1.(a) Figure 8.6 shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15A.

Calculate the capacitance and the rate of change of potential difference between the plates.

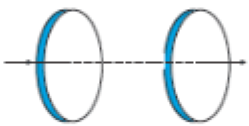

FIGURE 8.6

Answer:

Radius of the discs(r) = 12cm

Area of the discs(A) = $\pi r^2 = \pi(0.12)^2 = .045m^2$

Permittivity, $\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^2$

Distance between the two discs = 5cm=0.05m

$$Capacitance = \frac{\varepsilon_0 A}{d}$$

$$= \frac{8.85 \times 10^{-12} C^2 N^{-1} m^2 \times .045m^2}{0.05m}$$

$= 8.003 \times 10^{-12} F$

=8.003 pF

$$Rate\ of\ change\ of\ potential = \frac{dv}{dt}$$

But

$$V = \frac{Q}{C}$$

Therefore,

$$Rate\ of\ change\ of\ potential = \frac{d(\frac{Q}{C})}{dt} = \frac{dq}{Cdt} = \frac{i}{C}$$

$$= \frac{0.15A}{8.003pF}$$

$$= 1.87 \times 10^{10} Vs^{-1}$$

1(b). Figure 8.6 shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The

charging current is constant and equal to 0.15A.

Obtain the displacement current across the plates.

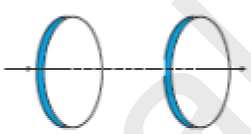

FIGURE 8.6

Answer:

The value of the displacement current will be the same as that of the conduction current which is given to be 0.15A. Therefore displacement current is also 0.15A.

1.(c) Figure 8.6 shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The
charging current is constant and equal to 0.15A.

Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

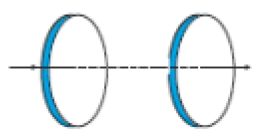

FIGURE 8.6

Answer:

Yes, Kirchoff's First rule (junction rule) is valid at each plate of the capacitor. This might not seem like the case at first but once we take into consideration both the conduction and displacement current the Kirchoff's first rule will hold good.

2.(a) A parallel plate capacitor (Fig. 8.7) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of $300 rad s^{-1}$.

What is the rms value of the conduction current?

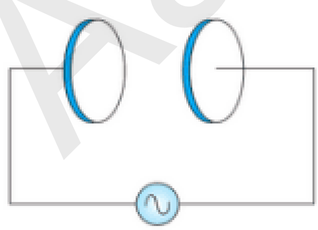

FIGURE 8.7

Answer:

Capacitance(C) of the parallel plate capacitor = 100 pF

Voltage(V) = 230 V

Angular Frequency (ω) = $300\ rad\ s^{-1}$

$$Rms\ Current(I) = \frac{Voltage}{Capacitive\ Reactance}$$

$$Capacitive\ Reactance(X_c) = \frac{1}{C\omega} = \frac{1}{100\ pF \times 300\ rad\ s^{-1}}$$

$$X_c = 3.33 \times 10^7\Omega$$

$$I = \frac{V}{X_c} = \frac{230V}{3.33 \times 10^7\Omega} = 6.9 \times 10^{-6}A$$

RMS value of conduction current is $6.9\mu A$

2.(b) A parallel plate capacitor (Fig. 8.7) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of $300rads^{-1}$

Is the conduction current equal to the displacement current?

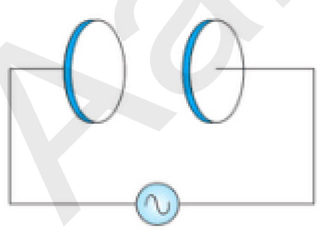

FIGURE 8.7

Answer:

Yes, conduction current is equal to the displacement current. This will be the case because otherwise, we will get different values of the magnetic field at the same point by taking two different surfaces and applying Ampere – Maxwell Law.

2.(c) A parallel plate capacitor (Fig. 8.7) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with a (angular) frequency of $300 rad\ s^{-1}$

Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

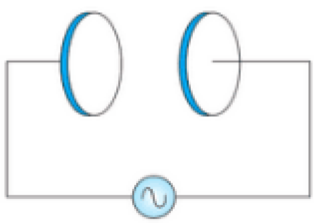

FIGURE 8.7

Answer:

We know the Ampere - Maxwells Law,

$$\oint B \cdot \vec{dl} = \mu_0 (i_c + \varepsilon_0 \frac{d\phi_E}{dt})$$

Between the plates conduction current $i_c = 0$.

For a loop of radius r smaller than the radius of the discs,

$$B(2\pi r) = \mu_0 i_d \frac{r^2}{R^2}$$

$$B = \mu_0 i_d \frac{r}{2\pi R^2}$$

Since we have to find the amplitude of the magnetic field we won't use the RMS value but the maximum value of current.

$$i_{max} = \sqrt{2} \times i_{rms}$$
$$i_{max} = \sqrt{2} \times 6.9\mu A$$
$$i_{max} = 9.76\mu A$$

The amplitude of B at a point 3.0 cm from the axis between the plates is $1.63 \times 10^{-11}T$.

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

Answer:

The speed with which these electromagnetic waves travel in a vacuum will be the same and will be equal to $3 \times 10^8 ms^{-1}$ (speed of light in vacuum).

4. 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?

Answer:

Since the electromagnetic wave travels along the z-direction its electric and magnetic field vectors are lying in the x-y plane as they are mutually perpendicular.

Frequency of wave = 30 MHz

Wavelength=

$$\frac{Speed\ of\ light}{Frequency} = \frac{3 \times 10^8}{30 \times 10^6}$$

$= 10m$.

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

Answer:

Frequency range = 7.5 MHz to 12 MHz

Speed of light = $3 \times 10^8 ms^{-1}$

Wavelength corresponding to the frequency of 7.5 MHz =

$$\frac{3 \times 10^8 ms^{-1}}{7.5 \times 10^6 Hz}$$

$= 40m$

Wavelength corresponding to the frequency of 12 MHz =

$$\frac{3 \times 10^8 ms^{-1}}{12 \times 10^6 Hz}$$

$= 25m$

The corresponding wavelength band is 25m to 40m.

6. 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?

Answer:

The frequency of the electromagnetic waves produced by the oscillation of a charged particle about a mean position is equal to the frequency of the oscillation of the charged particle. Therefore electromagnetic waves produced will have a frequency of 10^9 Hz.

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

Answer:

Magnetic Field (B_0)=510 nT = 510×10^{-9} T

Speed of light(c) = 3×10^8 ms $^{-1}$

Electric Field = $B_0 \times c$

= 510×10^{-9} T $\times 3 \times 10^8$ ms $^{-1}$

= 153 NC $^{-1}$

8. Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120N/C$ and that its frequency is $\nu = 50.0\ MHz$ (a) Determine, $B_0, \omega,\ k, \lambda$ (b) Find expressions for E and B.

Answer:

E_0 = 120 NC $^{-1}$

$\nu = 50.0\ MHz$

(a)

$$Magnetic\ Field\ amplitude(B0) = \frac{E_0}{c}$$

$$= \frac{120}{3 \times 10^8}$$

$$= 400nT$$

Angular frequency (ω) = 2 $\pi\nu$

$$= 2 \times \pi \times 50 \times 10^6$$

$= 3.14 \times 10^{8}$ rad s^{-1}

Propagation constant(k)

$$= \frac{2\pi}{\lambda}$$

$$= \frac{2\pi\nu}{\lambda\nu}$$

$$= \frac{\omega}{c}$$

$$= \frac{3.14 \times 10^8}{3 \times 10^8}$$

=1.05 rad m^{-1}

Wavelength(λ) = $\frac{c}{\nu}$

$$= \frac{3 \times 10^8}{50 \times 10^6} = 6m$$

Assuming the electromagnetic wave propagates in the positive z-direction the Electric field vector will be in the positive x-direction and the magnetic field vector will be in the positive y-direction as they are mutually perpendicular and $E_0 \times B_0$ gives the direction of propagation of the wave.

$$\vec{E} = E_0 sin(kx - \omega t)\hat{i}$$

$$= 120 sin(1.05x - 3.14 \times 10^8 t) NC^{-1}\hat{i}$$

$$\vec{B} = B_0 sin(kx - \omega t)\hat{j}$$

$$= 400 sin(1.05x - 3.14 \times 10^8 t)\ nT\hat{j}$$

9) The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula E = hv (for energy of a quantum of radiation: photon) and obtain the photon energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation?

Answer:

$$E = h\nu = \frac{hc}{\lambda}$$

$$E = h\nu = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} eV = \frac{12.375 \times 10^{-7}}{\lambda} eV$$

Now substitute the different range of wavelength in the electromagnetic spectrum to obtain the energy

EM wave	one wavelength is taken from the range	Energy in eV

Radio	1 m	1.2375×10^{-6}
Microwave	1 mm	1.2375×10^{-3}
Infra-red	1000 nm	1.2375
Light	500 nm	2.475
Ultraviolet	1nm	1237.5
X-rays	0.01 nm	123750
Gamma rays	0.0001 nm	12375000

10(a) In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of $20 \times 10^{10} Hz$ and amplitude $48 V m^{-1}$

What is the wavelength of the wave?

Answer:

Frequency(ν) =20×10^{10} Hz

$E_0 = 48$ Vm $^{-1}$

$$Wavelength(\lambda) = \frac{Speed\ of\ light(c)}{Frequency(\nu)}$$

$= \frac{3 \times 10^8}{20 \times 10^{10}}$

$= 1.5mm$

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

What is the amplitude of the oscillating magnetic field?

Answer:

The amplitude of the oscillating magnetic field(B_0) = $\frac{E_0}{c}$

$= \frac{48}{3 \times 10^8}$

$= 160nT$

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

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

Answer:

The average energy density of the Electric field(U_E)

$= \frac{1}{2}\epsilon E^2$

$= \frac{1}{2}\epsilon (Bc)^2$ (as E=Bc)

$= \frac{1}{2}\epsilon\frac{B^2}{\mu\epsilon}(c = \frac{1}{\sqrt{\mu\epsilon}})$

$=U_B$

Therefore the average energy density of the electric field is equal to the average energy density of the Magnetic field.

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

What is the direction of propagation?

Answer:

$$E = \left\{(3.1N/C)\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/st)]\right\}\hat{i}$$

The electric field vector is in the negative x-direction and the wave propagates in the negative y-direction.

11 (b) Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \left\{(3.1N/C)\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/st)]\right\}\hat{i}$$

What is the wavelength?

Answer:

From the equation of the wave given we can infer k = 1.8 rad m^{-1}

$$Wavelength(\lambda) = \frac{2\pi}{k}$$

$$= \frac{2\pi}{1.8}$$

$$= 3.49m$$

11 (c) Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \left\{(3.1N/C)\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/st)]\right\}\hat{i}$$

What is the frequency n?

Answer:

From the given equation of the electric field we can infer angular frequency(ω) = 5.4 $\times$ 10 ^{8} rad s $^{-1}$

Frequency(ν) = $\frac{\omega}{2\pi}$

$$= \frac{5.4 \times 10^8}{2\pi}$$

=8.6 $\times$ 10 ^{7} Hz

=86 MHz

11 (d) Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \left\{(3.1N/C)\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/st)]\right\}\hat{i}$$

What is the amplitude of the magnetic field part of the wave?

Answer:

From the given equation of the electric field, we can infer Electric field amplitude (E_0) =3.1 NC $^{-1}$

$$Magnetic field amplitude (B_0) = \frac{E_0}{c}$$

$$= \frac{3.1}{3 \times 10^8}$$

$=1.03 \times 10^{-7}$ T

11(e) Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \left\{(3.1N/C)\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/s)t]\right\}\hat{i}$$

Write an expression for the magnetic field part of the wave.

Answer:

As the electric field vector is directed along the negative x-direction and the electromagnetic wave propagates along the negative y-direction the magnetic field vector must be directed along the negative z-direction. ($-\hat{i} \times -\hat{k} = -\hat{j}$)

Therefore, $\vec{B} = \left\{B_0\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/s)t]\right\}\hat{k}$

$$\vec{B} = \left\{1.03 \times 10^{-7}\cos[(1.8rad/m)y + (5.4 \times 10^6 rad/s)t]\right\}T\hat{k}$$

12.(a) About 5% of the power of a 100 W light bulb is converted to visible radiation. What is the average intensity of visible radiation at a distance of 1m from the bulb?

Assume that the radiation is emitted isotropically and neglect reflection.

Answer:

Total power which is converted into visible radiation = 5% of 100W = 5W

The above means 5J of energy is passing through the surface of a concentric sphere(with the bulb at its centre) per second.

Intensity for a sphere of radius 1m

$$= \frac{5}{4\pi(1)^2}$$

=0.398 Wm $^{-2}$

12.(b) About 5% of the power of a 100 W light bulb is converted to visible radiation. What is the average intensity of visible radiation at a distance of 10 m? Assume that the radiation is emitted isotropically and neglect reflection.

Answer:

Total power which is converted into visible radiation = 5% of 100W = 5W

The above means 5J of energy is passing through the surface of a concentric sphere(with the bulb at its centre) per second.

Intensity for a sphere of radius 10 m

$$= \frac{5}{4\pi(10)^2}$$

=3.98 $\times$ 10 $^{-3}$ Wm $^{-2}$

13) Use the formula $\lambda_m T = 0.29 cmK$ to obtain the characteristic temperature ranges for different parts of the electromagnetic spectrum. What do the numbers that you obtain tell you?

Answer:

EM wave	one wavelength is taken from the range	Temperature $T = \frac{0.29}{\lambda}$
Radio	100 cm	$2.9 \times 10^{-3} K$
Microwave	0.1cm	2.9 K
Infra-red	100000ncm	2900K
Light	50000 ncm	5800K
Ultraviolet	100ncm	$2.9 \times 10^{6} K$
X-rays	1 ncm	$2.9 \times 10^{8} K$
Gamma rays	0.01 nm	$2.9 \times 10^{10} K$

These numbers indicate the temperature ranges required for obtaining radiations in different parts of the spectrum

14.(a) Given below are some famous numbers associated with electromagnetic radiations in different contexts in physics. State the part of the electromagnetic spectrum to which each belongs. 21 cm (wavelength emitted by atomic hydrogen in interstellar space).

Answer:

Radio waves

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

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

Answer:

Frequency(ν)=1057 MHz

Wavelength(λ) $= \frac{c}{\nu}$

$$= \frac{3 \times 10^8}{1057 \times 10^6}$$

=0.283 m

=28.3 cm

Radio waves

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

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].

Answer:

Using formula, $\lambda_m T = 0.29\ cmK$

$\lambda = \frac{0.29}{2.7}$

= 0.107cm

Microwaves.

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

$5890\dot{A} - 5896\dot{A}$ [double lines of sodium]

Answer:

Visible light.

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

14.4 keV [energy of a particular transition in ^{57}Fe nucleus associated with a famous high resolution spectroscopic method (Mössbauer spectroscopy)].

Answer:

E=14.4 keV

Wavelength(λ) = $\frac{hc}{E}$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{14.4 \times 10^{3} \times 1.6 \times 10^{-19}}$$

$= 0.85\ A^{0}$

X-rays

Answer the following questions

15. (a) Long distance radio broadcasts use short-wave bands. Why?

Answer:

Long-distance radio broadcasts use short-wave bands as these are refracted by the ionosphere.

Answer the following questions

15. (b) It is necessary to use satellites for long distance TV transmission. Why?

Answer:

As TV signals are of high frequencies they are not reflected by the ionosphere and therefore satellites are to be used to reflect them.

Answer the following questions

15 (c) Optical and radio telescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the earth. Why?

Answer:

X-rays are absorbed by the atmosphere and therefore the source of X-rays must lie outside the atmosphere to carry out X-ray astronomy and therefore satellites orbiting the earth are necessary but radio waves and visible light can penetrate through the atmosphere and therefore optical and radio telescopes can be built on the ground.

Answer the following questions

15. (d) The small ozone layer on top of the stratosphere is crucial for human survival. Why?

Answer:

The small ozone layer on top of the stratosphere is crucial for human survival as it absorbs the ultraviolet radiations coming from the sun which are very harmful to humans.

Answer the following questions

15. (e) If the earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now?

Answer:

If the earth did not have an atmosphere its average surface temperature be lower than what it is now as in the absence of atmosphere there would be no greenhouse effect.

Answer the following questions

15 f) Some scientists have predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth. What might be the basis of this prediction?

Answer:

The use of nuclear weapons would cause the formation of smoke clouds preventing the light from the sun reaching earth surface and it will also deplete the atmosphere and therefore stopping the greenhouse effect and thus doubling the cooling effect.