Exam 2 covers Ch. 28-33, Lecture, Discussion, HW, Lab

Exam 2 is Tue. Oct. 28, 5:30-7 pm, 2103 Ch
- Chapter 28: Electric flux & Gauss’ law
- Chapter 29: Electric potential & work
- Chapter 30: Electric potential & field
  - (exclude 30.7)
- Chapter 31: Current & Conductivity
- Chapter 32: Circuits
  - (exclude 32.8)
- Chapter 33: Magnetic fields & forces
  - (exclude 33.3, 33.6, 33.10, Hall effect)

Electric current produces magnetic field

- Current (flow of electric charges) in wire produces magnetic field.
- That magnetic field aligns compass needle

Law of Biot-Savart

Each element of current produces a contribution to the magnetic field.

\[ dB = \frac{\mu_0}{4\pi} \frac{I ds \times \hat{r}}{r^2} \]

Magnetic field from long straight wire: Direction

What direction is the magnetic field from an infinitely-long straight wire?

\[ dB = \frac{\mu_0}{4\pi} \frac{I ds \times \hat{r}}{r^2} \]

Current dependence

How does the magnitude of the B-field change if the current is doubled?

A) Is halved
B) Quadruples
C) Stays same
D) Doubles
E) Is quartered

Distance dependence

How does the magnitude of the B-field at 2 compare to that at 1?

A) \( B_2 = B_1 \)
B) \( B_2 = 2B_1 \)
C) \( B_2 = B_1/2 \)
D) \( B_2 = 4B_1 \)
E) \( B_2 = B_1/4 \)
Why?

- Biot-Savart says \( \frac{\mu_0 I ds \times \hat{r}}{4\pi r^2} \)
- Why \( B(r) \propto \frac{1}{r} \) instead of \( \frac{1}{r^2} \)?

Field from a circular loop

- Each current element produces \( dB \)
- All contributions add as vectors
- Along axis, all components cancel except for \( x \)-comp

Magnetic field from a current loop

- One loop: field still loops around the wire.
- Many loops: same effect

Long straight wire

- All current elements produce \( B \) out of page

\[
 dB = \frac{\mu_0 I ds \times \hat{r}}{4\pi r^2} = \frac{\mu_0 I}{4\pi r^2 \sin \theta} \left( r \frac{dx}{r^2} \right) = \frac{\mu_0 I}{2\pi r} \]

Add them all up:

\[
 B = \frac{\mu_0 I}{2\pi} \left( \frac{dx}{r^2} \right) = \frac{\mu_0 I}{2\pi} \left( \frac{x^2 + a^2}{r^2} \right)
\]

Magnetic field from a current loop

- Sequence of current loops can produce strong magnetic fields.
- This is an electromagnet

Solenoid electromagnet

- Sequence of current loops can produce strong magnetic fields.
- This is an electromagnet
Comparing Electric, Magnetic

- **Biot-Savart**:
  - calculate B-field from current distribution.
  - Resulting B-field is a vector, and...
  - complication: current (source) is a vector!
- **Coulomb**:
  - calculate E-field from charge distribution
  - Resulting E is a vector but charge (source) is not a vector

A shortcut: *Ampere’s law*

- Integral around closed path proportional to current passing through any surface bounded by path.

  ![Ampere's Law Diagram](image)

  - Ampere’s law
    \[ \int \mathbf{B} \cdot d\mathbf{s} = \mu_0 I \]

  - **Right-hand ‘rule’**:
    - Thumb in direction of positive current
    - Curled fingers show direction integration

  - **Manuscript Notes**:
    - Component of B along path
    - Path has constant \( r \)
    - Path length = \( 2\pi r \)

‘Testing’ Ampere’s law

- Long straight wire \( B(r) = \frac{\mu_0 I}{2\pi r} \), \( \mathbf{B} \perp \mathbf{r} \)

  \[ \int \mathbf{B} \cdot d\mathbf{s} \]

  - surface bounded by path

  - Circular path

  - Surface bounded by path

  \[ \mathbf{B}(r) = \frac{\mu_0 I}{2\pi r^2} \]

Using Ampere’s law

- Could have used Ampere’s law to calculate B

  \[ \int \mathbf{B} \cdot d\mathbf{s} = \int \mathbf{B} \cdot d\mathbf{s} = \int \mathbf{B} \cdot d\mathbf{s} = \mathbf{B} \cdot d\mathbf{s} = \mu_0 I \Rightarrow \mathbf{B} = \frac{\mu_0 I}{2\pi r} \]

  - Circular path
  - Surface bounded by path

Quick Quiz

- Supposed the wire has uniform current density. How does the magnetic field change inside the wire?
  - A. Increases with \( r \)
  - B. Decreases with \( r \)
  - C. Independent of \( r \)
  - D. None of the above

  \[ \int \mathbf{B} \cdot d\mathbf{s} = 2\pi r \mathbf{B} = \mu_0 I \Rightarrow \mathbf{B}(r) = \frac{\mu_0 I}{2\pi r^2} \]