Lecture 12
Magnetism
attraction

repulsion

ends together:
end pull unlike

ends apart:

magnetic forces push

each magnet has,
two distinct ends.
Magnetic south pole of Earth is near our geographic north pole.

Which is the smallest magnet:
1. an iron atom
2. an electron
3. the smallest iron crystal that can be fabricated
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(c) When velocity of charge is parallel to the current, force is zero.

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

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

...but electron charge is negative, so force is radially outward.
(a) Magnetic forces between parallel currents are attractive...

(b) ...and between antiparallel currents are repulsive.
We need to rewrite cross product relations.

\[
P = q \left( E + \frac{v \times B}{c} \right)
\]

on a charge \( q \) and magnetic field \( B \).
\[ \vec{F} = q \vec{v} \times \vec{B} \]

\[ = -q \vec{B} \times \vec{v} \]

...until you can curl your fingers through the smallest angle from \( \vec{v} \) toward \( \vec{B} \).

Your thumb then points in direction of \( \vec{F} \) for a positive charge.

Begin with fingers of your right hand pointing along \( \vec{v} \)... then rotate your arm...

\[ \hat{x} \times \hat{y} = \hat{z} \]
\[ \hat{y} \times \hat{x} = -\hat{z} \]
\[ \hat{z} \times \hat{x} = \hat{y} \]
\[ \hat{z} \times \hat{y} = -\hat{x} \]
\[ \hat{x} \times \hat{z} = -\hat{y} \]

\[ \vec{A} = a_x \hat{x} + a_y \hat{y} + a_z \hat{z} \]
\[ \vec{B} = b_x \hat{x} + b_y \hat{y} + b_z \hat{z} \]
\[ \mathbf{C} = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix} \]

What is the component of \( \mathbf{A} \times \mathbf{B} \)?
where is direction of force
(a) \( \hat{z} \), (b) \( -\hat{z} \) (c) \( \hat{y} \) (d) \( -\hat{y} \)

What is magnitude of force?
(a) \( q v B \sin \theta \) , (b) \( q v B \) (c) \( q v B \cos \theta \)
Number of magnetic field lines entering a closed surface...

Are there magnetic charges on Earth?

(1) yes
(2) no

...equals number leaving the surface.

\[ \Phi_B = \int_B \mathbf{B} \cdot d\mathbf{A} \]

Figure 29-18 Physics for Engineers and Scientists 3/e
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If thumb of your right hand is placed along direction of current...

...then fingers will curl around wire in direction of magnetic field.
Magnetic Field of a straight current
are parallel.

Fields between wires... individual magnetic fields add.
\[ \oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{\text{loop}} \]
What is $\int B \cdot ds$ for this path?
First, imagine a path at radius $r$ where we want to find $B$...

Constant current density within $r_0$.

What is magnetic field at radius $r$?

...and then determine amount of current crossing area inside that path.

Calculating $B$-fields with Ampere's Law.

What is magnetic field at radius $r$?