Reading Quiz
What is the result when we break a thin bar magnet in two pieces?

1. One piece has only a N pole. The other piece only a S pole.
2. One piece is still a bar magnet. The other piece is not a bar magnet.
3. Both pieces are bar magnets.
4. It depends on the magnet material.
5. It depends on whether the Hoos win the ACC swimming and diving crown.
Answer: 3

Try it and see. Both pieces become bar magnets. We have never seen a single magnetic pole.
Last Time

- More conceptual quizzes
- Kirchhoff’s rules
- Capacitors in series and parallel
- RC circuit – didn’t finish
Today

- Finish RC circuits
- Discuss meters
- Discuss applications
- Magnetism: iron filings, poles, bar magnets
- Magnetic field and magnetic force
- Motion of charged particle in magnetic field


Review: Tues., Feb. 15, Room 204, 5 – 6:15 pm
Do \textit{RC} time constant demo

\textit{RC} Time Constant (DECAY)

\begin{align*}
q(t) &= Qe^{-t/\tau} = CV \\
V &= \frac{Q}{C}e^{-t/\tau} = V_0e^{-t/\tau}
\end{align*}

\textit{C} is charged. Bullet cuts \textit{Gate 1}; \textit{C} discharges through resistor. Bullet cuts \textit{Gate 2}; \textit{C} stops discharging. Electrometer measures voltage drop across \textit{C}. 
Speed calculation

\[ V = V_0 e^{-t/\tau} \]

\[ \frac{V}{V_0} = e^{-t/\tau} \]

\[ \ln(\frac{V}{V_0}) = -\frac{t}{\tau} \]

\[ \ln(\frac{V_0}{V}) = \frac{t}{\tau} \]

\[ t = \tau \ln(\frac{V_0}{V}) = RC \ln(\frac{V_0}{V}) \]

\[ t = (180 \times 10^3 \, \Omega)(0.022 \times 10^{-6} \, F) \ln(\frac{V_0}{V}) \]

\[ t = 3.96 \times 10^{-3} \, s \ln(\frac{V_0}{V}) = \]

\[ v = \frac{d}{t} = \frac{1.0 \, m}{t} = \]
Applications of capacitors are numerous

- Intermittent windshield wipers
- Flashing yellow lights for safety
- Turn signals on car
- Flashing Christmas tree lights
- Camera photoflash
- Defibrillator – need energy delivered quickly
- Computer keyboard – keys act as capacitor
- Stud finder - demonstrate
Work Problems
21-67
21-90
We want ammeter to have very low resistance so it will not affect circuit. Ammeters go in series.
Measuring the Voltage in a Circuit

We want voltmeter to have very large resistance so it will not affect circuit. Voltmeters go in parallel across what is being measured.

\[
\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R_{\text{voltmeter}}}
\]
Show digital multimeter
Ch. 22 - Magnetism

Do demos with iron filings and magnets. Learn about magnetic fields.

Do demo with tiny magnetic arrows on overhead projector. Demonstrates directions of magnetic fields.
Some interesting facts

- Magnets come with N and S poles. Have never found an isolated pole. (monopole)
- Lodestone has been known for centuries; used in navigation for almost 1000 years.
- The direction of the magnetic field is the direction that the N pole of a magnet points.
- Magnetic fields make loops – never start and stop. (no magnetic monopoles, only dipoles)
- Magnetic field lines exit from the N pole and enter the S pole of a bar magnet.
- SI unit is tesla - T
Magnets Always Have Two Poles
Imagine using a test pole N; place it at any point and see where the force is. Just like we do for electric fields. We actually use small compasses to do this.
Do demo on magnetic deflection of an electron beam.

The result is that there is a force on a moving charge in a magnetic field.
Magnetic Force on a Moving Charge

(a) $\vec{B}$

(b) $\vec{v}$, $\vec{F}$, $q$, $\vec{B}$

(c) $\vec{v}$, $\vec{F}$, $q$, $\vec{B}$

(d) $F = 0$

(e) $v = 0$, $F = 0$

(f) $B = 0$

(g) $B \neq 0$

Bright spot where electron hits

Electron bends down because of magnetic field.

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The Magnetic Force on a Moving Charged Particle

We find maximum force when \( \vec{v} \perp \vec{B} \)

Maximum force

\[ F = |q|vB \sin \theta \]

Zero force
The Magnetic Force

Right-Hand Rule

\[ \vec{F}_B = q \vec{v} \times \vec{B} \]
Magnetic Field of the Earth
Van Allen Belts
(1958)
Aurora borealis (northern lights)
Helical Motion in a Magnetic Field

Remember

\[ \vec{F} = q\vec{v} \times \vec{B} \]
Convention to show vector directions

(a) \[ \vec{B} \text{ out} \]

Point of arrow

(b) \[ \vec{B} \text{ in} \]

Feather of arrow
The Magnetic Force for Positive and Negative Charges

\[ \vec{F}_B = q\vec{v} \times \vec{B} \]
Conceptual Quiz
A beam of electrons enters a region with a magnetic field as shown below. If the beam is deflected upward, the magnetic field must be oriented

1. downward       2. up
3. into the plane of the drawing       4. out of the plane of the drawing
5. to the left       6. to the right
7. none of the above - it is at an angle
8. need more information to determine
Conceptual Quiz
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7. none of the above - it is at an angle
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\[ \vec{F}_B = q\vec{v} \times \vec{B} \]
Conceptual Quiz
A beam of electrons enters a region with a magnetic field as shown below. If the beam is deflected upward, the magnetic field must be oriented

Force is up, so place right thumb up.
Velocity is to left, so point fingers to the left.
Curl your fingers towards you. Direction is towards us.
But charge is negative, so we reverse directions, and find that direction of magnetic field is into plane.
Answer is 3.
Circular Motion in a Magnetic Field
Charged Particle in a Circular Path

(a)

(b)
Operating Principle of a Mass Spectrometer

Several applications

\[ r = \frac{mv}{|q|B} \]
Forces on a charged particle that is moving perpendicularly to a uniform magnetic field.

Principle of cyclotron
Magnetic Force on a Current-Carrying Wire

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

\[ \vec{F} = q \frac{\Delta \vec{L}}{\Delta t} \times \vec{B} \]

\[ \vec{F} = \frac{q}{\Delta t} \Delta \vec{L} \times \vec{B} \]

\[ \vec{F} = I \vec{L} \times \vec{B} \]

\[ F = ILB \sin \theta \]
Work Problem 22-22
Conceptual Quiz
A negative particle moves upward along the trajectory shown. A magnetic field points toward the right. In which direction is the magnetic force on the particle?

1. up
2. down
3. into the plane of the drawing
4. out of the plane of the drawing
5. left
6. right
Answer: 4

Use the right hand rule to determine that the force must be out of the plane.
Conceptual Quiz

Cosmic rays (atomic nuclei stripped bare of their electrons) would continuously bombard Earth's surface if most of them were not deflected by Earth's magnetic field. Given that Earth is, to an excellent approximation, a magnetic dipole, the intensity of cosmic rays bombarding its surface is greatest at the

1. poles.
2. mid-latitudes.
3. equator.
We showed earlier that particles come in near the Earth and are affected by the Earth’s magnetic field. They feel a force and are deflected into spirals and spiral towards the N and S poles.
Conceptual Quiz

Particles representing the paths of 1, 2, and 3 have the same mass and charge magnitude. Which particle is moving most rapidly?

1. 1
2. 2
3. 3
Conceptual Quiz

Particles representing the paths of 1, 2, and 3 have the same mass and charge magnitude. Which particle is moving most rapidly?

1. 1
2. 2
3. 3

The radius of circular motion of a charged particle moving perpendicularly to a magnetic field is $r = \frac{mv}{qB}$. Particle 3 has the largest radius and, therefore, the largest speed. Note that it also has the greatest force exerted on it.
Work Problem 22-29
A beam of atoms enters a magnetic field region. What path will the atoms follow?
Atoms are neutral objects whose net charge is zero. Thus they do not experience a magnetic force.

Conceptual Quiz

• A beam of atoms enters a magnetic field region. What path will the atoms follow?

Follow-up: What charge would follow path #3? What about path #1?
Conceptual Quiz

A proton enters a uniform magnetic field that is perpendicular to the proton’s velocity. What happens to the kinetic energy of the proton?

1) it increases
2) it decreases
3) it stays the same
4) depends on the velocity direction
5) depends on the $B$ field direction
A proton enters a uniform magnetic field that is perpendicular to the proton’s velocity. What happens to the kinetic energy of the proton?

1) it increases
2) it decreases
3) it stays the same
4) depends on the velocity direction
5) depends on the $B$ field direction

The velocity of the proton changes **direction** but the **magnitude** (speed) doesn't change. Thus the **kinetic energy stays the same**.