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MJCPHY06
Electrodynamics and Electromagnetism

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Maxwell Equation in integral and differential form is given below

Summary of electric and magnetic equations known before ~1860:

Gauss's laws:

Integral form: $\oint \mathbf{E}(\mathbf{r}) \cdot d\mathbf{A} = \frac{Q_{in}}{\varepsilon_0}$

Differential form: $\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$

Integral form: $\oint \mathbf{B}(\mathbf{r}) \cdot d\mathbf{A} = 0$

Differential form: $\nabla \cdot \mathbf{B} = 0$

Faraday's law :

$$\int \mathbf{E}(\mathbf{r}) \cdot d\mathbf{s} = -\frac{d}{dt} \int \mathbf{B}(r) \cdot d\mathbf{A}$$

Couples **E** and **B** fields

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Ampere's law :

Integral form : $\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{in}$

Differential form : $\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$

$$\oint \mathbf{E}(\mathbf{r}) \cdot d\mathbf{A} = \frac{Q_{in}}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\oint \mathbf{B}(\mathbf{r}) \cdot d\mathbf{A} = 0$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\int \mathbf{E}(\mathbf{r}) \cdot d\mathbf{s} = -\frac{d}{dt} \int \mathbf{B}(r) \cdot d\mathbf{A}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{in}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$$

A changing magnetic flux produces an electric field – can a changing electric flux produce a magnetic field?

What happens to fields between capacitor plates with time varying charge?

Full Maxwell's equations

$$\oint \mathbf{E}(\mathbf{r}) \cdot d\mathbf{A} = \frac{Q_{in}}{\varepsilon_0}$$

$$\oint \mathbf{B}(\mathbf{r}) \cdot d\mathbf{A} = 0$$

$$\int \mathbf{E}(\mathbf{r}) \cdot d\mathbf{s} = -\frac{d}{dt} \int \mathbf{B}(r) \cdot d\mathbf{A}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{in} + \mu_0 \varepsilon_0 \frac{d}{dt} \int \mathbf{E}(r) \cdot d\mathbf{A}$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Some conclusions:

1. Without sources, there are no **E** or **B** fields
2. **E** and **B** can exist far from the sources

Maxwell's equations without sources

Maxwell's equations in free space ρ=0 and J=0

$$\oint \mathbf{E}(\mathbf{r})\cdot d\mathbf{A} = 0$$

$$\oint \mathbf{B}(\mathbf{r})\cdot d\mathbf{A} = 0$$

$$\int \mathbf{E}(\mathbf{r})\cdot d\mathbf{s} = -\frac{d}{dt}\int \mathbf{B}(r)\cdot d\mathbf{A}$$

$$\oint \mathbf{B}\cdot d\mathbf{s} = \mu_0\varepsilon_0 \frac{d}{dt}\int \mathbf{E}(r)\cdot d\mathbf{A}$$

$$\nabla\cdot\mathbf{E} = 0$$

$$\nabla\cdot\mathbf{B} = 0$$

$$\nabla\times\mathbf{E} = -\frac{\partial\mathbf{B}}{\partial t}$$

$$\nabla\times\mathbf{B} = \mu_0\varepsilon_0\frac{\partial\mathbf{E}}{\partial t}$$

Far from the charge and current sources the **E** and **B** fields

A. Always get smaller with increasing distance
B. Always get smaller at long times
C. Can maintain a steady amplitude at all times and distances

Thank you