#420527

Topic: Electromagnetic Spectrum

What physical quantity is the same for X-rays of wavelength $10^{-10}m$, red light of wavelength 6800 $\mathring{A}$ and radiowaves of wavelength 500m?

Solution

The speed in vacuum is the same for all, $c = 3 \times 10^8 m/s$

#420528

Topic: Nature of Electromagnetic Waves

A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the directions of its electric and magnetic field vectors? If the frequency of the wave is 30 MHz, what is its wavelength?

Solution

Wave travel along z-direction.

Electric and magnetic field are in XY plane and perpendicular to each other.

$\lambda = c/\nu = 10\ m$

#420529

Topic: Electromagnetic Spectrum

A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

Solution

$f_1 = 7.5 \times 10^6\ Hz$

$f_2 = 12 \times 10^6\ Hz$

$\lambda_1 = c/f_1 = 40\ m$

$\lambda_2 = c/f_2 = 25\ m$

So the range is 40m to 25m

#420530

Topic: Nature of Electromagnetic Waves

A charged particle oscillates about its mean equilibrium position with a frequency of $10^9\ Hz$. What is the frequency of the electromagnetic waves produced by the oscillator?

Solution

The frequency of an electromagnetic wave produced by the oscillator is same as that of charged particle oscillating about its mean position i.e., $10^9 Hz$.

#420531

Topic: Nature of Electromagnetic Waves

The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 510\ nT$. What is the amplitude of the electric field part of the wave?

Solution

$B_0 = 510 \times 10^{-9} T$

$C = 3 \times 10^8 m/s$

$E = cB_o = 153 N/C$

#420535

Topic: Nature of Electromagnetic Waves

Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120\ N/C$ and that its frequency is $\nu = 50.0 MHz$

(a) Determine, $B_0,\ \omega,\ k,\ and\ \lambda$

(b) Find the expression for E and B.

Solution

(a)

$B_o = E_o/c = 400nT$

$\omega = 2\pi\nu = 3.14 \times 10^8\ rad/s.$

$k = \omega/c = 1.05$ rad/m

$\lambda = c/\nu = 6m$

(b)

Suppose wave is moving along x-direction, Electric field be along y-direction and magnetic field along the z-direction.

$E = E_o sin(kx - \omega t)\hat{j} = 120 sin(1.05x - 3.14 \times 10^8 t)\hat{j}$

Similarly,

$B = 4 \times 10^{-7} sin(1.05x - 3.14 \times 10^8 t)\hat{k}$

#420544

Topic: Nature of Electromagnetic Waves

In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of $2.0\ \times\ 10^{10} Hz$ and amplitude $48\ V\ m^{-1}$.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) Show that the average energy density of the E field equals the average energy density of the B field. [c = 3 $\times 10^8 ms^{-1}$]

Solution

(a)

The wavelength is given by $\lambda = \dfrac{c}{v} = \dfrac{3 \times 10^8}{2 \times 10^{10}} = 1.5 \times 10^{-2} m$

(b)

$B_o = E_o/c = 1.6 \times 10^{-7} T$

(c)

Energy density due to the electric field, $E_E = \dfrac{1}{2}\epsilon_o E^2$

Energy density due to the magnetic field, $E_B = \dfrac{1}{2}B^2/\mu_o$

also, $c = \dfrac{1}{\sqrt{\epsilon_0 \mu_o}}$

on solving above equations, $E_E = E_B$

#420549

Topic: Nature of Electromagnetic Waves

Suppose that the electric field part of an electromagnetic wave in vacuum is $E\ =\ (3.1\ N/C)\ cos\ [(1.8\ rad/m)\ y\ +\ (5.4\ \times\ 10^6\ rad/s)\ t]\ \hat{i}$

(a) What is the direction of propagation?

(b) What is the wavelength λ ?

(c) What is the frequency v?

(d) What is the amplitude of the magnetic field part of the wave?

(e) Write an expression for the magnetic field part of the wave.

Solution

(a)

Electric field is directed along negative x-direction.

hence the direction of motion is along the negative y-direction.

(b)

From the given equation, $k = 1.8\ rad/m$

$\lambda = 2\pi/k = 3.49$

(c)

Frequency of wave is $\nu = \omega/2\pi = 8.6 \times 10^7 = 86\ Mhz$

(d)

For the given equation, $E_o = 3.1N/C$

$B_o = E_o/c = 1.03 \times 10^{-7} = 103nT$

(e)

Magnetic wave is directed along negative z-direction.

Thus, $B = B_o cos(ky + \omega t)\hat{k}$

$\Rightarrow B = 1.03 \times 10^{-7} cos(1.8y + 5.4 \times 10^6 t)\hat{k}$

#420617

Topic: Electromagnetic Spectrum

Given below are some famous numbers associated with electromagnetic radiations in different contexts in physics. State the part of the electromagnetic spectrum to which ea belongs.

(a) 21 cm (wavelength emitted by atomic hydrogen in interstellar space).

(b) 1057 MHz (frequency of radiation arising from two close energy levels in hydrogen; known as Lamb shift).

(c) 2.7 K [temperature associated with the isotropic radiation filling all space thought to be a relic of the big-bang origin of the universe].

(d) $5890\mathring{A} - 5896\mathring{A}$ [double lines of sodium]

(e) 14.4 ke V [energy of a particular transition in ^{57}Fe nucleus associated with a famous high resolution spectroscopic method ($\mathrm{M\ddot{o}ssbauer\ spectroscopy}$)].

Solution

(a)

Radio waves have wavelengths of 1mm to 100km. Hence, 21cm lies at short wavelength end of radio waves.

(b)

Radio waves belong to the shortest wavelength in the electromagnetic spectrum.

(c)

$\lambda_m = 0.29/T = 0.11cm$

This wavelength corresponds to the microwaves.

(d)

Lines from 400nm to 700nm lies in visible range. The range of 589nm lies in Yellow part of visible spectrum.

(e)

$E = h\nu$

$\nu = 3.4 \times 10^{18} Hz$

This corresponds to the X-rays.

#421454

Topic: Nature of Electromagnetic Waves

Light of wavelength 5000 $\dot{A}$ falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

Solution

$\lambda = 5000 \times 10^{-10}\ m$

$\nu = c/\lambda = 6 \times 10^{14} Hz$

For the reflected light, λ, ν remains same.

i is the incident angle. r is the reflected angle.

$i + r = 90^o$

By, law of reflection, $i = r$

$\Rightarrow i = r = 45^o$

#421480

Topic: Nature of Electromagnetic Waves

Let us list some of the factors, which could possibly influence the speed of wave propagation:

(i) nature of the source.

(ii) direction of propagation.

(iii) motion of the source and/or observer.

(iv) wavelength.

(v) intensity of the wave.

On which of these factors, if any, does

(a) The speed of light in vacuum

(b) The speed of light in a medium (say, glass or water), depend?

Solution

The speed of light in vacuum is a universal constant independent of all the factors listed and anything else. In particular, note the surprising fact that it is independent of the relative motion between the source and the observer. This fact is a basic axiom of Einsteins special theory of relativity.

The speed of light in a vacuum which is $3 \times 10^8 m/s$ is a universal constant. It is not affected by motion of source, the observer, or both. Hence, the given factor does not affec the speed of light in a vacuum

Out of the listed factors, the speed of light in a medium depends on the wavelength of light in that medium.

#421503

Topic: Electromagnetic Spectrum

Find the

(a) maximum frequency

(b) Minimum wavelength of X-rays produced by 30 kV electrons.

Solution

(a). Potential of the electrons, $V = 30kV = 3 \times 10^4 V$

Hence, energy of the electrons, $E = 3 \times 104eV$

Where,

e = Charge on an electron = $1.6 \times 10^{-19} C$

Maximum frequency produced by the X-rays is ν

The energy of the electrons is given by the relation is $E = h\nu$

Where,

h = Planck's constant = $6.626 \times 10^{-34} Js$

$\nu = E/h = 7.24 \times 10^{18} Hz$

(b). Energy of a electron, $E = 30 \times 10^3 eV$

Let Maximum frequency produced by the X-rays be ν

$\nu = E/h = 1.6 \times 10^{-19} \times 3 \times 10^4 / 6.626 \times 10^{-34} = 7.24 \times 10^{18} Hz$where h is the planck's constant.

The minimum wavelength produced by the X-rays is given as-

$\lambda = c/\nu = 0.0414nm$