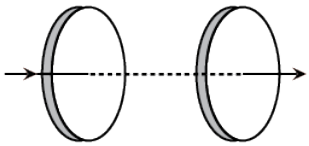
NCERT Solutions for Class-XII Physics

Chapter-8

NCERT Physics Class 12

1. 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 0.15 A.



(a) Calculate the capacitance and the rate of charge of potential difference between the plates.

(b) Obtain the displacement current across the plates.

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

1. Radius of each circular plate, r = 12 cm = 0.12 m

Distance between the plates, d = 5 cm = 0.05 m

Charging current I = 0.15 A

Permittivity of free space, $\epsilon_0 = 8.85\times10^{-12}\,C^2N^{-1}m^{-2}$

(a) Capacitance between the two plates is given by the relation, $C = \frac{\epsilon_0 A}{d}$

Where, A = Area of each plate = πr^2

$$C = \frac{\epsilon_0 \pi r^2}{d} = \frac{8.85\times10^{-12}\times\pi\times(0.12)^2}{0.05} = 8.0032\times10^{-12}\,F = 80.032\,pF$$

Charge on each plate, q = CV

Where,

V = Potential difference across the plates

Differentiation on both sides with respect to time (t) gives:

$$\frac{dq}{dt} = C\frac{dV}{dt}$$

But, $\frac{dq}{dt} = \text{current}\,(I)$

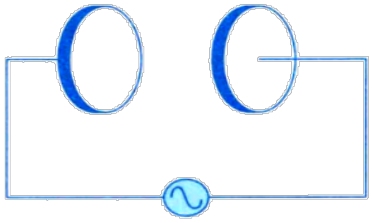
$$\therefore \frac{dV}{dt} = \frac{I}{C}$$

$$\Rightarrow \frac{0.15}{80.032\times10^{-12}} = 1.87\times10^{9}\ V/s$$

Therefore, the change in potential difference between the plates is 1.87×10^9 V/s.

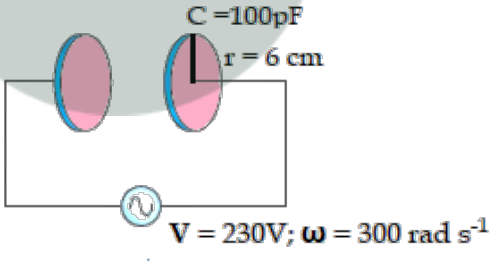
(b) The displacement current across the plates is the same as the conduction current.
Hence, the displacement current, i_d is 0.15 A.
(c) Yes
Kirchhoff's first rule is valid at each plate of the capacitor provided that we taken the sum of conduction and displacement for current.

2. 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}.



(a) What is the rms value of the conduction current?
(b) Is the conduction current equal to the displacement current?
(c) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

2. Given: Radius of circular plates R = 6.0 cm = 0.06 m
Capacitance C = 100 pF = 100 × 10^{-12} F
Voltage V = 230 V
Angular frequency, ω = 300 rad s^{-1}
The figure is:



(a) The root mean square value of the conduction current is given by the following relation:
$I_{rms} = V/X_c$
Where I_{rms} is the root mean square value of the conduction current
V is the voltage
X_c is the capacitive reactance and is given by $X_c = 1/\omega_c$
$\Rightarrow I_{r.m.s} = V \times \omega C$
Substituting the values we get
I_{rms} = 230 V × 300 rad s^{-1} × 100 × 10^{-12} F
$I_{rms} = 6.9 \times 10^{-6}$A = 6.9 μ A
(b) Yes, the conduction current is equal to the displacement current.
(c) Amplitude of magnetic field B at a point 3.0 cm from the axis between the plates is given by the following expression:

$$B = \frac{\mu_0 r}{2\pi R^2} I_0$$

Distance between the two plates = 3.0 cm = 0.03 m

μ_0 is the free space permeability and is equal to $4\pi \times 10^{-7}\ NA^{-2}$

I_0 is equal to the maximum value of current i.e., $\sqrt{2}I$

$$\Rightarrow B = \frac{4 \times 3.14 \times 10^{-7}\ NA^{-2} \times 0.03 m \times \sqrt{2} \times 6.9 \times 10^{-6} A}{2 \times 3.14 \times (0.06\ m)^2}$$

$$\Rightarrow B = \frac{3.7678 \times 10^{-13}}{0.022608} T$$

On calculating, we get 162.63

$\Rightarrow B = 1.66 \times 10^{-11}\ T$

3. What physical quantity is the same for X-rays of wavelength 10^{-10} m, red light of wavelength 6800 Å and radio waves of wavelength 500 m?

3. The speed of light (3×10^8 m/s) in a vacuum is the same for all wavelengths. It is independent of the wavelength in the vacuum.

4. A plate 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?

4. Given: The electromagnetic wave travels in vacuum along z-direction.

The direction of electric field vector and magnetic field vector will be in XY plane.

Frequency of the wave = 30 MHz

Converting into Hz, $v = 30 \times 10^6$ Hz

Wavelength of the wave can be calculated using the following relation:

$\lambda = c/v$

$$\Rightarrow \lambda = \frac{3 \times 10^8\ m/sec}{30 \times 10^6\ sec^{-1}}$$

$\Rightarrow \lambda = 10$ m

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

5. A radio can tune to minimum frequency, $v_1 = 7.5$ MHz $= 7.5 \times 10^6$ Hz

Maximum frequency, $v_2 = 12$ MHz $= 12 \times 10^6$ Hz, Speed of light, $c = 3 \times 10^8$ m/s

Corresponding wavelength for v_1 can be calculated as:

$$\lambda_1 = \frac{c}{v_1}$$

$$= \frac{3 \times 10^8}{7.5 \times 10^6} = 40\ m$$

Corresponding wavelength for v_2 can be calculated as:

$$\lambda_2 = \frac{c}{v_2}$$

$$= \frac{3\times10^8}{12\times10^6} = 25\,\text{m}$$

Thus, the wavelength band of the radio is 40 m to 25 m.

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?

6. The frequency of the electromagnetic waves produced by the oscillator is 10^9 Hz. This is because the frequency of the electromagnetic waves produced by the oscillator is equal to the frequency of the electromagnetic waves produced by the oscillator.

7. 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?

7. Amplitude of magnetic field of an electromagnetic wave in a vacuum,
$B_0 = 510$ nT $= 510 \times 10^{-9}$ T
Speed of light in vacuum, $c = 3 \times 10^8$ m/s
Amplitude of electric field of the electromagnetic wave is given by the relation,
$E = cB_0 = 3 \times 10^8 \times 510 \times 10^{-9} = 153$ N/C
Therefore, the electric field part of the wave is 153 N/C.

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

8. Given: Electric field amplitude of electromagnetic wave, $E_0 = 120$ N/C
Frequency of electromagnetic wave, v = 50 MHz
(a) Magnitude of magnetic field is given by the following expression:
$B_0 = E_0/c$

$$\Rightarrow B_0 = \frac{120\,\text{NC}^{-1}}{3\times10^8\,\text{ms}^{-1}}$$

$\Rightarrow B_0 = 40 \times 10^{-8}$ T
Converting it into nT, we get $B_0 = 400$ nT
Angular frequency can be calculated as follows:
$\omega = 2\pi v$
where ν is the linear frequency.
$\omega = 2 \times 3.14 \times 50 \times 10^6$ Hz
$\omega = 314 \times 10^6$ rad/s
$\omega = 3.14 \times 10^8$ rad/s

Propagation constant k is given by the following expression:

$k = \omega / c$

$$k = \frac{3.14 \times 10^{8}\ \text{rad s}^{-1}}{3 \times 10^{8}\ \text{ms}^{-1}}$$

$k = 1.05$ rad/m

Wavelength can be calculated by the following expression:

$\lambda = c/v$

$$\lambda = \frac{3 \times 10^{8}\ \text{ms}^{-1}}{3 \times 10^{8}\ \text{ms}^{-1}}$$

$\Rightarrow \lambda = 6$ m

(b) The expression for electric field and magnetic field can be written as follows:

Let a wave is propagating in positive x- direction.

Since all the three vectors are mutually perpendicular to each other. The electric field vector will be in positive y- direction and magnetic field vector will be in positive z-direction.

Electric field vector can be expressed in the form of equation as given below:

$$\Rightarrow \vec{E} = \vec{E}_0 \sin(kx - wt)\hat{j}$$

Substituting values in above equation we get

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

Magnetic field vector can be expressed in form of following equation:

$$\Rightarrow \vec{B} = \vec{B}_0 \sin(kx - wt)\hat{k}$$

Substituting values in above equation we get

$$\Rightarrow \vec{B} = 40 \times 10^{-8} \sin(1.05x - 3.14 \times 10^{8} t)\hat{k}$$

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?

9. Energy of a photon is given as:

$$E = hv = \frac{hc}{\lambda}$$

Where,

h = Planck's constant = 6.6×10^{-34} Js

c = Speed of light = 3×10^{8} m/s

λ = Wavelength of radiation

$$\therefore E = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} = \frac{19.8 \times 10^{-26}}{\lambda} \text{J}$$

$$= \frac{19.8 \times 10^{-26}}{\lambda \times 1.6 \times 10^{-19}} = \frac{12.375 \times 10^{-7}}{\lambda} \text{eV}$$

The given table lists the photon energies for different parts of an electromagnetic spectrum for different λ.

λ(m)	**10^{3}**	**1**	**10^{-3}**	**10^{-6}**	**10^{-8}**	**10^{-10}**	**10^{-12}**
E (eV)	12.375×10^{-10}	12.375×10^{-7}	12.375×10^{-4}	12.375×10^{-1}	12.375×10^{1}	12.375×10^{3}	12.375×10^{5}

The photon energies for the different parts of the spectrum of a source indicate the spacing of the relevant energy levels of the source.

10. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 Vm^{-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. [$c = 3 \times 10^{8}$ m s^{-1}]

10. Given: Frequency of electromagnetic wave $f = 2.0 \times 10^{10}$ Hz

Amplitude of the electromagnetic wave i.e., $E_0 = 48$ V m^{-1}

(a) Wavelength of the electromagnetic wave can be calculated as follows:

$V = c / \lambda$

also, $\lambda = c/v$

where c is the speed of light in vacuum

v is the frequency of electromagnetic wave

and λ is the wavelength of electromagnetic wave

Substituting the values

$$\lambda = \frac{3 \times 10^{8}\,ms^{-1}}{2 \times 10^{10}\,s^{-1}}$$

On calculating, we get

$\Rightarrow \lambda = 0.015$ m

(b) Amplitude of the electromagnetic wave i.e., $E_0 = 48$ V m^{-1}

Amplitude of the oscillating magnetic field is given by the following expression:

$B_0 = E_0/c$

$$B_0 = \frac{48\,Vm^{-1}}{3 \times 10^{8}\,ms^{-1}}$$

On calculating we get:

$\Rightarrow B_0 = 1.6 \times 10^{-7}$ Tesla

(c) The average energy density of the E field equals the average energy density of the B field can be proved as follows:

The energy density of electric field $U_E = \frac{1}{2} \in_0 E^2$ ...(i)

Where $\in_0$ is the permittivity of free space

The energy density of magnetic field is given as follows:

$$U_B = \frac{1}{2\mu_0} B^2 \qquad ...(ii)$$

Where μ_0 is the permeability of free space.

The relation between Electric field and magnetic field i.e., E and B is as follows:

$$E = \frac{1}{\sqrt{\epsilon_0 \mu_0}} B$$

On squaring both the sides, we get following relation

$$E^2 = \frac{1}{\epsilon_0 \mu_0} B^2$$

$$\text{Or, } E^2 \epsilon_0 = \frac{B^2}{\mu_0}$$

$$\frac{1}{2} \epsilon_0 E^2 = \frac{1}{2} \frac{B^2}{\mu_0}$$

From equation (i) and (ii), we get

$\therefore U_E = U_B$