Lecture 39 outline: 11/18/2020

- Magnetic fields and work
- Questions!
- Differential form of Ampere's Law
- Symettry between Faraday and Ampere
- Faraday's Law / Demo

Ch 5 Questions:

Magnets snap together. How can you say B does no work? (Edelman)

- Magnetic forces change particle's direction, how can this not do work?

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

- What's going on on p 218?

Ch 7 Questions:

- Why is it called EMF?

Maxwell's Equations

Gauss's Law

$$\oiint \vec{E} \cdot d\vec{a} = \frac{Q}{\epsilon_0}$$

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

The "no monopole" equation

$$\oiint \vec{B} \cdot d\vec{a} = \mu_0 Q_{monopole} = 0$$

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

Ampere's Law

$$\oint \vec{B} \cdot dl = \mu_0 I$$

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

Faraday's Law

$$\varepsilon = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{a}$$

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

Ampere's Law

Integral to

Differential form

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \int \vec{J}\cdot d\vec{a}$$

$$\int \nabla\times\vec{B}\cdot d\vec{a} = \mu_0 \int \vec{J}\cdot d\vec{a}$$

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

Ampere's Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \int \vec{J} \cdot d\vec{a}$$

$$\int \nabla \times \vec{B} \cdot d\vec{a} = \mu_0 \int \vec{J} \cdot d\vec{a}$$

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

Faraday's Law

$$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial}{\partial t} \Phi_B$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{a}$$

$$\int \nabla \times \vec{E} \cdot d\vec{a} = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{a}$$

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

Faraday's Law

$$\varepsilon = -\frac{\partial}{\partial t}\Phi_B \rightarrow \oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\Phi_B$$

$$\varepsilon = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{a} \rightarrow \oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{a}$$

$$\int \nabla\times\vec{E}\cdot d\vec{a} = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{a}$$

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

Faraday's Law:

- You get a current in a loop IF

- B changes magnitude
- Loop area changes
- Angle between B and area changes

Lenz's Law "Back EMF":

- Lenz's law is the minus sign in Faraday's law

- If you try to increase B through a loop, a current in the loop tries to prevent it from increasing

Example 1: Increase B

Example 2: Increase A

Example 3: Change angle between B and A

Ampere's Law

(with displacement current)

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \epsilon_0 \frac{\partial}{\partial t}\Phi_E$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \epsilon_0 \frac{\partial}{\partial t}\int \vec{E}\cdot d\vec{a}$$

$$\int \nabla\times\vec{B}\cdot d\vec{a} = \mu_0 \epsilon_0 \frac{\partial}{\partial t}\int \vec{E}\cdot d\vec{a}$$

$$\nabla\times\vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

Faraday's Law

$$\oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\Phi_B$$

$$\oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{a}$$

$$\int \nabla\times\vec{E}\cdot d\vec{a} = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{a}$$

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