About Exam 2

- **When and where**
  - Monday Oct. 25th 5:30-7:00 pm
  - (rooms to be announced)

- **Format**
  - Closed book, 20-25 multiple-choices questions, *(same style as midterm 1.)*
  - 1+1 8x11 formula sheet allowed, must be self prepared, no photo copying/download-printing of solutions, lecture slides, etc.
  - Bring a calculator (but no computer). Only basic calculation functionality can be used. Bring a 2B pencil for Scantron.
  - Fill in your ID and section # !

- **Special requests:**
  - All non-emergency requests shall have been settled by now.
  - All specially arranged tests (e.g. those at the alternative time) are held in our 202 labs. *(for approved requests only)*

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Chapters Covered

- Chapter 26: Capacitance.
- Chapter 27: Current and Resistance
- Chapter 28: DC Circuit
- Chapter 29: Magnetic Field.

We will not post past/sample exams as none that I can find are representative. Often those can be misleading.

Two off-class review sessions scheduled on Friday, Oct 22nd. *(See the email sent last week for time and room information.)*

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Physics 202, Lecture 14

Today’s Topics

- Sources of the Magnetic Field (Ch 30)
  - Review: The Ampere’s Law
  - Applications And Exercises of ampere’s Law
  - Straight line, Loop, Solenoid, Toroid

- Magnetism in Matter

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Summary:
Calculating B Field For A Given Current

- Two approaches:
  - Direct superposition (Biot-Savart Law)
  - Applying Ampere’s law to some symmetric cases

(Recall: Application of Gauss’s law for E. Fields)

\[
\vec{B} = \frac{\mu_0 I}{4\pi} \int_{\text{any closed path}} d\vec{s} \times \hat{r} \quad \text{direct superposition}
\]

\[
\oint \vec{B} \cdot d\vec{s} = \mu_0 I \quad \text{Ampere’s Law}
\]

(Later this lecture)
Exercise: Solenoid

- The B field inside an ideal solenoid is:  
  \[ B = \mu_0 n I \]

\( n = \frac{N}{L} \)

Segment 3 at \( \infty \)

Compare Solenoid and Bar Magnet

Loose Solenoid  
Tight Solenoid

Bar Magnet

Exercise: Toroid

- Text example 30.5) Show the B field inside a toroid is:
  
  hint: Use Ampere’s Law
  (See board)

\[ B = \frac{\mu_0 NI}{2\pi r} \]

Gauss’s Law Of Magnetism

- Recall: Gauss’s law for E. field:
  \[ \oint \mathbf{E} \cdot d\mathbf{A} = \frac{q}{\varepsilon_0} \]
  
  For any magnetic field \( \mathbf{B} \):
  \[ \oint \mathbf{B} \cdot d\mathbf{A} = 0 \]

  Magnetic flux:
  \[ d\Phi_B = \mathbf{B} \cdot d\mathbf{A} = B(dA)\cos\theta \]

- Notice that the right-hand side of the equation is always zero \( \rightarrow \) there is no net “magnetic charge” the so-called “magnetic mono-pole”
**Review: Electric Dipole Moments**

- Electric dipole moment $\mathbf{p}$.

$$\sum \mathbf{F} = 0$$
$$\mathbf{F} = \mathbf{p} \times \mathbf{E}$$
$$\mathbf{U} = \mathbf{p} \cdot \mathbf{E}$$

Dielectric material contains electric dipoles at atomic level.

In an external field $\mathbf{E}_0$, the dipoles line up:

$$\mathbf{E} = \mathbf{E}_0$$
$$\mathbf{C} = \kappa \mathbf{C}_0$$

(dielectric constant $\kappa > 1$)

**Review: Magnetic Dipole Moments**

- Magnetic dipole moment $\mu$.

$$\sum \mathbf{F} = 0$$
$$\mathbf{F} = \mathbf{\mu} \times \mathbf{B}$$
$$\mathbf{U} = -\mathbf{\mu} \cdot \mathbf{B}$$

Magnetic moment definition

Macrosopic

$$\mu = N A$$

Microscopic

$$\mu \propto L$$

angular momentum of orbiting or spin

$$\mu$$ in B Field

**Magnetism in Matter**

- Induced field $\mathbf{B}_{\text{ind}}$ in response to an external $\mathbf{B}_0$:

$$\mathbf{B}_{\text{ind}} = \chi \mathbf{B}_0$$

- the net field inside: $\mathbf{B} = \mathbf{B}_0 + \mathbf{B}_{\text{ind}} = (1 + \chi) \mathbf{B}_0 = (1 + \chi) (\mu_0 / \mu) \mathbf{B}_0$

$\mu_0$: magnetic permeability

$\chi$: magnetic susceptibility

Classification of Magnetic Matter

<table>
<thead>
<tr>
<th>Type</th>
<th>Direction of $\mathbf{B}_{\text{ind}}$</th>
<th>Strength of $\mathbf{B}_{\text{ind}}$</th>
<th>$\chi \mu_0 / \mu$</th>
<th>1</th>
<th>Contributing Elements</th>
<th>Domain of Magnetic Dipole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferromagnetic (e.g. Fe, Co, Ni, …)</td>
<td>Same as $\mathbf{B}_0$</td>
<td>Strong</td>
<td>$&gt; 0$ ($10^3$)</td>
<td>$\mu_{\text{atom}}$</td>
<td>Magnetic Dipole</td>
<td></td>
</tr>
<tr>
<td>Paramagnetic (e.g. Al, Ca, …)</td>
<td>Same as $\mathbf{B}_0$</td>
<td>Weak</td>
<td>$&gt; 0$ ($10^{-2}$)</td>
<td>$\mu_{\text{atom}}$</td>
<td>Magnetic Quadrupole</td>
<td></td>
</tr>
<tr>
<td>Diamagnetic (e.g. Cu, Au, …)</td>
<td>Opposite</td>
<td>Weak</td>
<td>$&lt; 0$ ($10^{-6}$)</td>
<td>Magnetic Quadrupole</td>
<td>Diamagnetic</td>
<td></td>
</tr>
<tr>
<td>Superconductor</td>
<td>Opposite</td>
<td>$-\mathbf{B}_0$</td>
<td>-1</td>
<td>Quantum eff.</td>
<td>Superconductors</td>
<td></td>
</tr>
</tbody>
</table>

Inside Ferromagnetic Material

- No external B field, permanent mag. moments exist, but oriented randomly

- no induced B field

- Magnetic moments line up in the direction of $\mathbf{B}_0$

- strong induced B field

Note: Inductance with a ferromagnetic core: $L = \mu_0 / \mu_0 L_0 \approx L_0$
Meissner Effect

- Certain superconductors (type I) exhibit perfect diamagnetism in superconducting state:
  - no magnetic field allowed inside (Meissner Effect)