🌈 Physics – Electromagnetic Waves (EM Waves)

Class 12 Board Exam Special Edition

Designed for **quick understanding + top marks** with **simple language, diagrams, mnemonics, solved numericals, PYQs, revision notes, and exam hacks**.

⭐ 1. THEORY IN SIMPLE WORDS (WITH VISUALS)

🌈 1.1 What Are Electromagnetic Waves?

Electromagnetic waves are waves made of **electric field (E)** and **magnetic field (B)** oscillating **together** and **perpendicular** to each other.

🎨 Visual:

```
E-field ↑
        → direction of wave
B-field ⊗ (into page)
```

Kid-friendly analogy

Think of EM waves as **two friends (E & B)** doing **jumping jacks**—
their arms move up–down and in–out, but they always stay **at 90°** to each other.

🌈 1.2 Who discovered them?

James Clerk **Maxwell** → predicted EM waves
Heinrich **Hertz** → experimentally proved them

🌈 1.3 Key Properties of EM Waves

- **They do NOT need a medium** → can travel in vacuum
- **Speed in vacuum**:

$$c = 3 \times 10^8 \text{ m/s}$$

- They are **transverse waves**
- Carry **energy + momentum**

🌈 1.4 Source of EM Waves

Accelerating (NOT constant) **charges** produce EM waves.

🎨 Visual:
A charge that "shakes" → creates ripples (waves).

🌈 1.5 Electromagnetic Spectrum

🎉 Increasing frequency → decreasing wavelength

Region	Wavelength	Frequency	Uses
Radio waves	Longest	Lowest	Broadcasting
Microwaves	cm	GHz	Ovens, radar
Infrared	warm objects	–	Remote controls
Visible	400–700 nm	–	Human vision
UV	shorter	high	Sterilization
X-rays	very short	–	Medical imaging
Gamma rays	shortest	highest	Cancer treatment

🌈 Color order of visible light

V I B G Y O R
(Violet → highest frequency)

🌈 1.6 Displacement Current

Maxwell added:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

Reason → explains EM wave propagation.

🌈 1.7 Speed of EM Waves

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

🌈 1.8 Momentum of EM Waves

$$p = \frac{E}{c}$$

Radiation pressure =

$$P = \frac{I}{c}$$

⭐ 2. KEY CONCEPTS & FORMULAS (REVISION TABLE)

Concept	Formula / Definition
EM wave speed	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$
Electric–magnetic relation	$\frac{E_0}{B_0} = c$
Displacement current	$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$
EM wave energy	equally shared by E & B
EM spectrum order	Radio → Micro → IR → Visible → UV → X-ray → Gamma
Wave speed	$c = f\lambda$
Radiation pressure	$P = I/c$

🌈 Mnemonics

✔ EM Spectrum Order

"Rabbits Mate In Very Unusual X-Games"
Radio → Microwave → Infrared → Visible → UV → X-ray → Gamma

✔ Visible Spectrum

"VIBGYOR" (Purple to Red)

✔ Electric Field leads Magnetic Field

"E comes before B in alphabet" → E leads B

⭐ 3. SOLVED NUMERICAL PROBLEMS

✔ Q1: Wave Speed Calculation

A wave has frequency $5 \times 10^{14} Hz$. Wavelength = $600nm$.
Check if it is an EM wave in vacuum.

Solution:

$$c = f\lambda = 5 \times 10^{14} \times 600 \times 10^{-9}$$

$$= 3 \times 10^{8} \text{ m/s}$$

Matches speed of EM waves → **YES**.

✔ Q2: Find frequency

Wavelength of X-ray = $1 \times 10^{-10} m$.

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{10^{-10}}$$

$$= 3 \times 10^{18} Hz$$

✔ Q3: Magnetic Field from Electric Field

Given: $E_0 = 300\ V/m$.
Find B_0.

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

$$B_0 = \frac{E_0}{c} = \frac{300}{3 \times 10^{8}}$$

$$= 1 \times 10^{-6}\ T$$

⭐ 4. PAST YEARS' BOARD QUESTIONS (SOLVED)

(Based on common Class 12 CBSE patterns)

✔ **Define displacement current.**
→ $I_d = \epsilon_0 \frac{d\Phi_E}{dt}$

✔ **Write two uses of X-rays.**
→ Surgery, baggage scanning.

✔ **Draw EM spectrum.**

✔ **State the relation between E and B in EM wave.**
→ $E_0/B_0 = c$

✔ **Derive speed of EM waves in vacuum.**

✔ **Which EM wave is used for satellite communication?**
→ Microwaves.

✔ **Name the EM wave produced by radioactive nuclei.**
→ Gamma rays.

⭐ 5. QUICK REVISION NOTES (1–2 PAGES)

🌈 EM Wave Summary

- EM waves = coupled **E and B fields**
- Transverse
- Travel in vacuum
- Produced by **accelerating charges**
- Carry **energy + momentum**
- Speed: $c = 3 \times 10^8 m/s$

🌈 EM Spectrum (Order → Frequency ↑)

```
Radio → Micro → IR → Visible → UV → X-Ray → Gamma
```

Visible = **VIBGYOR**

🌈 Displacement Current

Must for oscillating E-field. Completes Ampere's law.

🌈 Energy Share

Electric energy = Magnetic energy.

🌈 Important Relations

$$c = f\lambda$$

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

🌈 Uses of EM Waves (Table)

Wave	Uses
Radio	Broadcasting, TV
Micro	Ovens, satellites
IR	Remotes, night-vision
Visible	Human vision
UV	Water purification
X-ray	Medical imaging
Gamma	Cancer treatment

⭐ 6. PREDICTED QUESTIONS (2025 Boards)

Very Likely (5–6 marks)

- Derive speed of EM waves
- Explain displacement current
- Draw EM spectrum

Likely Short Questions (1–2 marks)

- What are EM waves?
- Give one property of EM waves
- Which EM wave is used in satellite phones?
- Define displacement current
- Give relation between E and B

Numericals

- Frequency/wavelength
- Value of B from E
- Radiation pressure

⭐ 7. EXAM TIPS & TRICKS

✔ Tip 1: EM Spectrum ALWAYS asked

Draw a clean diagram in 10 seconds:

```
Radio – Micro – IR – Visible – UV – X – Gamma
```

✔ Tip 2: Remember

$$c = 3 \times 10^8 \text{ m/s}$$

✔ Tip 3: Visible range = 400–700 nm

✔ Tip 4: E and B are always

- Perpendicular
- Oscillating
- In phase

✔ Tip 5: Write uses of waves EXACTLY as taught

Ex: Microwaves → satellite communication (CBSE favourite)

⭐ 8. VISUAL & KID-FRIENDLY MEMORY TOOLS

🎨 EM Wave Drawing (Super Easy)

```
E ↑↓
 → wave
B ↗↘
```

(E ⊥ B ⊥ direction)

🎨 EM Spectrum Cartoon

"Red Monkeys In Violet Uniforms eXercise Gracefully"
(Radio, Micro, IR, Visible, UV, X-ray, Gamma)

🎨 Light colors

ROYGBIV backwards
Red (longest λ) → Violet (shortest)

🎨 Displacement Current

Think of a **charging capacitor** "leaking imaginary current" between plates.