1 Remember

- $\overline{E} = \overline{E}(r,\, t) \rightarrow$ Electric field intensity .
- $\overline{D} = \epsilon \overline{E}$ Electric flux intensity .
- Permittivity $= \epsilon = \epsilon_0 \epsilon_r$
- $\overline{\rho}_v$ volume charge density (c/m^3) $= \overline{\rho}_v(r,\, t)$

- $\overline{H} = \overline{H}(r,\, t)$ Magnetic field intensity (A/m)
- $\overline{B} = \mu \overline{H}$ Magnetic flux density
- Permeability $= \mu = \mu_0 \mu_r$
- $\overline{J} = \overline{J}(r,\, t)$ current density (A/m^2)

- Note that all electric and magnetic quantities are functions in position and time.
- Note that electric charge is the source of electric field, while electric current is the source of magnetic field.

2 Maxwell's equations

Gauss's law :

$$\oiint \overline{D} \cdot \overline{ds} = Q_{\text{enc}} \qquad\qquad \nabla \cdot D = \overline{\rho_v}$$

Gauss's law for magnetism :

$$\oiint \overline{B} \cdot \overline{ds} = 0 \qquad\qquad \nabla \cdot B = 0$$

Faraday's law :

$$\text{emf} = \oint \overline{E} \cdot \overline{dl} \qquad\qquad \nabla \times E = -\frac{\partial \overline{B}}{\partial t}$$

Ampere's law :

$$I_{\text{enc}} = \oint \overline{H} \cdot \overline{dl} \qquad\qquad \nabla \times H = \overline{J}$$

3 Boundary conditions

For tangential components:

$$
\begin{aligned}
&E_{t_1} = E_{t_2} \\
&H_{t_1} = H_{t_2} \qquad\qquad \text{No sheet current density } \overline{I}_{sh} = 0 \\
&(\overline{H_1} - \overline{H_2}) \times \hat{n}_{12} = \overline{J}_{sh}
\end{aligned}
$$

For normal components:

$$
\begin{aligned}
D_{n_1} &= D_{n_2} \\
\epsilon_1 E_{n_1} &= \epsilon_2 E_{n_2}
\end{aligned}
$$

$$
\begin{aligned}
B_{n_1} &= B_{n_2} \\
\mu H_{n_1} &= \mu H_{n_2}
\end{aligned}
$$