Engineering Physics

(PHY1701)

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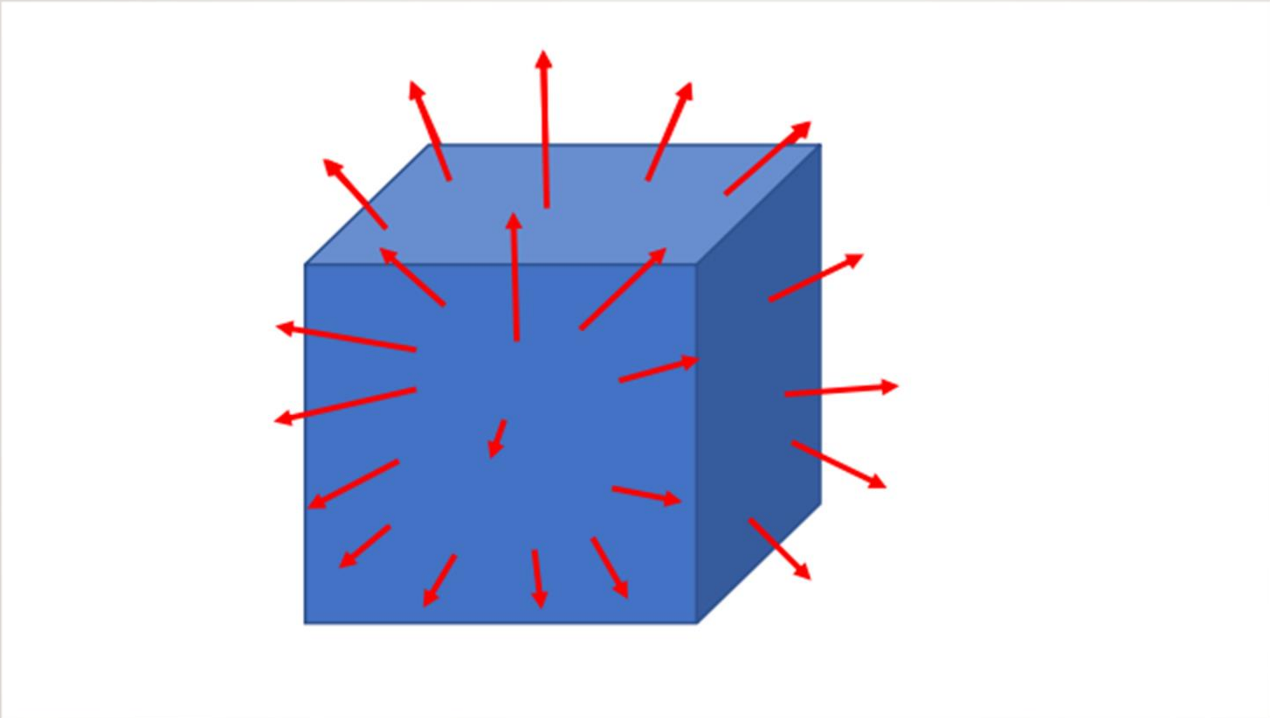
Contents

- Physics of Divergence, Gradient and Curl (DJG 13-20),
- Qualitative understanding of surface and volume integral (DJG 24, 26, 27),
- **Maxwell Equations (Qualitative)** (DJG 232, 321-327),
- Wave Equation (Derivation) (DJG 364-366), &
- EM Waves, Phase velocity, Group velocity, Group index*, (DJG 405)
- Hertz Experiment

❖ William Silfvast, Laser Fundamentals, 2008, Cambridge University Press.

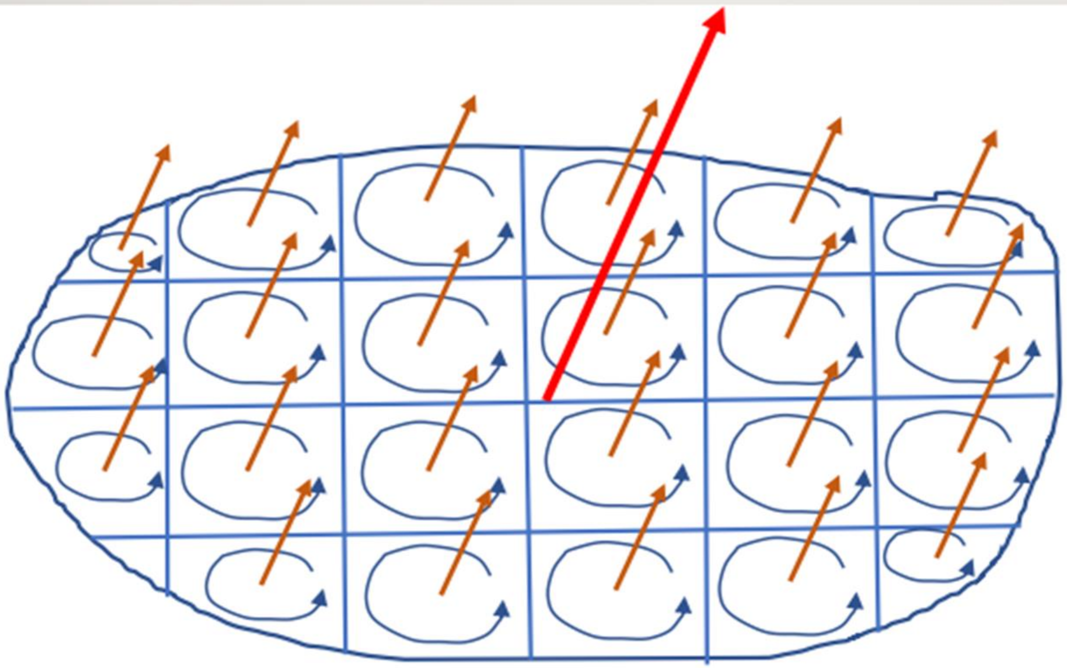
Gauss Divergence Theorem

$$\iiint \left(\vec{\nabla}\cdot\vec{A}\right) d^3\mathrm{v} = \oiint \vec{A}.d^2\vec{a}$$



Stokes Theorem

$$\iint \left(\vec{\nabla} \times \vec{A} \right) \cdot d^2\vec{a} = \oint \vec{A} \cdot d\vec{l}$$



Fundamental laws of Electromagnetism

$$1.\ \varphi_E = \oint_S E.dS = \frac{q}{\varepsilon_0}$$ **Gauss law of electrostatics**

$$2.\ \varphi_B = \oint_S B.dS = 0$$ **Gauss law of Magnetism**

$$3.\ e = -\frac{d\varphi_B}{dt} \quad or \quad \int E.dl = -\frac{d\varphi_B}{dt}$$ **Faraday's Law**

$$4.\ \int B.dl = \mu_0 i$$ **Ampere's Law**

Displacement current

- It is the rate of change of the Displacement vector $\vec{D}$.
- The displacement vector is defined as

$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$$

where $\vec{P}$ is the electric polarization vector.

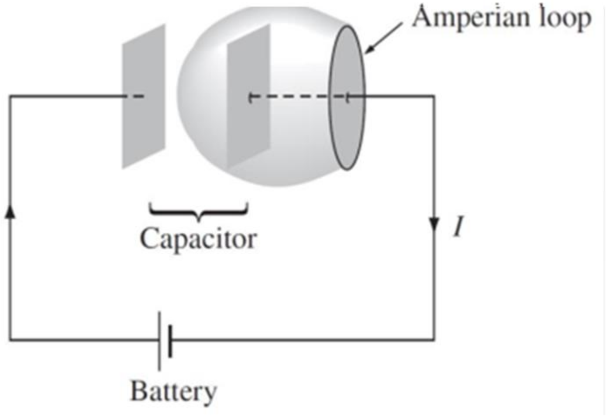
- $\vec{P} = 0$ in free space.

$$i_d = A \frac{dD}{dt}$$ **Displacement current**

$$J_d = \frac{dD}{dt}$$ **Displacement current density**

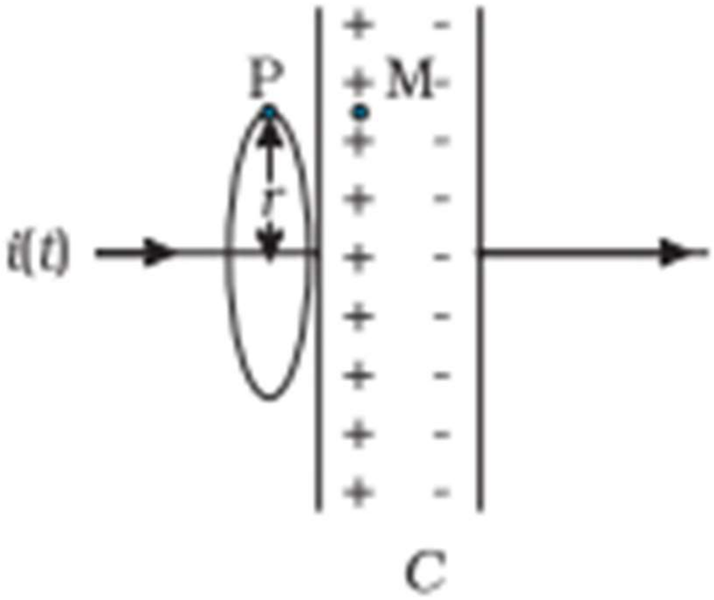
Displacement current

- Let us revisit Ampere's law for the following circuit.

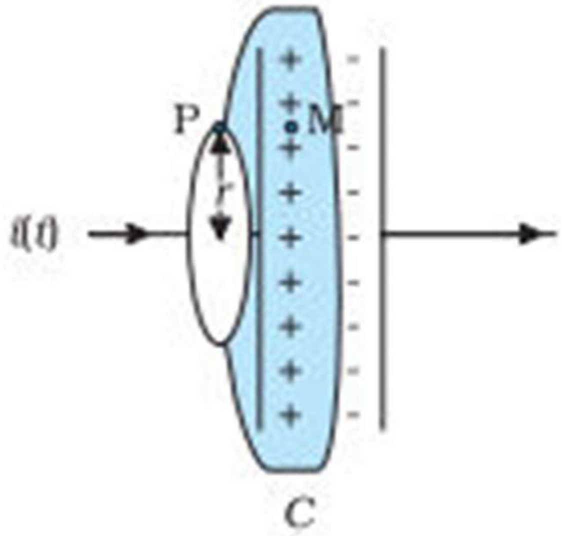


- Here both surfaces share the same Amperian loop.
- The dark shaded surface has *I* current flowing through it but the light shaded loop has no current.
- What happens if we include the extra term in Maxwell's equation**?**

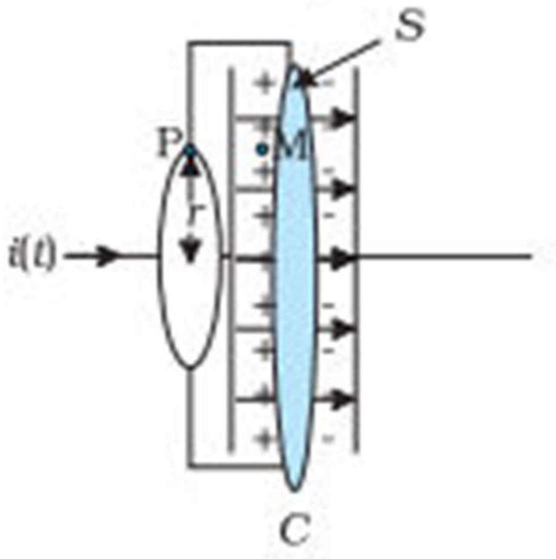
Displacement current



Pot-like surface



Tiffin-shaped surface



Modified form of Ampere's Law

$$\nabla \times B = \mu_0 J + some\ quantity$$

$$\nabla \times B = \mu_0 \left(J + \frac{\partial D}{\partial t} \right) = \mu_0 \left(J + J_D \right)$$

or

$$\nabla \times H = \left(J + \frac{\partial D}{\partial t} \right)$$

Maxwell's Electromagnetic Equations

The integral form of these equations are given by

$$\oint_S E.dS = \frac{q}{\varepsilon_0}$$

Gauss law of electrostatics

$$\oint_S B.dS = 0$$

Gauss law of Magnetism

$$\int E.dl = -\frac{d\phi_B}{dt}$$

Faraday's Law of electromagnetic induction

$$\int B.dl = \mu_0 i = \mu_0 \left[J + \varepsilon_0 \frac{\partial E}{\partial t} \right]$$

Ampere's Law

Maxwell's Electromagnetic Equations

The differential form of Maxwell equation are given by

$$divE = \frac{\rho}{\varepsilon} \quad or \quad \nabla .E = \frac{\rho}{\varepsilon}$$ **Gauss law of electrostatics**

$$divB = 0 \quad or \quad \nabla .B = 0$$ **Gauss law of Magnetism**

$$curl\ E = -\frac{\partial B}{\partial t}$$ **Faraday's Law of electromagnetic induction**

$$curl\ B = \mu_0 \left[J + \varepsilon_0 \frac{\partial E}{\partial t} \right]$$ **Ampere's Law**