PHYSICS

BOOKS - HC VERMA

ELECTROMAGNETIC WAVES

Example

1. A parallel - plate capacitor is being charged.Show that the displacement current across an area in the region between the

plates and parallel to it is equal to the conduction current in the connecting wires.

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2. The maximum electric field in a plane electromagnetic wave is $600NC^{-1}$. The wave is going in the x-direction and the electric field is in the y- direction. Find the maximum magnetic field in the wave and its direction.

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3. The electric field in an electromagnetic wave is given by $E(50NC^{-1})\sin\omega\left(t-\frac{x}{c}\right)$. Find the energy contained in a cylinder of cross section 10 cm^2 and length 50 cm along the x-axis.

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4. Find the intensity of the wave for energy density 1.1x10^-8 Jm^-3

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Worked Out Examples

1. A parallel- plate capacitor with plate area A and separation between the plates d, is charged by a constant current i. Consider a plane surface of area A/2 parallel to the plates and drawn summetrically between the plates. Find the displacement current through this area.

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2. A plane electromagnetic wave propagating in the x-direction has a wavelength of 5.0 mm. The electric field is in the y-direction and its maximum magnitude is $30V\left(m^{-1}\right)$. Write suitable equations for the electric and magnetic fields as a function of x and t.

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3. A light beam travelling in the x- direction is described by the electric field

$E_y = \left(300V\left(m^{-1}\right)\sin\omega(t-(x/c)\right).$ An electron is constrained to move along the y-direction with a speed $\left(2.0\times\left(10^7\right)m\left(s^{-1}\right)\right).$ Find the maximum electric force and the maximum magnetic force on the electron.

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4. Find the energy stored in a 60 cm length of a laser beam operating at 4 m W.

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5. Find the amplitude of the electric field in a parallel bean of light of intensity $2.0 W m^{-2}$.

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Question For Short Answers

1. In a microwave oven, the food is kept in a plastic container and the microwave is directed towards the food. The food is cooked without melting or

igniting the

plastic container. Explain.

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2. A metal rod is placed along the axis of a solenoid carrying a high-frequency alternating current. It is found that the rod gets heated. Explain why the rod gets heated .

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3. Can an electromagnetic wave be deflected by an electric field? By a magnetic field ?

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4. A wire carries an alternating current $i = i_0 \sin \omega t$. In there an electric field in the vicinity of the wire?

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5. A capacitor is connected to an alternating-current source. Is there a magnetic field between the plates ?

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6. Can an electromagnetic wave be polarized?

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7. A plane electromagnetic wave is passing through a region. Consider the quantities (a) electric field, (b) magnetic field , (c) electrical energy in a small volume and (d) magnetic energy in a small volume. Construct pairs of the quantities that oscillate with equal frequencies.

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Objective 1

1. A magnetic field is produced by

A. a moving charge

B. a changing electric field

C. none of them

D. both of them.

Answer: D

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2. A compass needle is placed in the gap of a parallel plate capacitor. The capacitor is connected to a battery through a resistance. The compass needle

A. does not deflect

B. deflects for a very short time and then comes back to the original position

C. deflects and remains deflected as long as the battery is connected

D. deflects and gradually comes to the original position in a time which is large compared to the time constant.

Answer: D

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3. The dimension of $\frac{1}{\mu_0 \varepsilon_0}$ is

A. $\frac{L}{T}$

B. $\frac{T}{L}$

C. $\frac{L^2}{T^2}$

D. $\frac{T^2}{L^2}$

Answer: C

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4. Electromagnetic waves are produced by

A. a static charge

B. a moving charge

C. an accelerating charge

D. chargeless particles.

Answer: C

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5. An electromagnetic wave going through vacuum is described by which of the following equation is true?

A. $(E_0)k = (B_0)\omega$

B. $(E_0)(B_0) = \omega k$

C. $(E_0)\omega = B_0 k$

D. none of these .

Answer: A

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6. An electric field `(vec E) and a magnetic field (vec B)exist in a region . The fields are not perpendicular to each other.

A. This is not possible

B. No electromagnetic wave is passing through the region.

C. An electromagnetic wave may be passing through the region

D. An electromagnetic wave is certainly passing through the region.

Answer: C

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7. Consider the following two statements regarding a linearly polarized, plane electromagnetic wave:

The electric field and the magnetic field have equal average values.

The electric energy and the magnetic energy have equal average values.

A. Both A and B are true.

B. A is false but B is true.

C. B is false but A is true.

D. Both A and B are false.

Answer: A

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8. A free electrons is placed in the path of a plane electromagnetic wave. The electron will start moving

A. along the electric field

B. along the magnetic field

C. along the direction of propagation of the waves

D. in a plane containing the magnetic field and the direction of propagation.

Answer: A

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9. A plane electromagnetic wave is incident on a material surface. The wave delivers momentum p and energy E.

A. $p = 0, E \neq 0.$

B. $p \neq 0, E = 0.$

C. $p \neq 0, E \neq 0.$

D. $p = 0, E = 0.$

Answer: A

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Objective 2

1. An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \omega t)$. Which of the following is/are independent of the wavelength?

A. k

B. ω

C. $\frac{k}{\omega}$

D. $k\omega$

Answer: C

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2. Displacement current goes through the gap between the plates of a capacitor when the charge of the capacitor

A. increase

B. decrease

C. does not change

D. is zero.

Answer: A::B

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3. Speed of electromagnetic wave is the same for all

A. for all wavelengths

B. in all media

C. for all intensities

D. for all frequencies .

Answer: C

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4. Which of the following have zero average value in a plane electromagnetic wave?

A. electric field

B. magnetic field

C. electric energy

D. magnetic energy.

Answer: A::B

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5. The energy contained in a small volume through which an electromagnetic wave is passing oscillates with

A. zero frequency

B. the frequency of the wave

C. half the frequency of the wave

D. double the frequency of the waves.

Answer: D

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Exercise

1. Show that the dimensions of the displacement current $\left(\varepsilon_0 \frac{d\Phi_E}{dt}\right)$ are that of an electric current.

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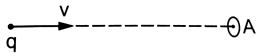
2. A point charge is moving along a straight line with a constant velocity v. Consider a small area A perpendicular to the direction of motion of the charge . Calculate the

displacement current through the area when its distance from the charge is x. The value of x is not large so that the electric field at any instant is essentially given by Coulomb's law.



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3. A parallel- plate capacitor having plate-area A and plate separation d is joined to a battery of emf ε and internal resistance R at t=0. Consider a plane surface of area A/2, parallel

to the plates and situated symmetrically between them. Find the displacement current through this surface as a function of time.

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4. Consider the situation of the previous problem. Define displacement resistance $\left(R_d = \frac{V}{i_d}\right)$ of the space between the plates where V is the potential difference between the plates and i_d is the displacement current.

Show that R_d varies with time as ` (R_d)= (R(e^(t/tau)-1).)

A.

B.

C.

D.

Answer:

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5. Using $B_0 = (\mu_0)H_0$, find the ratio $\left(\frac{E_0}{H_0}\right)$ for a plane electromagnetic wave propagating through vacuum. Show that it has the dimensions of electric resistance. This ratio is a universal constant called the impedance of free space.

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6. The sunlight reaching the earth has maximum electric field of 810V $\left(m^{-1}\right)$. What is

the maximum magnetic field in this light?

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7. The magnetic field in a plane electromagnetic wave is given by $B = (200(\mu)T)\sin[(4.0 \text{ x } (10^{15})(s^{-1})\left(t - \left(\frac{x}{c}\right)\right)\right]$. Find the maximum electric field and the average energy density corresponding to the electric field .

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8. A laser beam has intensity 2.5 x $(10^{14})W(m^{-2})$. Find the amplitudes of electric and magnetic fields in the beam.

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9. A laser beam has intensity 2.5 x $(10^{14})W(m^{-2})$. Find the amplitudes of electric and magnetic fields in the beam.

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