



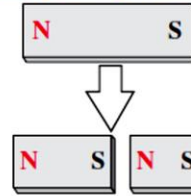
Chap5 Magnetic Field & Magnetic Force

Magnetic Field

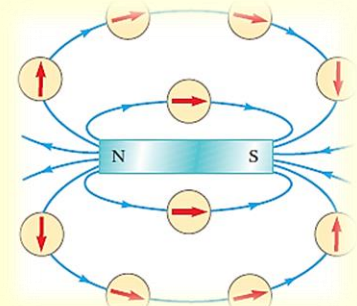
➤ Magnetism



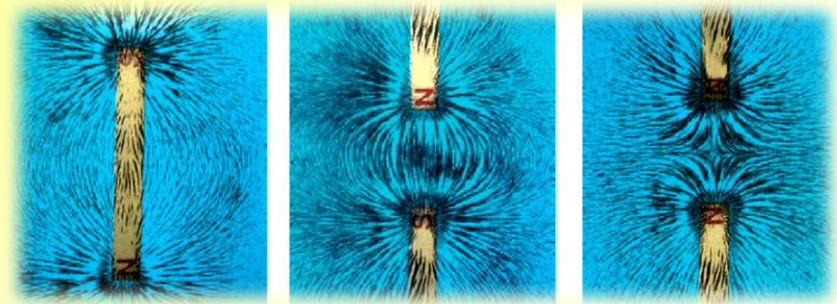
Breaking a magnet in two ...



... yields two magnets,
not two isolated poles.

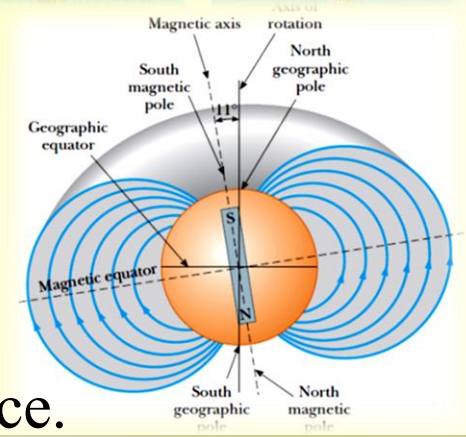


- Like magnetic poles **repel** each other; unlike magnetic poles **attract** each other.



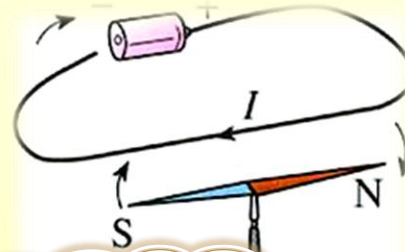
➤ Earth's magnetic field

- Magnetic declination: a difference between true north and north indicated by a compass.
- Angle of dip (inclination): angle between the Earth's magnetic field and the horizontal surface.



➤ Magnetic field due to currents

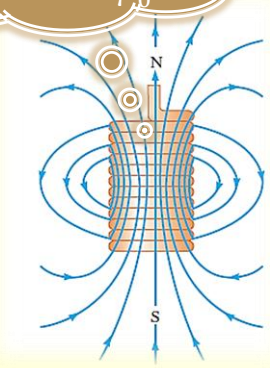
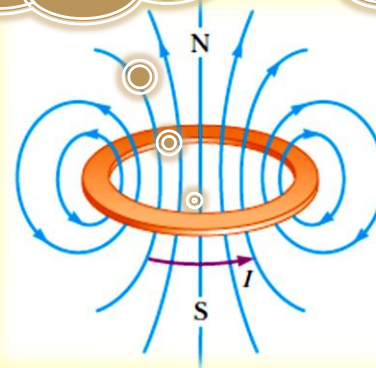
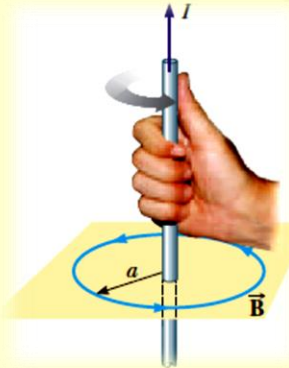
- Oersted discovered the magnetic effect of an electric current in 1820.



Magnetic field at the center: $B = \frac{\mu_0 I}{2R}$

Magnetic field inside the solenoid: $B = \mu_0 nI$

- Right-hand rule



Permeability of vacuum
 $(\mu_0 \equiv 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A})$

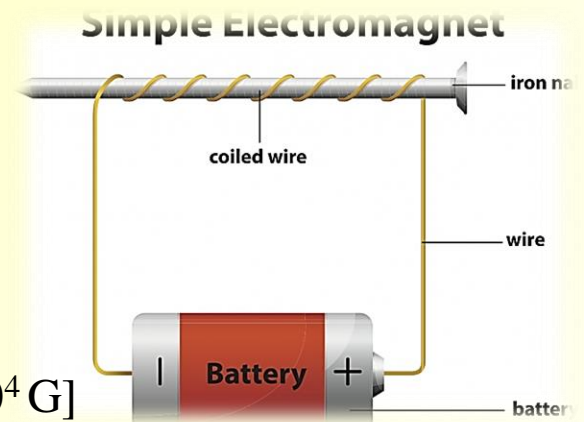
- Electromagnet = soft iron core + solenoid

- Ampere's circuital law

$$B = \frac{\mu_0 I}{2\pi r}$$

[SI unit for B : Tesla (T)]

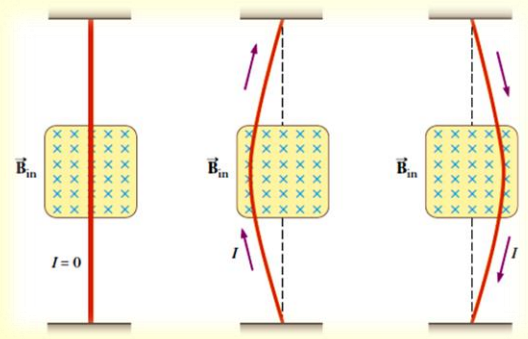
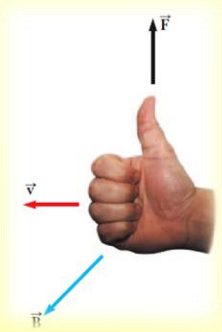
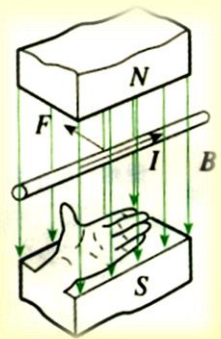
[cgs unit for B : Gauss (G); $1 \text{ T} = 10^4 \text{ G}$]



Magnetic Force on a current-carrying conductor

- Direction of the force:

- ✓ *Left-hand rule*
- ✓ *Right-hand rule*

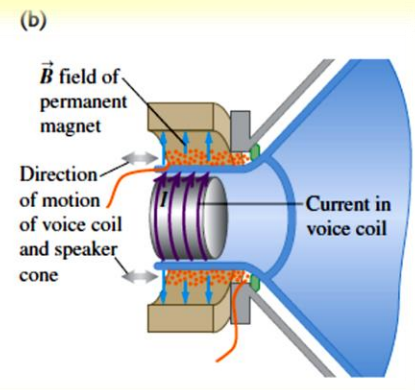
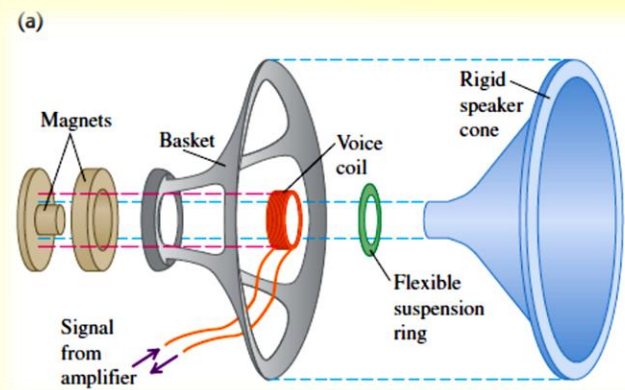
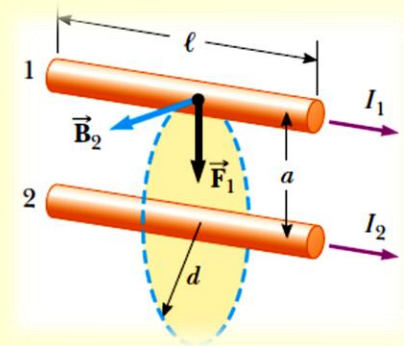


- Magnitude of the force:

$$F = B_{\perp} Il$$

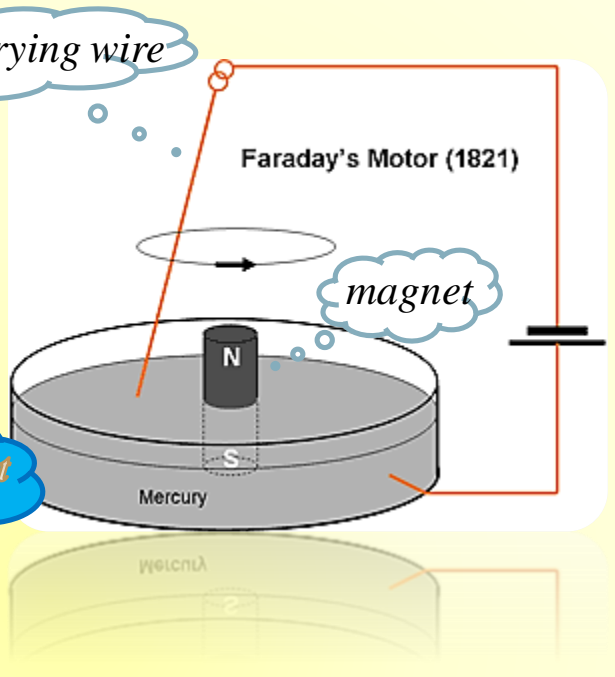
- Application:

- ✓ *Loudspeaker operation*



Electric Motors

- The first electric motor
- Torque on a current loop

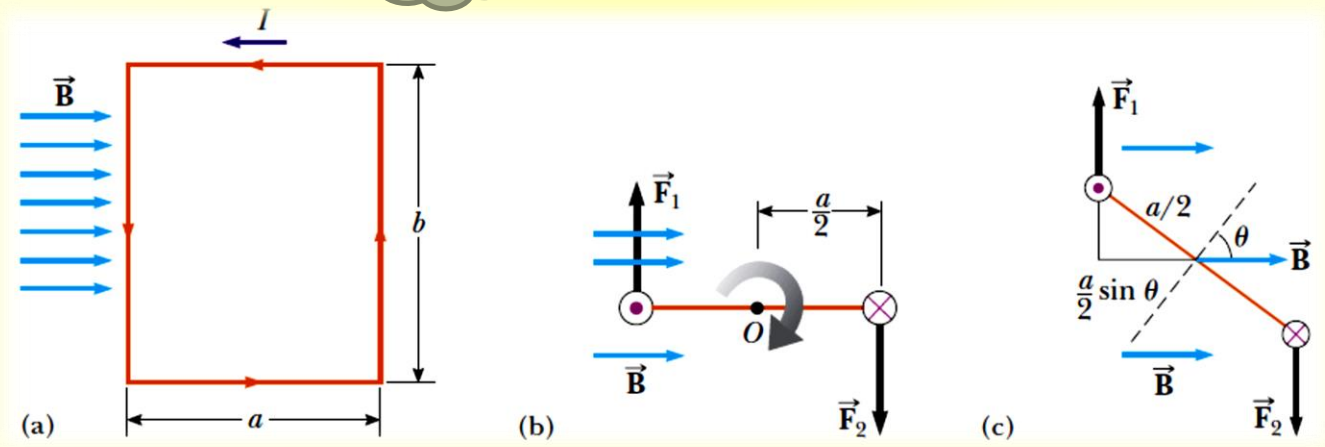


Magnetic moment
 $(\mu = NIA)$

For N -turns coils,

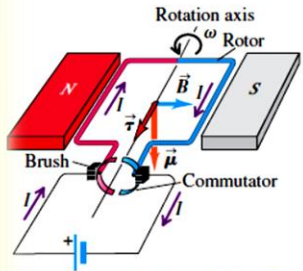
$$\tau_{\max} = NBIa = \mu B$$

vector



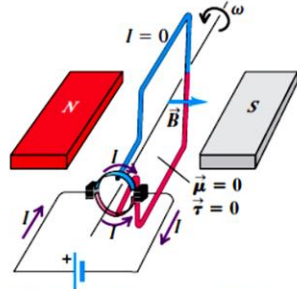
• DC electric motor

(a) Brushes are aligned with commutator segments.



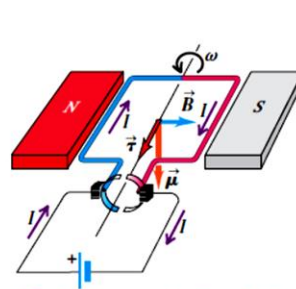
- Current flows into the red side of the rotor and out of the blue side.
- Therefore the magnetic torque causes the rotor to spin counterclockwise.

(b) Rotor has turned 90°.

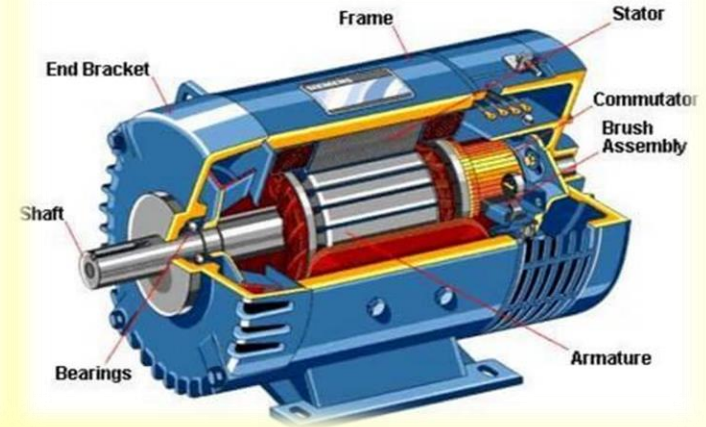


- Each brush is in contact with both commutator segments, so the current bypasses the rotor altogether.
- No magnetic torque acts on the rotor.

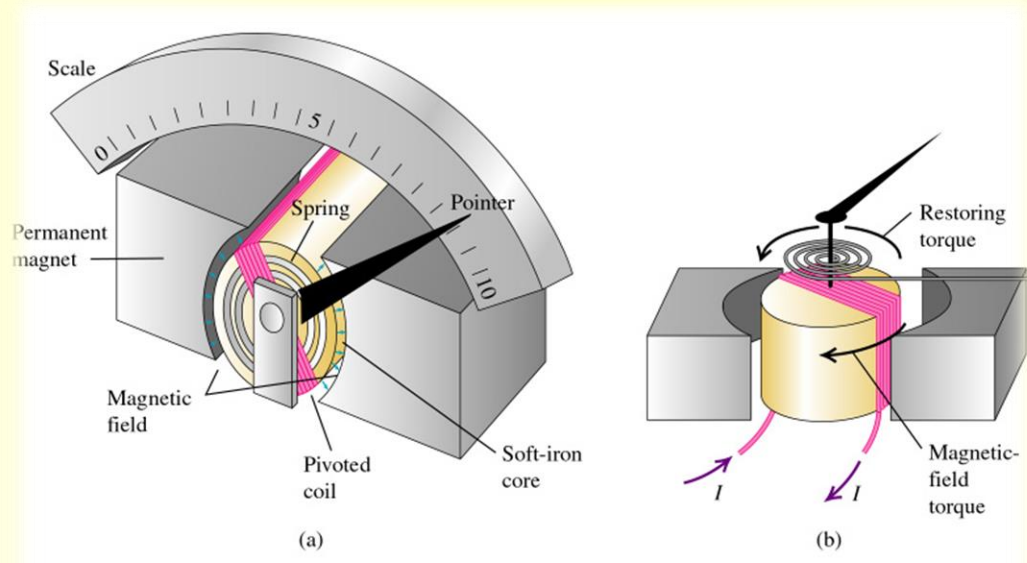
(c) Rotor has turned 180°.



- The brushes are again aligned with commutator segments. This time the current flows into the blue side of the rotor and out of the red side.
- Therefore the magnetic torque again causes the rotor to spin counterclockwise.



• Another application of magnetic torque: Galvanometer

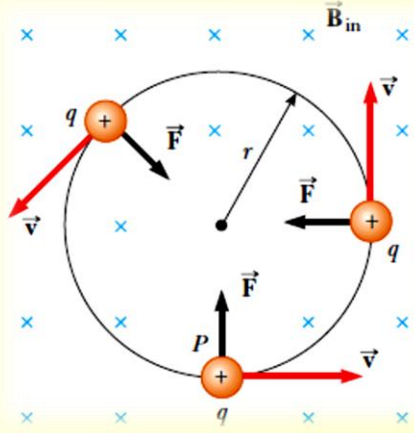


(a)

(b)

Motion of charged particles in a Magnetic Field

- With $v \perp B$, circular path



$$F = qvB$$

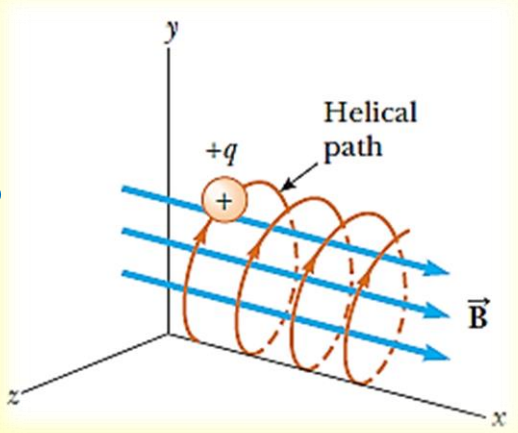
$$F = m \frac{v^2}{r}$$

Cyclotron frequency

$$r = \frac{mv}{Bq}$$

$$f = \frac{qB}{2\pi m}$$

- With v not perpendicular to B , spiral path



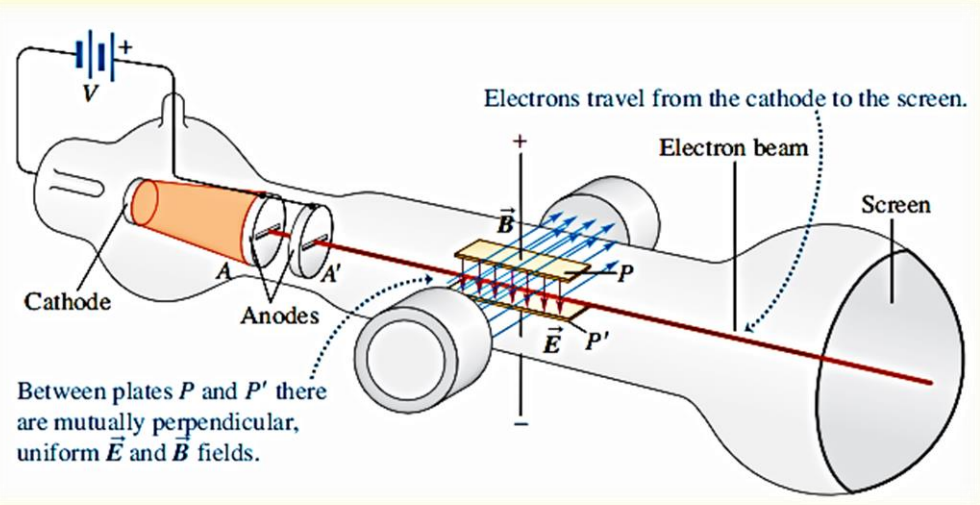
- Applications:

✓ Thomson's experiment

$$v = \frac{E}{B}$$

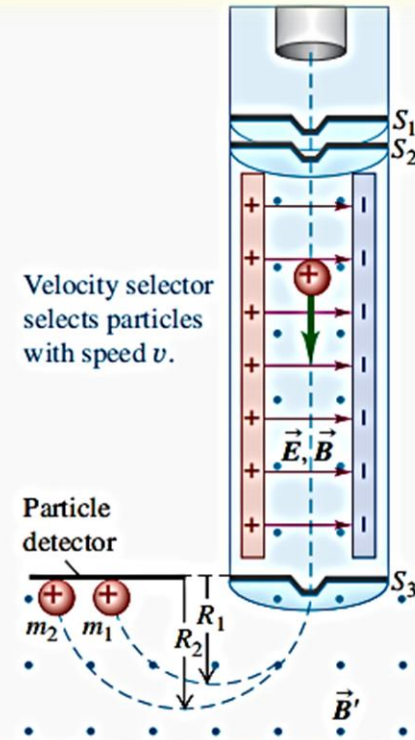
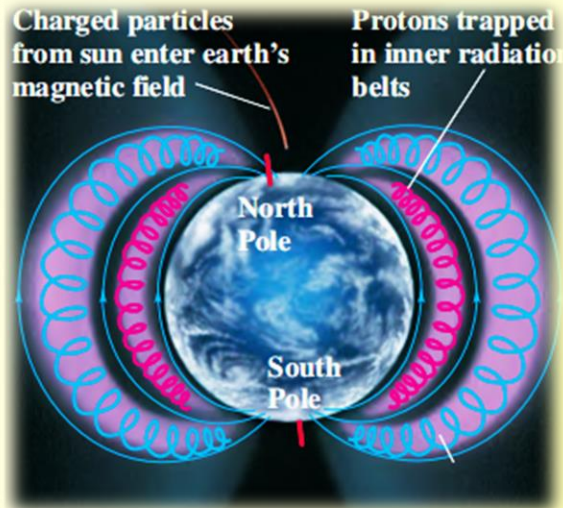
$$v = \sqrt{\frac{2eV}{m}}$$

$$\frac{e}{m} = \frac{E^2}{2VB^2}$$



✓ *Velocity selectors & mass spectrometers*

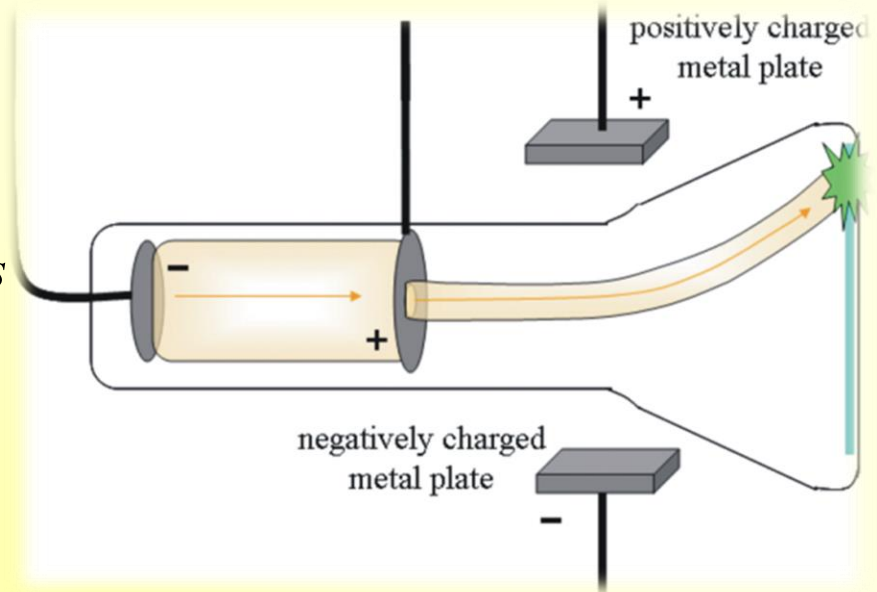
✓ *Van Allen radiation belts*



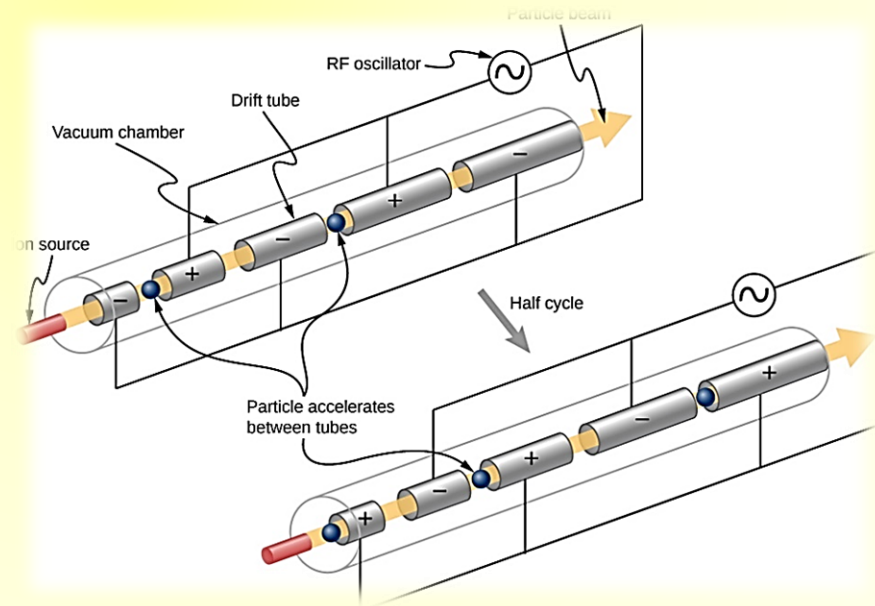
Magnetic field separates particles by mass; the greater a particle's mass, the larger is the radius of its path.

Particle Accelerators

- Linear accelerator (Linac)
 - ✓ *Early examples of linacs:
Thomson's cathode-ray tubes*

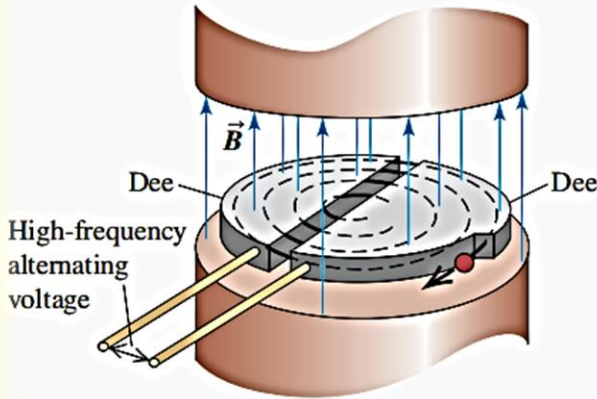


- ✓ *Traveling-electromagnetic-wave linacs*

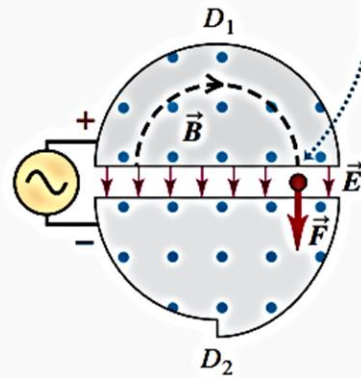


- Cyclotron

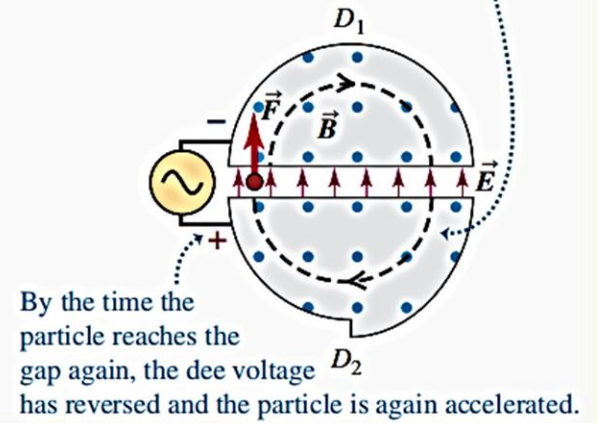
(a) Schematic diagram of a cyclotron



(b) As the positive particle reaches the gap, it is accelerated by the electric-field force ...



(c) ... and the next semicircular orbit has a larger radius.



- Synchrotron

✓ *LHC for CERN*

