Lecture # B
Magnetism
1. Consider two identical capacitors with capacitance $C$. One is charged with a charge $Q_0$ on its plates and the second with $2Q$. The ratio of the energy stored in the first to second capacitor is:

(a) $1$  
(b) $\frac{1}{2}$  
(c) $\frac{1}{4}$

2. 

Just before the switch is closed there is a charge $Q_0$ on the capacitor. When it is closed the charge decays as

$$Q = Q_0 \exp \left( -\frac{t}{\tau} \right)$$

where $\tau = ?$  
(a) $(R_1 + R_2)C$,  
(b) $R_1C$  
(c) $R_2C$  
(d) $\frac{R_1R_2}{R_1 + R_2}$

3. 

The total charge on $C_1$ and $C_2$ is $Q_0$ before the switch is closed.

After switch is closed, $Q$ decays as

$$\tau = ?$$  
(a) $\frac{R(C_1 + C_2)}{C_1}$  
(b) $R_1C_1$  
(c) $R_2C_2$  
(d) $\frac{R}{\frac{C_1C_2}{C_1+C_2}}$
Each magnet has two distinct ends.

Magnetic forces push like ends apart...

...and pull unlike ends together.

repulsion

attraction

Figure 29-1 Physics for Engineers and Scientists 3/e
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Magnetism

North pole of compass needle is attracted to south pole of bar magnet.
Magnetic south pole of Earth is near our geographic north pole.
Electric current in wire...

...exerts a magnetic force on compass needle.
<table>
<thead>
<tr>
<th>Description</th>
<th>Field Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>At surface of pulsar</td>
<td>$\approx 10^8$ T</td>
</tr>
<tr>
<td>Maximum achieved in laboratory:</td>
<td></td>
</tr>
<tr>
<td>Explosive compression of field lines</td>
<td>$1 \times 10^3$</td>
</tr>
<tr>
<td>Steady</td>
<td>45</td>
</tr>
<tr>
<td>In particle accelerator magnet</td>
<td>8</td>
</tr>
<tr>
<td>In large bubble-chamber magnet</td>
<td>2</td>
</tr>
<tr>
<td>In MRI magnet (a)</td>
<td>$1.5 \approx$</td>
</tr>
<tr>
<td>In sunspot (b)</td>
<td>$0.3 \approx$</td>
</tr>
<tr>
<td>Near small ceramic magnet</td>
<td>$2 \times 10^{-2}$</td>
</tr>
<tr>
<td>At surface of Sun</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Near household wiring (c)</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>At surface of Earth</td>
<td>$5 \times 10^{-5}$</td>
</tr>
<tr>
<td>In sunlight (rms)</td>
<td>$3 \times 10^{-6}$</td>
</tr>
<tr>
<td>In Crab Nebula (d)</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>In radio wave (rms)</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>In interstellar galactic space</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>Produced by human body</td>
<td>$3 \times 10^{-10}$</td>
</tr>
<tr>
<td>In shielded antimagnetic chamber</td>
<td>$2 \times 10^{-14}$</td>
</tr>
</tbody>
</table>
Interaction of currents together

\[ F_{12} = \frac{I_1 I_2}{d} \]

\[ F_{12} = -F_{21} \]

\[ F_{21} \]

\[ F_{12} \]

\[ d \]

\[ I_1 \]

\[ I_2 \]
Interaction of charge with current

When velocity of positive charge is parallel to the current, force is toward current.

When velocity of positive charge is away from the current, force is parallel to current.

When velocity of charge is tangent to a circle around the current, there is no magnetic force.

\[ \mathbf{F} \propto \frac{I q v}{r} \]

\[ \mathbf{F} = \frac{\mu_0}{2\pi} \frac{q v}{r} \]

\[ \mu_0 = 4\pi \times 10^{-7} \text{ N} \text{s/C} \]
Cross Product

\[ \hat{\mathbf{x}} \times \hat{\mathbf{y}} = \hat{\mathbf{z}} \times \hat{\mathbf{z}} = \mathbf{0} \]
\[ \hat{\mathbf{y}} \times \hat{\mathbf{x}} = \hat{\mathbf{z}} \]
\[ \hat{\mathbf{z}} \times \hat{\mathbf{x}} = \hat{\mathbf{y}} \]
\[ \hat{\mathbf{z}} \times \hat{\mathbf{z}} = \mathbf{0} \]

\[ \mathbf{C} = \mathbf{A} \times \mathbf{B} = (A_x \hat{x} + A_y \hat{y} + A_z \hat{z}) \times (B_x \hat{x} + B_y \hat{y} + B_z \hat{z}) \]
\[ = (A_y B_z - A_z B_y) \hat{x} \]
\[ + (A_z B_x - A_x B_z) \hat{y} \]
\[ + (A_x B_y - A_y B_x) \hat{z} \]

\[ |\mathbf{C}| = (\|\mathbf{A}\| \|\mathbf{B}\| \sin \theta) \]
Begin with fingers of your right hand pointing along $\mathbf{v}$...

...then rotate your arm...

...until you can curl your fingers through the smallest angle from $\mathbf{v}$ toward $\mathbf{B}$.

Your thumb then points in direction of $\mathbf{F}$ for a positive charge.

$$\mathbf{F} = q \mathbf{v} \times \mathbf{B}$$
There is a "magnetic field" $\mathbf{B}$ associated with the current in the indicated directions of the figure.

\[ |\mathbf{B}| = \frac{\mu_0 I}{2\pi r} \]

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If thumb of your right hand is placed along direction of current...

current

$\mathbf{B}$ - field is directed in same direction compass needles would point

...then fingers will curl around wire in direction of magnetic field.
At any point, direction of magnetic field is tangent to a circle around current.

Magnitude of magnetic field decreases inversely with distance from current.

\[ B_1 = \frac{x_0 I}{2\pi r} \]