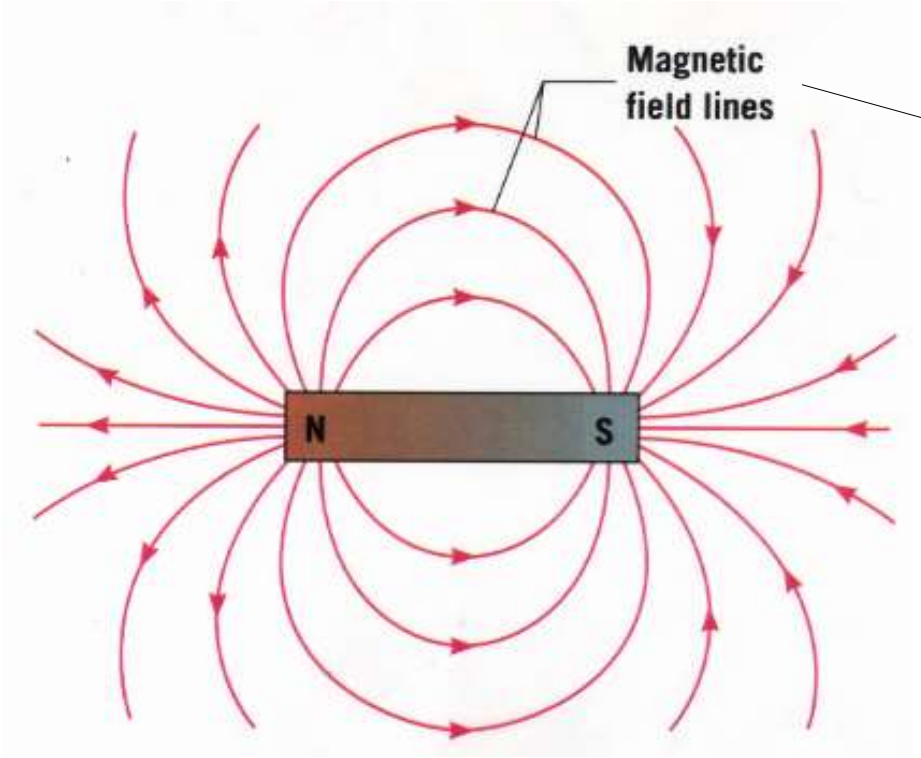
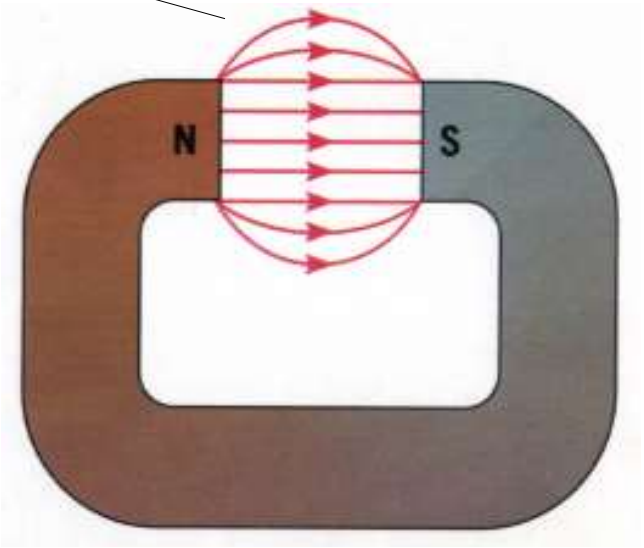
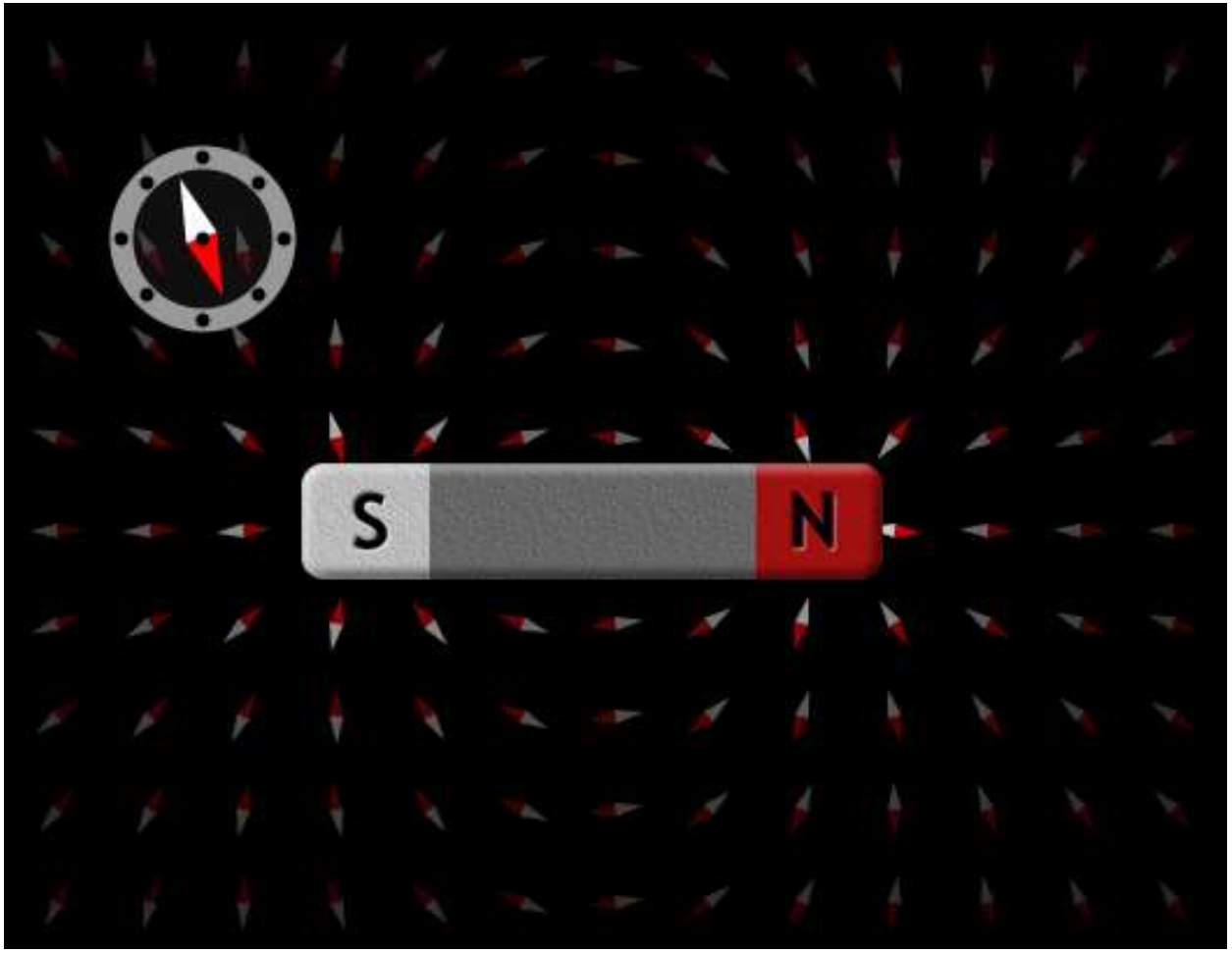
Magnets, Magnetic Fields





Simulation



We have studied:

- Electrostatics (stationary charges)
- Magnetostatics (stationary magnets)

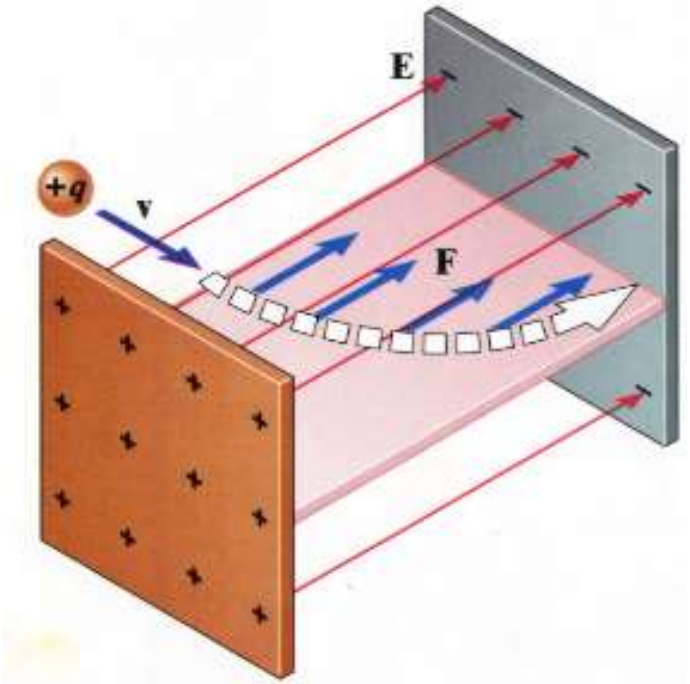
Connections between electric and magnetic forces

Is there one?

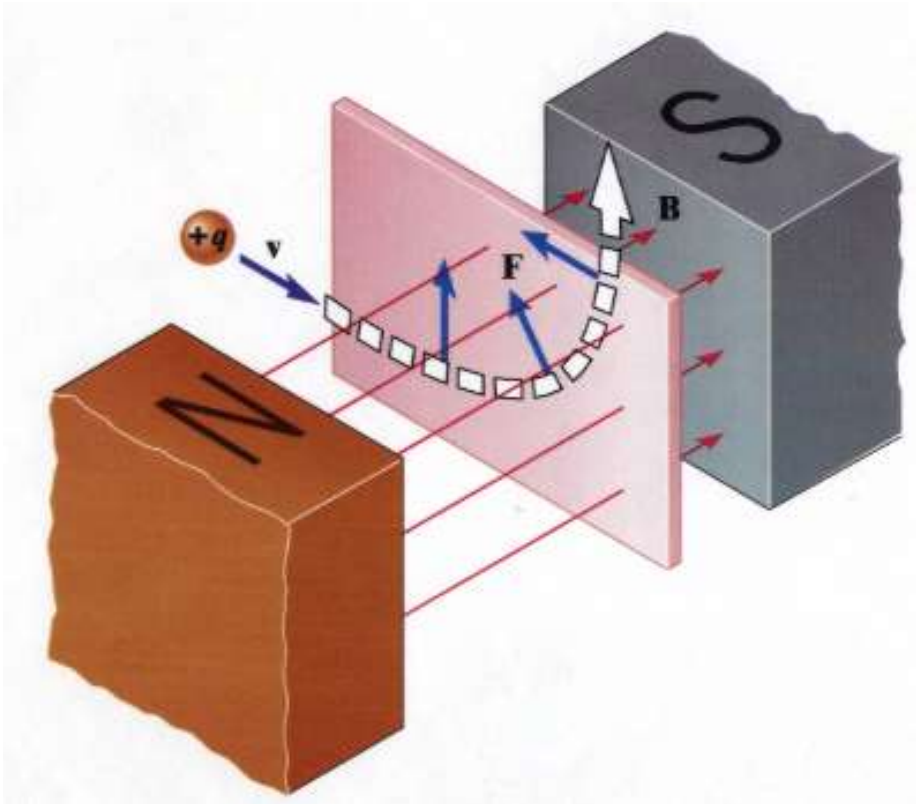
Electrodynamics

- Moving charges feel magnetic force
- Moving charges generate magnetic fields
- Electric motors
- Magnetic induction and electric generators

Force on a moving charge

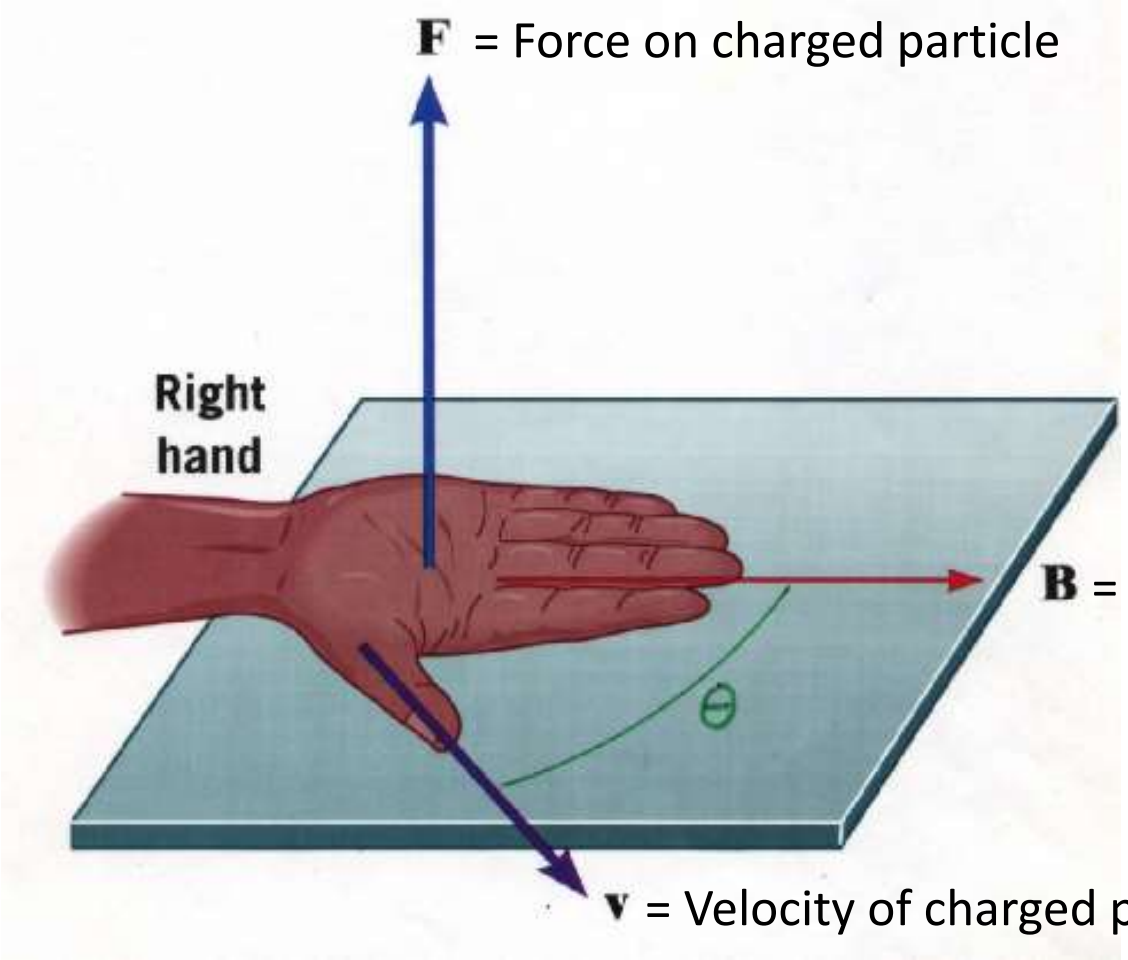


Electric force



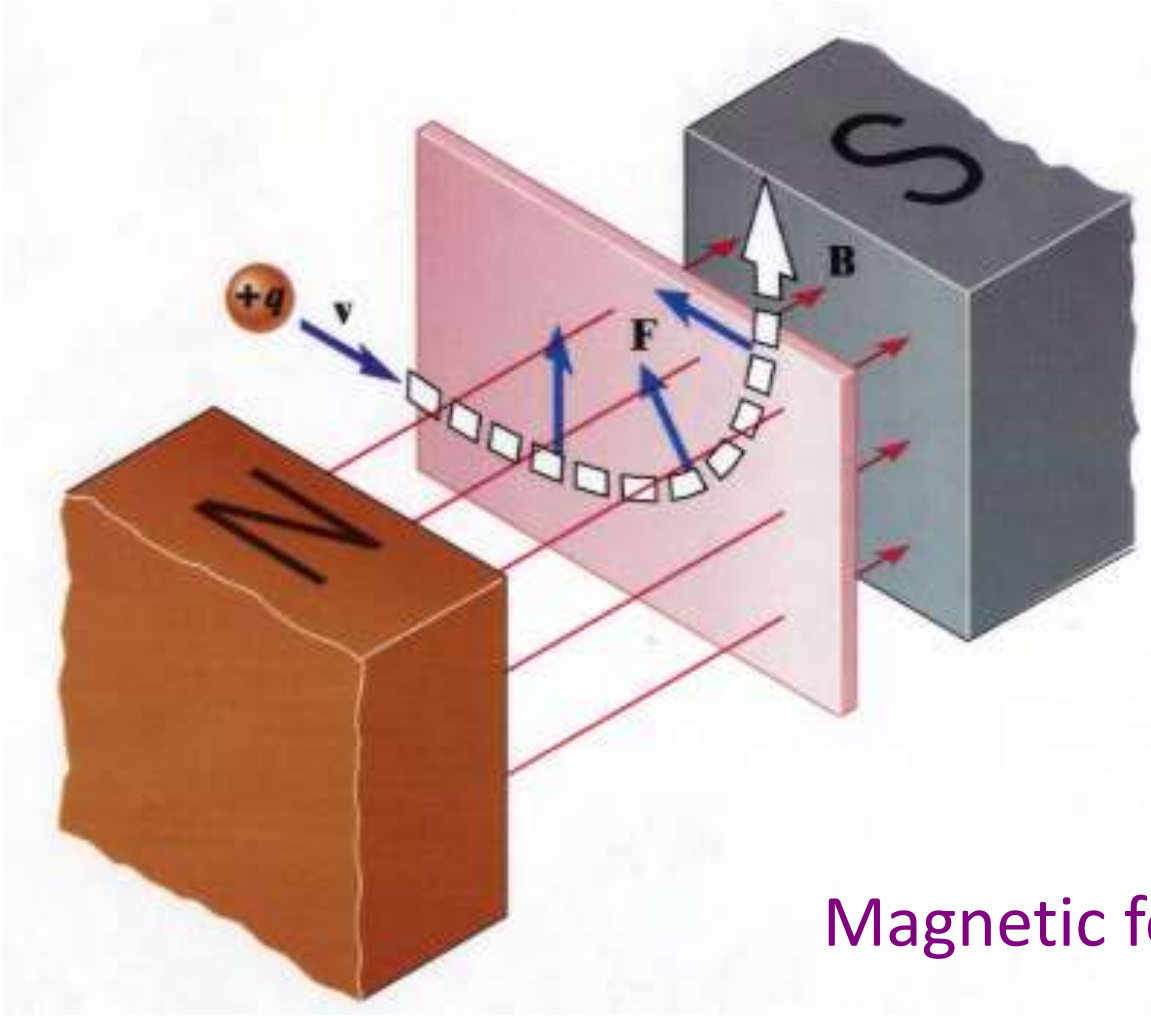
Magnetic force

Force on a moving charge



The “right hand rule” (for positive charge)

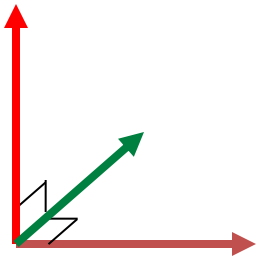
Force on a moving charge



Magnetic force

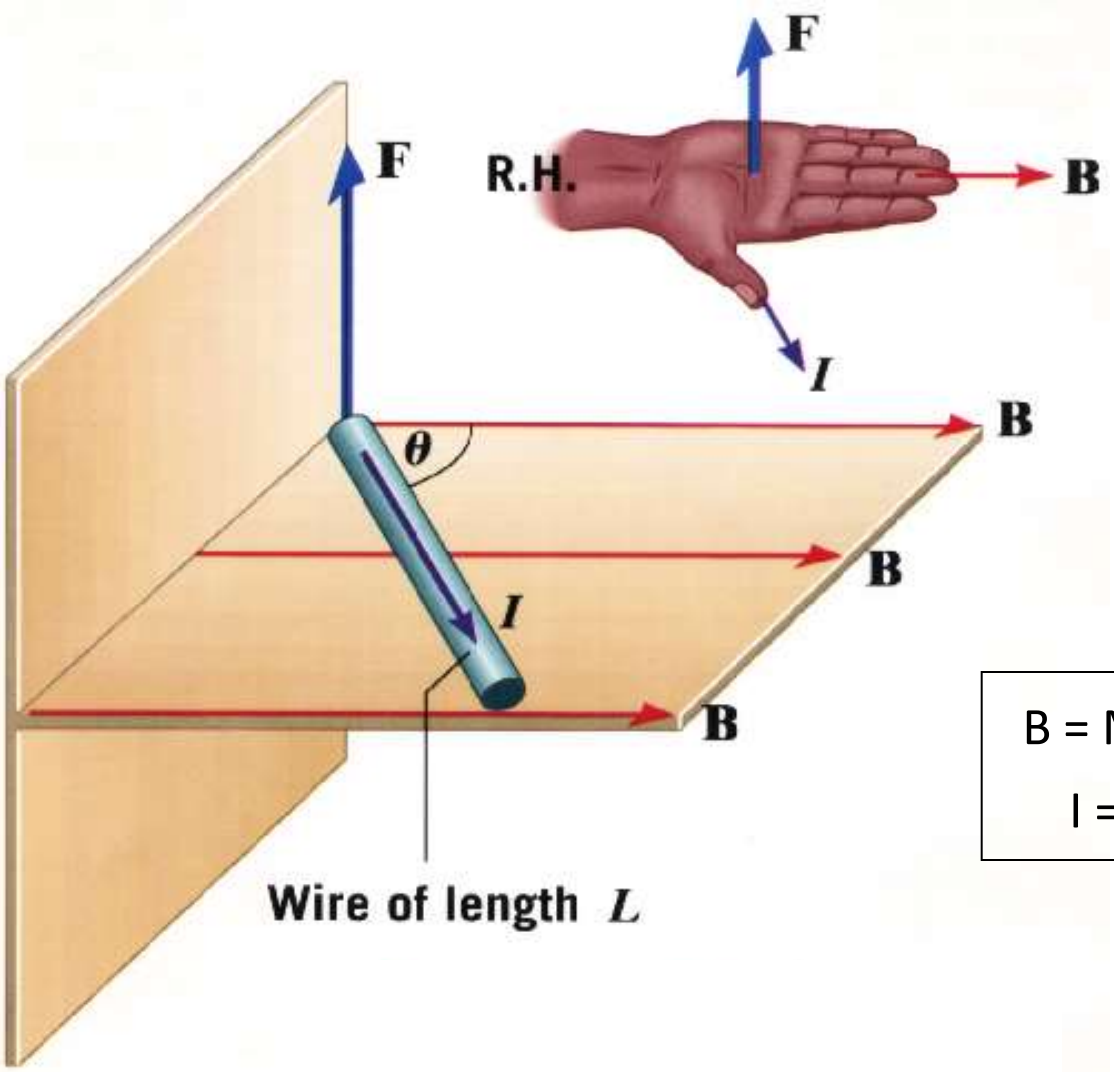
Magnetic forces: Principles

- Three-way rule:
  - Force is perpendicular to magnetic field and to current (or particle velocity)



- Reversal rule:
  - Flip of charge, current, velocity, field, … flips resulting force

Force on a current-carrying wire



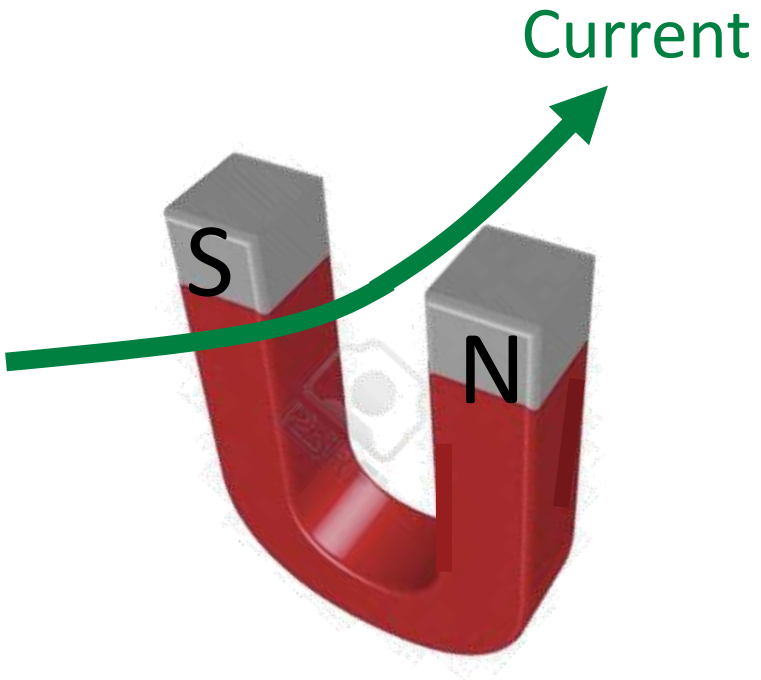
B = Mag. Field

I = current

Demo!

Demos:
Right Hand Rule
Ampere's Motor

In which direction will the wire move?



Clicker

A) Down

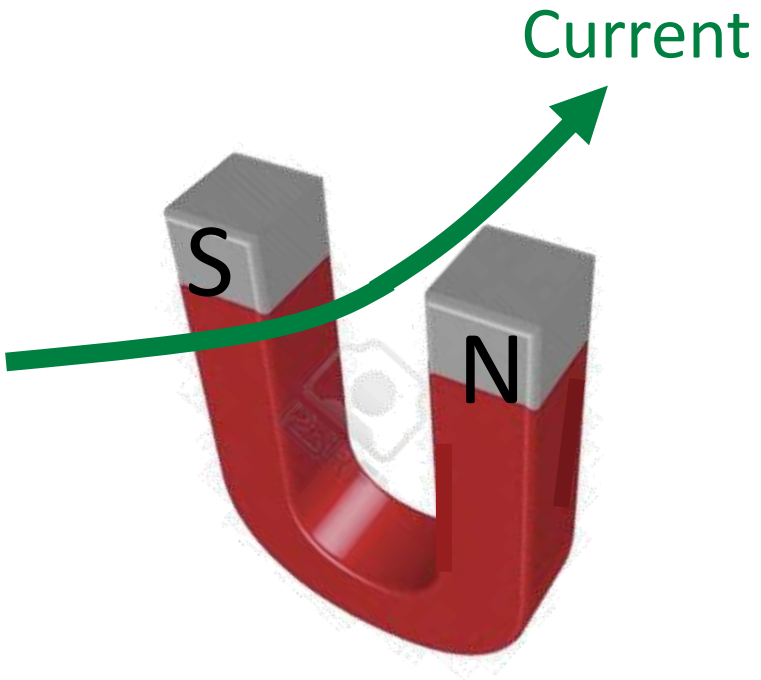
B) Up

C) Left

D) Right

E) It will not move

In which direction will the wire move?



Clicker

A) Down

B) Up

C) Left

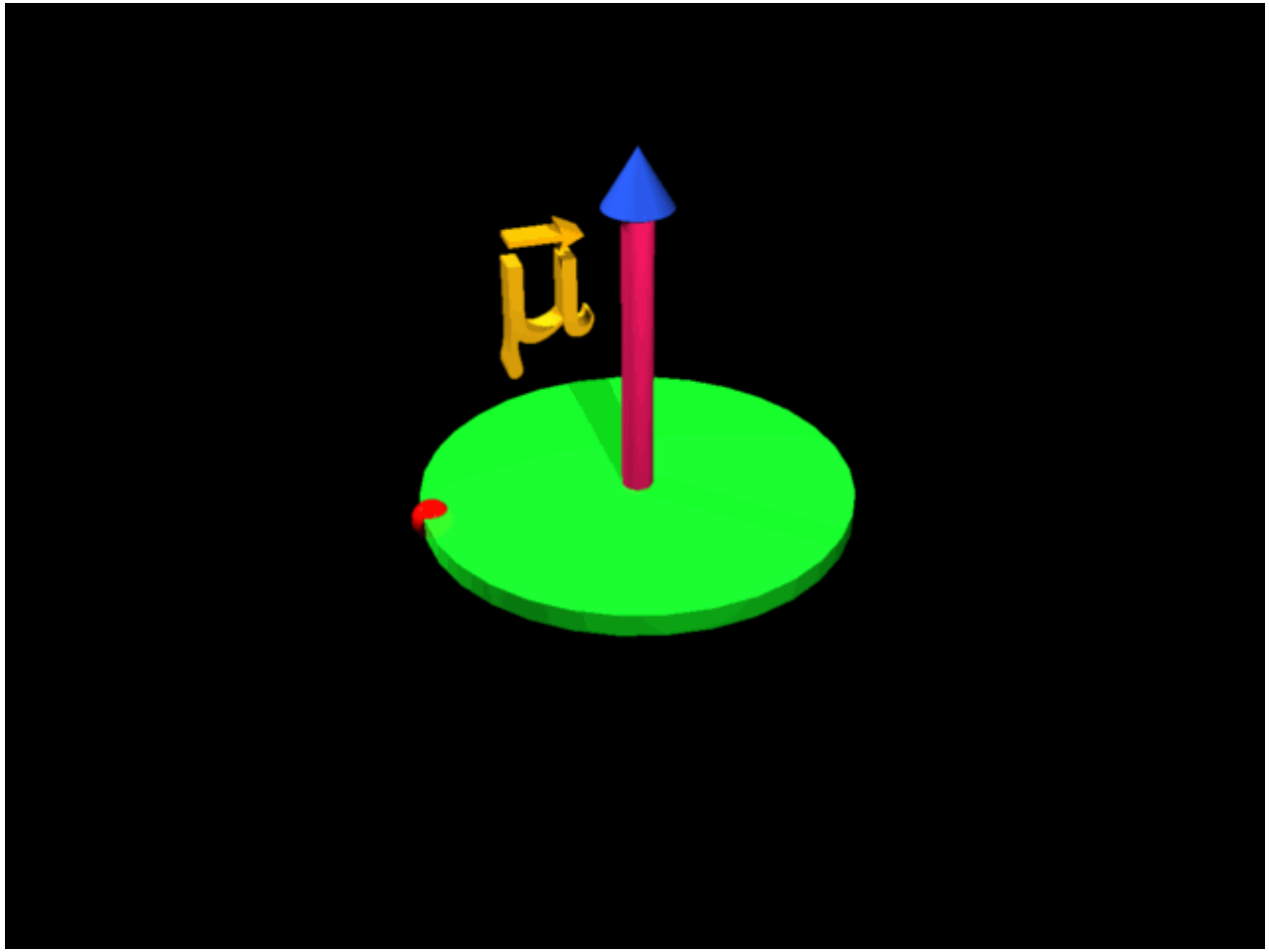
D) Right

E) It will not move

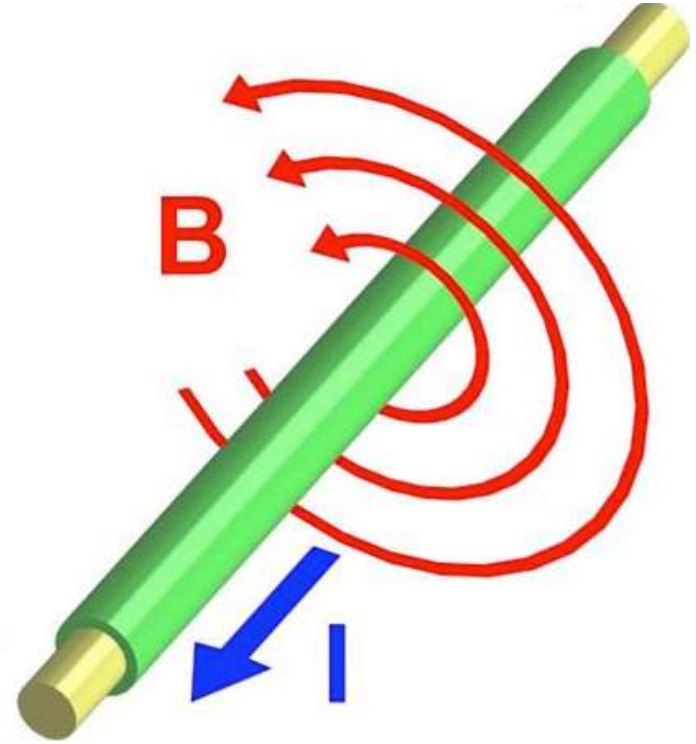
Electrodynamics

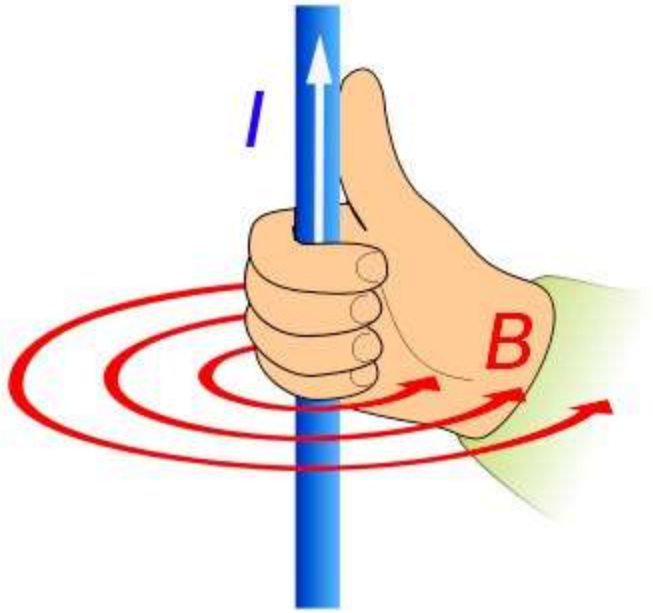
- Moving charges feel magnetic force
- Moving charges generate magnetic fields
- Electric motors
- Magnetic induction and electric generators

Actually, all magnetism comes from moving charges, at atomic level!



Magnetic field around a current carrying wire





B = Mag. Field

I = current

Alternate “right hand rule”

Demos: Magnetic field around a current carrying wire

Demos: Magnetic field around a current carrying wire

Anti-parallel currents

Clicker Question

A current flows through two parallel wires, in the same direction. The wires will experience a magnetic force

A. pulling them together

B. pushing them apart

C. no magnetic force if the wires are not moving

D. the magnetic force will be perpendicular to the wire separation

Clicker Question

A current flows through two parallel wires, in the same direction. The wires will experience a magnetic force

A. pulling them together

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C. no magnetic force if the wires are not moving

D. the magnetic force will be perpendicular to the wire separation

Demos: Magnetic field around a current carrying wire

Anti-parallel currents

Clicker

Will wires carrying anti-parallel currents go

A) Closer together

B) Farther apart

C) Up

D) Down

E) Do nothing

Demos: Magnetic field around a current carrying wire

Anti-parallel currents

Clicker

Will wires carrying anti-parallel currents go

A) Closer together

B) Farther apart

C) Up

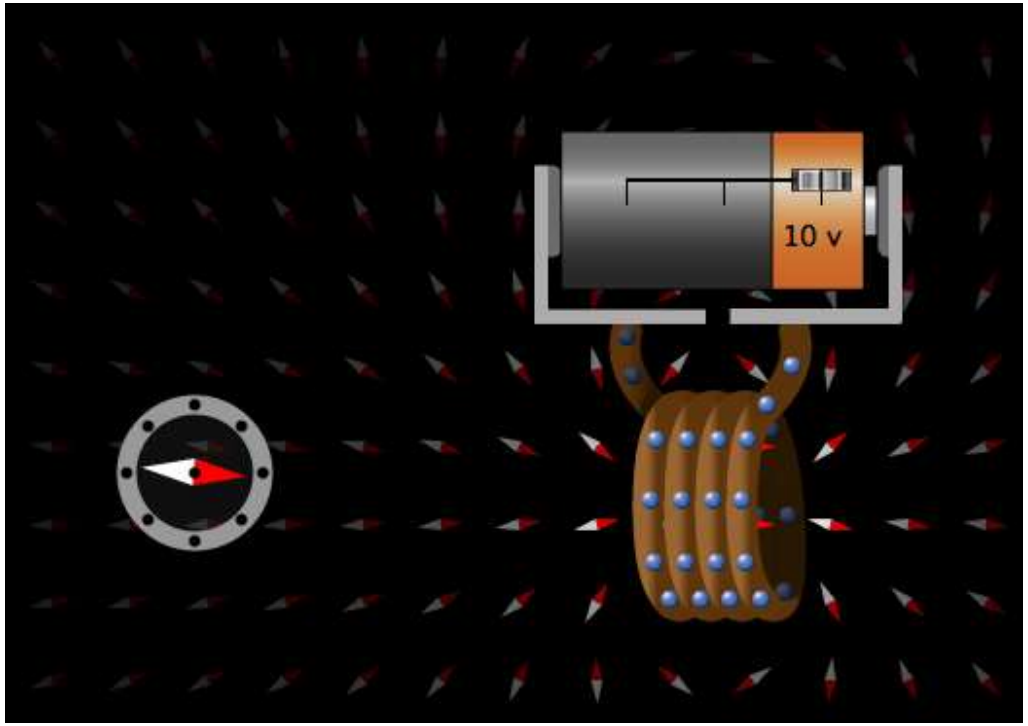
D) Down

E) Do nothing

Simulation: Electromagnet

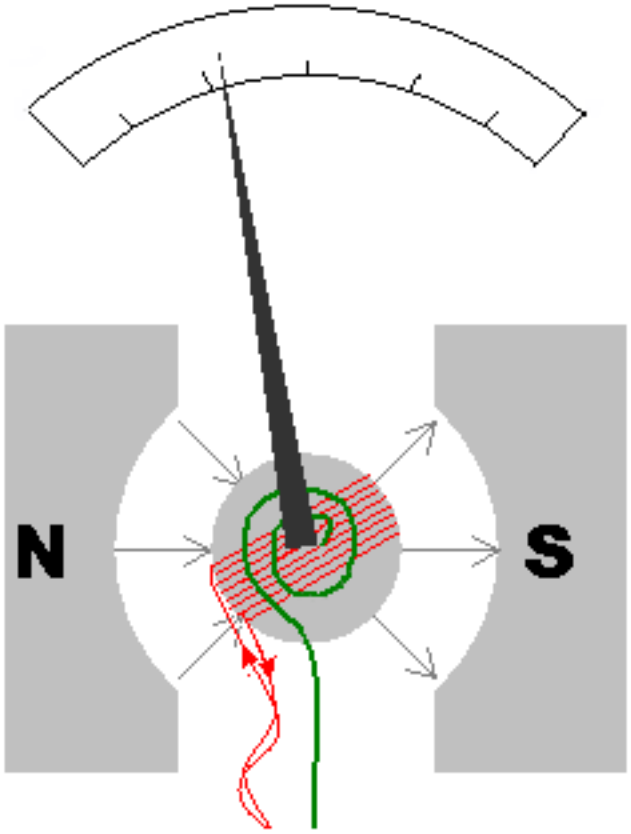
What if we loop wire into a coil?

We get a magnetic field produced by the electric current!



Galvanometer (current meter)

Galvanometer measures current

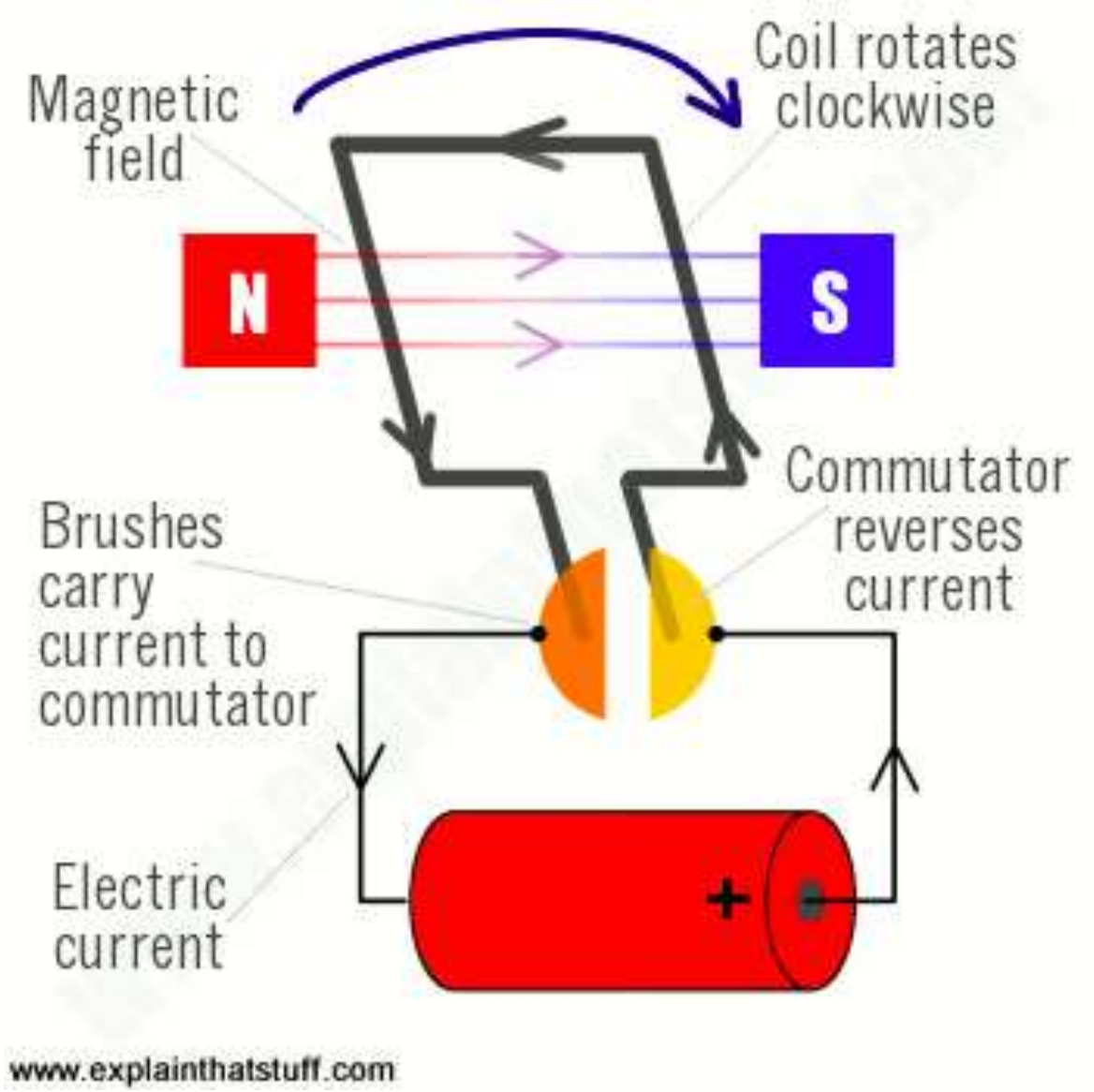


What happens if we move a bar magnet through a coil?

Electrodynamics

- Moving charges feel magnetic force
- Moving charges generate magnetic fields
- Electric motors
- Magnetic induction and electric generators

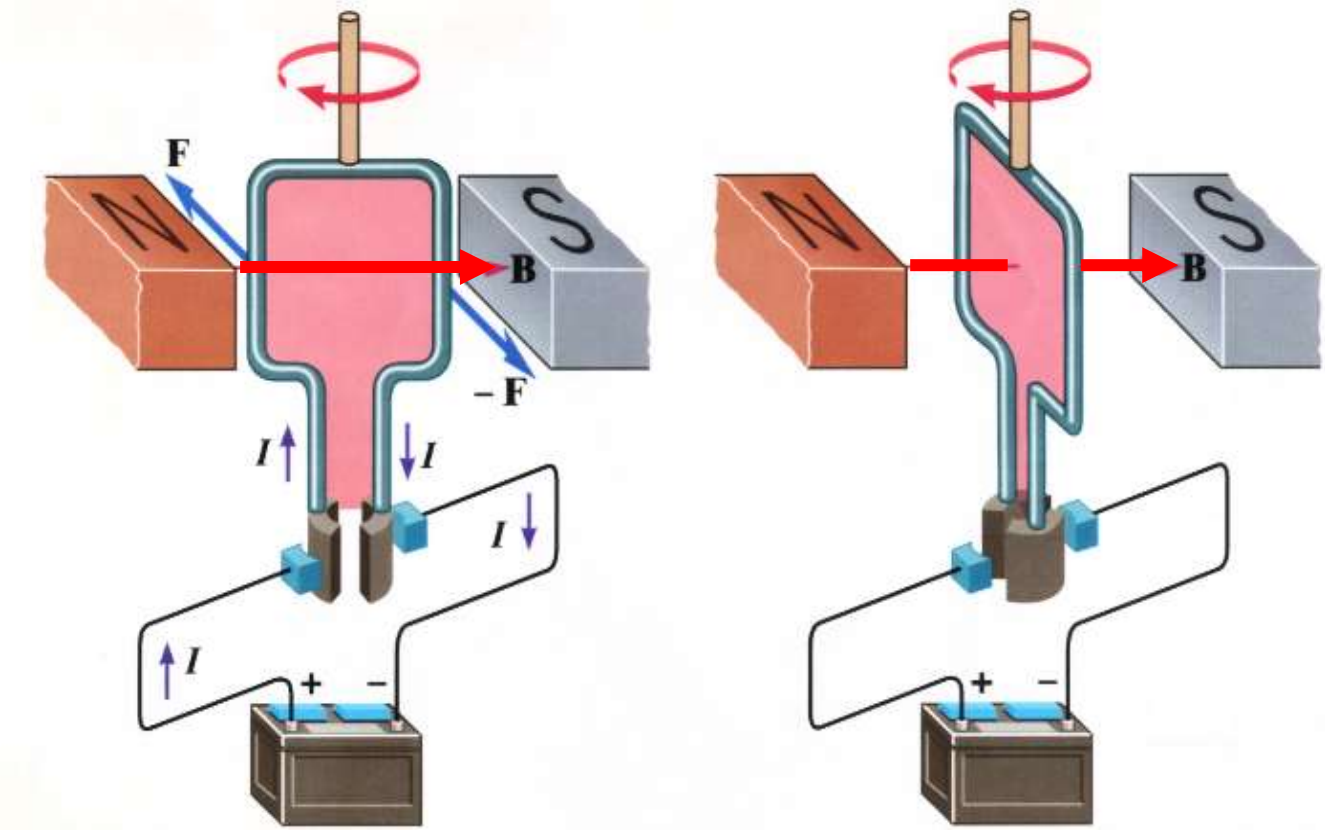
Electric Motor



Electric motors involve rotating coils of wire which are driven by the magnetic force exerted by a magnetic field on an electric current.

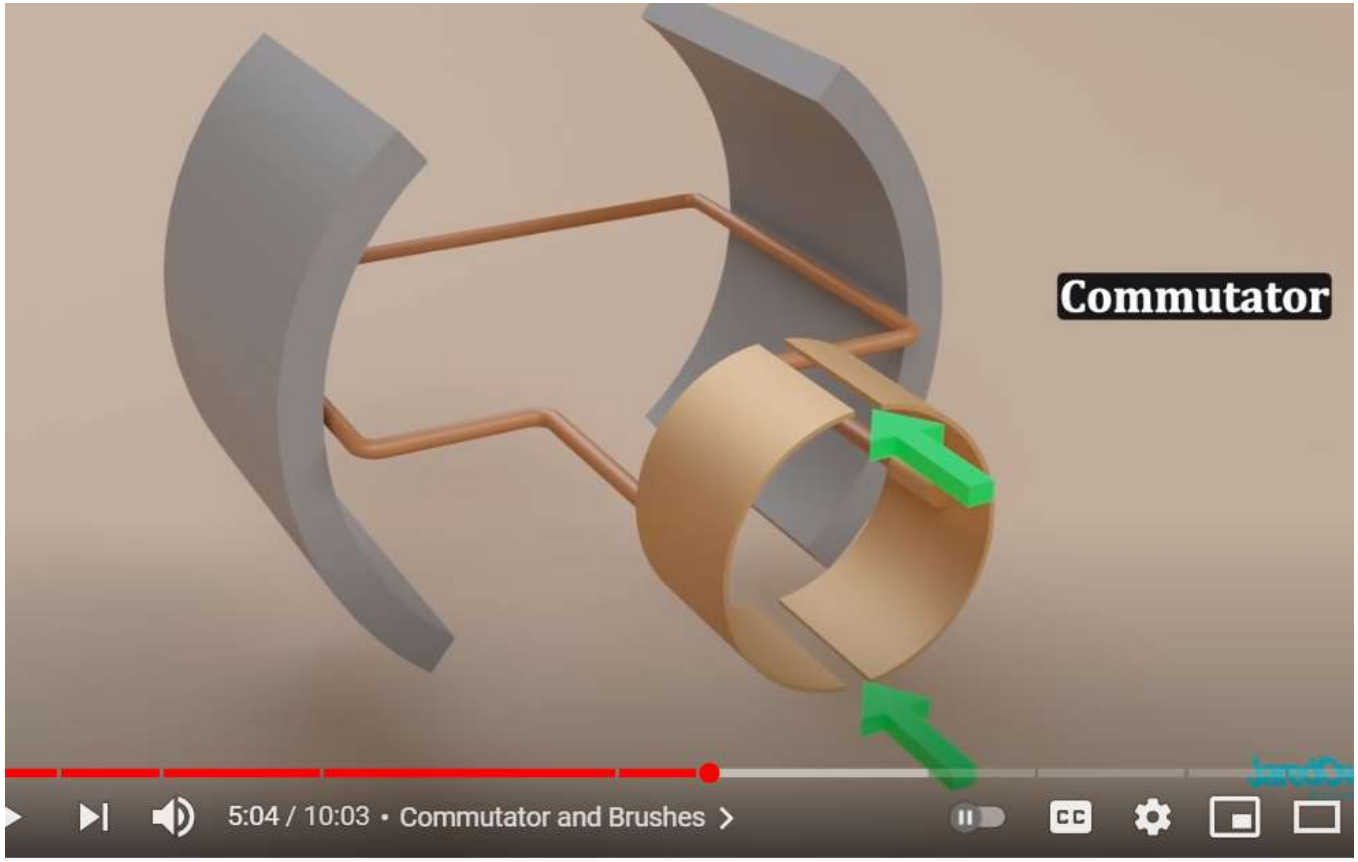
Energy transformation: electrical energy → mechanical energy

Electric motors



- When electric current passes through a coil in a magnetic field, the magnetic force produces a *torque* which turns the motor
- Electric current is supplied externally (through a commutator)
- The magnetic force acts <u>perpendicular</u> to both the wire (direction of current) and the magnetic field

Electric motor video



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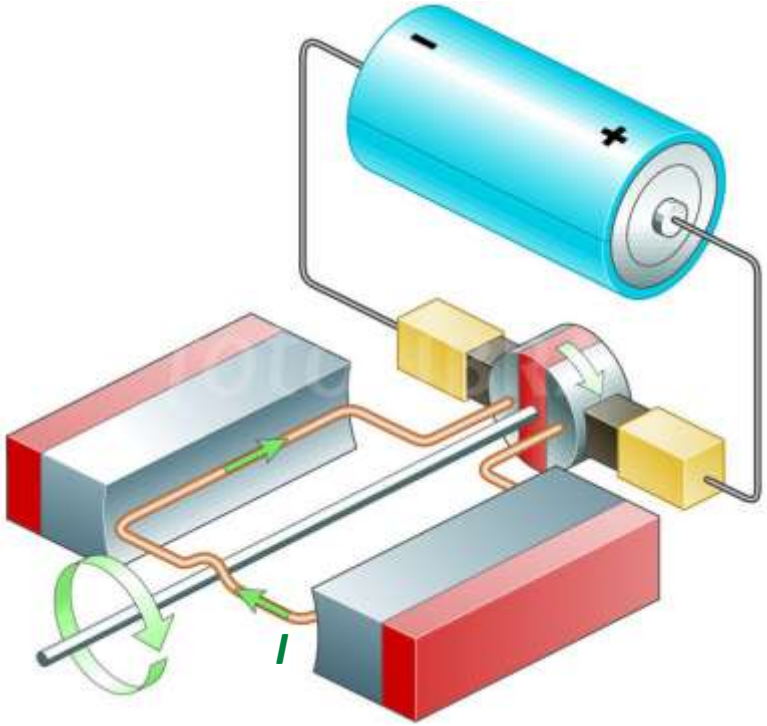
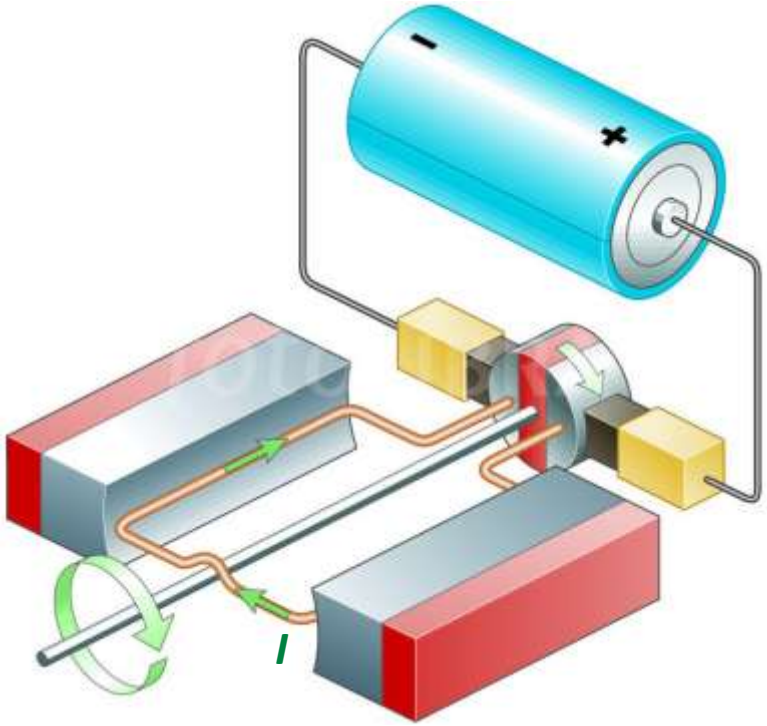


In this motor, the current flows as indicated, making the motor spin clockwise as shown. The magnetic field points

A. Up
B. Down
C. From left to right
D. From right to left

Clicker



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