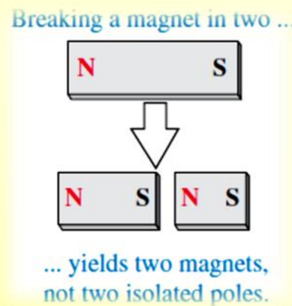
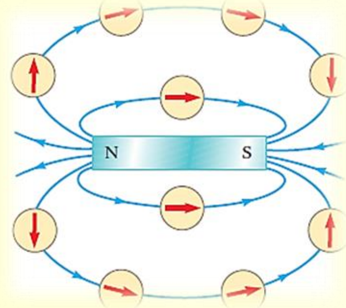
Chap5 Magnetic Field & Magnetic Force

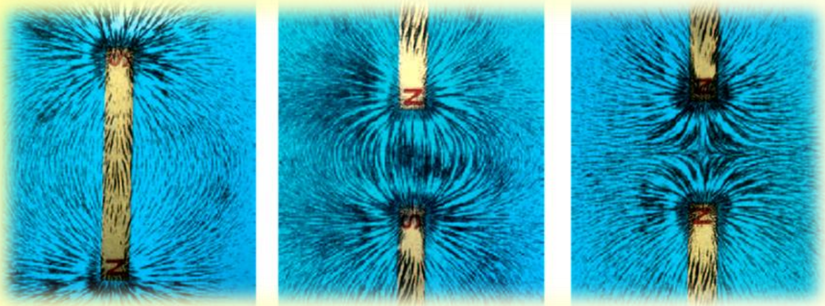
Magnetic Field

➢ Magnetism

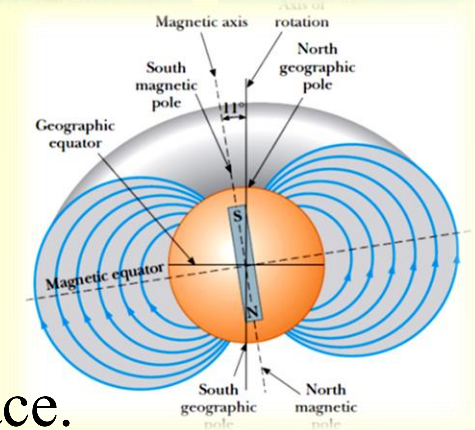




- Like magnetic poles repel each other; unlike magnetic poles attract each other.



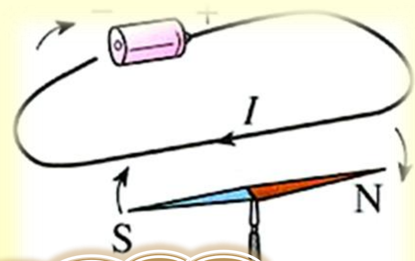
➢ Earth's magnetic field



- 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

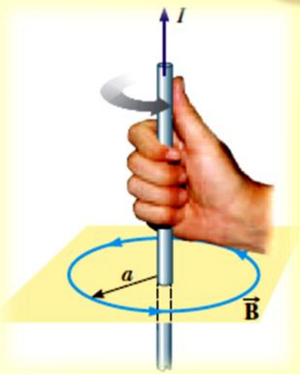
- Oersted discovered the magnetic effect of an electric current in 1820.

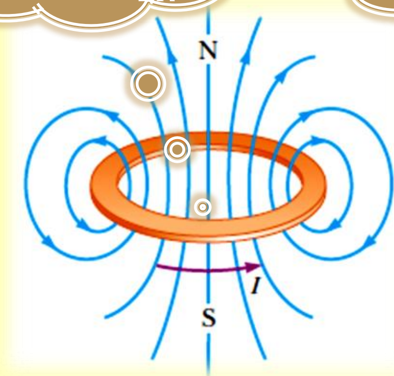


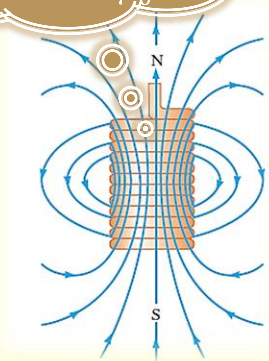
Magnetic field at the center: $B = \frac{\mu_0 I}{2R}$

Magnetic field inside the solenoid: $B = \mu_0 n I$

- Right-hand rule

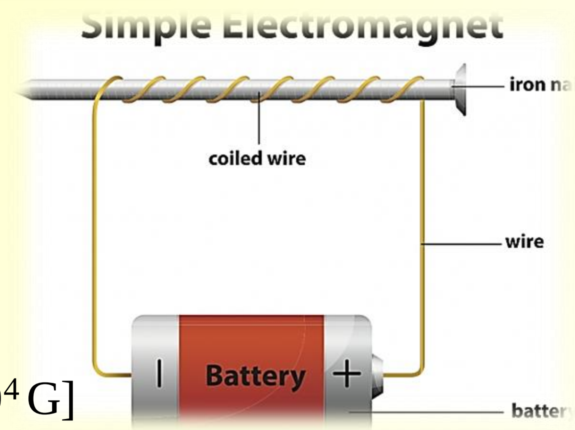






Permeability of vacuum
$(\mu_0 \equiv 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A})$

- Electromagnet = soft iron core + solenoid



- Ampere's circuital law

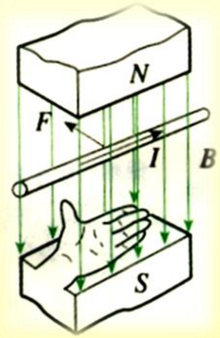
$$B = \frac{\mu_0 I}{2\pi r}$$

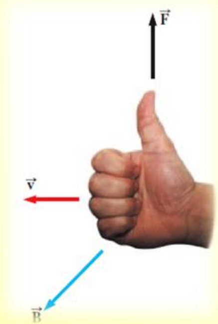
[SI unit for *B*: Tesla (T)]

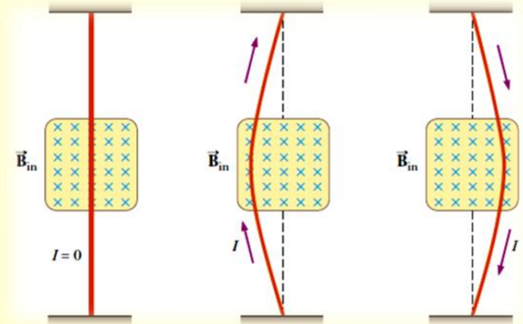
[cgs unit for *B*: Gauss (G); 1 T = 10^4 G]

Magnetic Force on a current-carrying conductor

- Direction of the force:
  - ✓ *Left-hand rule*
  - ✓ *Right-hand rule*

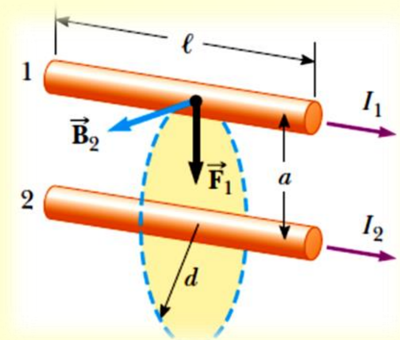




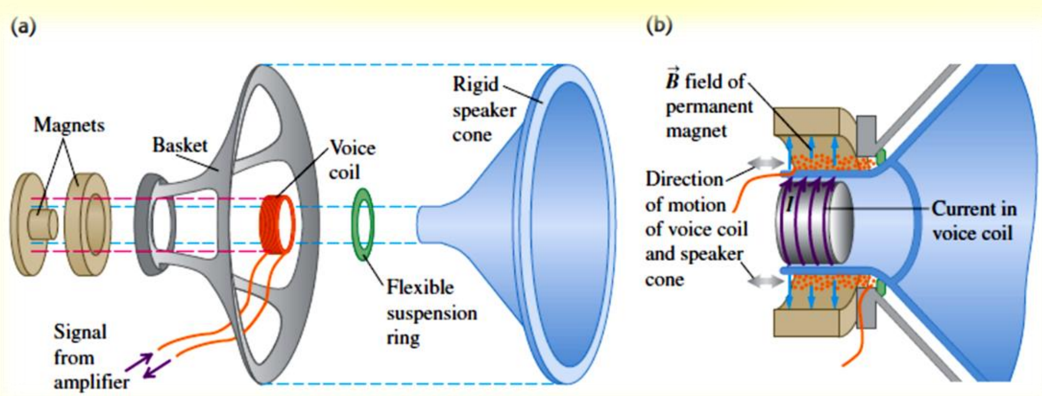


- Magnitude of the force:

$$F = B_{\perp} I l$$

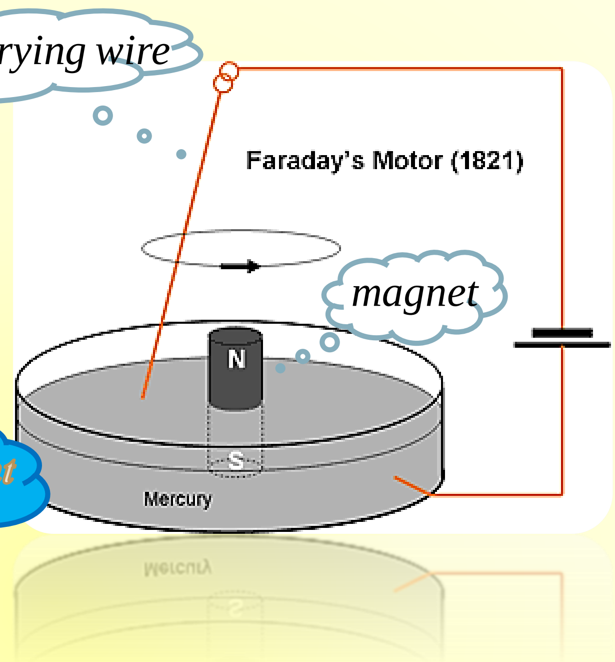


- Application:
  - ✓ *Loudspeaker operation*



Electric Motors

- The first electric motor



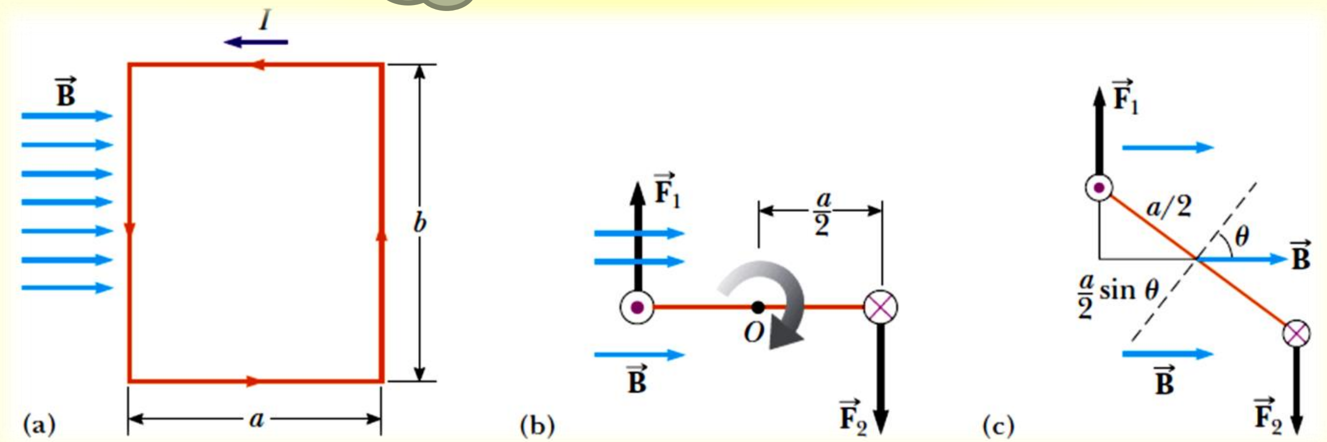
- Torque on a current loop

For N-turns coils,

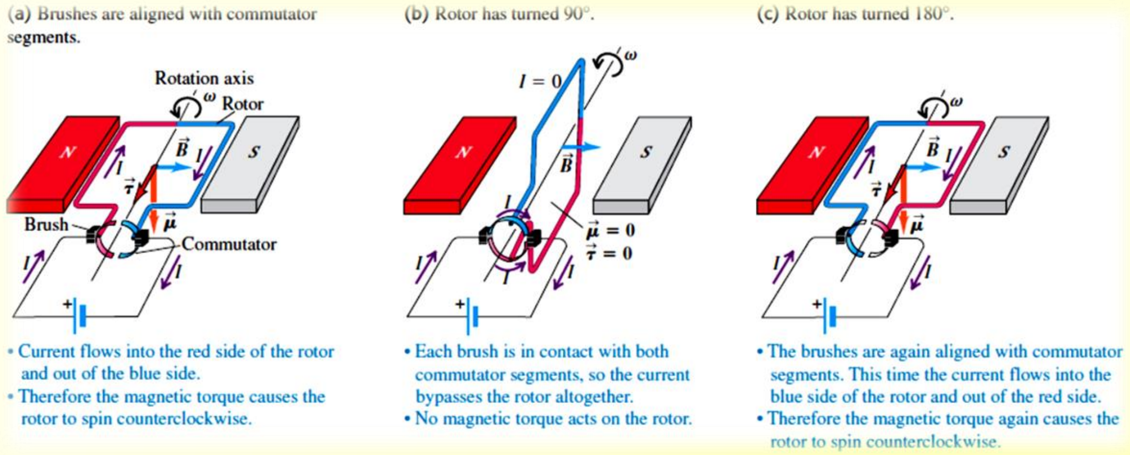
Magnetic moment ($\mu = NIA$)

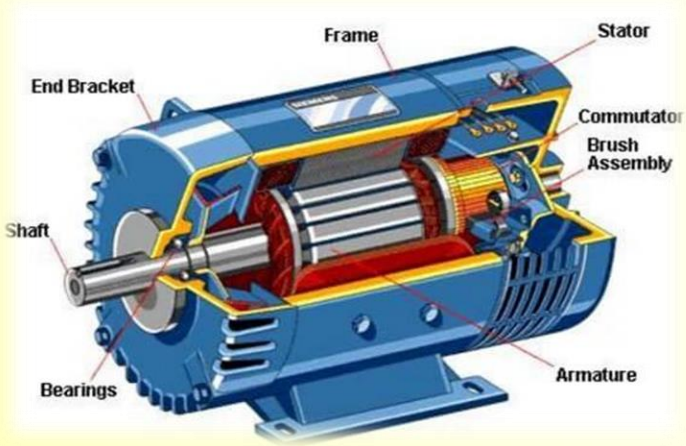
$$\tau_{\max} = NBIA = \mu B$$

vector

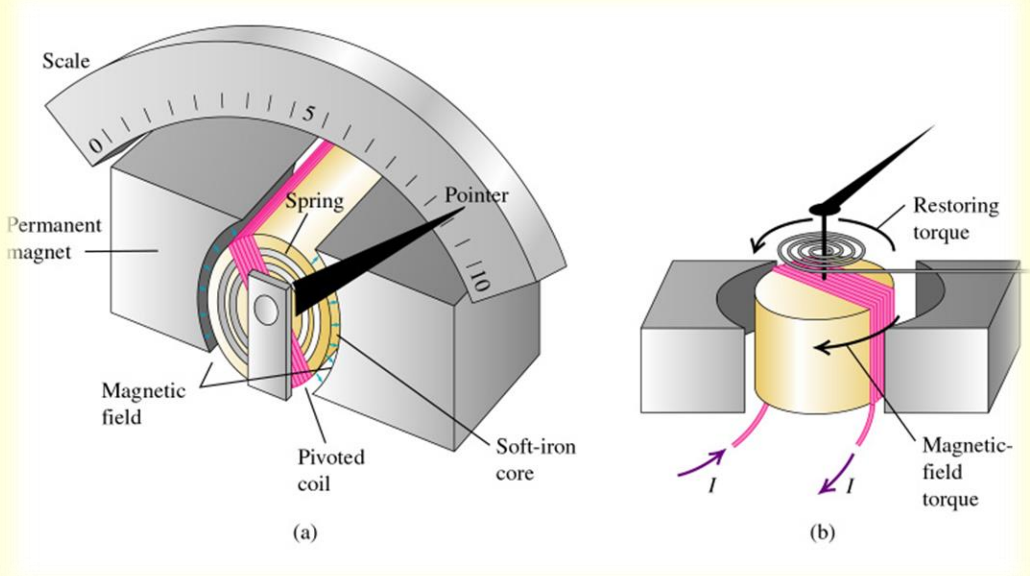


- DC electric motor



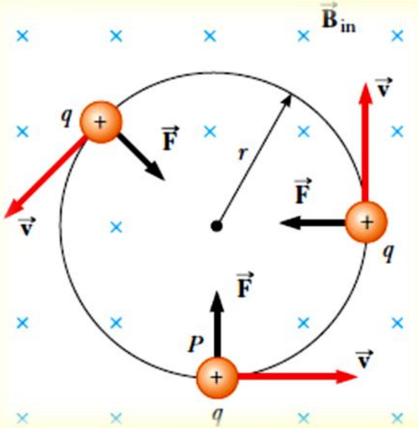


- Another application of magnetic torque: Galvanometer



Motion of charged particles in a Magnetic Field

- With $v \perp B$, circular path



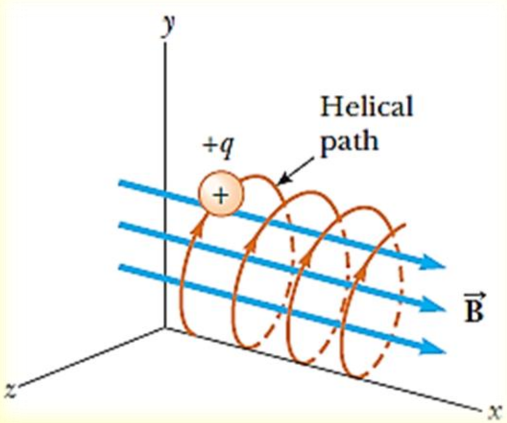
$$F = qvB$$
$$F = m\frac{v^2}{r}$$

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

Cyclotron frequency

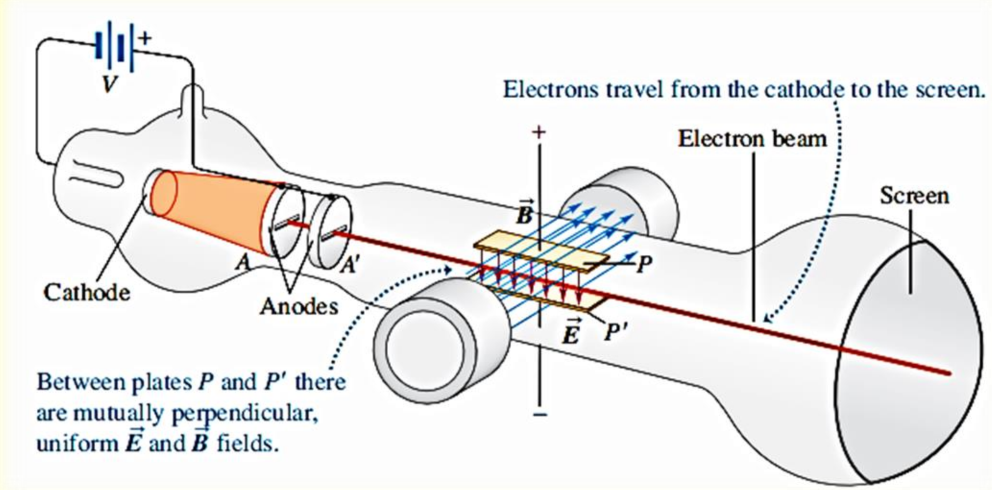
$$f = \frac{qB}{2\pi m}$$

- With v not perpendicular to B, spiral path



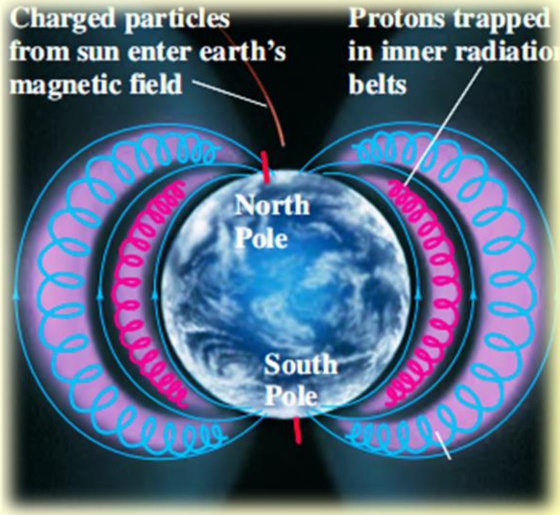
- Applications:
  - ✓ *Thomson's experiment*

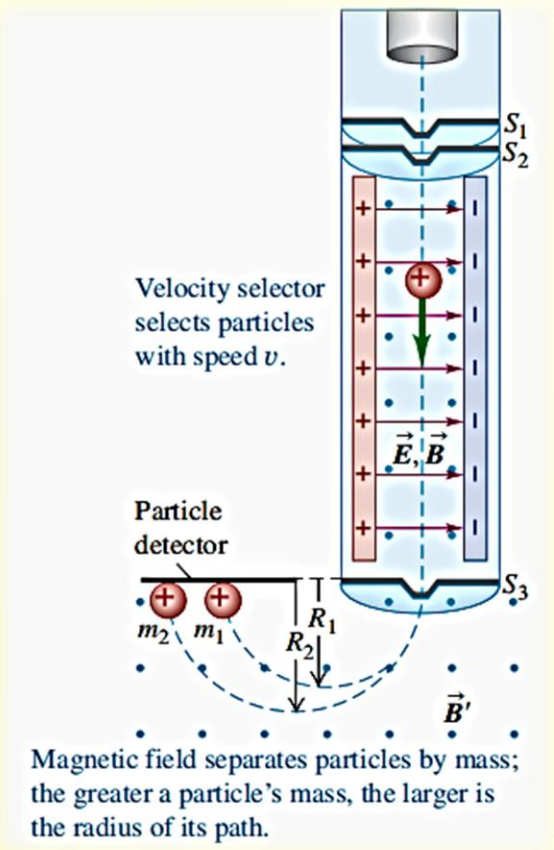
$$v = \frac{E}{B}$$
$$v = \sqrt{\frac{2eV}{m}}$$
$$\frac{e}{m} = \frac{E^2}{2VB^2}$$



- ✓ *Velocity selectors & mass spectrometers*

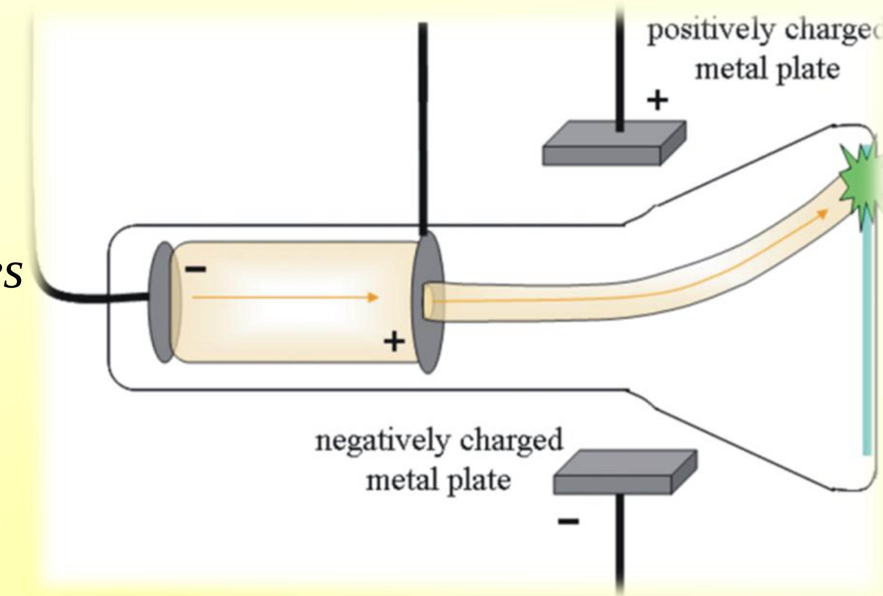
- ✓ *Van Allen radiation belts*



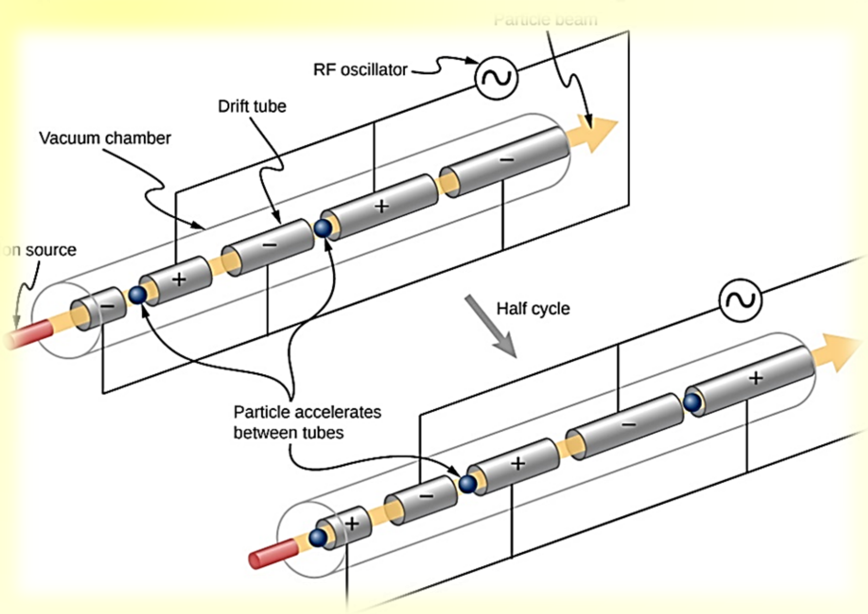


Particle Accelerators

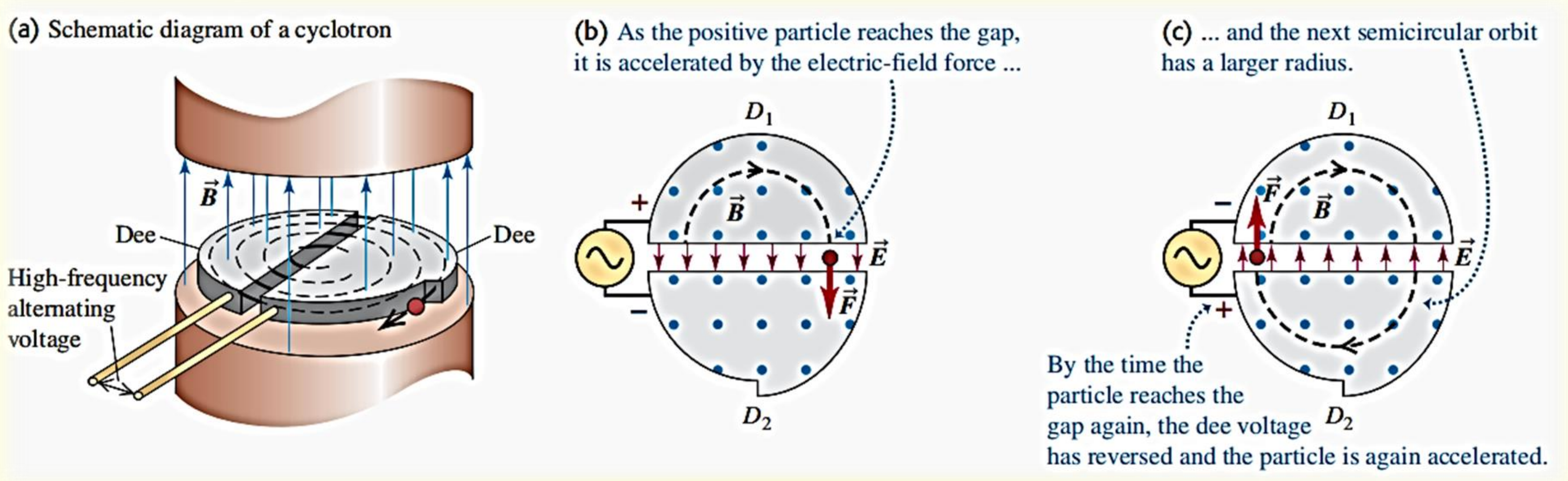
- Linear accelerator (Linac)
  - ✓ *Early examples of linacs: Thomson's cathode-ray tubes*



  - ✓ *Traveling-electromagnetic-wave linacs*



- Cyclotron



- Synchrotron
  - ✓ *LHC for CERN*