CHAPTER

32 Electromagnetic Waves

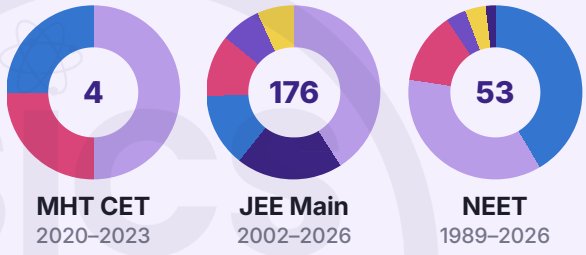
MHT CET · JEE · NEET Physics

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EXAM WEIGHTAGE



	CET	JEE	NEET
Nature of EM Waves & Wave Equation	2 (50%)	72 (41%)	19 (36%)
Electromagnetic Spectrum & Atmosphere	1 (25%)	24 (14%)	22 (42%)
Energy Density & Intensity	0 (0%)	35 (20%)	1 (2%)
Speed of EM Waves in a Medium	1 (25%)	20 (11%)	7 (13%)
Displacement Current, Maxwell's Equations & Production	0 (0%)	13 (7%)	2 (4%)
Momentum & Radiation Pressure	0 (0%)	12 (7%)	2 (4%)

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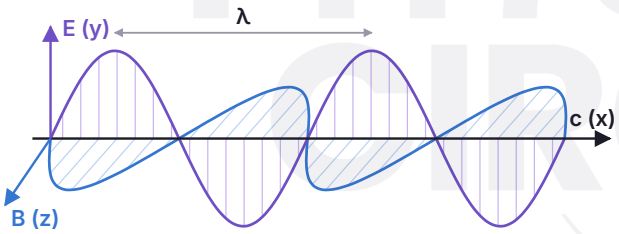
01 CONCEPT Nature of EM Waves & Their Direction

IN ONE LINE

A changing electric field makes a changing magnetic field, and a changing magnetic field makes a changing electric field. Together they travel as a **transverse wave**.

32.1.1 What is an EM wave?

- E and B oscillate with time and keep creating each other.
- They need **no material medium**; they travel through vacuum at speed c.
- They are **transverse**; polarization proves this.
- They carry **energy and momentum**.
- They carry no charge, so E and B fields do **not deflect** them.
- The electric vector causes the optical effects, so it is called the **light vector**.



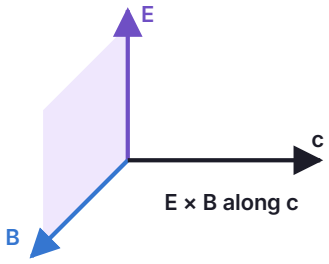
E and B oscillate in phase, at right angles to each other and to c

32.1.2 E and B together

- E and B are always **in phase**: both reach maximum and zero together.
- E ⊥ B, and both are ⊥ to the direction of travel.

32.1.3 Direction of propagation

$$\text{direction of travel} = \mathbf{E} \times \mathbf{B}$$



E, B and c form a right-handed set

E along	B along	Wave travels along
+x	+y	+z
+y	+z	+x
+z	+x	+y

- Use $\hat{i} \times \hat{j} = \hat{k}$, $\hat{j} \times \hat{k} = \hat{i}$, $\hat{k} \times \hat{i} = \hat{j}$.
- Reversing the order gives a minus sign.
- Unit vector along travel: $\hat{k} = \hat{E} \times \hat{B}$.

32.1.4 B from k and E

$$\mathbf{B} = \frac{\mathbf{k} \times \mathbf{E}}{\omega}$$

- **k** is the propagation vector, along the direction of travel.
- A wave along y can have only x and z components of E and B.
- For valid E and B directions: $\mathbf{E} \cdot \mathbf{B} = 0$, and **E** × **B** is along the travel.

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Solved Examples 01 Nature of EM Waves & Their Direction

SOLVED 1 MHT CET 2023 · 13 May · Shift 1

Select the 'WRONG' statement out of the following.

(a) Electromagnetic waves do not require any medium for their propagation.
(b) Electromagnetic waves can travel through vacuum with speed of light
(c) Material medium is necessary for propagation of electromagnetic waves.
(d) Electromagnetic waves are transverse in nature.

STEP 1 EM waves are oscillating E and B fields; fields need no matter
STEP 2 So they travel through vacuum at speed c
STEP 3 Wrong statement: **material medium is necessary**

Answer: **(c)**

SOLVED 2 AIEEE 2002

Electromagnetic waves are transverse in nature is evident by

(a) polarization (b) interference
(c) reflection (d) diffraction

STEP 1 Interference, reflection and diffraction happen for longitudinal waves also
STEP 2 Only transverse waves can be polarized
STEP 3 Answer: **polarization**

Answer: **(a)**

SOLVED 3 NEET 2024

The property which is not of an electromagnetic wave travelling in free space is that:

(a) They are transverse in nature
(b) The energy density in electric field is equal to energy density in magnetic field
(c) They travel with a speed equal to $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$
(d) They originate from charges moving with uniform speed

STEP 1 A uniformly moving charge radiates no EM wave
STEP 2 Accelerated charges produce EM waves
STEP 3 Not a property: **charges moving with uniform speed**

Answer: **(d)**

SOLVED 4 AIPMT 2007

The electric and magnetic field of an electromagnetic wave are

(a) in opposite phase and perpendicular to each other
(b) in opposite phase and parallel to each other
(c) in phase and perpendicular to each other
(d) in phase and parallel to each other.

STEP 1 E and B reach maxima and zero together: in phase
STEP 2 E $\perp$ B, and both $\perp$ direction of travel
STEP 3 **In phase and perpendicular**

Answer: **(c)**

SOLVED 5 JEE Main 2022 · 27 Jul · Shift 2

Identify the correct statements about electromagnetic waves.
(A) In a plane EM wave E and B must be perpendicular to each other and direction of propagation should be along E or B.
(B) The energy is divided equally between electric and magnetic fields.
(C) E and B are parallel to each other and perpendicular to the direction of propagation.
(D) E, B and the direction of propagation must be perpendicular to each other.
(E) The ratio of amplitude of B to amplitude of E equals the speed of light.

(a) (D) only (b) (B) and (D) only
(c) (B), (C) and (E) only (d) (A), (B) and (E) only

STEP 1 E, B and c are mutually perpendicular: (D) true; (A), (C) false
STEP 2 $\frac{E_0}{B_0} = c$, so (E) is false
STEP 3 $u_E = u_B$, so (B) true. Answer: **(B) and (D)**

Answer: **(b)**

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Solved Examples 01 Nature of EM Waves & Their Direction (contd.)

SOLVED 6 JEE Main 2023 · 13 Apr · Shift 2

In an electromagnetic wave, at an instant and at particular position, the electric field is along the negative z-axis and magnetic field is along the positive x-axis. Then the direction of propagation of electromagnetic wave is:

(a) at 45° angle from positive y-axis (b) positive y-axis
(c) negative y-axis (d) positive z-axis

STEP 1 Direction of travel = E × B
STEP 2 $(-\hat{k}) \times (\hat{i}) = -(\hat{k} \times \hat{i}) = -\hat{j}$
STEP 3 Along **negative y-axis**

Answer: **(c)**

SOLVED 7 JEE Main 2023 · 25 Jan · Shift 1

An electromagnetic wave is transporting energy in the negative z direction. At a certain point and certain time the direction of electric field of the wave is along positive y direction. What will be the direction of the magnetic field of the wave at that point and instant?

(a) Negative direction of y (b) Positive direction of z
(c) Positive direction of x (d) Negative direction of x

STEP 1 E × B must point along $-\hat{k}$, with E along $\hat{j}$
STEP 2 $\hat{j} \times \hat{i} = -\hat{k}$
STEP 3 So B is along **positive x**

Answer: **(c)**

SOLVED 8 JEE Main 2021 · 20 Jul · Shift 2

In an electromagnetic wave the electric field vector and magnetic field vector are given as $\mathbf{E} = E_0\hat{i}$ and $\mathbf{B} = B_0\hat{k}$ respectively. The direction of propagation of electromagnetic wave is along :

(a) $\hat{k}$ (b) $\hat{j}$
(c) $(-\hat{k})$ (d) $(-\hat{j})$

STEP 1 Direction of travel = E × B
STEP 2 $\hat{i} \times \hat{k} = -\hat{j}$
STEP 3 Along $-\hat{j}$

Answer: **(d)**

SOLVED 9 JEE Main 2021 · 18 Mar · Shift 2

A plane electromagnetic wave propagating along y-direction can have the following pair of electric field and magnetic field components.

(a) E_x, B_z or E_z, B_x (b) E_x, B_y or E_y, B_x
(c) E_y, B_y or E_z, B_z (d) E_y, B_x or E_x, B_y

STEP 1 E and B must both be ⊥ to y, so neither can have a y component
STEP 2 They must also be ⊥ to each other
STEP 3 Allowed pairs: $\mathbf{E_x, B_z}$ **or** $\mathbf{E_z, B_x}$

Answer: **(a)**

SOLVED 10 JEE Main 2020 · 2 Sep · Shift 2

In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i} - 2\hat{j}$, respectively. What is the unit vector along direction of propagation of the wave?

(a) $\frac{1}{\sqrt{5}}(\hat{i} + 2\hat{j})$ (b) $\frac{1}{\sqrt{5}}(2\hat{i} + \hat{j})$
(c) $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$ (d) $\frac{1}{\sqrt{2}}(\hat{j} + \hat{k})$

STEP 1 $\mathbf{E} \times \mathbf{B} = \hat{k} \times (2\hat{i} - 2\hat{j})$
STEP 2 $= 2\hat{j} + 2\hat{i}$
STEP 3 Unit vector = $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$

Answer: **(c)**

SOLVED 11 JEE Main 2026 · 6 Apr · Shift 2

For an electromagnetic wave propagating through vacuum, k, E and ω represent propagation vector, electric field and angular frequency, respectively. The magnetic field associated with this wave is represented by:

(a) $\frac{\mathbf{E} \times \mathbf{k}}{\omega}$ (b) $\frac{\mathbf{k} \times \mathbf{E}}{\omega}$
(c) $\omega(\mathbf{E} \times \mathbf{k})$ (d) $\omega(\mathbf{k} \times \mathbf{E})$

STEP 1 B must be ⊥ to both k and E, with E × B along k
STEP 2 Magnitude: $|B| = \frac{E}{c} = \frac{kE}{\omega}$ (since $c = \frac{\omega}{k}$)
STEP 3 $\mathbf{B} = \frac{\mathbf{k} \times \mathbf{E}}{\omega}$

Answer: **(b)**

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02 CONCEPT Wave Equation, $E_0 = cB_0$ & Force on a Charge

IN ONE LINE

The two fields follow the same sine wave. The ratio of their amplitudes is always the wave speed: $E_0 = cB_0$.

32.2.1 Wave along +x

$$E_y = E_0 \sin(kx - \omega t)$$

$$B_z = B_0 \sin(kx - \omega t)$$

- E_0, B_0: amplitudes of the fields.
- Other forms: $\sin(\omega t - kx)$, or $\sin \omega\left(t - \frac{x}{c}\right)$.

$$k = \frac{2\pi}{\lambda} \cdot \omega = 2\pi f$$

$$c = f\lambda = \frac{\omega}{k}$$

32.2.2 What the equation tells you

In the phase	Meaning
$kx - \omega t$	travels along +x
$kx + \omega t$	travels along −x
number with x	k, and $\lambda = \frac{2\pi}{k}$
number with t	ω, and $f = \frac{\omega}{2\pi}$
number in front	amplitude

32.2.3 $E_0 = cB_0$

$$\frac{E_0}{B_0} = \frac{E}{B} = c$$

- True at every point and every instant, not only at the peaks.
- So $\frac{B}{E} = \frac{1}{c}$.
- The frequency is not needed to find one field from the other.

$$E_0 = \sqrt{2}\, E_{rms} \cdot B_0 = \sqrt{2}\, B_{rms}$$

32.2.4 B from E, or E from B

- Step 1: amplitude from $E_0 = cB_0$.
- Step 2: keep the **same phase**: same sin or cos, same bracket.
- Step 3: direction from E × B = direction of travel.

32.2.5 Lorentz force

$$F = qE + q(v \times B)$$

- Electric force: $F_E = qE$.
- Magnetic force, $v \perp B$: $F_B = qvB$.
- Since E = cB:

$$\frac{F_E}{F_B} = \frac{c}{v}$$

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Solved Examples 02 Wave Equation, $E_0 = cB_0$ & Force on a Charge

SOLVED 1 AIPMT 2012 · Prelims

The electric field associated with an em wave in vacuum is given by $E = \hat{i}\, 40 \cos(kz - 6 \times 10^8 t)$, where E, z and t are in volt/m, meter and seconds respectively. The value of wave vector k is

(a) $2\ m^{-1}$ (b) $0.5\ m^{-1}$
(c) $6\ m^{-1}$ (d) $3\ m^{-1}$

STEP 1 $\omega = 6 \times 10^8$ rad/s, read from the equation
STEP 2 $c = \frac{\omega}{k}$, so $k = \frac{\omega}{c}$
STEP 3 $k = \frac{6 \times 10^8}{3 \times 10^8} = \mathbf{2\ m^{-1}}$

Answer: **(a)**

SOLVED 2 NEET 2020 · Phase 2

The magnetic field in a plane electromagnetic wave is given by, $B_y = 2 \times 10^{-7} \sin(\pi \times 10^3 x + 3\pi \times 10^{11} t)$ T. Calculate the wavelength.

(a) $\pi \times 10^{-3}$ m (b) $\pi \times 10^3$ m
(c) 2×10^{-3} m (d) 2×10^3 m

STEP 1 $k = \pi \times 10^3$ rad/m
STEP 2 $\lambda = \frac{2\pi}{k}$
STEP 3 $\lambda = \frac{2\pi}{\pi \times 10^3} = \mathbf{2 \times 10^{-3}\ m}$

Answer: **(c)**

SOLVED 3 AIPMT 2009

The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$; $E_y = 2.5 \cos[(2\pi \times 10^6)t - (\pi \times 10^{-2})x]$ N/C; $E_z = 0$. The wave is

(a) moving along x direction with frequency 10^6 Hz and wavelength 100 m.
(b) moving along x direction with frequency 10^6 Hz and wavelength 200 m.
(c) moving along −x direction with frequency 10^6 Hz and wavelength 200 m.
(d) moving along y direction with frequency $2\pi \times 10^6$ Hz and wavelength 200 m.

STEP 1 ωt and kx have opposite signs: moving along +x
STEP 2 $f = \frac{\omega}{2\pi} = 10^6$ Hz
STEP 3 $\lambda = \frac{2\pi}{k} = \frac{2\pi}{\pi \times 10^{-2}} = \mathbf{200\ m}$

Answer: **(b)**

SOLVED 4 JEE Main 2026 · 2 Apr · Shift 2

An electromagnetic wave travels in free space along the x-direction. At a particular point in space and time, $\mathbf{B} = 2 \times 10^{-7} \hat{j}$ T is associated with this wave. The value of corresponding electric field at this point is ___ V/m.

(a) $60\ \hat{k}$ (b) $-60\ \hat{k}$
(c) $30\ \hat{k}$ (d) $-600\ \hat{k}$

STEP 1 $E = cB = 3 \times 10^8 \times 2 \times 10^{-7} = 60$ V/m
STEP 2 $\mathbf{E} \times \mathbf{B}$ must be along $\hat{i}$, with B along $\hat{j}$
STEP 3 $(-\hat{k}) \times \hat{j} = \hat{i}$, so $\mathbf{E} = \mathbf{-60\ \hat{k}}$

Answer: **(b)**

SOLVED 5 NEET 2017

In an electromagnetic wave in free space that root mean square value of the electric field is $E_{rms} = 6$ V m^{-1}. The peak value of the magnetic field is

(a) 2.83×10^{-8} T (b) 0.70×10^{-8} T
(c) 4.23×10^{-8} T (d) 1.41×10^{-8} T

STEP 1 $E_0 = \sqrt{2}\, E_{rms} = 6\sqrt{2}$ V/m
STEP 2 $B_0 = \frac{E_0}{c}$
STEP 3 $B_0 = \frac{6 \times 1.414}{3 \times 10^8} = \mathbf{2.83 \times 10^{-8}\ T}$

Answer: **(a)**

SOLVED 6 MHT CET 2023 · 9 May · Shift 2

A charge 'q' moves with velocity 'v' through electric (E) as well as magnetic field (B). Then the force acting on it is

(a) $q(\mathbf{v} \times \mathbf{B})$ (b) $q(\mathbf{B} \times \mathbf{v})$
(c) $q(\mathbf{E} \times \mathbf{v})$ (d) $q\mathbf{E} + q(\mathbf{v} \times \mathbf{B})$

STEP 1 Electric force = $q\mathbf{E}$
STEP 2 Magnetic force = $q(\mathbf{v} \times \mathbf{B})$
STEP 3 Total (Lorentz force) = $\mathbf{qE + q(v \times B)}$

Answer: **(d)**

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ELECTROMAGNETIC WAVES

LEVEL 1 · EASY

Topic-wise Previous Year Questions

MHT CET · NEET · JEE Main

119	20	6
questions	concepts	topics

CONTENTS

01	Nature of EM Waves & Wave Equation	Q 1–47	47 Qs
02	Displacement Current, Maxwell's Equations & Production	Q 48–53	6 Qs
03	Speed of EM Waves in a Medium	Q 54–68	15 Qs
04	Energy Density & Intensity	Q 69–82	14 Qs
05	Momentum & Radiation Pressure	Q 83–87	5 Qs
06	Electromagnetic Spectrum & Atmosphere	Q 88–119	32 Qs
	Answer key		

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TOPIC 01

Nature of EM Waves & Wave Equation

47 PYQs · Easy 47 · Medium 0 · Difficult 0 | MHT CET 2 · NEET 15 · JEE 30

Concepts covered: Nature of EM waves (8) · Direction of E, B and propagation (14) · Reading the wave equation (4) · Field values: E0 = cB0 (19) · Writing B from E and E from B (1) · Force on a charge (1)

LEVEL 1 · EASY 47 questions

◆ Nature of EM waves 8 Qs

1. Select the 'WRONG' statement out of the following.
MHT CET 2023 · 13 MAY · SHIFT 1
(a) Electromagnetic waves do not require any medium for their propagation.
(b) Electromagnetic waves can travel through vacuum with speed of light
(c) Material medium is necessary for propagation of electromagnetic waves.
(d) Electromagnetic waves are transverse in nature.

2. The property which is not of an electromagnetic wave travelling in free space is that:
NEET 2024
(a) They are transverse in nature
(b) The energy density in electric field is equal to energy density in magnetic field
(c) They travel with a speed equal to $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$
(d) They originate from charges moving with uniform speed

3. Which of the following statements is false for the properties of electromagnetic waves?
AIPMT 2010 · PRELIMS
(a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
(b) The energy in electromagnetic wave is divided equally between electric and magnetic vectors.
(c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
(d) These waves do not require any material medium for propagation.

4. The electric and magnetic field of an electromagnetic wave are
AIPMT 2007
(a) in opposite phase and perpendicular to each other
(b) in opposite phase and parallel to each other
(c) in phase and perpendicular to each other
(d) in phase and parallel to each other.

5. The electric and magnetic field of an electromagnetic wave are
AIPMT 1994
(a) in opposite phase and perpendicular to each other
(b) in opposite phase and parallel to each other
(c) in phase and perpendicular to each other
(d) in phase and parallel to each other

6. Given below are two statements:
Statement I: Electromagnetic waves are not deflected by electric and magnetic field. Statement II: The amplitude of electric field and the magnetic field in electromagnetic waves are related to each other as $E_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} B_0$.
In the light of the above statements, choose the correct answer from the options given below:
JEE MAIN 2023 · 29 JAN · SHIFT 2
(a) Both Statement I and Statement II are true
(b) Statement I is true and Statement II is false
(c) Both Statement I and Statement II are false
(d) Statement I is false but Statement II is true

7. Select the correct statement from the following:
JEE MAIN 2013 · 23 APR · SHIFT 1
(a) Electromagnetic waves cannot travel in vacuum.
(b) Electromagnetic waves are longitudinal waves.
(c) Electromagnetic waves are produced by charges moving with uniform velocity.
(d) Electromagnetic waves carry both energy and momentum as they propagate through space.

8. Electromagnetic waves are transverse in nature is evident by
AIEEE 2002
(a) polarization (b) interference
(c) reflection (d) diffraction

◆ Direction of E, B and propagation 14 Qs

9. For a plane electromagnetic wave propagating in x-direction, which one of the following combination gives the correct possible directions for electric field (E) and magnetic field (B) respectively?
NEET 2021
(a) $-\hat{j}+\hat{k}, -\hat{j}+\hat{k}$ (b) $\hat{j}+\hat{k}, \hat{j}+\hat{k}$
(c) $-\hat{j}+\hat{k}, -\hat{j}-\hat{k}$ (d) $\hat{j}+\hat{k}, -\hat{j}-\hat{k}$

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10. An EM wave is propagating in a medium with a velocity $\vec{v} = v\,\hat{i}$. The instantaneous oscillating electric field of this em wave is along +y axis. Then the direction of oscillating magnetic field of the em wave will be along

NEET 2018

(a) –z direction (b) +z direction
(c) –y direction (d) –x direction

11. The electric and the magnetic field, associated with an e.m. wave, propagating along the +z-axis, can be represented by

AIPMT 2011 · PRELIMS

(a) $\left[\vec{E} = E_0\hat{i}, \vec{B} = B_0\hat{j}\right]$ (b) $\left[\vec{E} = E_0\hat{k}, \vec{B} = B_0\hat{i}\right]$
(c) $\left[\vec{E} = E_0\hat{j}, \vec{B} = B_0\hat{i}\right]$ (d) $\left[\vec{E} = E_0\hat{j}, \vec{B} = B_0\hat{k}\right]$

12. The velocity of electromagnetic wave is parallel to

AIPMT 2002

(a) $\vec{B} \times \vec{E}$ (b) $\vec{E} \times \vec{B}$ (c) $\vec{E}$ (d) $\vec{B}$

13. A plane electromagnetic wave propagates along the + x direction in free space. The components of the electric field, $\vec{E}$ and magnetic field, $\vec{B}$ vectors associated with the wave in Cartesian frame are

JEE MAIN 2025 · 29 JAN · SHIFT 2

(a) E_x, B_y (b) E_y, B_x (c) E_y, B_z (d) E_z, B_y

14. In an electromagnetic wave, at an instant and at particular position, the electric field is along the negative z -axis and magnetic field is along the positive x-axis. Then the direction of propagation of electromagnetic wave is:

JEE MAIN 2023 · 13 APR · SHIFT 2

(a) at 45° angle from positive y-axis
(b) positive y-axis
(c) negative y-axis
(d) positive z-axis

15. An electromagnetic wave is transporting energy in the negative z direction. At a certain point and certain time the direction of electric field of the wave is along positive y direction. What will be the direction of the magnetic field of the wave at that point and instant?

JEE MAIN 2023 · 25 JAN · SHIFT 1

(a) Negative direction of y
(b) Positive direction of z
(c) Positive direction of x
(d) Negative direction x

16. If $\vec{E}$ and $\vec{K}$ represent electric field and propagation vectors of the EM waves in vacuum, then magnetic field vector is given by:
(ω - angular frequency):

JEE MAIN 2023 · 24 JAN · SHIFT 1

(a) $\frac{1}{\omega}\left(\overline{K} \times \overline{E}\right)$ (b) $\overline{K} \times \overline{E}$
(c) $\omega\left(\overline{K} \times \overline{E}\right)$ (d) $\omega\left(\overline{E} \times \overline{K}\right)$

17. In an electromagnetic wave the electric field vector and magnetic field vector are given as $\vec{E} = E_0\hat{i}$ and $\vec{B} = B_0\hat{k}$ respectively. The direction of propagation of electromagnetic wave is along:

JEE MAIN 2021 · 20 JUL · SHIFT 2

(a) $\left(\hat{k}\right)$ (b) $\hat{j}$ (c) $\left(-\hat{k}\right)$ (d) $\left(-\hat{j}\right)$

18. A plane electromagnetic wave propagating along y-direction can have the following pair of electric field $\left(\vec{E}\right)$ and magnetic field $\left(\vec{B}\right)$ components.

JEE MAIN 2021 · 18 MAR · SHIFT 2

(a) Ex, Bz or Ez, Bx (b) Ex, By or Ey, Bx
(c) Ey, By or Ez, Bz (d) Ey, Bx or Ex, By

19. In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i} - 2\hat{j}$, respectively. What is the unit vector along direction of propagation of the wave?

JEE MAIN 2020 · 2 SEP · SHIFT 2

(a) $\frac{1}{\sqrt{5}}\left(\hat{i} + 2\hat{j}\right)$ (b) $\frac{1}{\sqrt{5}}\left(2\hat{i} + \hat{j}\right)$
(c) $\frac{1}{\sqrt{2}}\left(\hat{i} + \hat{j}\right)$ (d) $\frac{1}{\sqrt{2}}\left(\hat{j} + \hat{k}\right)$

20. An electromagnetic wave is represented by the electric field $\vec{E} = E_0\hat{n}\sin\left[\omega t + (6y - 8z)\right]$. Taking unit vectors in x, y and z directions to be $\hat{i}, \hat{j}, \hat{k}$, the direction of propagation $\hat{s}$, is:

JEE MAIN 2019 · 12 APR · SHIFT 1

(a) $\hat{s} = \frac{3\hat{i} - 4\hat{j}}{5}$ (b) $\hat{s} = \frac{-4\hat{k} + 3\hat{j}}{5}$
(c) $\hat{s} = \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$ (d) $\hat{s} = \frac{4\hat{j} - 3\hat{k}}{5}$

21. For plane electromagnetic waves propagating in the z direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively?

JEE MAIN 2015 · 11 APR · SHIFT 1

(a) $\left(\hat{i} + 2\hat{j}\right)$ and $\left(2\hat{i} - \hat{j}\right)$
(b) $\left(-2\hat{i} - 3\hat{j}\right)$ and $\left(3\hat{i} - 2\hat{j}\right)$
(c) $\left(2\hat{i} + 3\hat{j}\right)$ and $\left(\hat{i} + 2\hat{j}\right)$
(d) $\left(3\hat{i} + 4\hat{j}\right)$ and $\left(4\hat{i} - 3\hat{j}\right)$

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22. An electromagnetic wave in vacuum has the electric and magnetic field $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that of wave propagation by $\vec{k}$. Then
AIEEE 2012
(a) $\vec{X} \| \vec{B}$ and $\vec{X} \| \vec{B} \times \vec{E}$
(b) $\vec{X} \| \vec{E}$ and $\vec{k} \| \vec{E} \times \vec{B}$
(c) $\vec{X} \| \vec{B}$ and $\vec{k} \| \vec{E} \times \vec{B}$
(d) $\vec{X} \| \vec{E}$ and $\vec{k} \| \vec{B} \times \vec{E}$

◆ Reading the wave equation 4 Qs

23. The magnetic field in a plane electromagnetic wave is given by,
$B_y = 2 \times 10^{-7} \sin(\pi \times 10^3 x + 3\pi \times 10^{11} t)$ T
Calculate the wavelength.
NEET 2020 · PHASE 2
(a) $\pi \times 10^{-3}$ m (b) $\pi \times 10^{3}$ m
(c) 2×10^{-3} m (d) 2×10^{3} m

24. The electric field associated with an em wave in vacuum is given by
E = $i\hat{}$ 40 cos (kz – 6 × 108 t) where E, z and t are in volt/m, meter and seconds respectively. The value of wave vector k is
AIPMT 2012 · PRELIMS
(a) 2 m−1 (b) 0.5 m −1 (c) 6 m−1 (d) 3 m−1

25. The wavelength of light of frequency 100 Hz is
AIPMT 1999
(a) 2×10^6 m (b) 3×10^6 m
(c) 4×10^6 m (d) 5×10^6 m

26. If frequency of electromagnetic wave is 60 MHz and it travels in air along z direction then the corresponding electric and magnetic field vectors will be mutually perpendicular to each other and the wavelength of the wave (in m) is:
JEE MAIN 2024 · 1 FEB · SHIFT 2
(a) 2.5 (b) 5 (c) 10 (d) 2

◆ Field values: E0 = cB0 19 Qs

27. In a plane electromagnetic wave travelling in free space, the electric field component oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 $\mathrm{Vm^{-1}}$. Then the amplitude of oscillating magnetic field is: (Speed of light in free space $= 3 \times 10^8$ m $\mathrm{s^{-1}}$)
NEET 2023
(a) 1.6×10^{-8} T (b) 1.6×10^{-7} T
(c) 1.6×10^{-6} T (d) 1.6×10^{-9} T

28. The ratio of the magnitude of the magnetic field and electric field intensity of a plane electromagnetic wave in free space of permeability μ_0 and permittivity ε_0 is (Given that c - velocity of light in free space)
NEET 2022 · PHASE 2
(a) $\frac{\sqrt{\mu_0 \varepsilon_0}}{c}$ (b) c (c) $\frac{1}{c}$ (d) $\frac{c}{\sqrt{\mu_0 \varepsilon_0}}$

29. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagatting in vacuum is equal to
AIPMT 2012 · MAINS
(a) the speed of light in vacuum
(b) reciprocal of speed of light in vacuum
(c) the ratio of magnetic permeability to the electric susceptibility of vacuum
(d) unity

30. An electromagnetic wave travels in free space along the x-direction. At a particular point in space and time, $\vec{B} = 2 \times 10^{-7} \hat{j}$ T is associated with this wave. The value of corresponding electric field $\vec{E}$ at this point is _____ V/m.
JEE MAIN 2026 · 2 APR · SHIFT 2
(a) 60 $\hat{k}$ (b) −60 $\hat{k}$ (c) 30 $\hat{k}$ (d) −600 $\hat{k}$

31. A plane electromagnetic wave of frequency 35 MHz travels in free space along the X-direction. At a particular point (in space and time) $\vec{E} = 9.6\hat{j}$ V/m. The value of magnetic field at this point is:
JEE MAIN 2024 · 29 JAN · SHIFT 2
(a) $9.6\hat{j}T$ (b) $3.2 \times 10^{-8}\hat{i}T$
(c) $9.6 \times 10^{-8}\hat{k}T$ (d) $3.2 \times 10^{-8}\hat{k}T$

32. A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\vec{E} = 6.6\hat{j}$ V/m. What is $\vec{B}$ at this point?
JEE MAIN 2023 · 11 APR · SHIFT 2
(a) $-2.2 \times 10^{-8}\hat{i}T$ (b) $2.2 \times 10^{-8}\hat{i}T$
(c) $2.2 \times 10^{-8}\hat{k}T$ (d) $-2.2 \times 10^{-8}\hat{k}T$

33. The amplitude of magnetic field in an electromagnetic wave propagating along y-axis is 6.0×10^{-7} T. The maximum value of electric field in the electromagnetic wave is
JEE MAIN 2023 · 10 APR · SHIFT 2
(a) 6.0×10^{-7} $\mathrm{Vm^{-1}}$ (b) 5×10^{14} $\mathrm{Vm^{-1}}$
(c) 180 $\mathrm{Vm^{-1}}$ (d) 2×10^{15} $\mathrm{Vm^{-1}}$

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34. The electric field and magnetic field components of an electromagnetic wave going through vacuum is described by
$E_x = E_o \sin(kz - \omega t)$
$B_y = B_o \sin(kz - \omega t)$
Then the correct relation between E_0 and B_0 is given by
JEE MAIN 2023 · 24 JAN · SHIFT 2
(a) $E_oB_o = \omega k$ (b) $E_0 = kB_0$
(c) $kE_0 = \omega B_0$ (d) $\omega E_0 = kB_0$

35. A plane electromagnetic wave propagating in free space has amplitude of electric field of $900 \frac{N}{C}$. The amplitude of magnetic field will be :_____
JEE MAIN 2022 · 30 JUL · SHIFT 2
(a) 9 μT (b) 27 μT (c) 3 μT (d) 270 GT

36. The oscillating magnetic field in a plane electromagnetic wave is given by $B_y = 5 \times 10^{-6} \sin 1000\pi \left(5x - 4 \times 10^8 t\right) T$. The amplitude of electric field will be:
JEE MAIN 2022 · 26 JUL · SHIFT 2
(a) 15×10^2 Vm^{-1} (b) 5×10^{-6} Vm^{-1}
(c) 16×10^{12} Vm^{-1} (d) 4×10^2 Vm^{-1}

37. Light wave travelling in air along x-direction is given by $E_y = 540 \sin \pi \times 10^4 (x - ct)\, Vm^{-1}$. Then, the peak value of magnetic field of wave will be (Given c = 3 × 108 ms−1)
JEE MAIN 2022 · 25 JUL · SHIFT 2
(a) 18×10^{-7} T (b) 54×10^{-7} T
(c) 54×10^{-8} T (d) 18×10^{-8} T

38. An expression for oscillating electric field in a plane electromagnetic wave is given as Ez = 300 sin(5π × 103x – 3π × 1011t) Vm^{-1}
Then, the value of magnetic field amplitude will be:
(Given: speed of light in Vacuum c = 3 × 108 ms−1)
JEE MAIN 2022 · 30 JUN · SHIFT 1
(a) 1×10^{-6} T (b) 5×10^{-6} T
(c) 18 × 109 T (d) 21 × 109 T

39. A plane electromagnetic wave of frequency 100 MHz is travelling in vacuum along the x-direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8} \hat{k} T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point?
JEE MAIN 2021 · 18 MAR · SHIFT 1
(a) 0.6 $\hat{j}$ V/m (b) 6.0 $\hat{k}$ V/m
(c) 6.0 $\hat{j}$ V/m (d) 0.6 $\hat{k}$ V/m

40. A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time,
$\vec{B} = 8.0 \times 10^{-8}\, \hat{z}$T. The value of electric field at this point is:
(speed of light = 3 × 108 ms −1)
$\hat{x}$ $\hat{y}$ $\hat{z}$ are unit vectors along x, y and z directions.
JEE MAIN 2021 · 16 MAR · SHIFT 1
(a) 2.6 $\hat{x}$ V/m (b) – 24 $\hat{x}$ V/m
(c) 24 $\hat{x}$ V/m (d) –2.6 $\hat{y}$ V/m

41. A plane electromagnetic wave travels in free space along the x-direction. The electric field component of the wave at a particular point of space and time is E = 6 V m–1 along y-direction. Its corresponding magnetic field component, B would be:
JEE MAIN 2019 · 8 APR · SHIFT 1
(a) 2 × 10–8 T along y-direction
(b) 6 × 10–8 T along z-direction
(c) 2 × 10–8 T along z-direction
(d) 6 × 10–8 T along x-direction

42. If the magnetic field of a plane electromagnetic wave is given by (the speed of light = 3 × 108 m/s) B = 100 × 10–6 $\sin\left[2\pi \times 2 \times 10^{15} \left(t - \frac{x}{c}\right)\right]$ then the maximum electric field associated with it is -
JEE MAIN 2019 · 10 JAN · SHIFT 1
(a) 4.5 × 104 N/C (b) 4 × 104 N/C
(c) 6 × 104 N/C (d) 3 × 104 N/C

43. A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x- direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}\, V/m$. The corresponding magnetic field $\vec{B}$, at that point will be:
JEE MAIN 2019 · 9 JAN · SHIFT 1
(a) 18.9×10^{-8} $\hat{k}$T (b) 2.1×10^{-8} $\hat{k}$T
(c) 6.3×10^{-8} $\hat{k}$T (d) 18.9 × 108 $\hat{k}$T

44. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is:
JEE MAIN 2013
(a) $3V/m$ (b) $6V/m$ (c) $9V/m$ (d) $12V/m$

45. A plane electromagnetic wave with frequency of 30 MHz travels in free space. At particular point in space and time, electric field is 6 V/m. The magnetic field at this point will be x × 10^{-8} T. The value of x is _____.
JEE MAIN 2021 · 27 AUG · SHIFT 2 *(Numerical)*

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◆ Writing B from E and E from B 1 Q

46. The electric field in a plane electromagnetic wave is given by $E_z = 60\cos\left(5x + 1.5 \times 10^9 t\right)\mathrm{V/m}$ Then expression for the corresponding magnetic field is (here subscripts denote the direction of the field):

NEET 2025

(a) $Bz = 60\cos\left(5x + 1.5 \times 10^9 t\right)T$

(b) $B_y = 60\sin\left(5x + 1.5 \times 10^9 t\right)T$

(c) $B_y = 2 \times 10^{-7}\cos\left(5x + 1.5 \times 10^9 t\right)T$

(d) $B_x = 2 \times 10^{-7}\cos\left(5x + 1.5 \times 10^9 t\right)T$

◆ Force on a charge 1 Q

47. A charge 'q' moves with velocity 'v' through electric (E) as well as magnetic field (B). Then the force acting on it is

MHT CET 2023 · 9 MAY · SHIFT 2

(a) $\mathrm{q}(\vec{\mathrm{v}} \times \vec{\mathrm{B}})$

(b) $\mathrm{q}(\vec{\mathrm{B}} \times \vec{\mathrm{v}})$

(c) $\mathrm{q}(\vec{\mathrm{E}} \times \vec{\mathrm{v}})$

(d) $\vec{\mathrm{qE}} + \mathrm{q}(\vec{\mathrm{v}} \times \vec{\mathrm{B}})$

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TOPIC 02

Displacement Current, Maxwell's Equations & Production

6 PYQs · Easy 6 · Medium 0 · Difficult 0 | MHT CET 0 · NEET 2 · JEE 4

Concepts covered: Displacement current (1) · Maxwell's equations (3) · Production of EM waves (2)

LEVEL 1 · EASY 6 questions

◆ Displacement current 1 Q

48. If ϵ_0 denotes the permittivity of free space and Φ_E is the flux of the electric field through the area bounded by the closed surface, then dimensions of $\left(\epsilon_0 \frac{d\phi_E}{dt}\right)$ are that of:

JEE MAIN 2025 · 7 APR · SHIFT 1

(a) electric charge (b) electric field
(c) electric current (d) electric potential

◆ Maxwell's equations 3 Qs

49. Match List - I with List - II.

List - I Relation	List - II Law
A. $\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{d}{dt} \oint \vec{B} \cdot \overrightarrow{da}$	I. Ampere's circuital law
B. $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 \left(I + \epsilon_0 \frac{d\phi_E}{dt}\right)$	II. Faraday's laws of electromagnetic induction
C. $\oint \vec{E} \cdot \overrightarrow{da} = \frac{1}{\epsilon_0} \int_v \rho dv$	III. Ampere - Maxwell law
D. $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 I$	IV. Gauss's law of electrostatics

Choose the correct answer from the options given below:

JEE MAIN 2026 · 23 JAN · SHIFT 1

(a) A-I, B-IV, C-III, D-II
(b) A-II, B-III, C-IV, D-I
(c) A-IV, B-I, C-II, D-III
(d) A-II, B-III, C-I, D-IV

50. Which of the following Maxwell's equation is valid for time varying conditions but not valid for static conditions:

JEE MAIN 2023 · 13 APR · SHIFT 1

(a) $\oint \vec{E} \cdot \overrightarrow{dl} = 0$ (b) $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 I$
(c) $\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{\partial \phi_B}{\partial t}$ (d) $\oint \vec{D} \cdot \overrightarrow{dA} = Q$

51. Match List I with List II

	List I		List II
A.	Gauss's Law in Electrostatics	I.	$\oint \vec{E} . \overrightarrow{dl} = -\frac{d\phi_B}{dt}$
B.	Faraday's Law	II.	$\oint \vec{B} . \overrightarrow{dA} = 0$
C.	Gauss's Law in Magnetism	III.	$\oint \vec{B} . \overrightarrow{dl} = \mu_0 i_c + \mu_0 \in_0 \frac{d\phi_E}{dt}$
D.	Ampere-Maxwell Law	IV.	$\oint \vec{E} . \overrightarrow{ds} = \frac{q}{\in_0}$

Choose the correct answer from the options given below:

JEE MAIN 2023 · 25 JAN · SHIFT 2

(a) A-I, B-II, C-III, D-IV
(b) A-III, B-IV, C-I, D-II
(c) A-IV, B-I, C-II, D-III
(d) A-II, B-III, C-IV, D-I

◆ Production of EM waves 2 Qs

52. Out of the following options which one can be used to produce a propagating electromagnetic wave?

NEET 2016 · PHASE 1

(a) A chargeless particle
(b) An accelerating charge
(c) A charge moving at constant velocity
(d) A stationary charge

53. The electromagnetic radiations are caused by

AIPMT 1999

(a) a stationary charge
(b) uniformly moving charges
(c) accelerated charges
(d) all of the above

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TOPIC 03

Speed of EM Waves in a Medium

15 PYQs · Easy 15 · Medium 0 · Difficult 0 | MHT CET 0 · NEET 5 · JEE 10

Concepts covered: Speed in a medium (11) · Refractive index and dielectric constant (1) · Frequency and wavelength in a medium (3)

LEVEL 1 · EASY 15 questions

◆ Speed in a medium 11 Qs

54. When light propagates through a material medium of relative permittivity εr and relative permeability μr, the velocity of light, v is given by (c-velocity of light in vacuum)

NEET 2022 · PHASE 1

(a) v = c (b) $v = \sqrt{\frac{\mu_r}{\varepsilon_r}}$

(c) $v = \sqrt{\frac{\varepsilon_r}{\mu_r}}$ (d) $v = \frac{c}{\sqrt{\varepsilon_r \mu_r}}$

55. For a transparent medium, relative permeability and permittivity, μ_r and ε_r are 1.0 and 1.44 respectively. The velocity of light in this medium would be,

NEET 2019

(a) 4.32×10^8 m/s (b) 2.5×10^8 m/s

(c) 3×10^8 m/s (d) 2.08×10^8 m/s

56. The velocity of electromagnetic radiation in a medium of permittivity $\varepsilon 0$ and permeability $\mu 0$ is given by

AIPMT 2008

(a) $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ (b) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ (c) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ (d) $\sqrt{\mu_0 \varepsilon_0}$

57. The ratio of speeds of electromagnetic waves in vacuum and a medium, having dielectric constant $k = 3$ and permeability of $\mu = 2\mu_0$, is (μ_0 = permeability of vacuum)

JEE MAIN 2026 · 23 JAN · SHIFT 2

(a) 6 : 1 (b) 3 : 2 (c) $\sqrt{6}$: 1 (d) 36 : 1

58. Electromagnetic waves travel in a medium with speed of 1.5×10^8 m s^{-1}. The relative permeability of the medium is 2.0. The relative permittivity will be:

JEE MAIN 2024 · 6 APR · SHIFT 1

(a) 4 (b) 1 (c) 2 (d) 5

59. Given below are two statements:

Statement I: A time varying electric field is a source of changing magnetic field and vice-versa. Thus a disturbance in electric or magnetic field creates EM waves.

Statement II: In a material medium, the EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. In the light of the above statements, choose the correct answer from the options given below.

JEE MAIN 2022 · 27 JUN · SHIFT 2

(a) Both Statement I and Statement II are true

(b) Both Statement I and Statement II are false

(c) Statement I is correct but Statement II is false

(d) Statement I is incorrect but Statement II is true

60. The electromagnetic waves travel in a medium at a speed of 2.0×108 m/s. The relative permeability of the medium is 1.0. The relative permittivity of the medium will be:

JEE MAIN 2022 · 25 JUN · SHIFT 2

(a) 2.25 (b) 4.25 (c) 6.25 (d) 8.25

61. Electric field in a plane electromagnetic wave is given by E = 50 sin(500x – 10×1010 t) V/m The velocity of electromagnetic wave in this medium is:
(Given C = speed of light in vacuum)

JEE MAIN 2021 · 27 AUG · SHIFT 1

(a) $\frac{3}{2}$ C (b) C (c) $\frac{2}{3}$ C (d) $\frac{C}{2}$

62. The relative permittivity of distilled water is 81. The velocity of light in it will be: (Given $\mu_r = 1$)

JEE MAIN 2021 · 27 JUL · SHIFT 1

(a) 4.33×107 m/s (b) 2.33×107 m/s

(c) 3.33×107 m/s (d) 5.33×107 m/s

63. If an optical medium possesses a relative permeability of $\frac{10}{\pi}$ and relative permittivity of $\frac{1}{0.0885}$, then the velocity of light is greater in vacuum than that in this medium by _____ times.
$(\mu_0 = 4\pi \times 10^{-7}\text{H/m}, \epsilon_0 = 8.85 \times 10^{-12}\text{ F/m}, c = 3 \times 10^8\text{ m/s})$

JEE MAIN 2025 · 4 APR · SHIFT 2 *(Numerical)*

64. An electromagnetic wave of frequency 5 GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in this medium is _____ × 107 m/s.

JEE MAIN 2021 · 24 FEB · SHIFT 1 *(Numerical)*

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◆ Refractive index and dielectric constant 1 Q

65. If ε_0 and μ_0 are the electric permittivity and magnetic permeability in a free space, ε and μ are the corresponding quantities in medium, the index of refraction of the medium is

AIPMT 1997

(a) $\sqrt{\frac{\varepsilon_0\mu_0}{\varepsilon\mu}}$ (b) $\sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}}$ (c) $\sqrt{\frac{\varepsilon_0\mu}{\varepsilon\mu_0}}$ (d) $\sqrt{\frac{\varepsilon}{\varepsilon_0}}$

◆ Frequency and wavelength in a medium 3 Qs

66. An electromagnetic wave of frequency $\upsilon = 3.0$ MHz passes from vaccum into a dielectric medium with relative permittivity $\varepsilon_r = 4.0$. Then

NEET 2013

(a) Wavelength is doubled and frequency becomes half.
(b) Wavelength is halved and frequency remains unchanged.
(c) Wavelength and frequency both remain unchanged.
(d) Wavelength is doubled and frequency unchanged.

67. An electromagnetic wave of frequency $\upsilon = 3.0\ MHz$ passes from vacuum into a dielectric medium with permittivity $\in = 4.0$. Then

AIEEE 2004

(a) wave length is halved and frequency remains unchanged
(b) wave length is doubled and the frequency becomes half
(c) wave length is doubled and the frequency remains unchanged
(d) wave length and frequency both remain unchanged.

68. An electromagnetic wave of frequency 3 GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be _____ $\times 10^{-2}$ cm.

JEE MAIN 2021 · 24 FEB · SHIFT 2 *(Numerical)*

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TOPIC 04

Energy Density & Intensity

14 PYQs · Easy 14 · Medium 0 · Difficult 0 | MHT CET 0 · NEET 1 · JEE 13

Concepts covered: Energy density of E and B fields (6) · Energy density from amplitude and energy in a volume (3) · Intensity from field amplitudes (4) · Point source and bulb (1)

LEVEL 1 · EASY 14 questions

◆ Energy density of E and B fields 6 Qs

69. The energy density associated with electric field $\vec{E}$ and magnetic field $\vec{B}$ of an electromagnetic wave in free space is given by (ϵ_0 – permittivity of free space, μ_0 – permeability of free space)

JEE MAIN 2023 · 6 APR · SHIFT 2

(a) $U_E = \frac{\epsilon_0 E^2}{2}, U_B = \frac{B^2}{2\mu_0}$

(b) $U_E = \frac{E^2}{2\epsilon_0}, U_B = \frac{\mu_0 B^2}{2}$

(c) $U_E = \frac{\epsilon_0 E^2}{2}, U_B = \frac{\mu_0 B^2}{2}$

(d) $U_E = \frac{E^2}{2\epsilon_0}, U_B = \frac{B^2}{2\mu_0}$

70. For the plane electromagnetic wave given by $E = E_0 \sin(\omega t - kx)$ and $B = B_0 \sin(\omega t - kx)$, the ratio of average electric energy density to average magnetic energy density is

JEE MAIN 2023 · 6 APR · SHIFT 1

(a) 1 (b) 4 (c) 2 (d) 1/2

71. The ratio of average electric energy density and total average energy density of electromagnetic wave is:

JEE MAIN 2023 · 1 FEB · SHIFT 2

(a) 1 (b) 3 (c) 2 (d) $\frac{1}{2}$

72. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (Ue) and magnetic (Um) fields is:

JEE MAIN 2021 · 16 MAR · SHIFT 1

(a) Ue = Um (b) Ue ≠ Um (c) Ue < Um (d) Ue > Um

73. The energy associated with electric field is (UE) and with magnetic field is (UB) for an electromagnetic wave in free space. Then:

JEE MAIN 2019 · 9 JAN · SHIFT 2

(a) $U_E = \frac{U_B}{2}$ (b) $U_E > U_B$

(c) $U_E < U_B$ (d) $U_E = U_B$

74. During the propagation of electromagnetic waves in a medium:

JEE MAIN 2014

(a) Electric energy density is double of the magnetic energy density.

(b) Electric energy density is half of the magnetic energy density.

(c) Electric energy density is equal to the magnetic energy density.

(d) Both electric and magnetic energy of densities are zero.

◆ Energy density from amplitude and energy in a volume 3 Qs

75. The electric field in an electromagnetic wave is given as

$\vec{E} = 20 \sin\omega\left(t - \frac{x}{c}\right)\hat{j} NC^{-1}$

where ω and c are angular frequency and velocity of electromagnetic wave respectively. The energy contained in a volume of 5×10^{-4} m^3 will be

(Given $\varepsilon_0 = 8.85 \times 10^{-12} C^2/Nm^2$)

JEE MAIN 2023 · 11 APR · SHIFT 1

(a) 17.7×10^{-13} J (b) 28.5×10^{-13} J

(c) 8.85×10^{-13} J (d) 88.5×10^{-13} J

76. An electromagnetic wave of frequency 1×1014 hertz is propagating along z - axis. The amplitude of electric field is 4 V/m. If $\in_0 = 8.8 \times 10^{-12}$ C2/N-m2, then average energy density of electric field will be:

JEE MAIN 2014 · 11 APR · SHIFT 1

(a) 35.2×10^{-10} J/m3 (b) 35.2×10^{-11} J/m3

(c) 35.2×10^{-12} J/m3 (d) 35.2×10^{-13} J/m3

77. The rms value of the electric field of the light coming from the Sun is 720 N/C. The average total energy density of the electromagnetic wave is

AIEEE 2006

(a) $4.58 \times 10^{-6}\ J/m^3$ (b) $6.37 \times 10^{-9}\ J/m^3$

(c) $81.35 \times 10^{-12}\ J/m^3$ (d) $3.3 \times 10^{-3}\ J/m^3$

◆ Intensity from field amplitudes 4 Qs

78. The ratio of contributions made by the electric field and magnetic field components to the intensity of an electromagnetic wave is: (c = speed of electromagnetic waves)

NEET 2020 · PHASE 1

(a) 1: 1 (b) 1: c (c) 1: c2 (d) c: 1

79. In the given electromagnetic wave $E_y = 600 \sin(\omega t - kx) Vm^{-1}$, intensity of the associated light beam is (in W/m^2): (Given $\epsilon_0 = 9 \times 10^{-12} C^2\ N^{-1}\ m^{-2}$)

JEE MAIN 2024 · 6 APR · SHIFT 2

(a) 486 (b) 729 (c) 243 (d) 972

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80. A plane electromagnetic wave propagating in x-direction is described by

$E_y = \left(200\text{Vm}^{-1}\right) \sin\left[1.5 \times 10^7 t - 0.05x\right]$;

The intensity of the wave is:

(Use $\epsilon_0 = 8.85 \times 10^{-12}\text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$)

JEE MAIN 2024 · 27 JAN · SHIFT 1

(a) $35.4\ \text{Wm}^{-2}$ (b) $53.1\ \text{Wm}^{-2}$

(c) $26.6\ \text{Wm}^{-2}$ (d) $106.2\ \text{Wm}^{-2}$

81. The electric field in an electromagnetic wave is given by E = 56.5 sin ω(t – x/c) NC^{-}1. Find the intensity of the wave if it is propagating along x-axis in the free space.

(Given: $\varepsilon_0 = 8.85 \times 10^{-}12\text{C}2\text{N}^{-1}\text{m}^{-}2$)

JEE MAIN 2022 · 25 JUN · SHIFT 1

(a) $5.65\ \text{Wm}^{-2}$ (b) $4.24\ \text{Wm}^{-2}$

(c) $1.9 \times 10^{-7}\ \text{Wm}^{-2}$ (d) $56.5\ \text{Wm}^{-2}$

◆ Point source and bulb 1 Q

82. A point light source emits E.M. waves in free space. A detector, placed at a distance of L m, measures the intensity as I_o. The detector is now shifted to another location on the same spherical surface ensuring the angle between original location and new location as 45°. The measured intensity at new location will be ____.

JEE MAIN 2026 · 6 APR · SHIFT 1

(a) $\frac{I_o}{4}$ (b) I_o (c) $\frac{I_0}{\sqrt{2}}$ (d) $\frac{I_o}{2}$

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TOPIC 05

Momentum & Radiation Pressure

5 PYQs · Easy 5 · Medium 0 · Difficult 0 | MHT CET 0 · NEET 1 · JEE 4

Concepts covered: Momentum of EM waves (5)

LEVEL 1 · EASY 5 questions

83. A radiation of energy 'E' falls normally on a perfectly reflecting surface. The momentum transferred to the surface is (C = Velocity of light)

AIPMT 2015 · CANCELLED PAPER

(a) $\frac{2E}{C^2}$ (b) $\frac{E}{C^2}$ (c) $\frac{E}{C}$ (d) $\frac{2E}{C}$

84. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): The electromagnetic wave exerts pressure on the surface on which they are allowed to fall.

Reason (R): There is no mass associated with the electromagnetic waves.

In the light of the above statements, choose the correct answer from the options given below:

JEE MAIN 2026 · 5 APR · SHIFT 2

(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

85. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): Electromagnetic waves carry energy but not momentum.

Reason (R): Mass of a photon is zero.

In the light of the above statements, choose the most appropriate answer from the options given below:

JEE MAIN 2025 · 29 JAN · SHIFT 1

(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 false but (R) is true
(d) (A) is true but (R) is false

86. Given below are two statements:

Statement I: Electromagnetic waves carry energy as they travel through space and this energy is equally shared by the electric and magnetic fields.

Statement II: When electromagnetic waves strike a surface, a pressure is exerted on the surface. In the light of the above statements, choose the most appropriate answer from the options given below:

JEE MAIN 2024 · 31 JAN · SHIFT 2

(a) Statement I is incorrect but Statement II is correct.
(b) Both Statement I and Statement II are correct.
(c) Statement I is correct but Statement II is incorrect.
(d) Both Statement I and Statement II are incorrect.

87. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is

AIEEE 2004

(a) Ec (b) $2E/c$ (c) E/c (d) E/c^2

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TOPIC 06

Electromagnetic Spectrum & Atmosphere

32 PYQs · Easy 32 · Medium 0 · Difficult 0 | MHT CET 1 · NEET 18 · JEE 13

Concepts covered: Order of the spectrum and wavelength ranges (19) · Uses of EM waves (8) · Greenhouse, ozone and radio propagation (5)

LEVEL 1 · EASY 32 questions

◆ Order of the spectrum and wavelength ranges 19 Qs

88. The electromagnetic radiation which has the smallest wavelength are
NEET 2024
(a) X-rays (b) Gamma rays
(c) Ultraviolet rays (d) Microwaves

89. The E.M. wave with shortest wavelength among the following is,
NEET 2020 · PHASE 2
(a) Microwaves (b) Ultraviolet rays
(c) X-rays (d) Gamma-rays

90. Which colour of the light has the longest wavelength?
NEET 2019
(a) blue (b) violet (c) red (d) green

91. The energy of the em waves is of the order of 15 keV. To which part of the spectrum does it belong?
AIPMT 2015
(a) Ultraviolet rays (b) γ-rays
(c) X-rays (d) Infra-red rays

92. The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is
AIPMT 2011 · PRELIMS
(a) microwave, infrared, ultraviolet, gamma rays
(b) gamma rays, ultraviolet, infraref, microwaves
(c) microwaves, gamma rays, infrared, ultraviolet
(d) infrared, microwave, ultraviolet, gamma rays

93. If λv, λx and λm represent the wavelengths of visible light, X-rays and microwaves respectively, then
AIPMT 2005
(a) $\lambda_m > \lambda_x > \lambda_v$ (b) $\lambda_m > \lambda_v > \lambda_x$
(c) $\lambda_v > \lambda_x > \lambda_m$ (d) $\lambda_v > \lambda_m > \lambda_x$

94. Which of the following rays are not electromagnetic waves?
AIPMT 2003
(a) X-rays (b) γ-rays
(c) β-rays (d) heat rays

95. Which of the following has minimum wavelength?
AIPMT 2002
(a) X-rays (b) Ultraviolet rays
(c) γ-rays (d) Cosmic rays

96. The frequency order for γ-rays (a), X-rays (b), UV rays (c) is
AIPMT 2000
(a) b > a > c (b) a > b > c
(c) c > b > a (d) a > c > b

97. Which of the following electromagnetic radiations have the smaller wavelength?
AIPMT 1994
(a) X-rays (b) γ-rays
(c) UV waves (d) microwaves

98. Which of the following electromagnetic radiations have the longest wavelength?
AIPMT 1989
(a) X-rays (b) γ-rays
(c) Microwaves (d) Radiowaves

99. Arrange the following in the ascending order of wavelength (λ):
(A) Microwaves (λ_1)
(B) Ultraviolet rays (λ_2)
(C) Infrared rays (λ_3)
(D) X-rays (λ_4)
Choose the most appropriate answer from the options given below:
JEE MAIN 2025 · 24 JAN · SHIFT 2
(a) $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$ (b) $\lambda_4 < \lambda_2 < \lambda_3 < \lambda_1$
(c) $\lambda_3 < \lambda_4 < \lambda_2 < \lambda_1$ (d) $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$

100. Arrange the following in the ascending order of wavelength:
A. Gamma rays (λ_1)
B. x - rays (λ_2)
C. Infrared waves (λ_3)
D. Microwaves (λ_4)
Choose the most appropriate answer from the options given below
JEE MAIN 2024 · 4 APR · SHIFT 2
(a) $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$ (b) $\lambda_2 < \lambda_1 < \lambda_4 < \lambda_3$
(c) $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$ (d) $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$

101. Which is the correct ascending order of wavelengths?
JEE MAIN 2022 · 26 JUN · SHIFT 2
(a) $\lambda_{visible} < \lambda_{X\text{-ray}} < \lambda_{gamma\text{-ray}} < \lambda_{microwave}$
(b) $\lambda_{gamma\text{-ray}} < \lambda_{X\text{-ray}} < \lambda_{visible} < \lambda_{microwave}$
(c) $\lambda_{X\text{-ray}} < \lambda_{gamma\text{-ray}} < \lambda_{visible} < \lambda_{microwave}$
(d) $\lambda_{microwave} < \lambda_{visible} < \lambda_{gamma\text{-ray}} < \lambda_{X\text{-ray}}$

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102. Choose the correct option relating wave lengths of different parts of electromagnetic wave spectrum:
JEE MAIN 2020 · 4 SEP · SHIFT 1
(a) λradio waves > λmicro waves > λvisible > λx-rays
(b) λvisible > λx-rays > λradio waves > λmicro waves
(c) λvisible < λmicro waves < λradio waves < λx-rays
(d) λx-rays < λmicro waves < λradio waves < λ visible

103. Arrange the following electromagnetic radiations per quantum in the order of increasing energy: A: Blue light B: Yellow light
C: X-ray D: Radiowave.
JEE MAIN 2016
(a) C, A, B, D (b) B, A, D, C
(c) D, B, A, C (d) A, B, D, C

104. If microwaves, X rays, infrared, gamma rays, ultra-violet, radio waves and visible parts of the electromagnetic spectrum are represented by M, X, I, G, U, R and V, the following is the arrangement in ascending order of wavelength:
JEE MAIN 2014 · 19 APR · SHIFT 1
(a) R, M, I, V, U, X and G (b) M, R, V, X, U, G and I
(c) G, X, U, V, I, M and R (d) I, M, R, U, V, X and G

105. Photons of an electromagnetic radiation has an energy 11 keV each. To which region of electromagnetic spectrum does it belong?
JEE MAIN 2013 · 9 APR · SHIFT 1
(a) X-ray region (b) Ultra violet region
(c) Infrared region (d) Visible region

106. Which of the following are not electromagnetic waves?
AIEEE 2002
(a) cosmic rays (b) gamma rays
(c) β-rays (d) X-rays

◆ Uses of EM waves 8 Qs

107. The following table presents the part of the electromagnetic spectrum and their corresponding major applications.

	Part of the electromagnetic spectrum		Applications
P.	Microwave	I.	For purifying the water
Q.	UV rays	II.	For warming the food
R.	Gamma rays	III.	For AM and FM communication systems
S.	Radio wave	IV.	For treating the Cancer cells

The correct option is:
RE-NEET 2026
(a) P-II, Q-IV, R-III, S-I
(b) P-I, Q-II, R-III, S-IV
(c) P-I, Q-IV, R-II, S-III
(d) P-II, Q-I, R-IV, S-III

108. We consider the radiation emitted by the human body. Which one of the following statements is true?
AIPMT 2003
(a) The radiation emitted is in the infra-red region
(b) The radiation emitted only during the day
(c) The radiation is emitted during the summers and absorbed during the winters
(d) The radiation emitted lies in the ultraviolet region and hence is not visible

109. The structure of solids is investigated by using
AIPMT 1992
(a) cosmic rays (b) X-rays
(c) γ-rays (d) infra-red radiations

110. Match List I with List II

LIST I		LIST II	
A.	Microwaves	I.	Physiotherapy
B.	UV rays	II.	Treatment of cancer
C.	Infra-red light	III.	Lasik eye surgery
D.	X-ray	IV.	Aircraft navigation

Choose the correct answer from the options given below:
JEE MAIN 2023 · 31 JAN · SHIFT 2
(a) A - IV, B - III, C - I, D - II
(b) A - II, B - IV, C - III, D - I
(c) A - III, B - II, C - I, D - IV
(d) A - IV, B - I, C - II, D - III

111. Match List - I with List - II:

	List - I		List - II
(a)	UV rays	(i)	Diagnostic tool in medicine
(b)	X-rays	(ii)	Water purification
(c)	Microwave	(iii)	Communication, Radar
(d)	Infrared wave	(iv)	Improving visibility in foggy days

Choose the correct answer from the options given below:
JEE MAIN 2022 · 29 JUL · SHIFT 1
(a) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)
(b) (a)-(ii), (b)-(i), (c)-(iii), (d)-(iv)
(c) (a)-(ii), (b)-(iv), (c)-(iii), (d)-(i)
(d) (a)-(iii), (b)-(i), (c)-(ii), (d)-(iv)

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112. Match List-I with List-II:

	List - I		List - II
(a)	Ultraviolet rays	(i)	Study crystal structure
(b)	Microwaves	(ii)	Greenhouse effect
(c)	Infrared rays	(iii)	Sterilizing surgical instrument
(d)	X-rays	(iv)	Radar system

Choose the correct answer from the options given below:

JEE MAIN 2022 · 27 JUN · SHIFT 1

(a) (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i)
(b) (a)-(iii), (b)-(i), (c)-(ii), (d)-(iv)
(c) (a)-(iv), (b)-(iii), (c)-(ii), (d)-(i)
(d) (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)

113. In free space, an electromagnetic wave of 3 GHz frequency strikes over the edge of an object of size $\frac{\lambda}{100}$, where λ is the wavelength of the wave in free space. The phenomenon, which happens there will be:

JEE MAIN 2022 · 26 JUN · SHIFT 1

(a) Reflection (b) Refraction
(c) Diffraction (d) Scattering

114. Microwave oven acts on the principle of:

JEE MAIN 2016 · 9 APR · SHIFT 1

(a) transferring electrons from lower to higher energy levels in water molecule
(b) giving rotational energy to water molecules
(c) giving vibrational energy to water molecules
(d) giving translational energy to water molecules

◆ Greenhouse, ozone and radio propagation 5 Qs

115. In amplitude modulation,

MHT CET 2020 · 16 OCT · SHIFT 1

(a) amplitude remains constant but frequency. changes according to information signal
(b) amplitude of carrier wave changes according to information signal
(c) both amplitude and frequency changes according to information signal
(d) both amplitude and frequency do not change according to information signal

116. What is the cause of Green house effect?

AIPMT 2002

(a) infra-red rays (b) ultra violet rays
(c) X-rays (d) radio waves.

117. Biological importance of ozone layer is

AIPMT 2001

(a) it stops ultraviolet rays
(b) ozone layer reduces green house effect
(c) ozone layer reflects radio waves
(d) ozone layer controls O2/H2 ratio in atmosphere.

118. Ozone layer blocks the radiations of wave length

AIPMT 1999

(a) less than 3×10^{-7} m (b) equal to 3×10^{-7} m
(c) more than 3×10^{-7} m (d) all of the above

119. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of

AIPMT 1993 *(Not in current JEE/NEET syllabus)*

(a) sky wave (b) ground wave
(c) sea wave (d) both (1) and (2)

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ANSWER KEY

Shaded by level: **Easy**

01 Nature of EM Waves & Wave Equation

1. (c)	2. (d)	3. (c)	4. (c)	5. (c)	6. (b)	7. (d)	8. (a)	9. (c)	10. (b)
11. (a)	12. (b)	13. (c)	14. (c)	15. (c)	16. (a)	17. (d)	18. (a)	19. (c)	20. (c)
21. (b)	22. (b)	23. (c)	24. (a)	25. (b)	26. (b)	27. (b)	28. (c)	29. (b)	30. (b)
31. (d)	32. (c)	33. (c)	34. (c)	35. (c)	36. (d)	37. (a)	38. (b)	39. (c)	40. (b)
41. (c)	42. (d)	43. (b)	44. (b)	45. 2	46. (c)	47. (d)			

02 Displacement Current, Maxwell's Equations & Production

48. (c)	49. (b)	50. (c)	51. (c)	52. (b)	53. (c)				

03 Speed of EM Waves in a Medium

54. (d)	55. (b)	56. (a)	57. (c)	58. (c)	59. (c)	60. (a)	61. (c)	62. (c)	63. 6
64. 15	65. (b)	66. (b)	67. (a)	68. 667					

04 Energy Density & Intensity

69. (a)	70. (a)	71. (d)	72. (a)	73. (d)	74. (c)	75. (c)	76. (c)	77. (a)	78. (a)
79. (a)	80. (b)	81. (b)	82. (b)						

05 Momentum & Radiation Pressure

83. (d)	84. (b)	85. (c)	86. (b)	87. (b)					

06 Electromagnetic Spectrum & Atmosphere

88. (b)	89. (d)	90. (c)	91. (c)	92. (a)	93. (b)	94. (c)	95. (d)	96. (b)	97. (b)
98. (d)	99. (b)	100. (a)	101. (b)	102. (a)	103. (c)	104. (c)	105. (a)	106. (c)	107. (d)
108. (a)	109. (b)	110. (a)	111. (b)	112. (a)	113. (d)	114. (c)	115. (b)	116. (a)	117. (a)
118. (a)	119. (d)								

Note: *"Bonus" = no option is correct as the question is printed (dropped in the official key). Numerical questions show the numerical answer.*

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