Electromagnetic Waves

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. The wavelength of an electromagnetic wave of frequency 1×10^{11} Hz in vacuum is:
(a) 3×10^{-4} m **(b)** 3×10^{19} m **(c)** 0.03 m **(d)** 3×10^{-3} m

2. The electric field of an electromagnetic wave has amplitude 222 V/m. The amplitude of its magnetic field is:
(a) 7.4×10^{-7} T **(b)** 6.66×10^{10} T **(c)** 7.4×10^{-5} T **(d)** 7.4×10^{-9} T

3. Electromagnetic radiation of wavelength 450 nm is:
(a) microwaves **(b)** radio waves **(c)** gamma rays **(d)** visible light

4. Which electromagnetic waves are used for physical therapy by heating?
(a) infrared **(b)** visible light **(c)** ultraviolet **(d)** gamma rays

5. Maxwell added to Ampere's law a term called the:
(a) displacement current **(b)** induced emf
(c) eddy current **(d)** drift current

6. Light travels at 2×10^8 m/s in a medium. Its refractive index is:
(a) 3 **(b)** 2/3 **(c)** 2 **(d)** 3/2

7. The voltage across a 10 μF capacitor rises at 30×10^3 V/s. The displacement current between its plates is:
(a) 0.3 A **(b)** 3×10^5 A **(c)** 3.33×10^{-4} A **(d)** 3×10^{-4} A

8. Assertion (A): An electromagnetic wave of frequency 1×10^{12} Hz has a wavelength of 3×10^{-4} m in vacuum.
Reason (R): The wavelength of an electromagnetic wave equals its frequency divided by c.
(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. A radio station broadcasts at 102 MHz. Find the wavelength of its waves.

10. The magnetic field of a plane electromagnetic wave has amplitude 30×10^{-8} T. Find the amplitude of its electric field.

11. A 14 μF parallel-plate capacitor is being charged so that its voltage rises at 6×10^{3} V/s. Find the displacement current between the plates and the conduction current in the wires.

12. Name the region of each wavelength and arrange them in order of increasing frequency: 550 nm, 10 μm, 1 cm.

13. A radio signal from a space probe 8×10^{12} m away travels to the Earth. How long does it take?

14. Light of wavelength 560 nm in air enters a medium of refractive index 5/3. Find its speed, wavelength and frequency in the medium.

15. (a) Which waves are used for studying crystal structure? (b) Which region does a wavelength of 1,500 m belong to?

16. A wave has wavelength 4×10^{-7} m in vacuum. Find its frequency and name its region.

Section C — Word problems — 4 × 4 = 16 marks

17. A plane electromagnetic wave of frequency 3×10^{14} Hz travels along x in vacuum, and its electric field amplitude is 102 V/m. Find its wavelength, its angular frequency, the amplitude of its magnetic field, and the direction of B if E is along y.

18. A radar pulse returns 270 μs after it is sent. How far away is the aircraft? Which kind of wave does radar use, and why?

19. A 19 μF capacitor with plates 9 mm apart is charged at a rate that makes its voltage rise by 31×10^{3} V every second. Find the displacement current, the rate of change of the electric field between the plates, and explain why the magnetic field just outside the gap is the same as near the wires.

20. Four waves have wavelengths 10 μm, 10^{-13} m, 300 m, 10^{-10} m. Name each region, give one use of each, and list them from lowest to highest photon energy.

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Answer key

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Q	Answer	Working
1	**(d) 3×10^{-3} m**	$\lambda = c/f$
2	**(a) 7.4×10^{-7} T**	$B_0 = E_0/c$
3	**(d) visible light**	visible light: 400 nm to 700 nm
4	**(a) infrared**	—
5	**(a) displacement current**	—
6	**(d) 3/2**	$n = c/v$
7	**(a) 0.3 A**	$I_d = \varepsilon_0 \, d\Phi_E/dt = C \, dV/dt$
8	**(c) A is true, but R is false.**	A is true: $\lambda = c/f = 3 \times 10^8 \div (1 \times 10^{12}) = 3 \times 10^{-4}$ m. R is false.
9	**2.94 m**	$\lambda = c/f = 3 \times 10^8 \div (102 \times 10^6)$
10	**90 V/m**	$E_0 = cB_0$
11	**both 0.084 A**	the displacement current equals the conduction current: $C \, dV/dt$
12	**550 nm: visible light; 10 µm: infrared; 1 cm: microwaves. Increasing frequency: 1 cm, 10 µm, 550 nm**	frequency rises as wavelength falls
13	**2.67×10^4 s**	$t = d/c = 8 \times 10^{12} \div (3 \times 10^8)$
14	**1.8×10^8 m/s; 336 nm; 5.36×10^{14} Hz (unchanged)**	$v = c/n$; $\lambda = \lambda_0/n$; f stays the same
15	**(a) X-rays; (b) radio waves**	radio waves: above 0.1 m
16	**7.5×10^{14} Hz; visible light**	$f = c/\lambda$; visible light: 400 nm to 700 nm
17	**1×10^{-6} m; $6 \times 10^{14}\pi$ rad/s; 3.4×10^{-7} T; along z**	$\lambda = c/f$; $\omega = 2\pi f$; $B_0 = E_0/c$; E × B points along the direction of travel
18	**4.05×10^4 m; microwaves, because their short wavelength reflects well from aircraft and they pass through clouds**	distance = ct/2 (there and back)
19	**0.589 A; $dE/dt = 3.44 \times 10^6$ V/(m s); the displacement current in the gap equals the conduction current in the wires, so Ampere–Maxwell gives the same field**	$I_d = C \, dV/dt$; $E = V/d$
20	**10 µm: infrared (TV remote controls and night vision); 10^{-13} m: gamma rays (treating some cancers and sterilising food); 300 m: radio waves (AM and FM broadcasting); 10^{-10} m: X-rays (photographing broken bones). Lowest to highest energy: 300 m, 10 µm, 10^{-10} m, 10^{-13} m**	energy rises as wavelength falls