Lecture 40 outline: 11/20/2020

- Final Exam, Thursday 12/10 @1:30 pm
  Remote, via Zoom
- Faraday's Law
- Inductance/Capacitance/Resistance
- Mutual Inductance

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

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

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

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

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

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

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

$$\varepsilon = -\frac{\partial}{\partial t}\Phi_B \rightarrow$$

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

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

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

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":

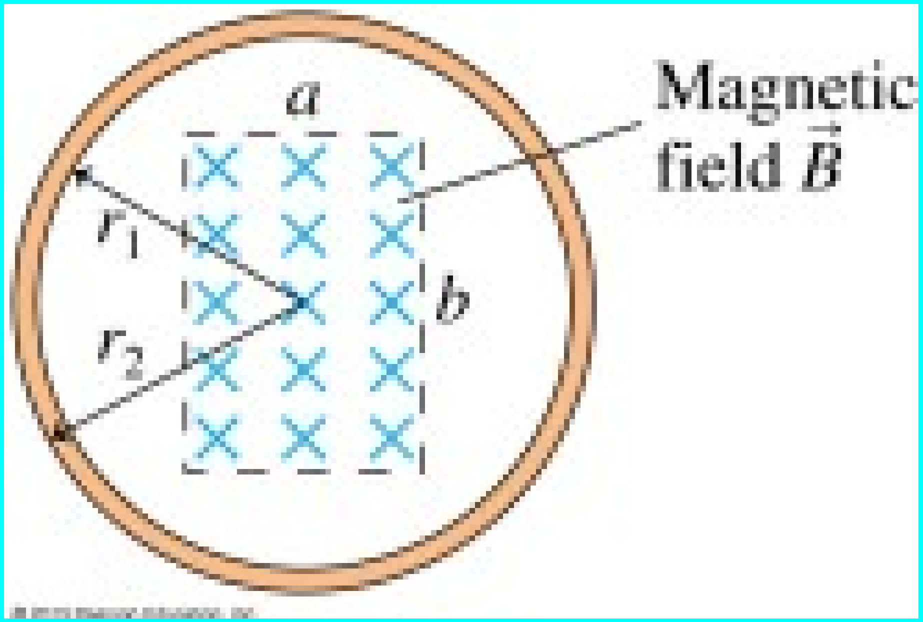
- Lenz's law is the minus sign in Faraday's law

- If you try to increase B through a loop, a current in the loop tries to prevent it from increasing
- This induced current also produces an opposing magnetic field, as we saw with eddy currents and the magnet that would not fall onto the copper plate

Example 1: Change magnitude of B

What is the EMF if $\vec{B} = k\,t^3\,\hat{z}$

A) $\varepsilon = k\,t^3\,\pi\,r_1^2$



B) $\varepsilon = 3\,k\,t^2\,\pi\,r_1^2$

C) $\varepsilon = k\,t^3\,\pi\,r_2^2$

D) $\varepsilon = 3\,k\,t^2\,a\,b$

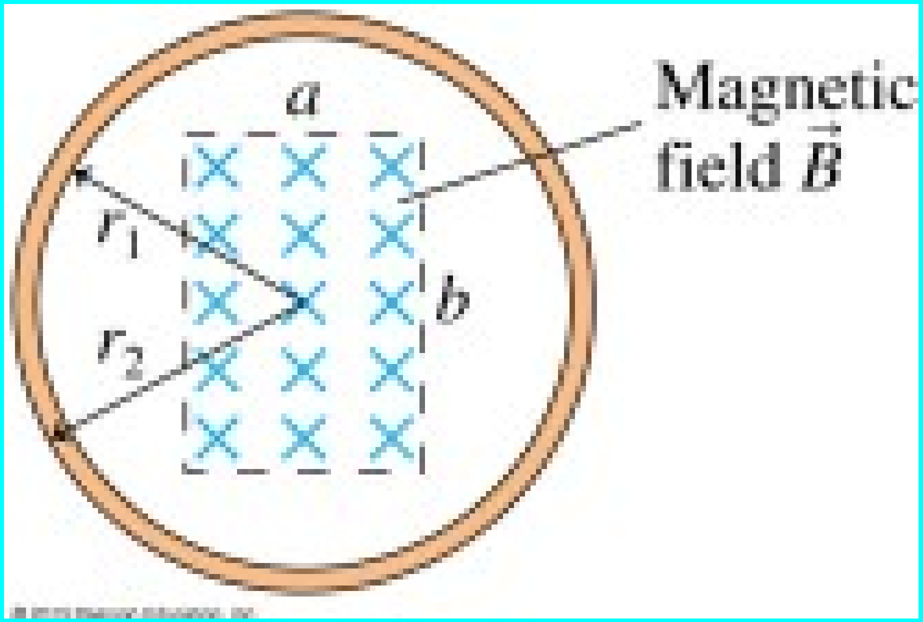
What direction does

The induced current flow if $\vec{B} = -k\,t^3\,\hat{z}$?

A) Clockwise

B) CCW

C) It's zero



What direction does

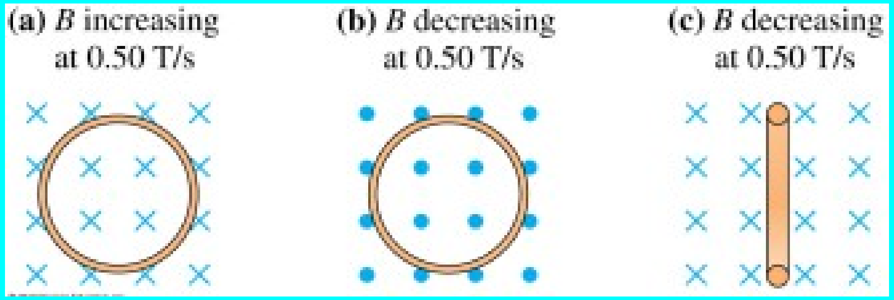
The induced current flow in each case?

A) CCW, CW, CCW

B) CCW, CCW, CCW

C) CCW, CW, Zero

D) CCW, CCW, Zero



C) It's zero

Example 2: Change magnitude of A

Example 3: Change angle between B and A

Inductance, Capacitance, Resistance

Mutual Inductance

Ampere's Law

(with displacement current)

Faraday's Law

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

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

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

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

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

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

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

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