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CLASS 12 PHYSICS NCERT SOLUTIONS

NCERT Solutions for Class 12 Physics Chapter 8: Electromagnetic Waves – Free PDF Download

Chapter 8 introduces electromagnetic waves -- how Maxwell's addition of displacement current to Ampere's law leads to self-sustaining, mutually perpendicular oscillations of the electric and magnetic fields that travel through vacuum at the speed of light. These worked solutions cover displacement current, wave prop...

Contents

Chapter 8 introduces electromagnetic waves — how Maxwell's addition of displacement current to Ampere's law leads to self-sustaining, mutually perpendicular oscillations of the electric and magnetic fields that travel through vacuum at the speed of light. These worked solutions cover displacement current, wave properties, and the electromagnetic spectrum.

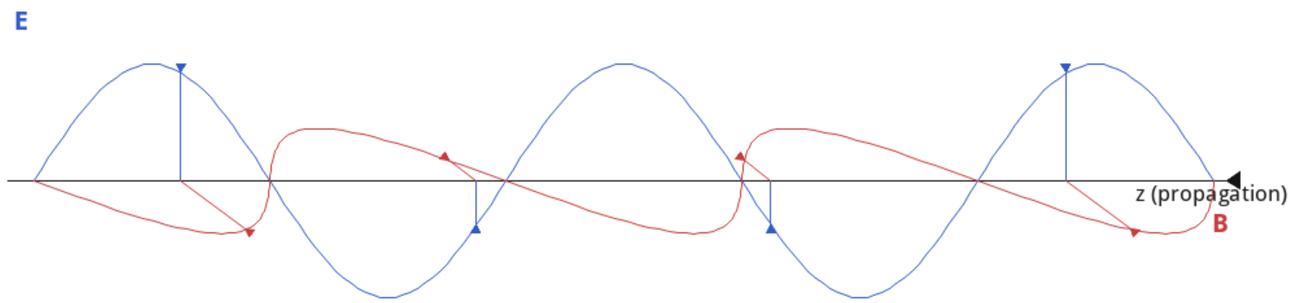
NCERT Exercise Solutions

8.1 A capacitor made of two circular plates, each of radius 12cm, separated by 5.0cm, is being charged by an external source with a constant current of 0.15A. (a) Calculate the capacitance of the capacitor and the rate of change 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.
Ans: (a) Capacitance $C=\varepsilon_0 A/d=\varepsilon_0 \pi R^2/d=(8.854\times10^{-12}\times\pi\times0.12^2)/0.05\approx$**8.01pF**. Rate of change of potential difference $dV/dt=I/C=0.15/(8.01\times10^{-12})\approx$**$1.87\times10^{10}$ V/s**. (b) The displacement current between the plates equals the conduction current in the connecting wires at every instant ($I_d=\varepsilon_0 d\Phi_E/dt=I$), so $I_d=$**0.15A**. (c) Kirchhoff's junction rule, using conduction current alone, appears to fail at a capacitor plate since the conduction current seems to stop there. But once Maxwell's displacement current is included, the current is continuous everywhere — the conduction current flowing into a plate exactly equals the displacement current flowing between the plates — so the (generalized) junction rule is **valid** at each plate.

8.2 A parallel plate capacitor made of circular plates, each of radius 6.0cm, has a capacitance C=100pF. The capacitor is connected to a 230V ac supply with an angular frequency of 300 rad/s. (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 the magnetic field B at a point 3.0cm from the axis between the plates.
Ans: (a) For a capacitor in an ac circuit, $I_{rms}=V_{rms}\omega C=230\times300\times100\times10^{-12}\approx$**6.9μA**. (b) **Yes** — the rms displacement current between the plates is exactly equal to the rms conduction current in the leads, both 6.9μA, at every instant. (c) Using $B=(\mu_0 I_0 r)/(2\pi R^2)$ for a point inside the plates ($r<R$), with peak current $I_0=\sqrt{2}\times I_{rms}\approx9.76\mu A$, r=0.03m and R=0.06m: $B\approx$**1.63×10^{-11} T**.

8.3 X-rays, visible light (red), and radio waves are all electromagnetic waves, yet their wavelengths differ enormously — X-rays around 10^{-10} m, red light around 6800Å, and radio waves around 500m. What physical quantity is the same for all three, regardless of this huge difference in wavelength?
Ans: Their **speed of propagation in vacuum** is identical — every electromagnetic wave, no matter its wavelength or frequency, travels through vacuum at the same speed, $c\approx$**3×10^8 m/s**. Only the wavelength and frequency (related by $\lambda\nu=c$) differ across the spectrum.

8.4 A plane electromagnetic wave travels in vacuum along the z-direction. (a) What can you say about the directions of the electric and magnetic field vectors? (b) If the frequency of the wave is 30MHz, what is its wavelength?
Ans: (a) Both E and B oscillate perpendicular to the direction of propagation (the z-axis) **and** perpendicular to each other — for instance, if E points along the x-axis, B points along the y-axis — and the two fields oscillate exactly in phase with each other. (b) $\lambda=c/f=(3\times10^8)/(30\times10^6)=$**10m**.



Plane EM wave along z: E and B oscillate in phase, mutually perpendicular, and perpendicular to z.

8.5 A radio can tune in to any station in the 7.5MHz to 12MHz band. What is the corresponding wavelength band?
Ans: Using $\lambda=c/f$: at f=7.5MHz, $\lambda=$**40m**; at f=12MHz, $\lambda=$**25m**. So the wavelength band runs from about **25m to 40m** (wavelength decreases as frequency increases).

8.6 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 this oscillation?
Ans: An accelerating (oscillating) charge radiates an electromagnetic wave at exactly the same frequency as its own oscillation, so the emitted wave's frequency is also **10^9 Hz (1GHz)**.

8.7 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?
Ans: For an electromagnetic wave in vacuum, $E_0=cB_0=(3\times10^8)\times(510\times10^{-9})=$**153 N/C**.

8.8 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, ω, k, and λ. (b) Find expressions for E and B.
Ans: (a) $B_0=E_0/c=120/(3\times10^8)=$**$4.0\times10^{-7}$ T (400nT)**. $\omega=2\pi\nu=2\pi\times50\times10^6\approx$**$3.14\times10^8$ rad/s**. $\lambda=c/\nu=$**6m**. $k=2\pi/\lambda\approx$**1.05 rad/m**. (b) Taking the wave to propagate along the x-axis with E along y and B along z (any such mutually-consistent choice is valid): $E=E_0\cos(kx-\omega t)\hat{j}=120\cos(1.05x-3.14\times10^8t)\hat{j}$ N/C, and $B=B_0\cos(kx-\omega t)\hat{k}=4.0\times10^{-7}\cos(1.05x-3.14\times10^8t)\hat{k}$ T.

8.9 Use the formula $E=h\nu$ (for a photon's energy) to obtain the photon energy, in eV, for representative frequencies across different parts of the electromagnetic spectrum. In what way are the very different scales of photon energy you obtain related to the sources that typically produce electromagnetic radiation in each band?
Ans: Using $E=h\nu$ with $h=4.14\times10^{-15}$ eV·s (Planck's constant expressed in eV·s), representative photon energies work out to roughly: radio waves ($\nu\approx10^6$ Hz) $\approx4\times10^{-9}$ eV; microwaves ($\nu\approx10^{10}$ Hz) $\approx4\times10^{-5}$ eV; infrared ($\nu\approx10^{13}$ Hz) ≈0.04eV; visible light ($\nu\approx5\times10^{14}$ Hz) $\approx$**2.1eV**; ultraviolet ($\nu\approx10^{16}$ Hz) ≈41eV; X-rays ($\nu\approx3\times10^{18}$ Hz) $\approx1.2\times10^4$ eV; and gamma rays ($\nu\approx5\times10^{20}$ Hz) $\approx2\times10^6$ eV. Photon energy climbs by roughly fifteen orders of magnitude from radio waves to gamma rays. This directly reflects the very different physical processes that generate each band: the low-energy radio and microwave photons come from

macroscopic oscillating currents in antennas and circuits; infrared and visible photons come from molecular vibrations and outer electron transitions in atoms; the higher-energy ultraviolet and X-ray photons require inner-shell atomic transitions or rapidly decelerated high-energy electrons; and only the most violent nuclear and astrophysical processes — radioactive nuclear transitions, supernovae, neutron stars — can concentrate enough energy into a single photon to produce gamma rays.

8.10 In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and has an amplitude of 48V/m. (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.
Ans: (a) $\lambda=c/v=(3\times10^8)/(2.0\times10^{10})=0.015$m=**1.5cm**. (b) $B_0=E_0/c=48/(3\times10^8)\approx$**$1.6\times10^{-7}$ T (160nT)**. (c) The average energy density of the electric field is $u_E=\frac{1}{4}\varepsilon_0E_0^2$, and of the magnetic field is $u_B=\frac{1}{4}B_0^2/\mu_0$. Substituting $B_0=E_0/c$ and using $c^2=1/(\mu_0\varepsilon_0)$: $u_B=\frac{1}{4}(E_0/c)^2/\mu_0=\frac{1}{4}E_0^2\varepsilon_0=u_E$. So the two average energy densities are **exactly equal** — an electromagnetic wave carries its energy split evenly between its electric and magnetic parts.

Class 12 Physics Chapter 8 – Notes and Extra Questions

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