Review - Chaps. 26 - DC Circuits

- Current: \( I = \frac{dQ}{dt} \)

\[ R_i = \frac{\Delta V}{I} \] (Ohm’s Law)

- Kirchhoff:
  \[ \sum I_{in} = \sum I_{out} \]

\[ \sum \Delta V = 0 \]

- Power: \( P = I\Delta V \)

Review - Chaps. 27 - Capacitance & Field Energy

- Capacitance: \( C = \frac{Q}{\Delta V} \)

\[ C_p = \sum_i C_i \quad \frac{1}{C_x} = \sum_i \frac{1}{C_i} \]

- Dielectrics: \( \kappa = \frac{|E_a|}{|E|} \]

\[ C = \kappa C_0 \]

- Stored Energy & Electric Energy Density

\[ U = Q^2/2C \quad U = 0.5CV^2 \quad u_e = 0.5\varepsilon_0 E^2 \]

Review - Chap. 28 - Magnetic Field

\[ d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2} \]

\[ \vec{B} = \int d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2} \]

\[ \Phi_B = \int \vec{B} \cdot \hat{n}dA \quad \Phi_{B, total} = \oint \vec{B} \cdot \hat{n}dA = 0 \]

\[ C = \frac{1}{4\pi} \vec{B} \cdot d\vec{l} = \mu_0 I_{through} \quad \text{Ampere’s Law} \]

\[ \vec{m} = IA\hat{n} \quad \text{Magnetic Moment} \]

Review - Chap. 29 Magnetic Forces & Materials

\[ \vec{F}_{mag} = q\vec{v} \times \vec{B} \quad d\vec{F} = I\vec{d}\times \vec{B} \]

\[ \vec{F} = \vec{I}\vec{l} \times \vec{B} \quad \text{(uniform B)} \]

\[ \vec{\tau} = \vec{m} \times \vec{B} \]

\[ \sum \vec{n}_i \]

\[ M = \frac{i}{Volume} \]

\[ \vec{M} = \chi_m(B_{applied} / \mu_0) = \chi_m \vec{H} \]

Dynamic Fields / Induced Fields

- Dynamic Fields - Fields that change in time
  - Changing magnetic field produces electric field
  - Changing electric field produces magnetic field

- First effect leads to \textit{induced emf} \( \varepsilon_{ind} \)
  - Amount of induced emf in a circuit \( \propto \text{rate of change of magnetic flux} \phi_B \) through the circuit

\[ \varepsilon_{ind} = \frac{d\phi_B}{dt} \] Faraday’s Law

- where \( \phi_B \) is the total magnetic flux through \( N \) turns of circuit

\[ \phi_B = N \int \vec{B} \cdot \hat{n}dA \]

- Unit of \( \phi_B \): Weber (Wb) ; Unit of \( \varepsilon_{ind} \): V
Example 1

- 10 turns of wire form coil of area 0.5 $m^2$

- $t = 0$

- $t = 0.1\ s$

- $B = 0$

- $B = 3T$

- Q1 - What is $\varepsilon_{\text{ind}}$ at $t = 0.1s$

Example 2

- Square coil of 4 turns has area 0.5 $m^2$. A uniform magnetic field makes a 30° angle with the normal to the area. The field strength as a function of time is $B = (0.5T)(1 - t/4s)$.

\[
\Phi_B = N \int B \cdot \mathbf{dA} = NBA \cos \theta
\]

\[
= 10(0.5m^2)(\cos 45\degree)(0.5T)(1 - t/4s)
\]

\[
\frac{\Delta \Phi_B}{dt} = -(10)(0.5)(0.866)\ Wb(-1/4s)
\]

$\varepsilon_{\text{ind}} = 1.08V$

Lenz’s Law

- We wrote Faraday’s Law with a - sign; the - sign is an expression of Lenz’s Law:
  - Induced emf acts to oppose the change in magnetic flux that creates it

- If we increase the magnetic flux through a circuit, an emf develops which generates cancelling flux

- If we decrease the magnetic flux through the circuit, the induced emf produces additive flux which tries to maintain the previous flux

- Example - coil on last slide has flux decreasing [$B = 0.5T(1-t/4s)$]. Would induced current in coil be clockwise or counterclockwise?

Q2: In which of the following cases would there be induced current flowing clockwise in the loop?