,}47 \times 10^{-28}\ J$

$f = 97{,}6$ MHz
$= 97{,}6 \times 10^{6}$ Hz
$= 9{,}76 \times 10^{7}$ Hz

3.1.2 $c = f\lambda$

$\therefore 3 \times 10^{8} = f(1{,}5 \times 10^{3})$

$\therefore f = \frac{3 \times 10^{8}}{1{,}5 \times 10^{3}}$

$= 2 \times 10^{5}\ Hz$

$= 0{,}2\ MHz$

The frequency is not 2 MHz but 0,2 MHz

3.1.3 increase

3.1.4 The energy is inversely proportional to the wavelength. If the wavelength decreases, the energy will increase.

3.2.1 Radio waves

3.2.2 Radio waves have a low frequency and energy and is therefore not harmful to your body.

3.2.3 The wavelength of the 2 GHz signal will be longer, but the energy transferred will be lower than that of the 5 GHz signal.

3.2.4 $E = hf$

$= (6{,}63 \times 10^{-34})(5 \times 10^{9})$

$= 3{,}315 \times 10^{-24}\ J$

$f = 5$ GHz
$= 5 \times 10^{9}$ Hz