Lecture 8:
Magnets and Magnetism

Magnets

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- Materials that attract other metals

- Three classes: natural, artificial and electromagnets
- Permanent or Temporary
- CRITICAL to electric systems:
  - Generation of electricity
  - Operation of motors
  - Operation of relays

Magnets

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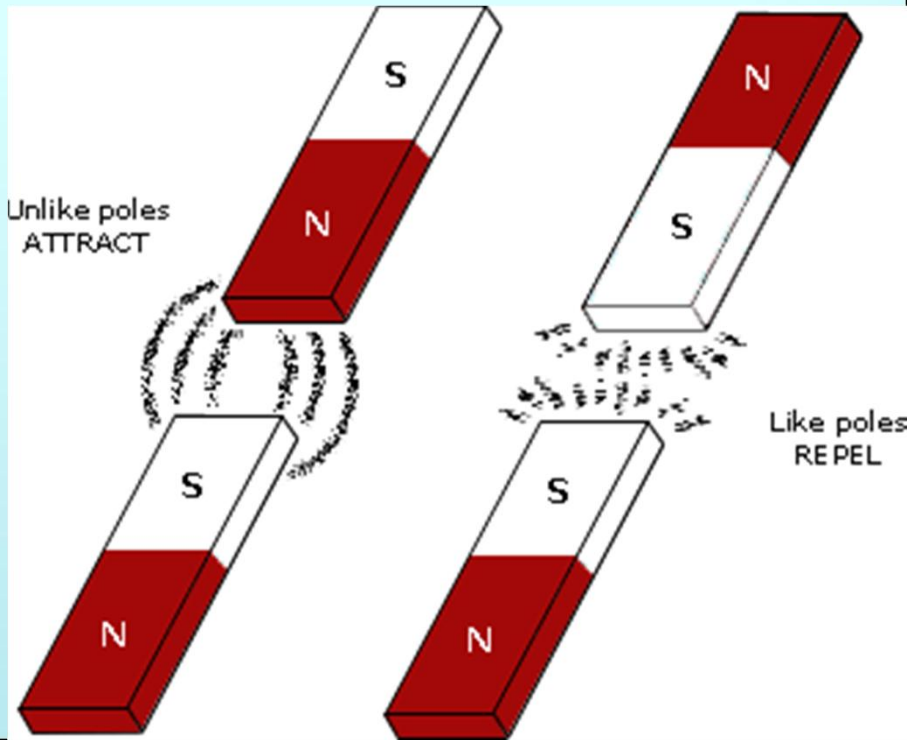
- Laws of magnetic attraction and repulsion
  - Like magnetic poles repel each other
  - Unlike magnetic poles attract each other
  - Closer together, greater the force



Magnetic Fields and Forces

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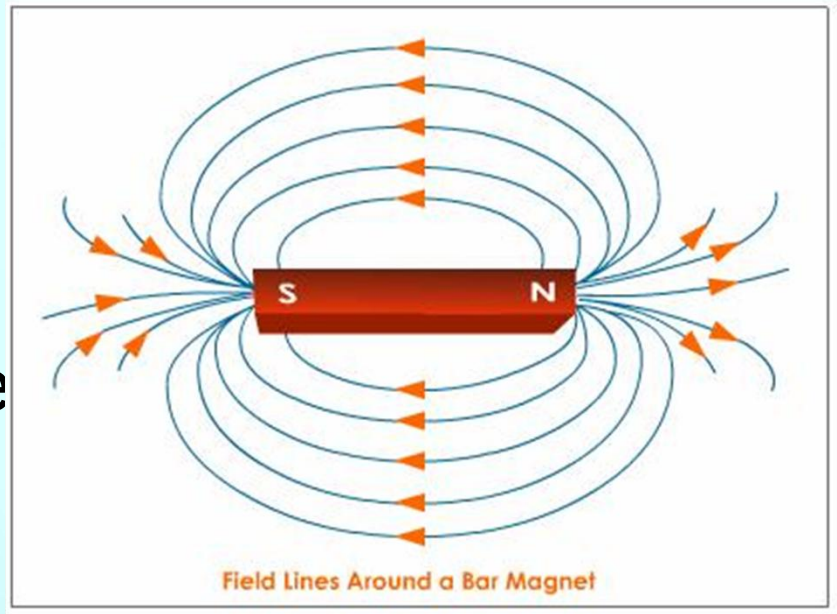
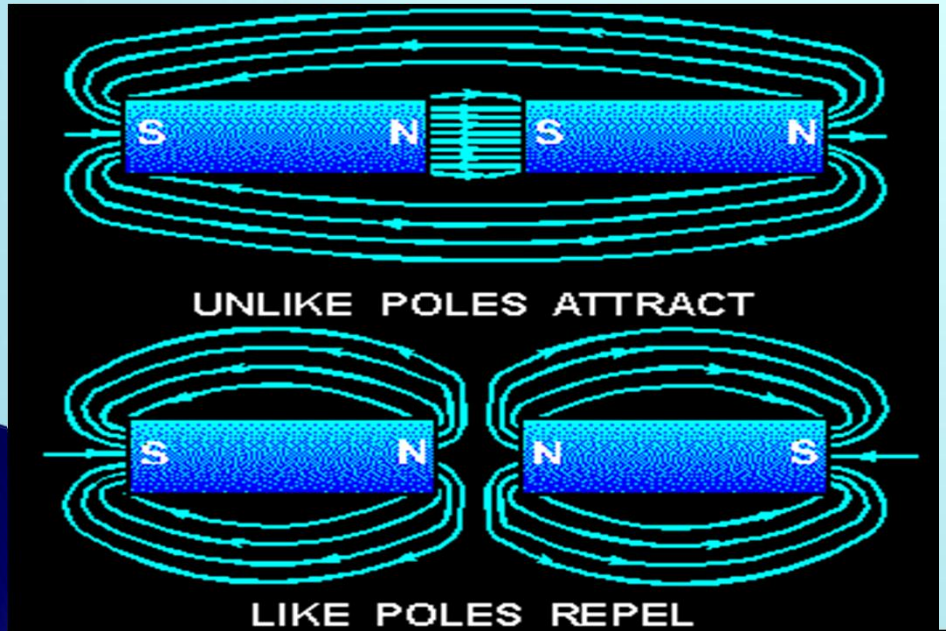
- Magnetic lines of force
  - Lines indicating magnetic field
  - Direction from N to S
  - Density indicates strength
- Magnetic field is region where force exists



Field Lines Around a Bar Magnet



Magnetic Theories

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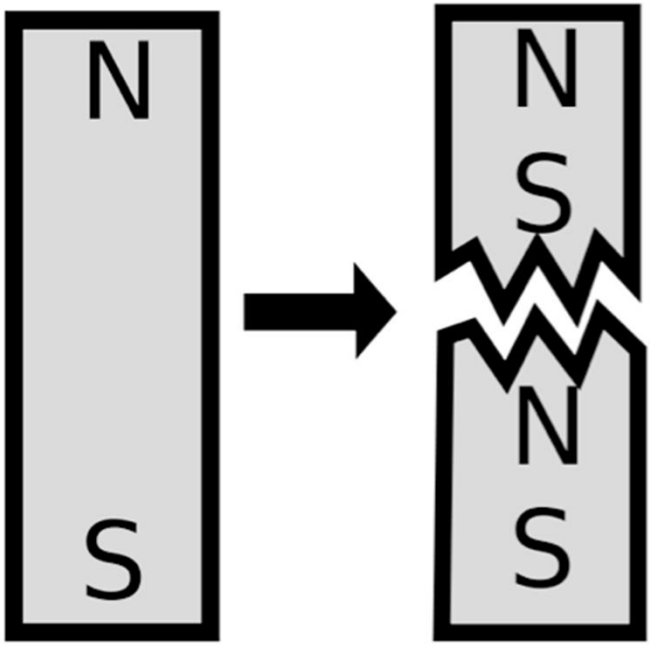
Molecular theory of magnetism

Magnets can be split into two magnets



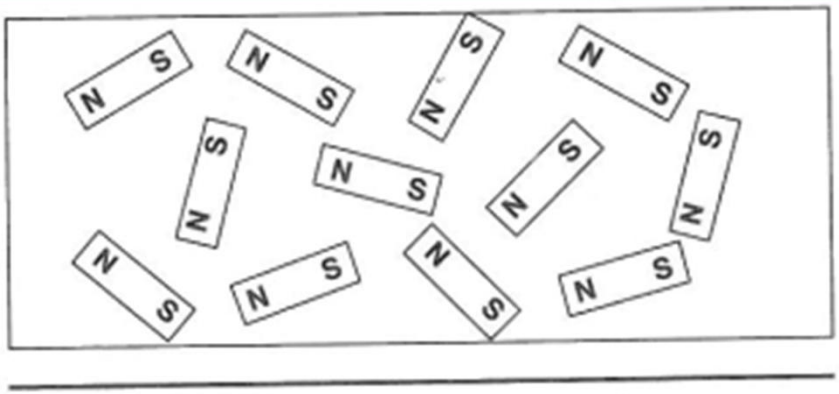


FIGURE 6–6 Unmagnetized material.

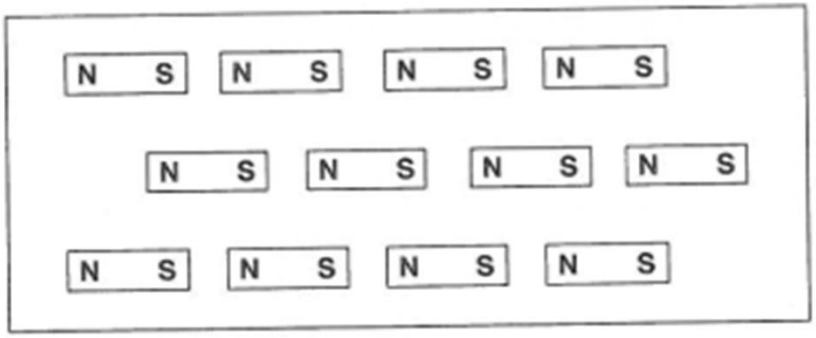


FIGURE 6–5 Magnetized material.

Magnetic Theories

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Molecular theory of magnetism

Split down to molecular level

When unmagnetized, randomness, fields cancel

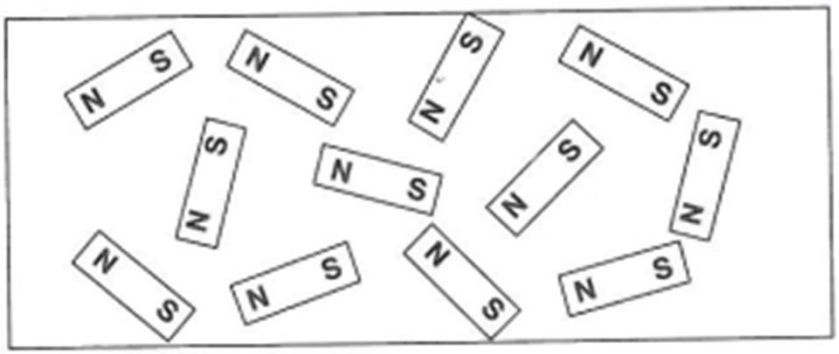

FIGURE 6–6 Unmagnetized material.

When magnetized, order, fields combine

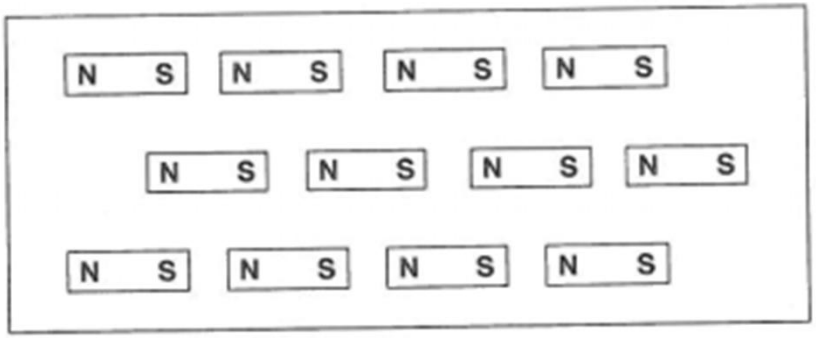

FIGURE 6–5 Magnetized material.

Magnetic Theories

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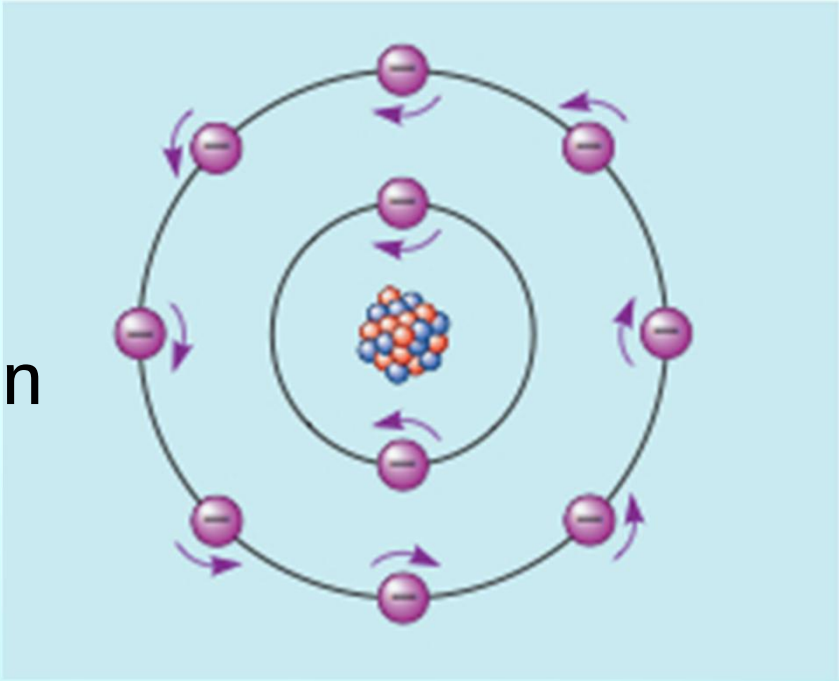
Electron theory of magnetism

- Electrons spin as they orbit (similar to earth)
- Spin produces magnetic field
- Magnetic direction depends on direction of rotation
- Non-magnets → equal number of electrons spinning in opposite direction



- Magnets → more spin one way than other

Electromagnetism

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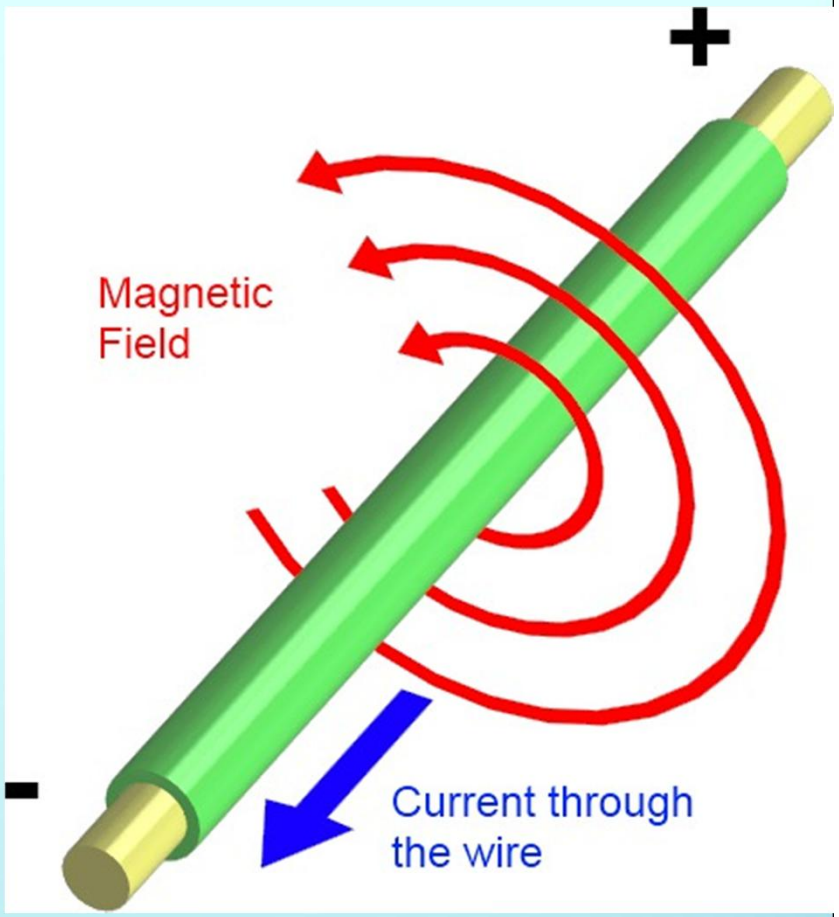
- Movement of electric charge induces magnetic field

- Strength of magnetic field increases as current increases and vice versa



Right Hand Rule (Conductor)

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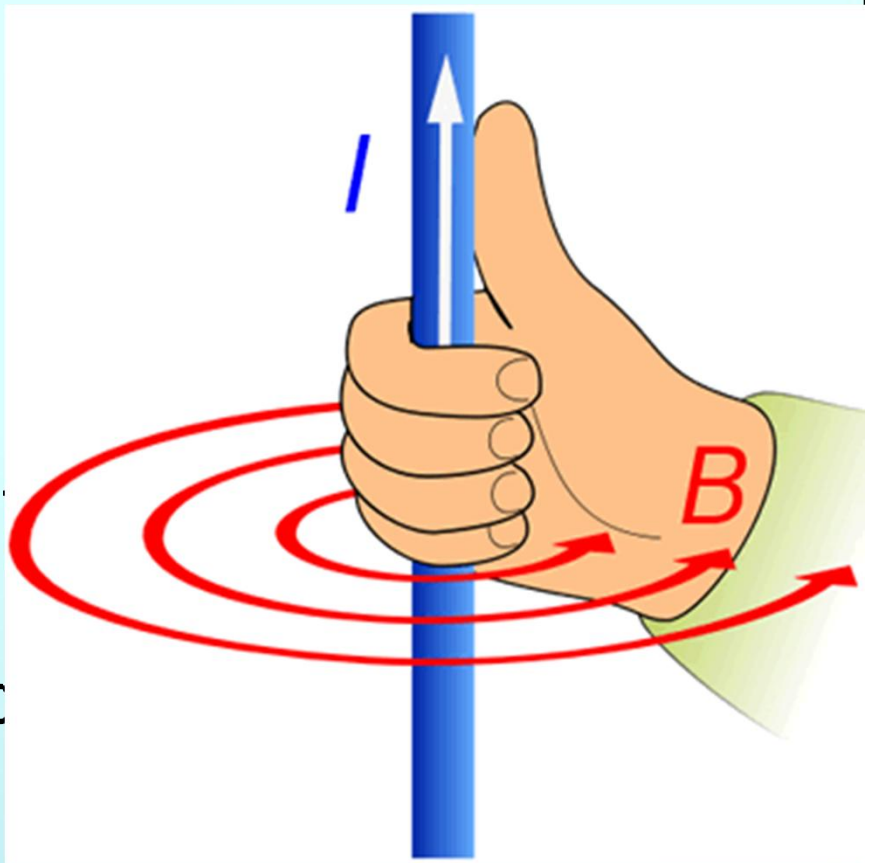
- Determines direction of magnetic field
- Imagine grasping conductor with right hand
- Thumb in direction of curren flow (not electron flow)
- Fingers curl in the direction c magnetic field



DO NOT USE LEFT HAND RULE IN BOOK

Example

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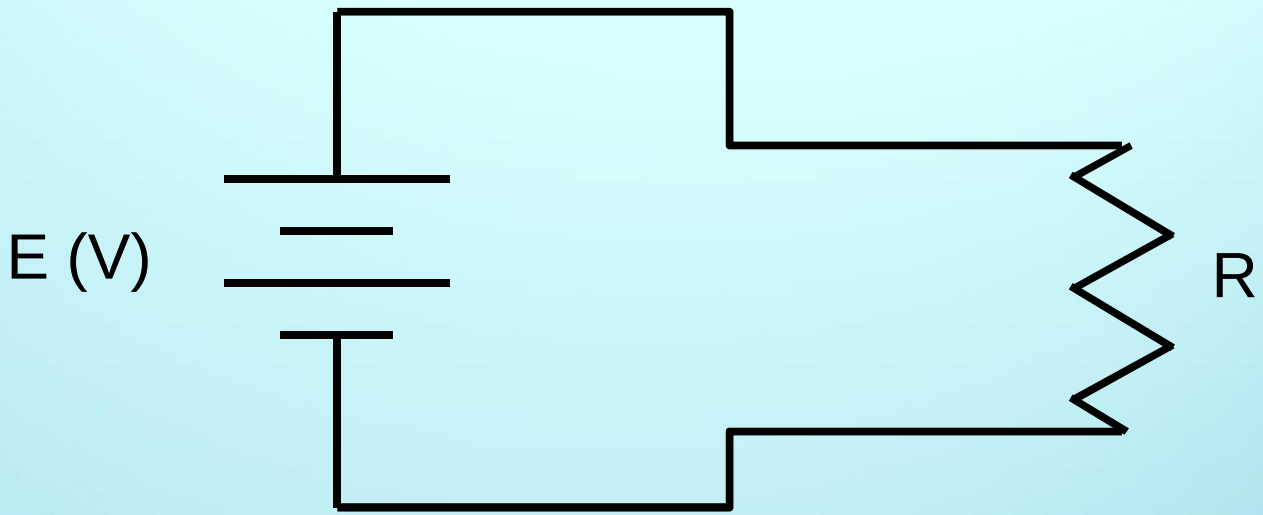
Draw magnetic field lines around conduction path



Another Example

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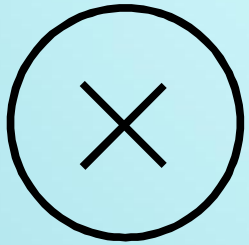
- Draw magnetic field lines around conductors

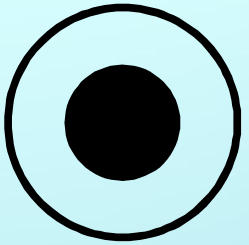
Conductor

current into page



Conductor

current out of page



Conductor coils

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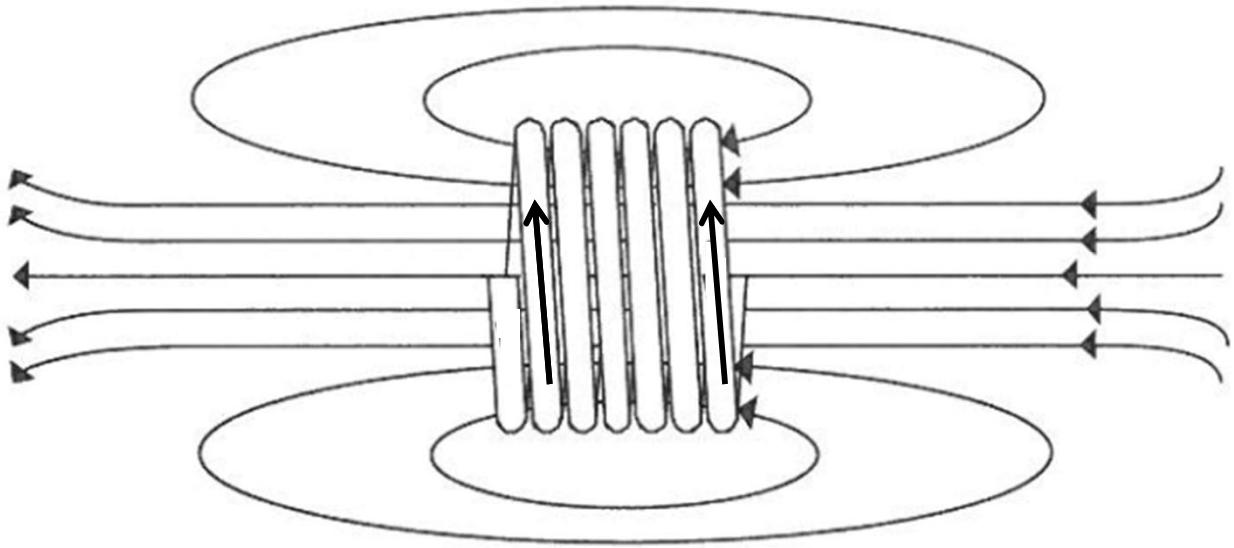
- Single conductor not very useful
- Multiple winds of a conductor required for most applications,
  - e.g. electromagnet, motors, solenoids
- Strength of magnetic field now dependent on current magnitude and number of turns



Right Hand Rule (Coil)

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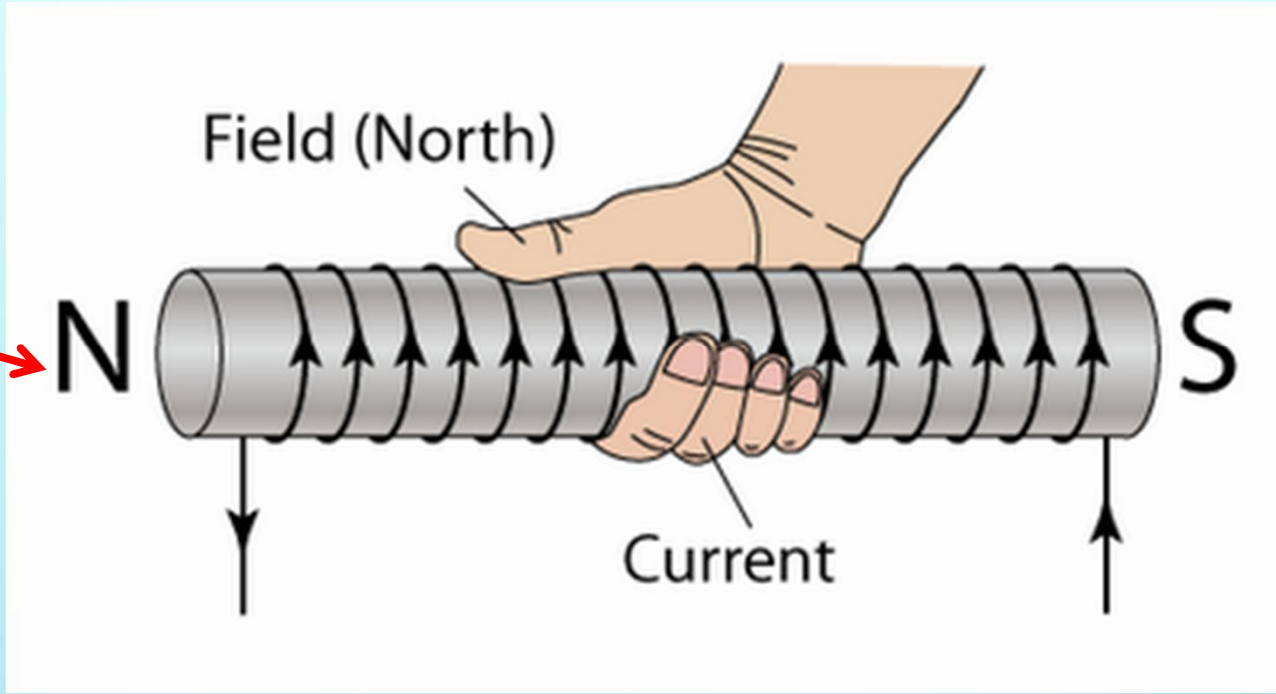
- Imagine grasping coil with right hand
- Fingers in direction of current flow (not electron flow)
- Thumb points in direction of magnetic field through coil

Creates electromagnet



DO NOT USE LEFT HAND RULE IN BOOK

Example

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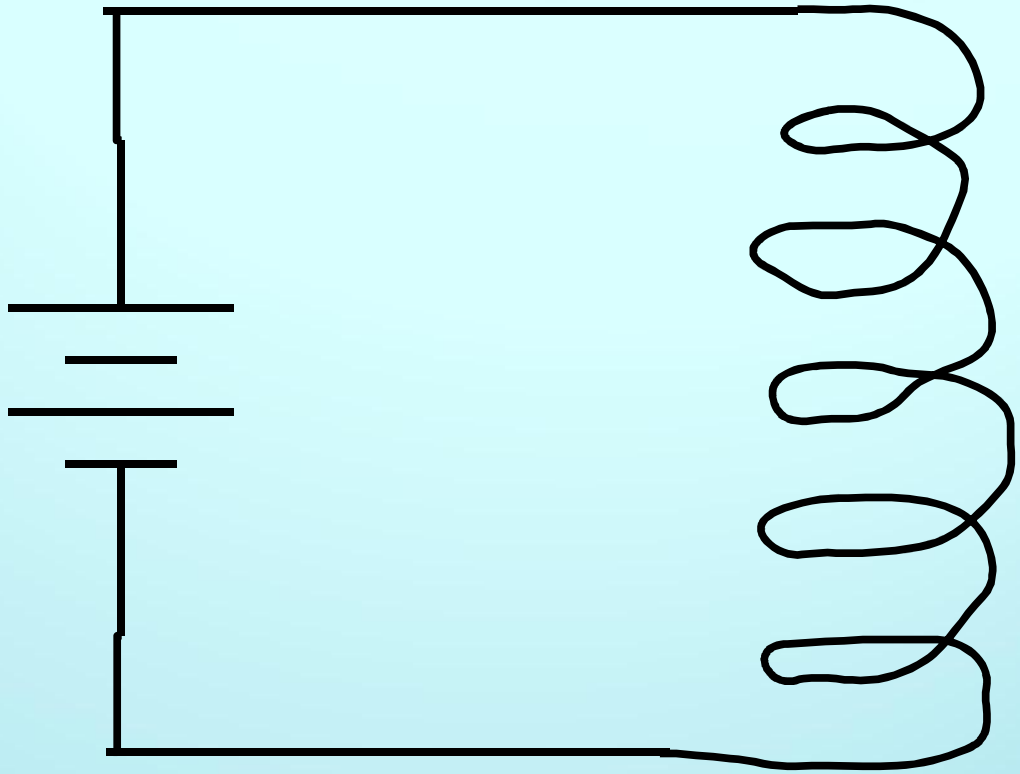
- Draw magnetic field lines through and around coil



Magnetic Force on Moving Charge

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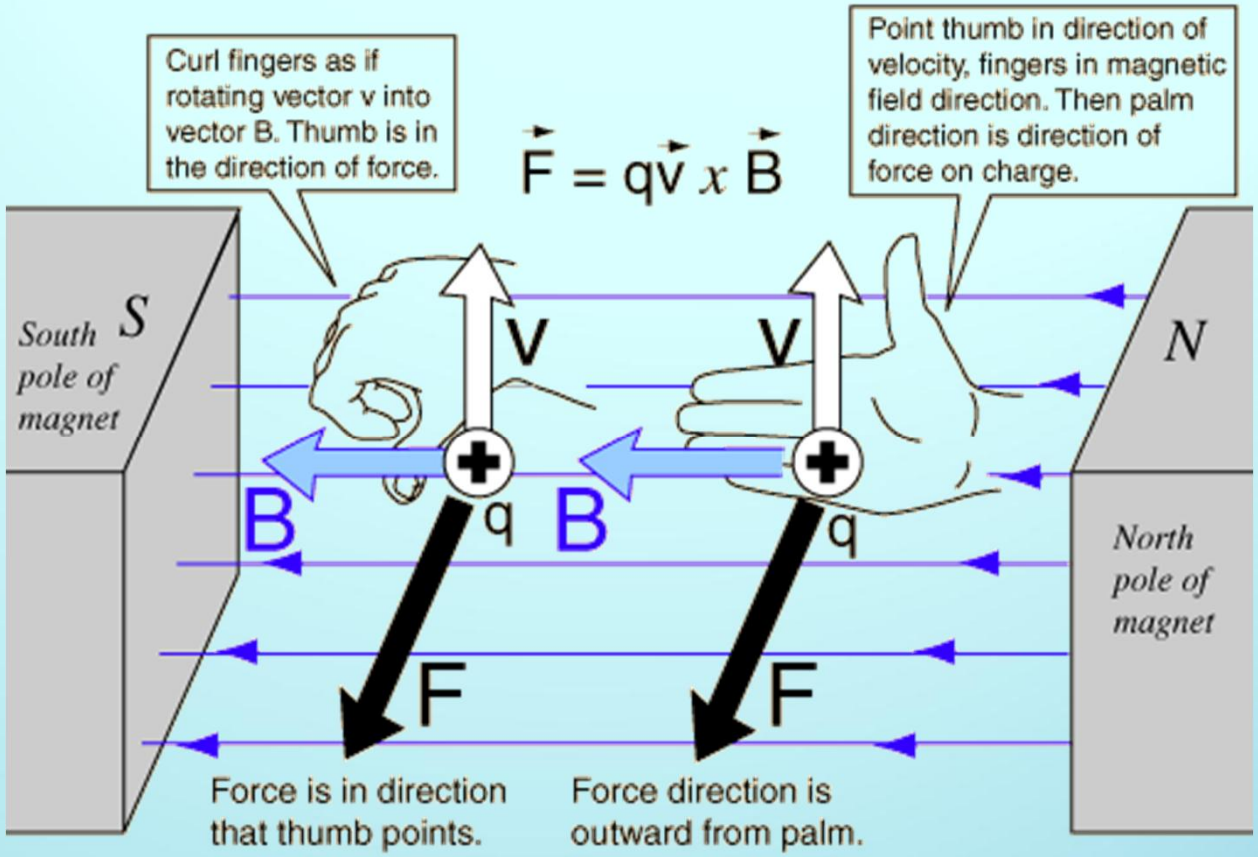
- A magnetic field has a force on a moving charge
- Lorentz Force Law (don't need to know, just telling you)

Two right hand rules.

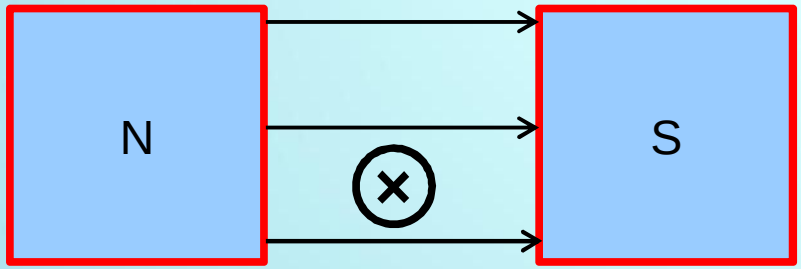
Choose which one is best for you.

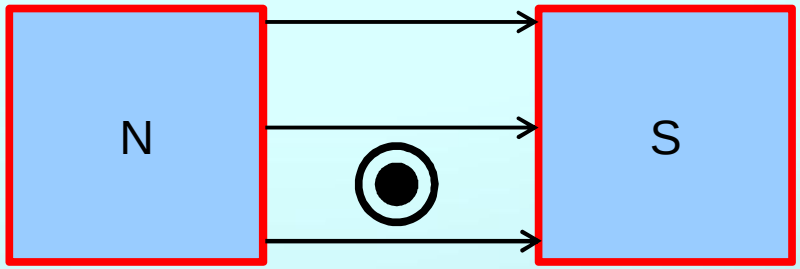
I like the one on the right.



Example

Draw direction of force on conductors

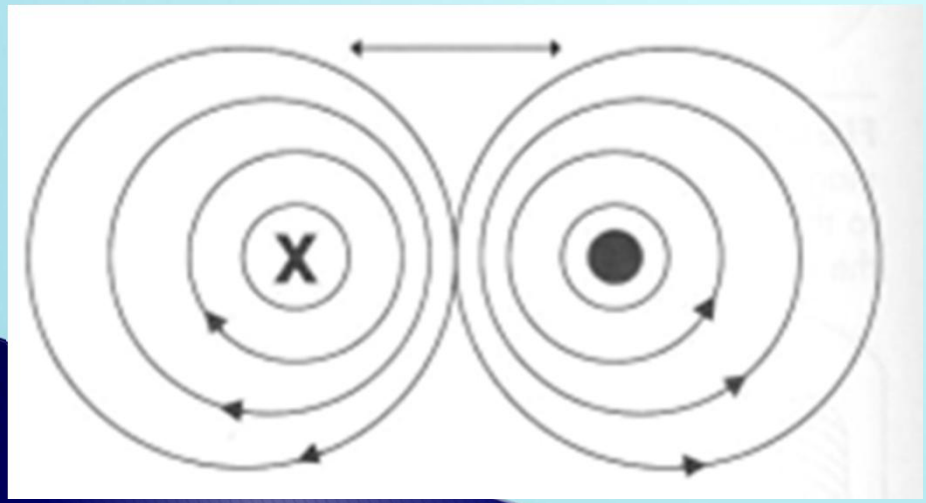




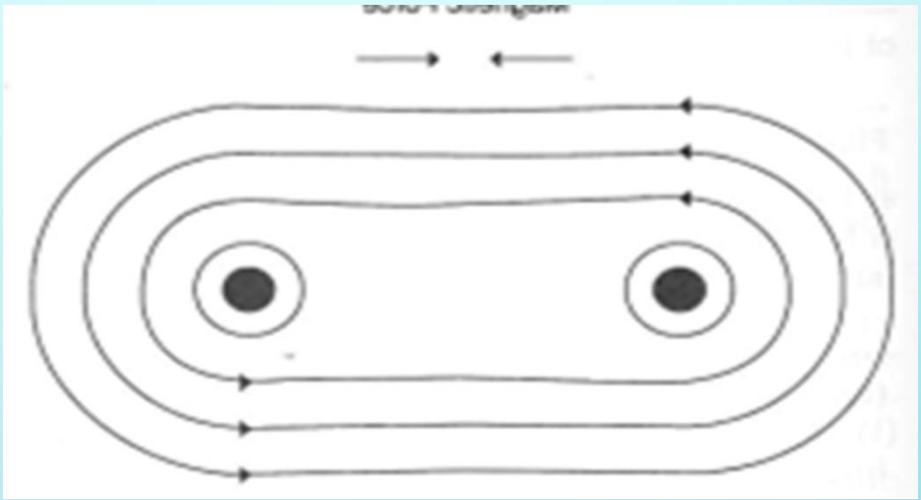
Another Example

What about mutual force on conductors due to induced magnetic fields?

Force Repels



Force Attracts



Magnetic Circuits

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- Magnetic Flux in circuit similar to current
  - Unit: Maxwells (Mx) = 1 magnetic line of force.
- Magnetomotive Force (mmf) similar to voltage
  - Unit: Gilberts (Gb) = the mmf that will establish a flux of 1 Mx in a magnetic circuit having a reluctance (rel) of 1 unit.
  - In electromagnets mmf is proportional to coil current and number of turns
- Reluctance (rel) is similar to resistance
  - Material's opposition to magnetic flux
- Permeance is similar to conductance
  - inverse of reluctance
  - Material's ability to conduct magnetic flux

Magnetic Circuits

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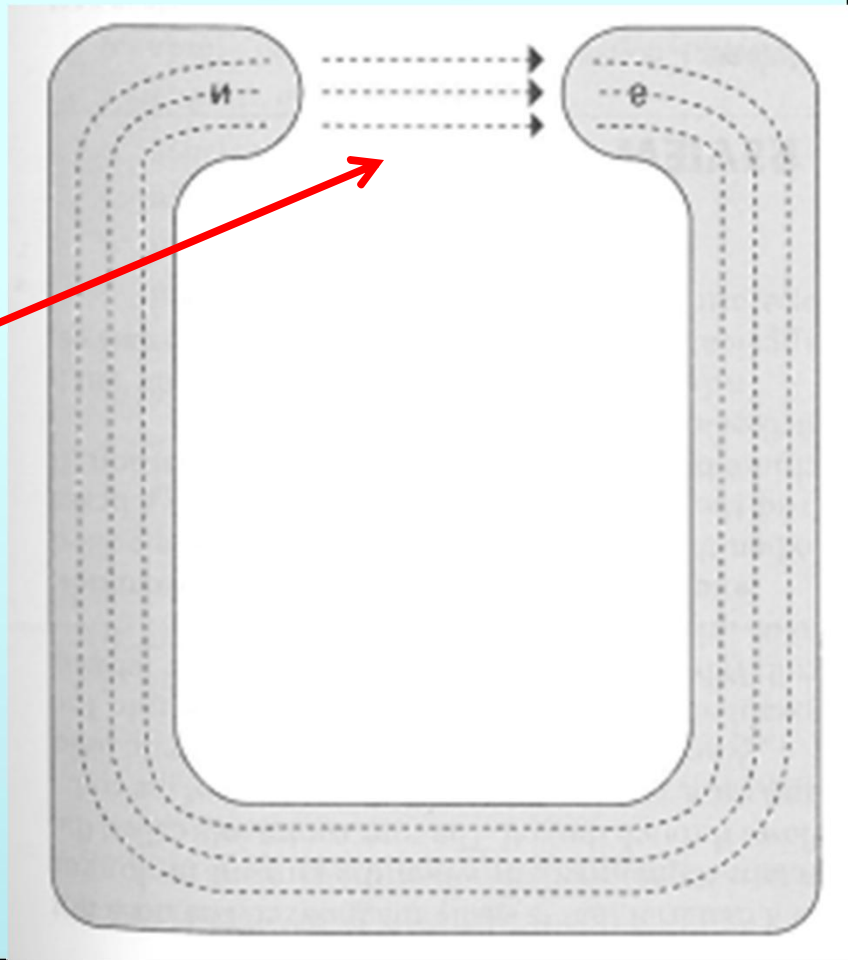
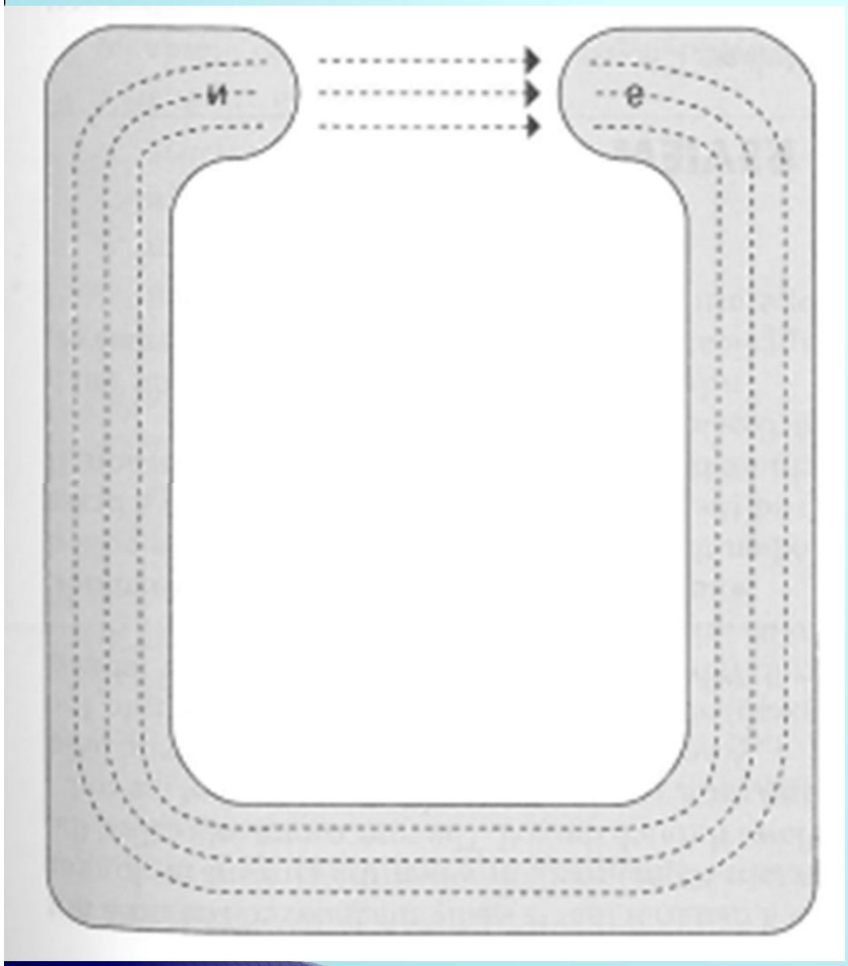
- Permeability of air is low (high reluctance)
- Permeability of soft iron is high (low reluctance)

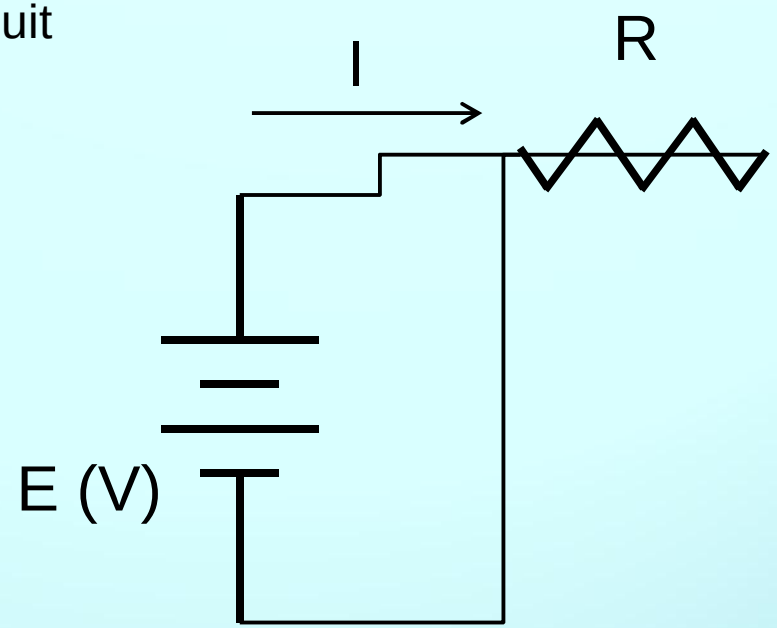
Majority of reluctance in air gap



Magnetic Circuits



Analogous circuit



$$\Phi = \frac{f}{\Re} \qquad \text{(Eq. 6.1)}$$

where Φ = flux, in maxwells (Mx)
f = mmf, in gilberts (Gb)
$\Re$ = units of reluctance