

Electromagnetic Waves — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
 (2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
 (3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Displacement Current and Maxwell's Equations

1. Define displacement current and write its expression.
2. Show that the displacement current in a charging capacitor equals the conduction current.
3. State why Maxwell modified Ampere's circuital law.

Properties of Electromagnetic Waves

1. List four properties of electromagnetic waves.
2. Write the relation between E_0 and B_0 in vacuum and derive the speed of EM waves.
3. Explain the transverse nature of electromagnetic waves.

Energy, Intensity and Momentum

1. Show that the average energy density is shared equally between E and B fields.
2. An EM wave has intensity 30 W/m^2 . Find the radiation pressure on complete absorption.
3. Write the expressions for the momentum and radiation pressure of an EM wave.

The Electromagnetic Spectrum

1. Arrange the EM spectrum in increasing order of wavelength.
2. Name the EM waves with the longest and shortest wavelengths.
3. Give the wavelength range of the visible spectrum.

Applications of EM Waves

1. Give two uses each of microwaves and ultraviolet radiation.
2. Give two uses each of infrared and X-rays.
3. Name the EM radiation used in a microwave oven, a TV remote and medical radiography.

Part B — Integrated problems (multi-topic)

1. A parallel-plate capacitor with circular plates of radius 0.1 m is being charged. If the conduction current is 2 A , find the displacement current and the rate of change of electric flux.
2. An electromagnetic wave in vacuum has an electric field amplitude of 60 V/m . Find the magnetic field amplitude, the average energy density and the intensity of the wave.

3. A radio wave has a frequency of 3×10^9 Hz. Find its wavelength and state to which region of the EM spectrum it belongs.
4. An EM wave of intensity 1.5 W/m^2 falls normally on a perfectly reflecting surface. Find the radiation pressure exerted.
5. The electric field of an EM wave is $E = 30 \sin(6 \times 10^8 t - 2x) \text{ V/m}$. Find its frequency, wavelength and the amplitude of the magnetic field.

Answer Key

Displacement Current and Maxwell's Equations

$I_d = \epsilon_0 d\Phi_E/dt$; in a charging capacitor it equals the conduction current. Maxwell added it to make Ampere's law consistent.

Properties of Electromagnetic Waves

Transverse; E & B direction of propagation; $E_0 = cB_0$; $c = 1/\sqrt{\mu_0\epsilon_0}$; they carry energy and momentum and need no medium.

Energy, Intensity and Momentum

$u_E = \frac{1}{2}\epsilon_0 E^2$, $u_B = B^2/2\mu_0$; these are equal. Momentum = U/c ; radiation pressure = I/c (absorbed). For $I = 30 \text{ W/m}^2$: $P = 1 \times 10^{-7} \text{ Pa}$.

The Electromagnetic Spectrum

Increasing wavelength: gamma, X-ray, UV, visible, IR, microwave, radio. Visible: 400–700 nm.

Applications of EM Waves

Microwaves: radar, ovens, communication. UV: sterilisation, water purification. IR: remotes, night vision. X-rays: radiography, security. Gamma: cancer therapy, sterilisation.

Integrated problems

1: $I_d = 2 \text{ A}$; $d\Phi_E/dt = I_d/\epsilon_0 \approx 2.3 \times 10^{11} \text{ V}\cdot\text{m/s}$. 2: $B_0 = E_0/c = 2 \times 10^{-7} \text{ T}$; $u \approx 1.6 \times 10^{-8} \text{ J/m}^3$; $I \approx 4.8 \text{ W/m}^2$. 3: $\lambda = c/f = 0.1 \text{ m}$ (radio/microwave). 4: $P = 2I/c \approx 1 \times 10^{-8} \text{ Pa}$. 5: $\omega = 6 \times 10^8 \text{ rad/s} \approx 9.5 \times 10^7 \text{ Hz}$; $k = 2\pi/\lambda = \pi \text{ m}^{-1} \approx 3.14 \text{ m}^{-1}$; $B_0 = 30/c = 1 \times 10^{-7} \text{ T}$.