ELECTROMAGNETIC WAVES — NEET PHYSICS

Comprehensive Formula Sheet for Revision

1. DISPLACEMENT CURRENT & MAXWELL'S EQUATIONS

Displacement Current

Arises due to a time-varying electric flux between capacitor plates (Maxwell's correction to Ampere's Law):

$$i_d = \varepsilon_0 \frac{d\Phi_E}{dt} \tag{1}$$

- Total current inside capacitor = conduction current outside plates
- Ensures continuity of current in AC circuits

Ampere–Maxwell Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_c + i_d) \tag{2}$$

Maxwell's Equations (Conceptual Summary)

- Gauss's Law (Electricity): electric flux from charges
- Gauss's Law (Magnetism): no magnetic monopoles, net flux = 0
- Faraday's Law: changing B produces E
- Ampere–Maxwell Law: changing E (or current) produces B

2. NATURE OF ELECTROMAGNETIC WAVES

- Transverse waves: $\vec{E}$, $\vec{B}$, and direction of propagation are mutually perpendicular
- $\vec{E}$ and $\vec{B}$ oscillate in phase (zero and maxima together)
- Do not require a material medium — can travel through vacuum
- Carry energy and momentum but no net charge

3. SPEED OF ELECTROMAGNETIC WAVES

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/s} \tag{3}$$

- In a medium: $v = \dfrac{1}{\sqrt{\mu\varepsilon}} = \dfrac{c}{n}$
- Refractive index: $n = \dfrac{c}{v} = \sqrt{\varepsilon_r \mu_r}$
- Ratio of amplitudes: $\dfrac{E_0}{B_0} = c$
- At every instant: $E = cB$

4. ENERGY IN ELECTROMAGNETIC WAVES

- Electric energy density: $u_E = \dfrac{1}{2}\varepsilon_0 E^2$
- Magnetic energy density: $u_B = \dfrac{B^2}{2\mu_0}$
- Equal sharing: $u_E = u_B$
- Average total energy density:

$$u_{avg} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0} \tag{4}$$

5. POYNTING VECTOR & INTENSITY

- Rate of energy flow per unit area:

$$S = \frac{EB}{\mu_0} \tag{5}$$

- Intensity (time-averaged Poynting vector):

$$I = \frac{1}{2}\varepsilon_0 c E_0^2 = \frac{c B_0^2}{2\mu_0} \tag{6}$$

- Point source: $I = \dfrac{P}{4\pi r^2}$ (power spreads over a sphere)

6. MOMENTUM & RADIATION PRESSURE

- Momentum carried: $p = \dfrac{U}{c}$
- Fully absorbing surface: Pressure $= \dfrac{I}{c}$
- Fully reflecting surface: Pressure $= \dfrac{2I}{c}$
- Force = Pressure × Area

7. ELECTROMAGNETIC SPECTRUM

- **Radio waves** (> 0.1 m): LC oscillators; communication, broadcasting
- **Microwaves** (0.1 m -1 mm): Klystron/magnetron; radar, satellite links
- **Infrared** (1 mm -700 nm): Hot bodies; thermal imaging, remote controls
- **Visible light** ($700 - 400$ nm): Atomic transitions; vision
- **Ultraviolet** (400 nm -1 nm): Sun, arc lamps; sterilization
- **X-rays** (1 nm -10^{-3} nm): Sudden deceleration of electrons; medical imaging

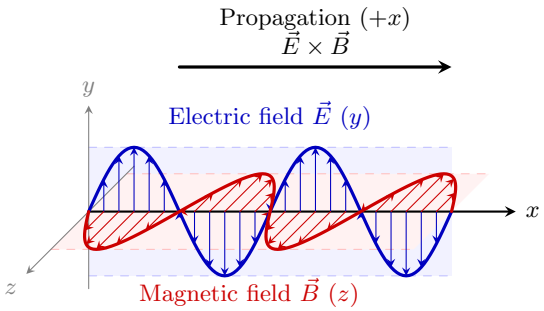
- **Gamma rays** ($< 10^{-3}$ nm): Nuclear decay; cancer treatment

Increasing wavelength order:
$\gamma < X\text{-ray} < UV <$ visible $< IR <$ microwave $<$ radio

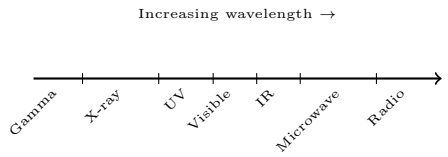
8. STANDARD SHORTCUTS

- Wave relation: $c = f\lambda$
- E–B ratio always equals c, never a fixed number times c
- Both $u_E = u_B$ always — a very common conceptual MCQ trap
- Radiation pressure of a mirror is double that of a black surface for same intensity

KEY DIAGRAMS



$\vec{E} \perp \vec{B} \perp \hat{x}$; both fields oscillate in phase.
Perspective view; field amplitudes drawn on separate scales.



Electromagnetic Spectrum (short to long wavelength)

MOST IMPORTANT FORMULAS AT A GLANCE

Concept	Key Formula
Displacement current	$i_d = \varepsilon_0 \dfrac{d\Phi_E}{dt}$
Speed of EM wave	$c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$
E–B relation	$E_0/B_0 = c$
Avg. energy density	$u_{avg} = \dfrac{1}{2}\varepsilon_0 E_0^2$
Intensity	$I = \dfrac{1}{2}\varepsilon_0 c E_0^2$
Radiation pressure (absorb)	$P = I/c$
Radiation pressure (reflect)	$P = 2I/c$
Refractive index	$n = c/v$

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