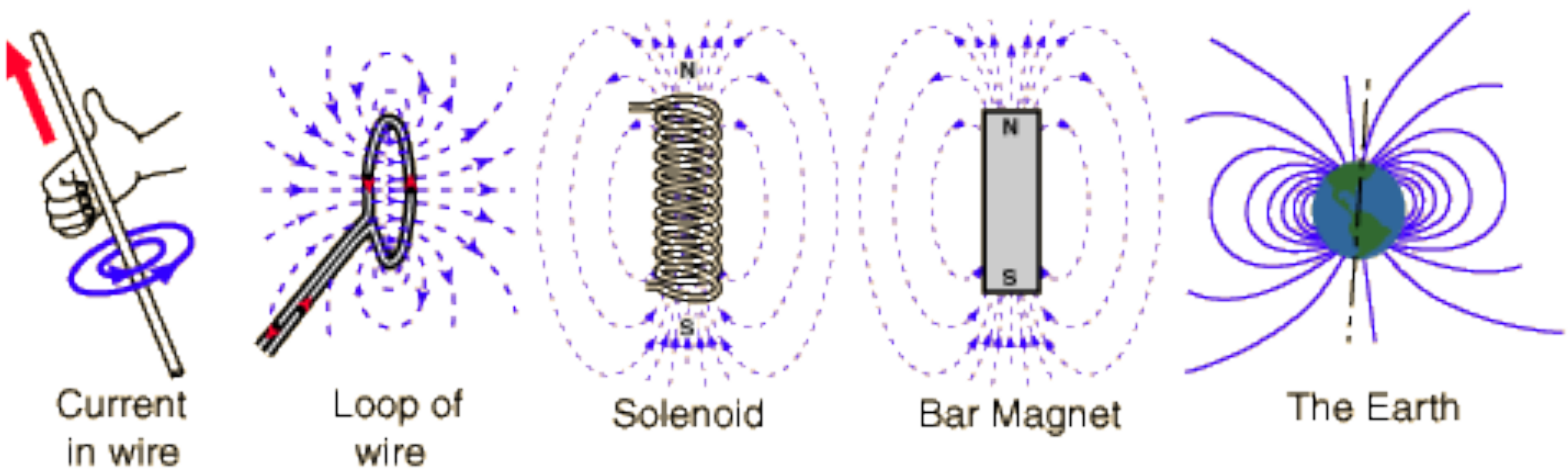
Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Magnetic Fields



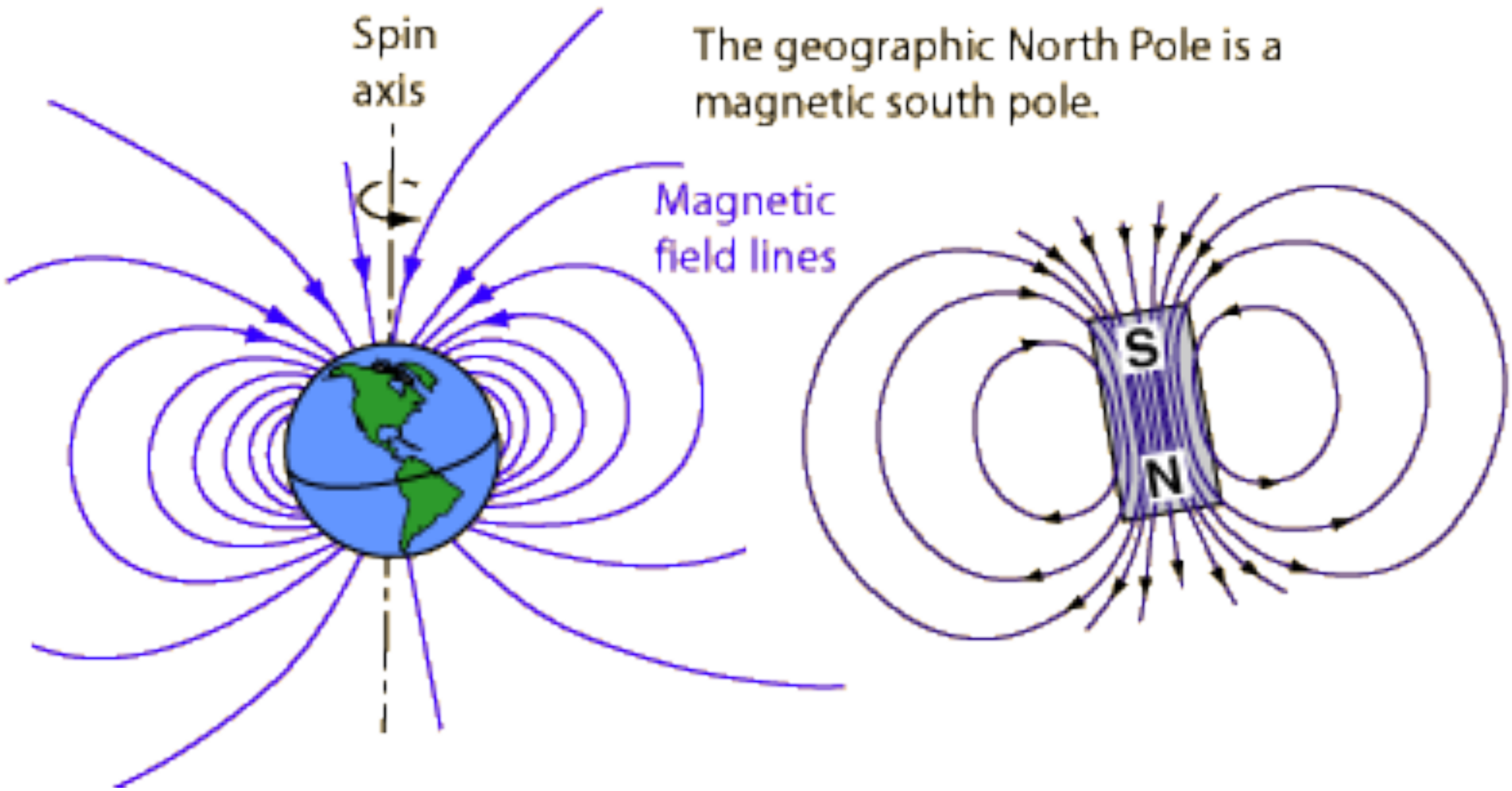
Magnetic Field Sources

Magnetic Field Units

How big is a 1 Tesla Magnetic Field?

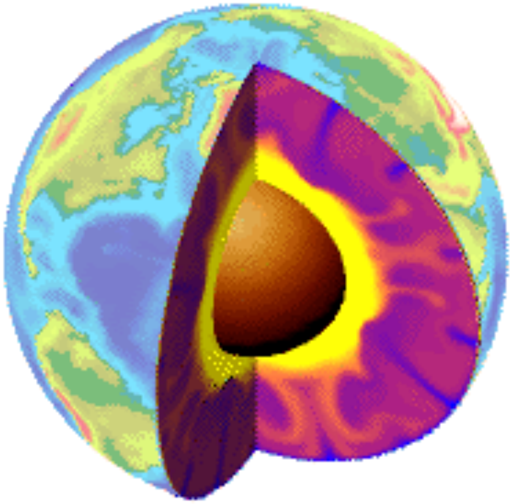
Interstellar Space	10^{-10} Tesla
Human Being	10^{-10} Tesla
Earth's Surface	$5\text{x}10^{-5}$ Tesla
Sun's Surface	10^{-2} Tesla
Small Bar Magnet	10^{-2} Tesla
Experiment Magnet	1 Tesla
Maximum Steady Magnet	30 Tesla
Maximum in Explosive Magnet	1000 Tesla
Surface of Neutron Star	10^{8} Tesla

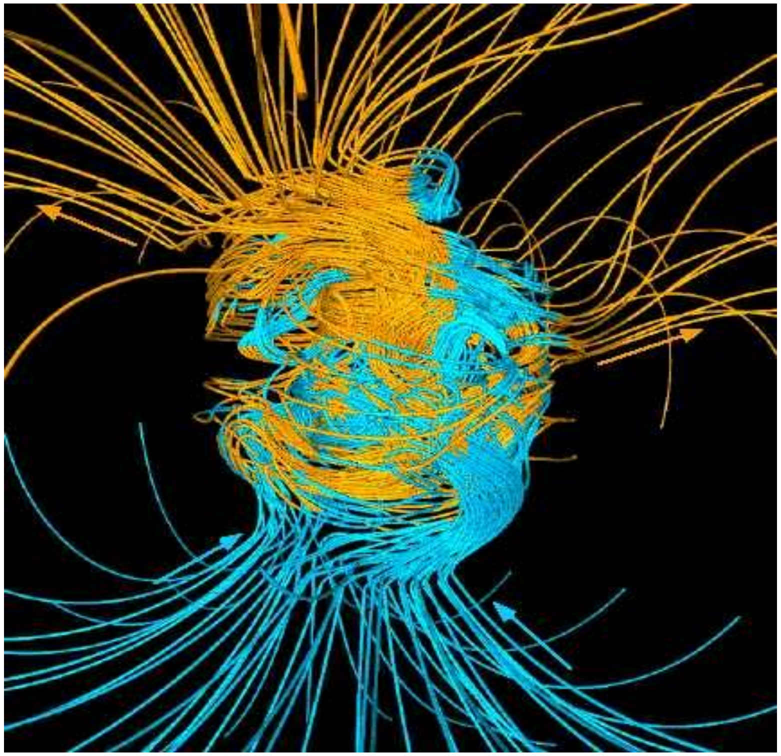
Earth


Spin
axis
The geographic North Pole is a
magnetic south pole.
Magnetic
field lines
S
N

Magnetohydrodynamic Dynamos

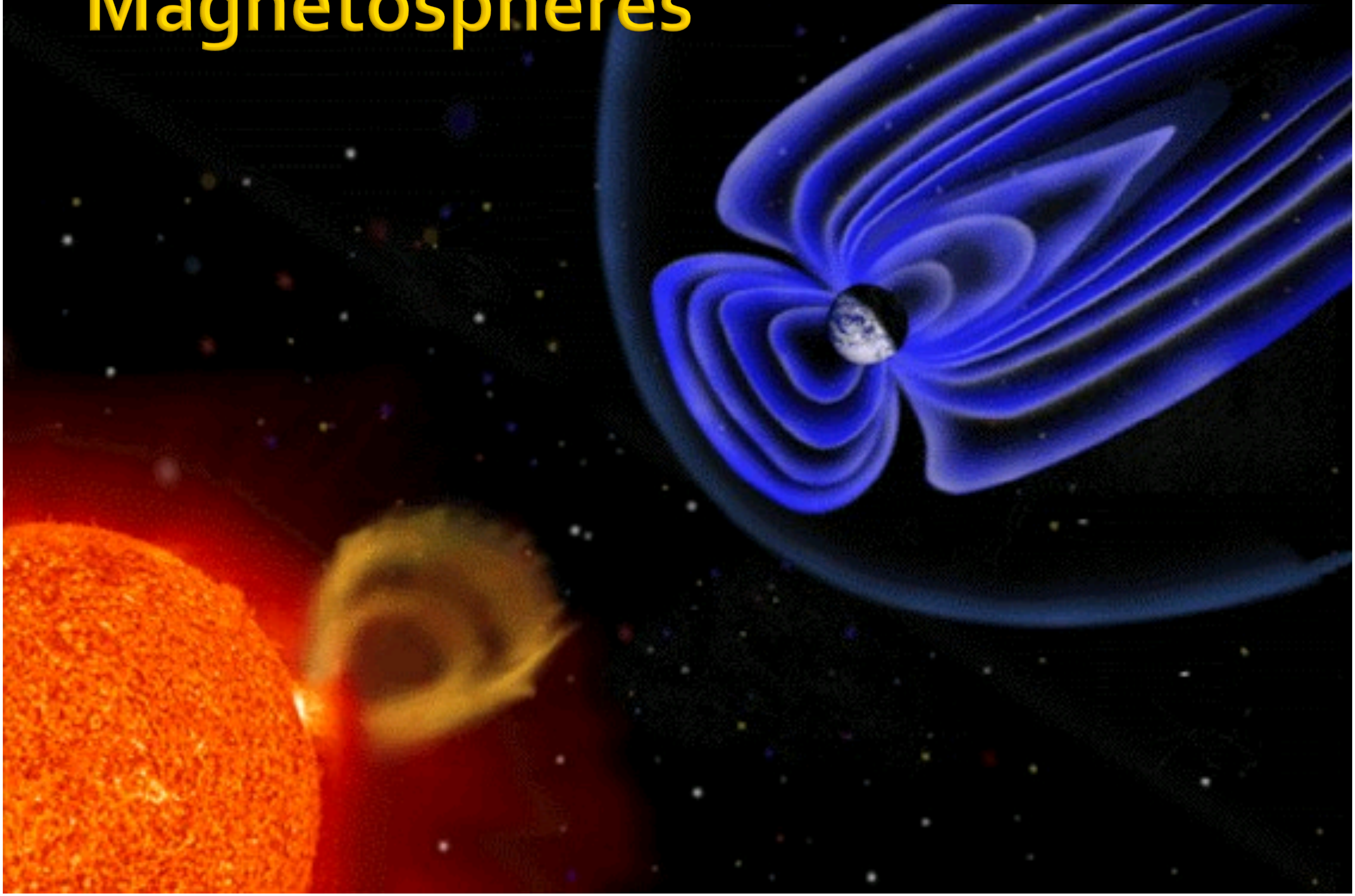
- Rotation
- Convection
- Currents => Magnetic Field



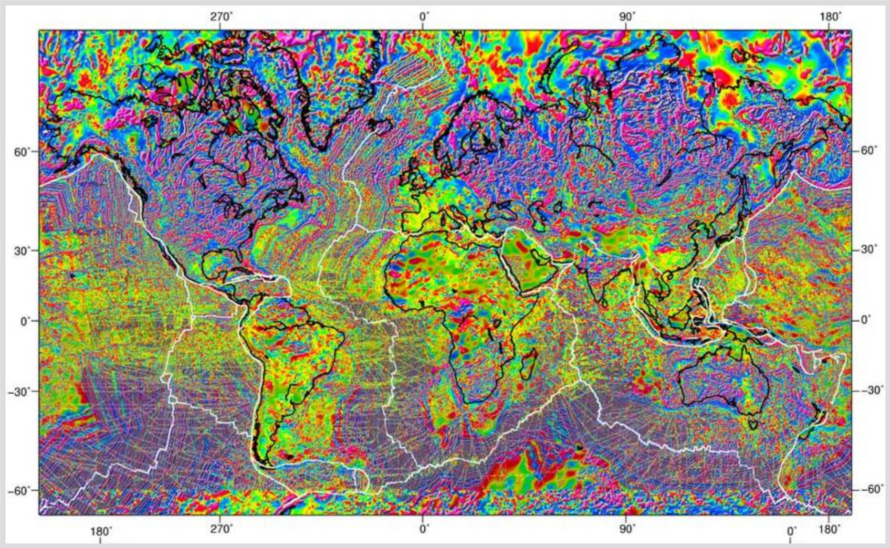


Glatzmaier and Roberts, 1995

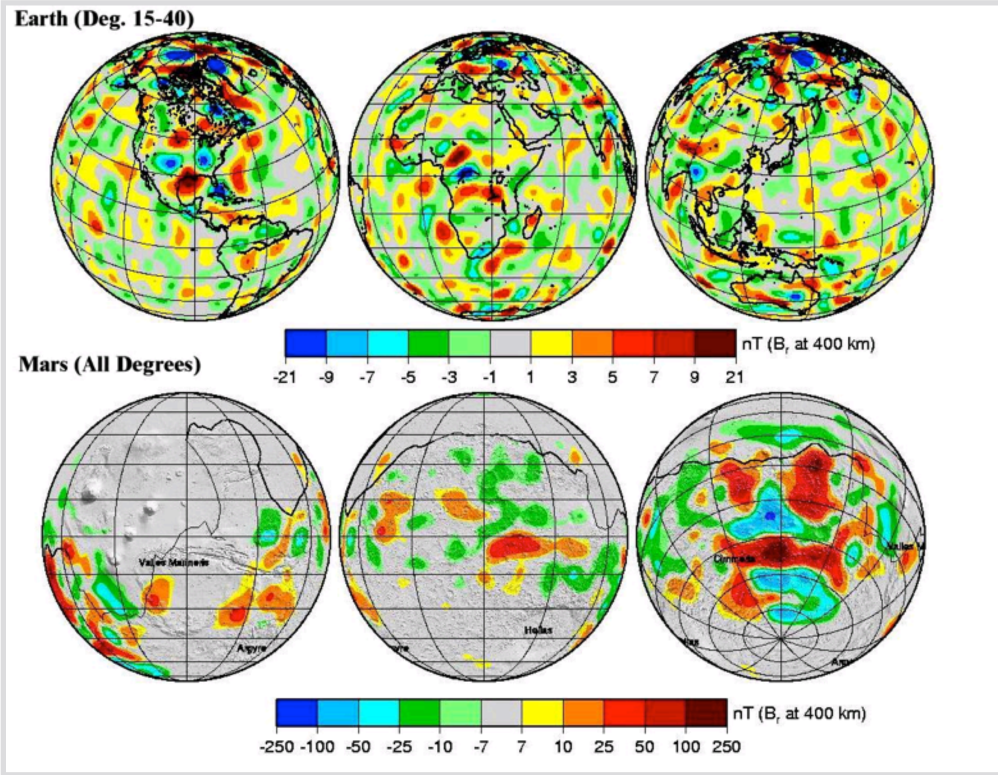
Magnetospheres



Crustal Magnetization in the Solar System

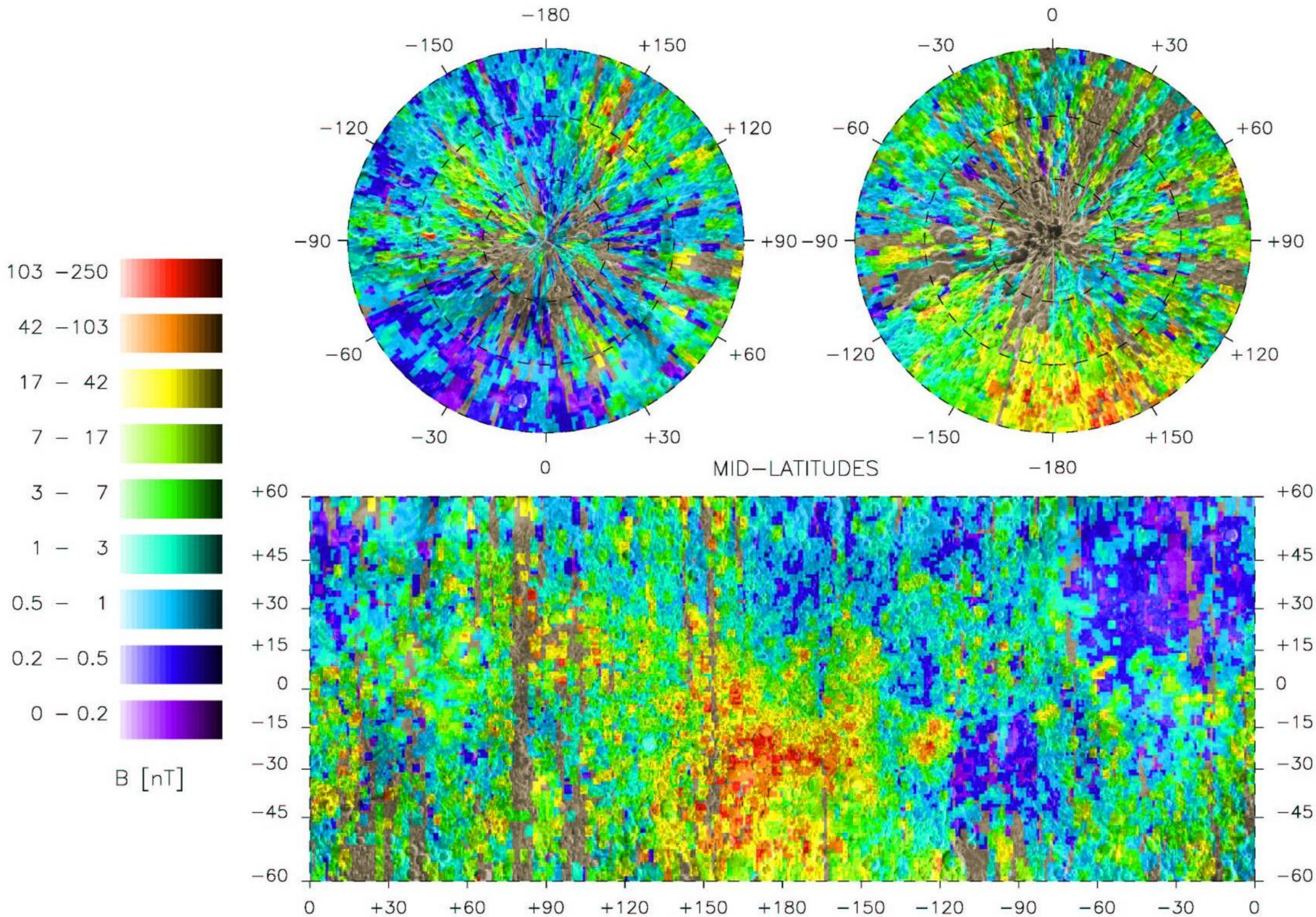


Aeromagnetic (near surface)



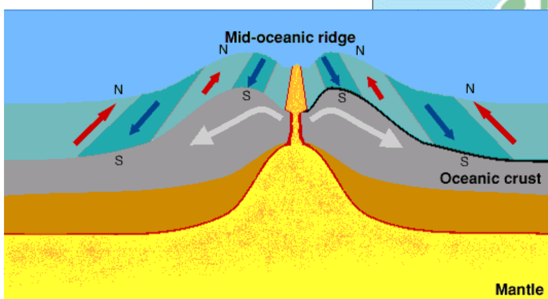
Orbital Data

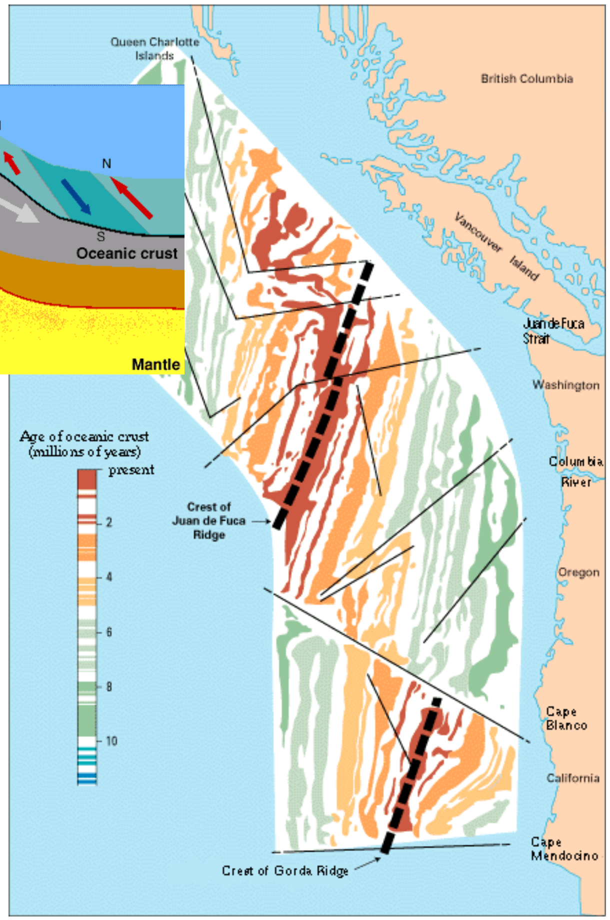
Moon's Magnetic Field



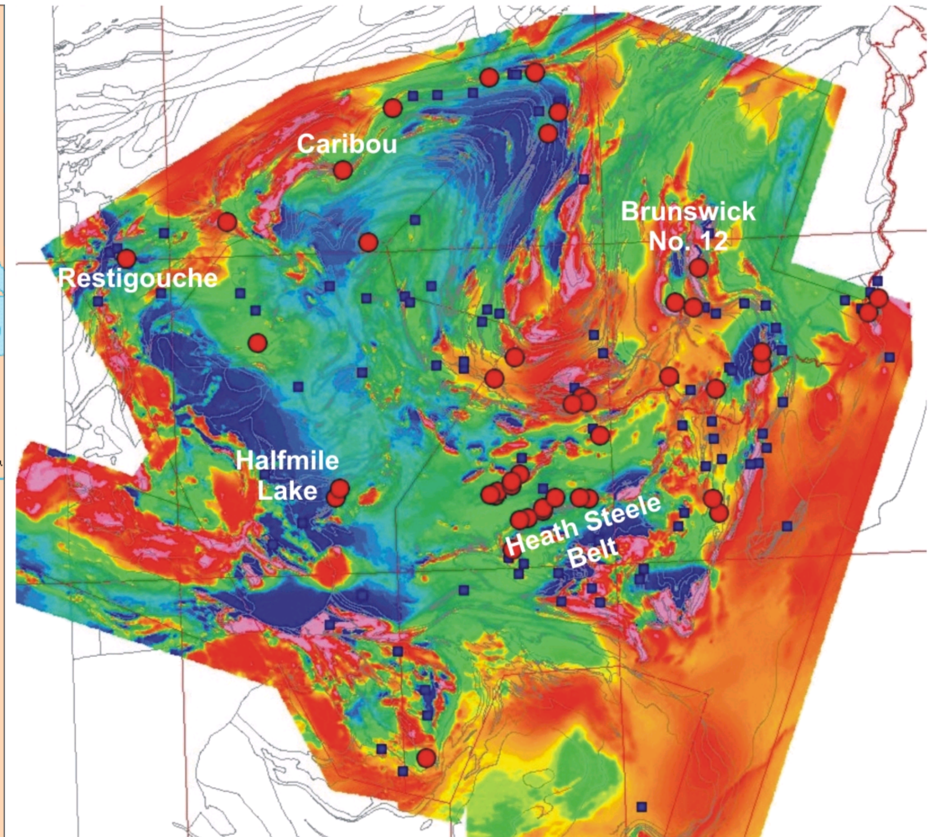
Halekas et al., 2003

Crustal Magnetization as a Window on the Interior



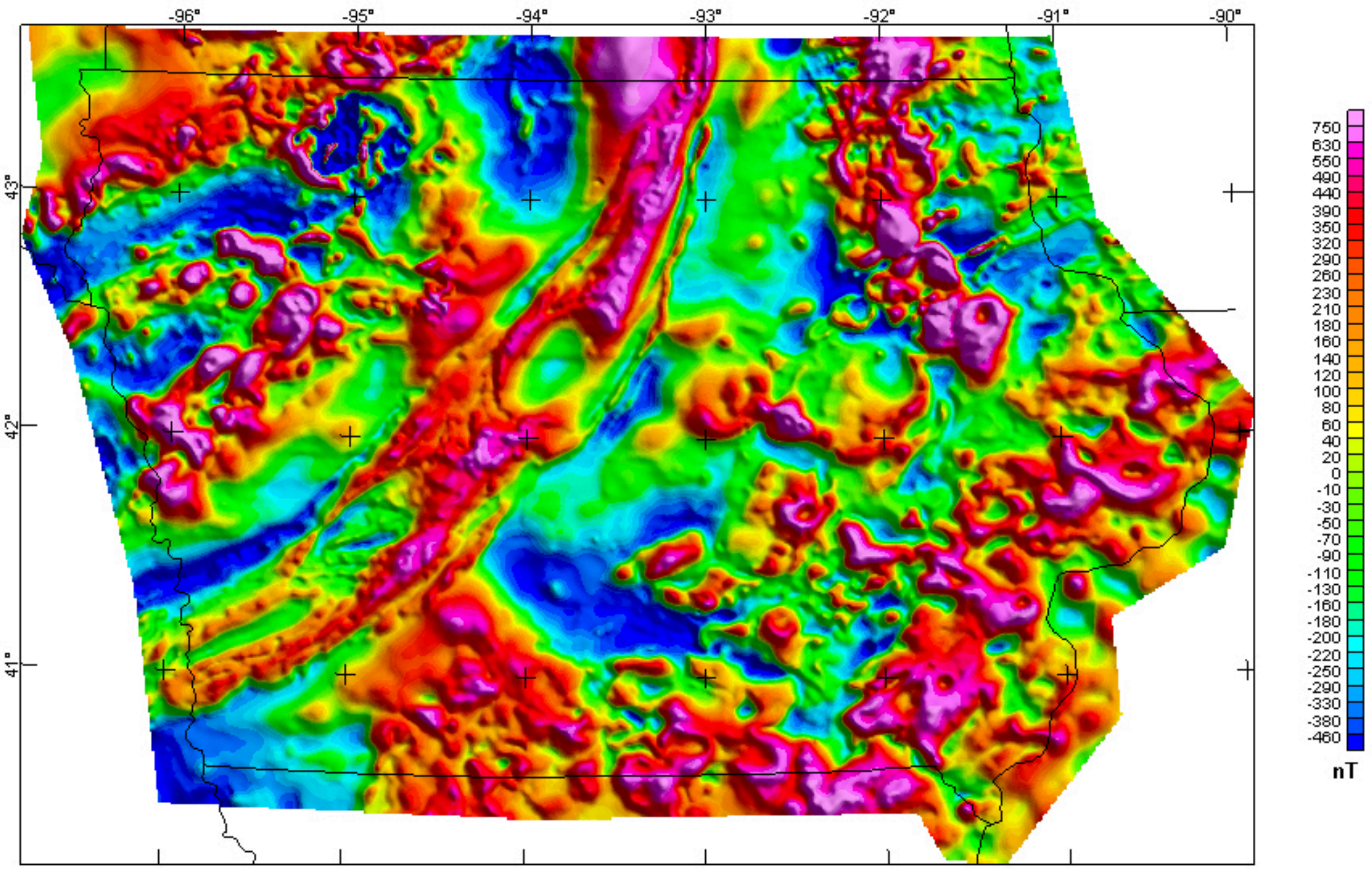


Sea-Floor Spreading / Plate Tectonics

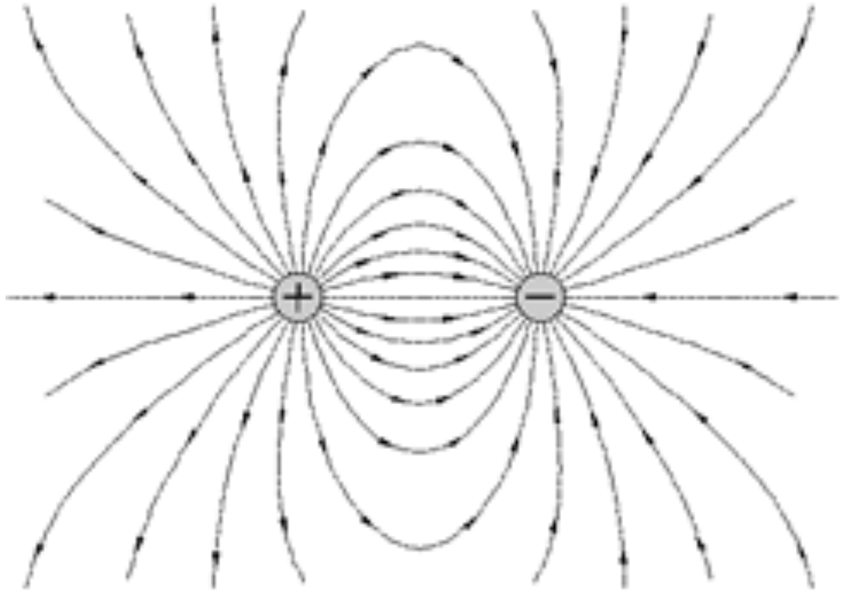


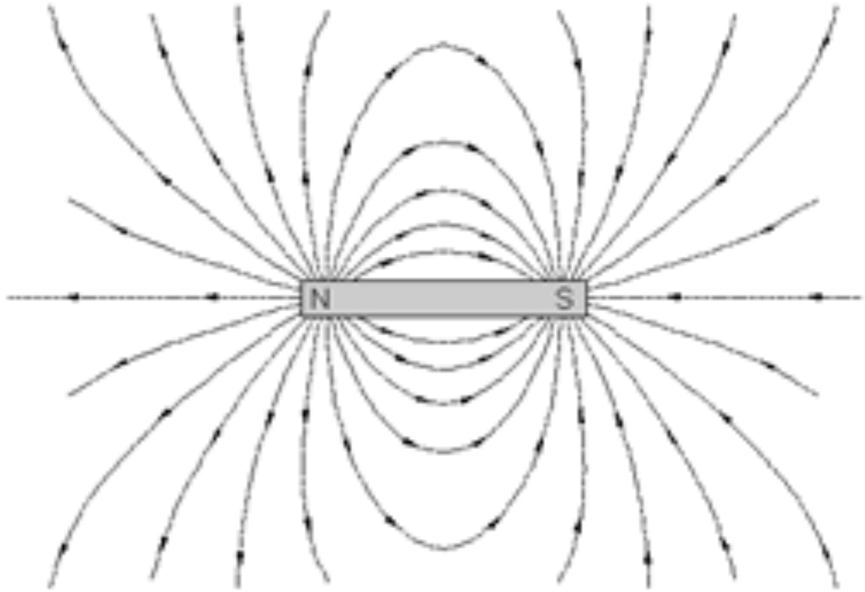
Prospecting

Crustal Magnetic Field of Iowa

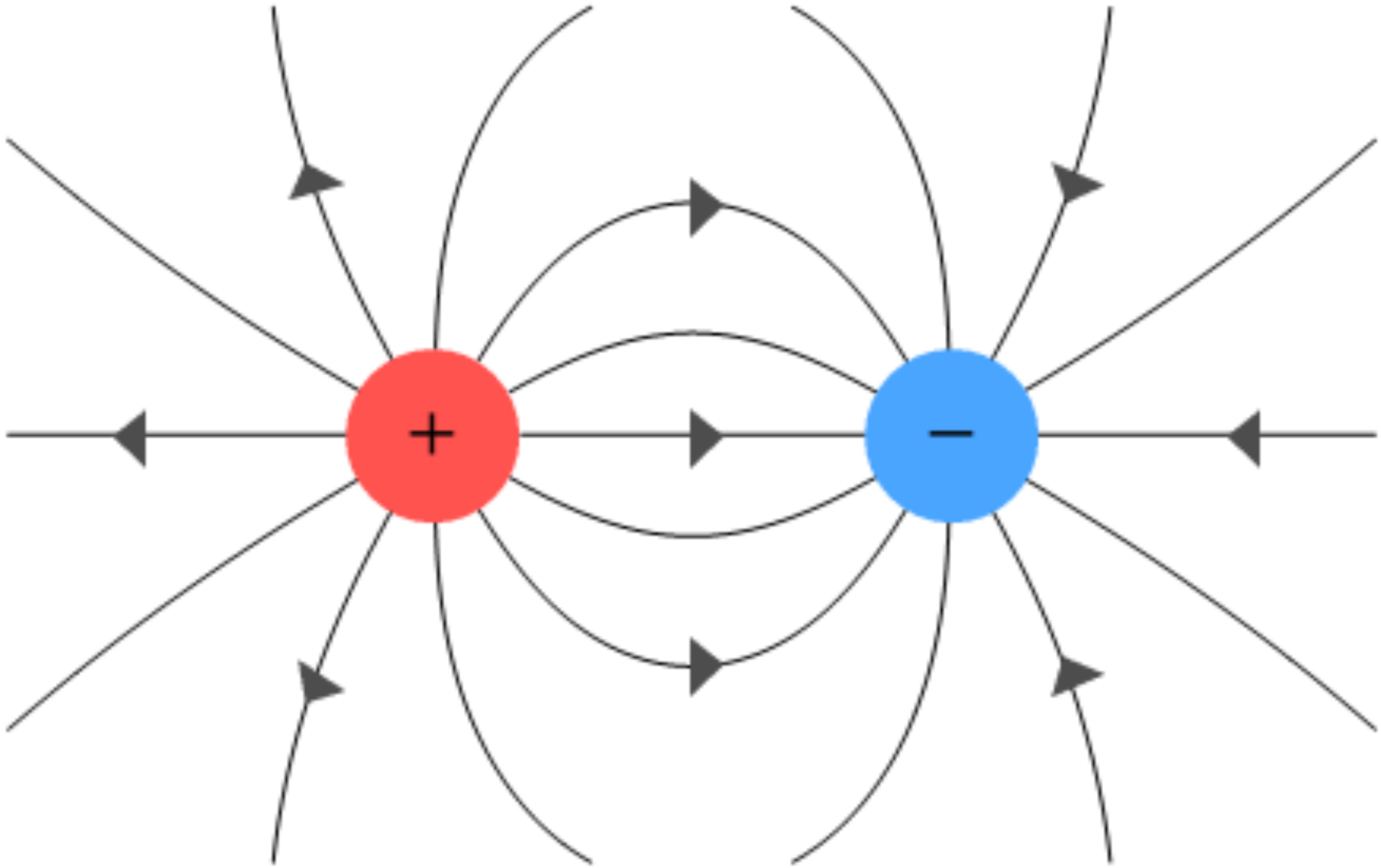


Magnetic and Electric Field Lines

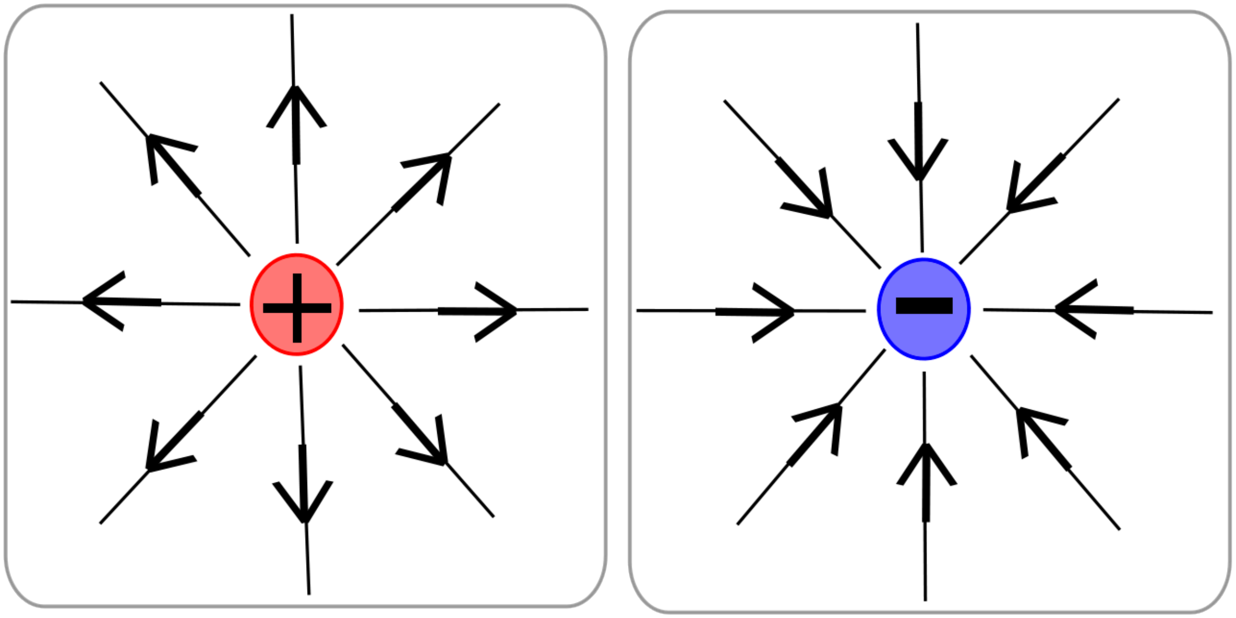


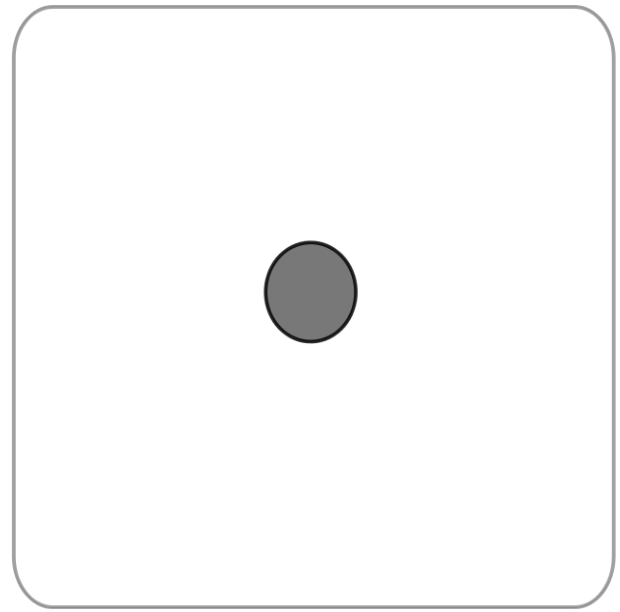


Electric Dipole Field

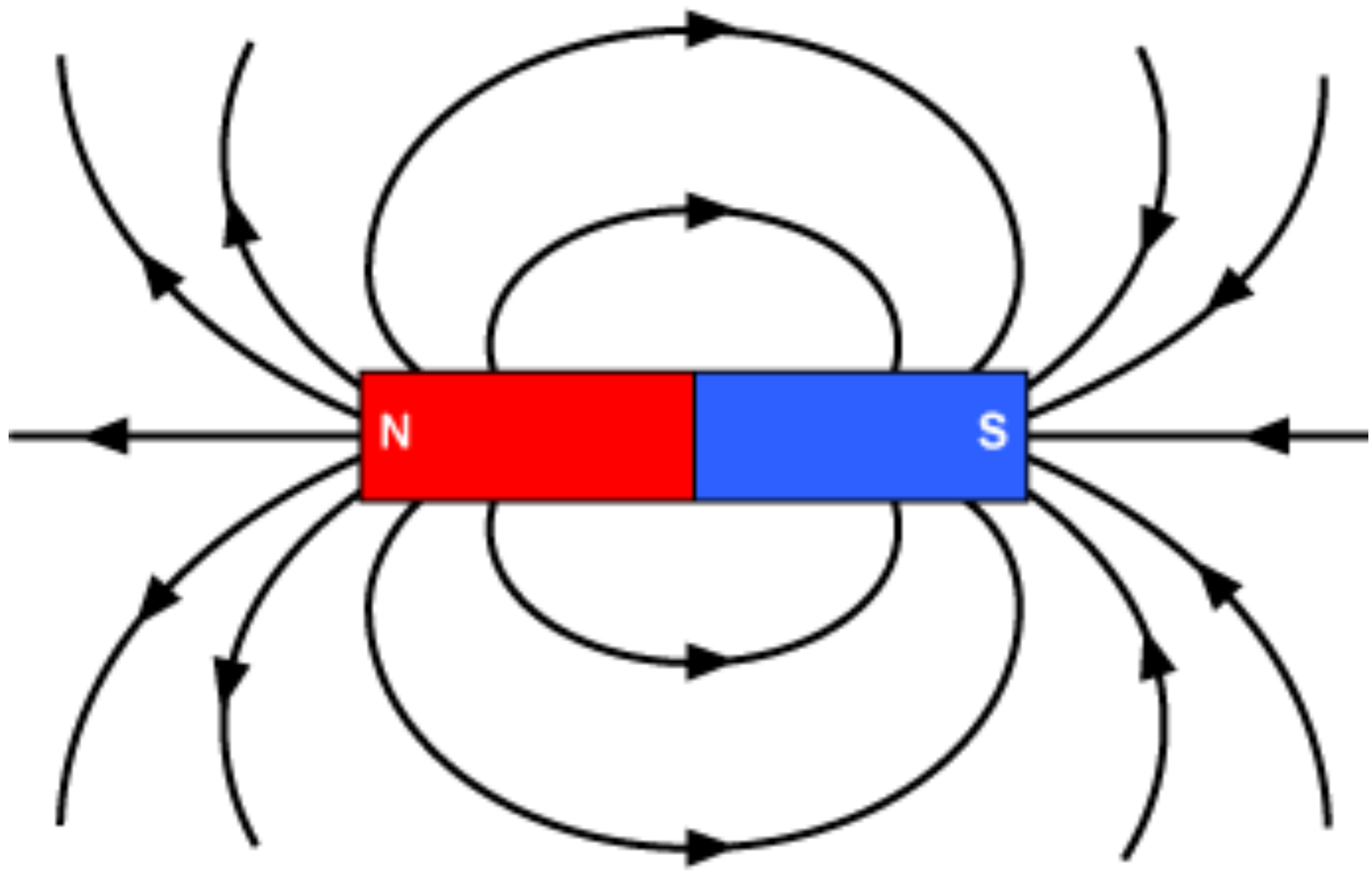


Electric Field Produced by Charges

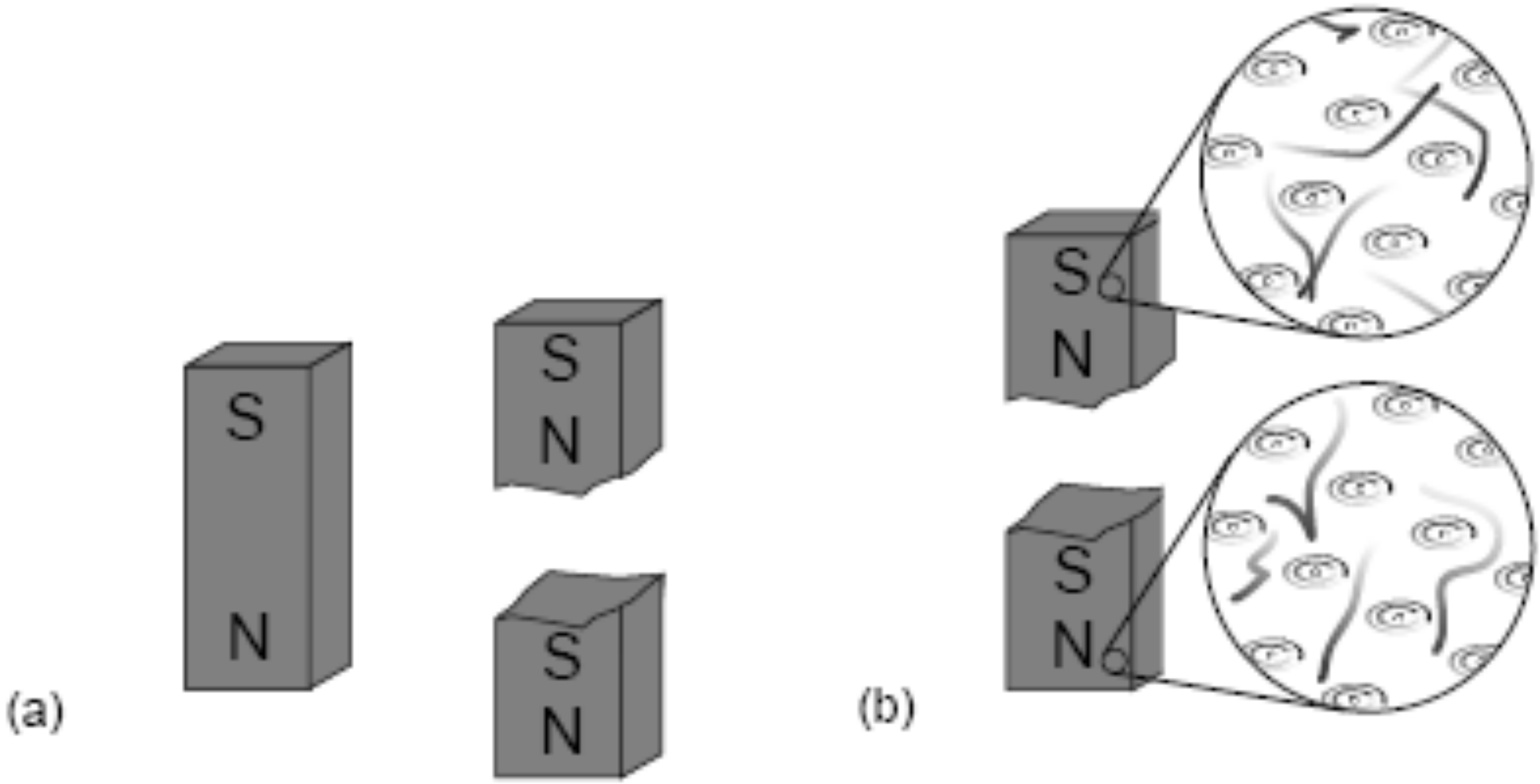




Magnetic Dipole Field

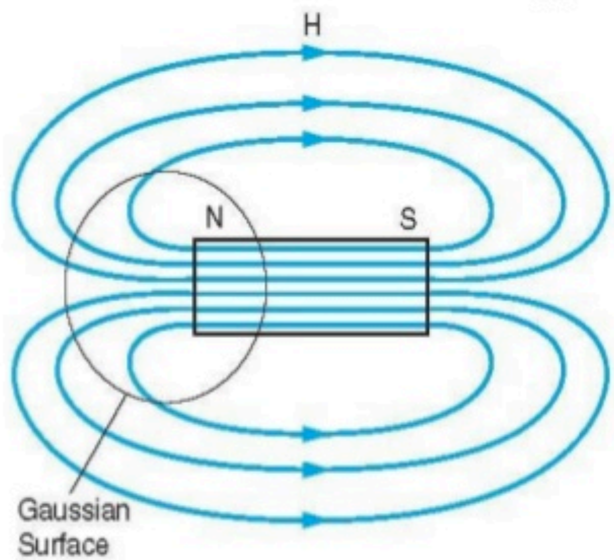


Cannot Split a Magnetic Dipole



Magnetic Gauss's Law

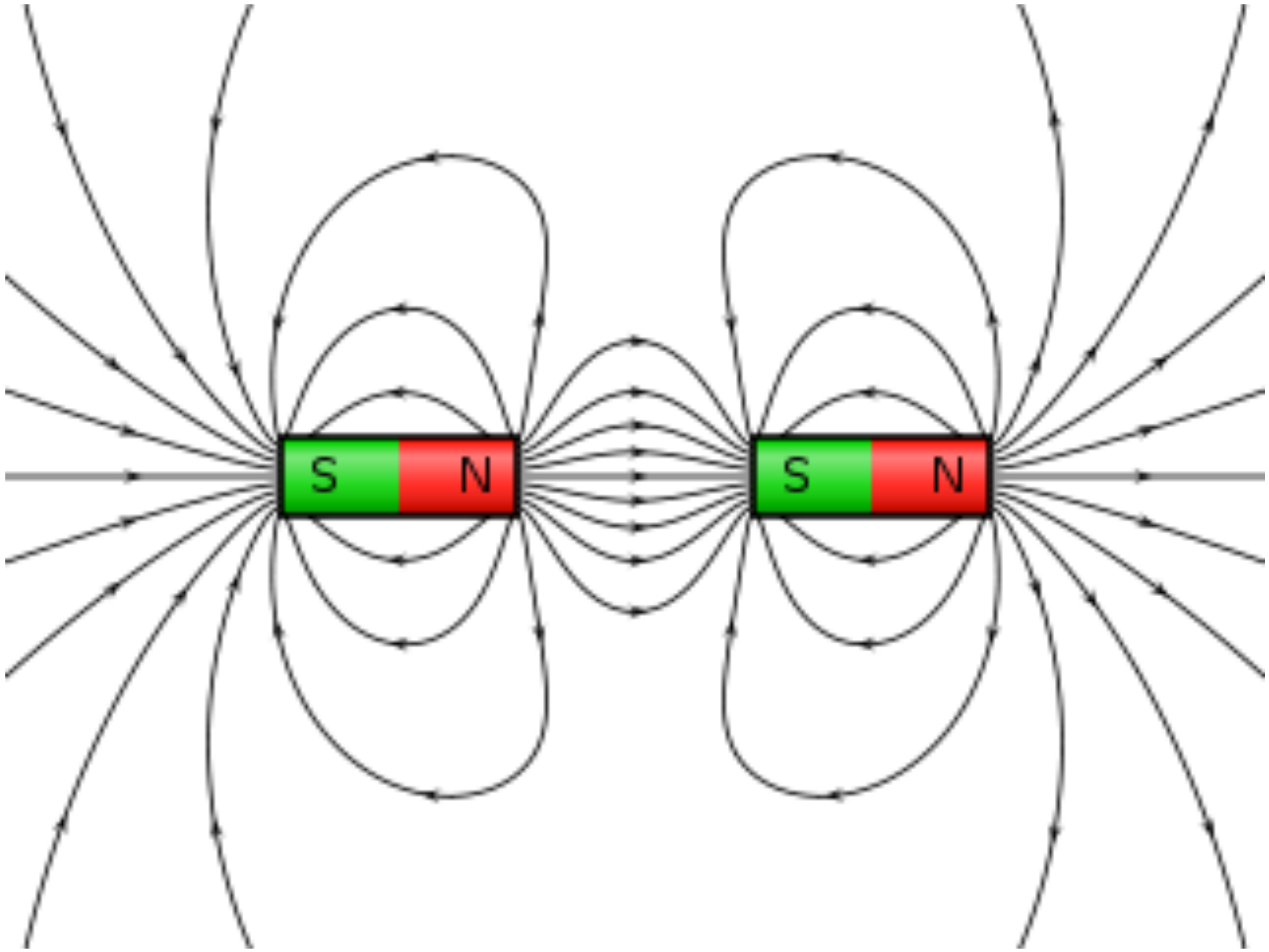
Law of conservation
of magnetic flux



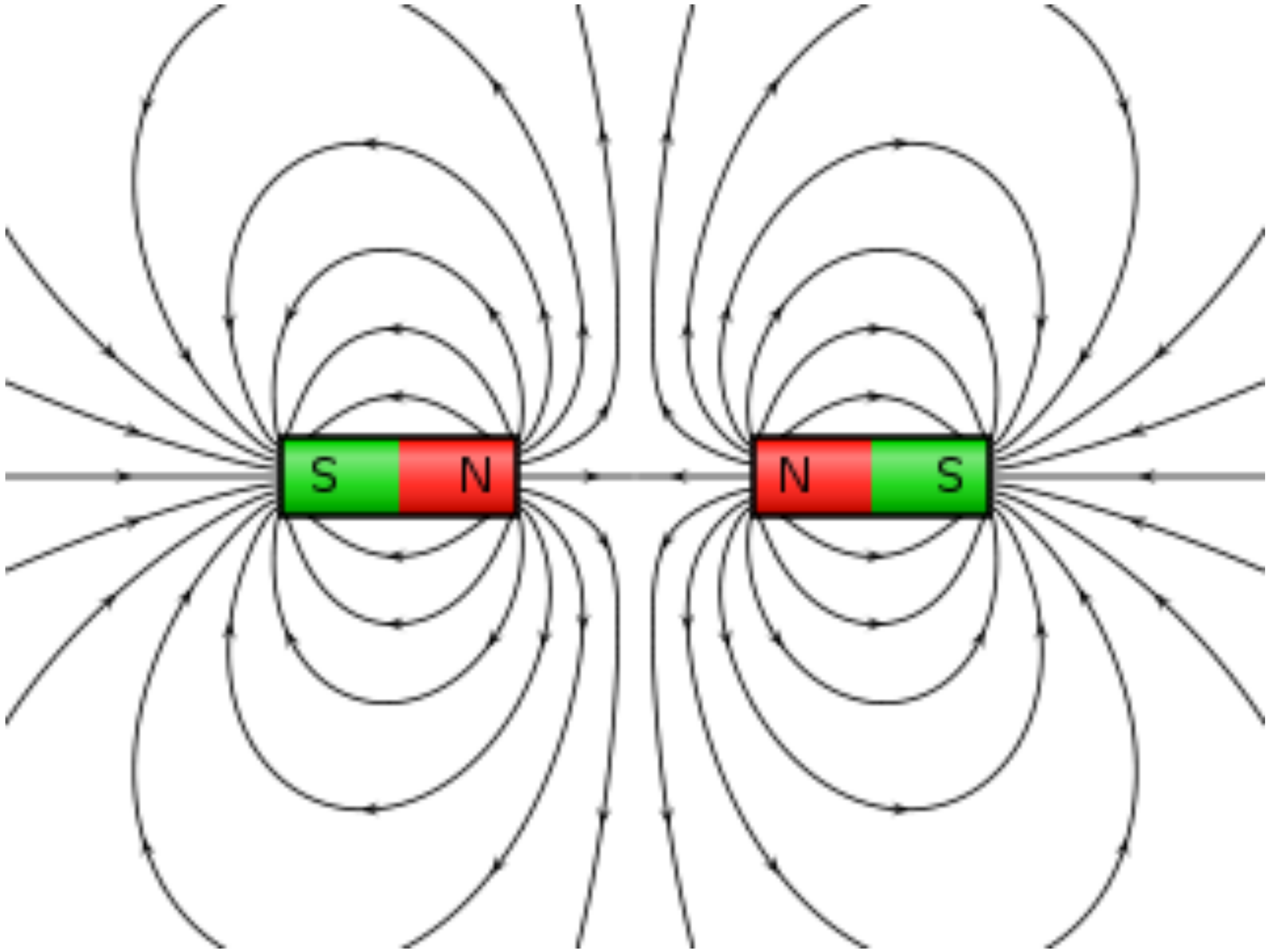
$$\oint_S \overline{B} \bullet d\overline{s} = 0$$

Law of conservation of magnetic flux or Gauss's law for magnetostatic field

Two Dipoles



Two Dipoles



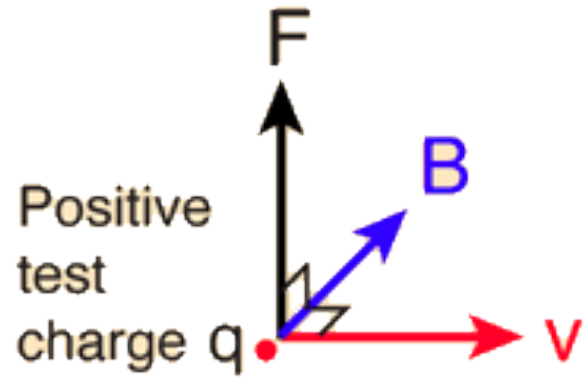
Forces We Have Encountered

$$F_g = \frac{Gm_1 m_2}{r^2} = mg$$

$$F = k\frac{q_1 q_2}{r^2} = qE$$

Magnetic Field Force

$$\vec{F} = q\vec{v} \ x \ \vec{B}$$



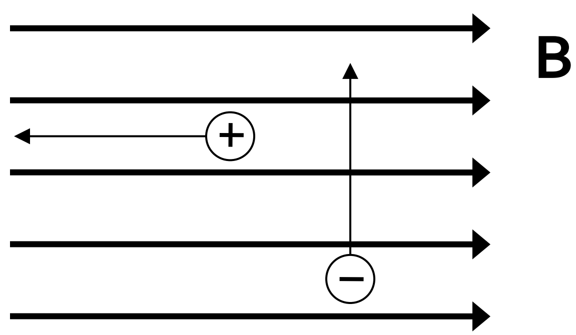
Concept Check

A negative particle and a positive particle are moving with certain velocities in a constant, uniform magnetic field, as shown. The direction of the B-field is to the right. The (+) particle is moving directly left; the (–) particle is moving directly up.

The force on the **negative** particle due to the B-field is

A: in B: out C: zero

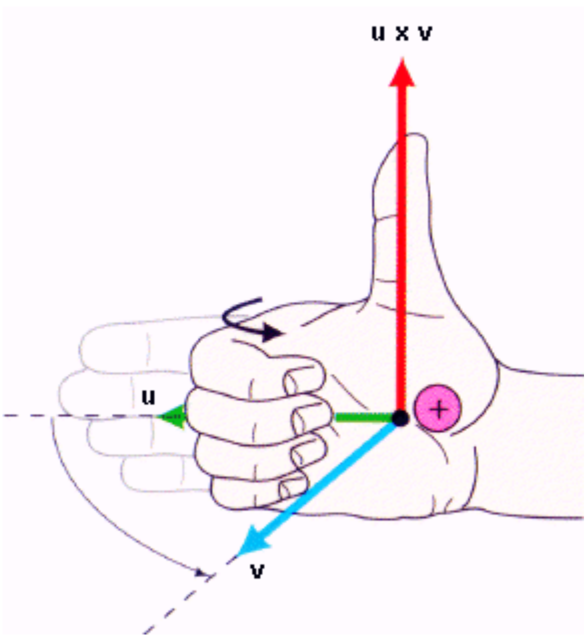
D: right E: left



Right Hand Rule Redux

Vector Cross Product – **Right Hand Rule**

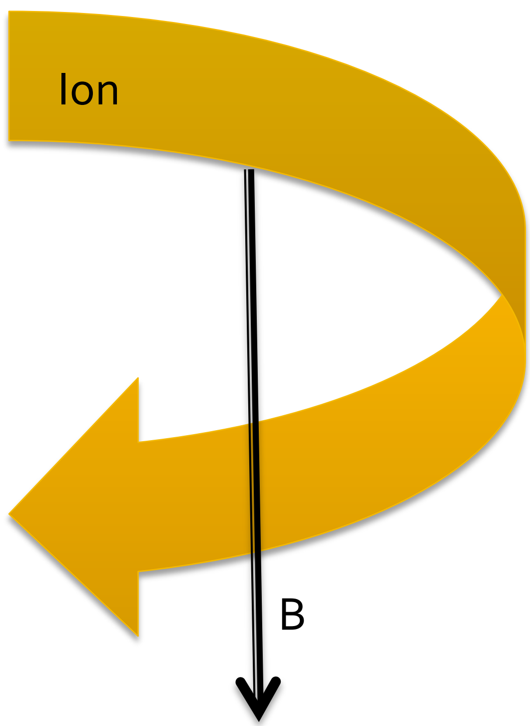
$$\vec{u} \times \vec{v}$$



- Fingers in direction of first vector.
- Bend them into direction of second vector.
- Thumb points in cross product direction.

If your hand does not bend that way, flip it around!

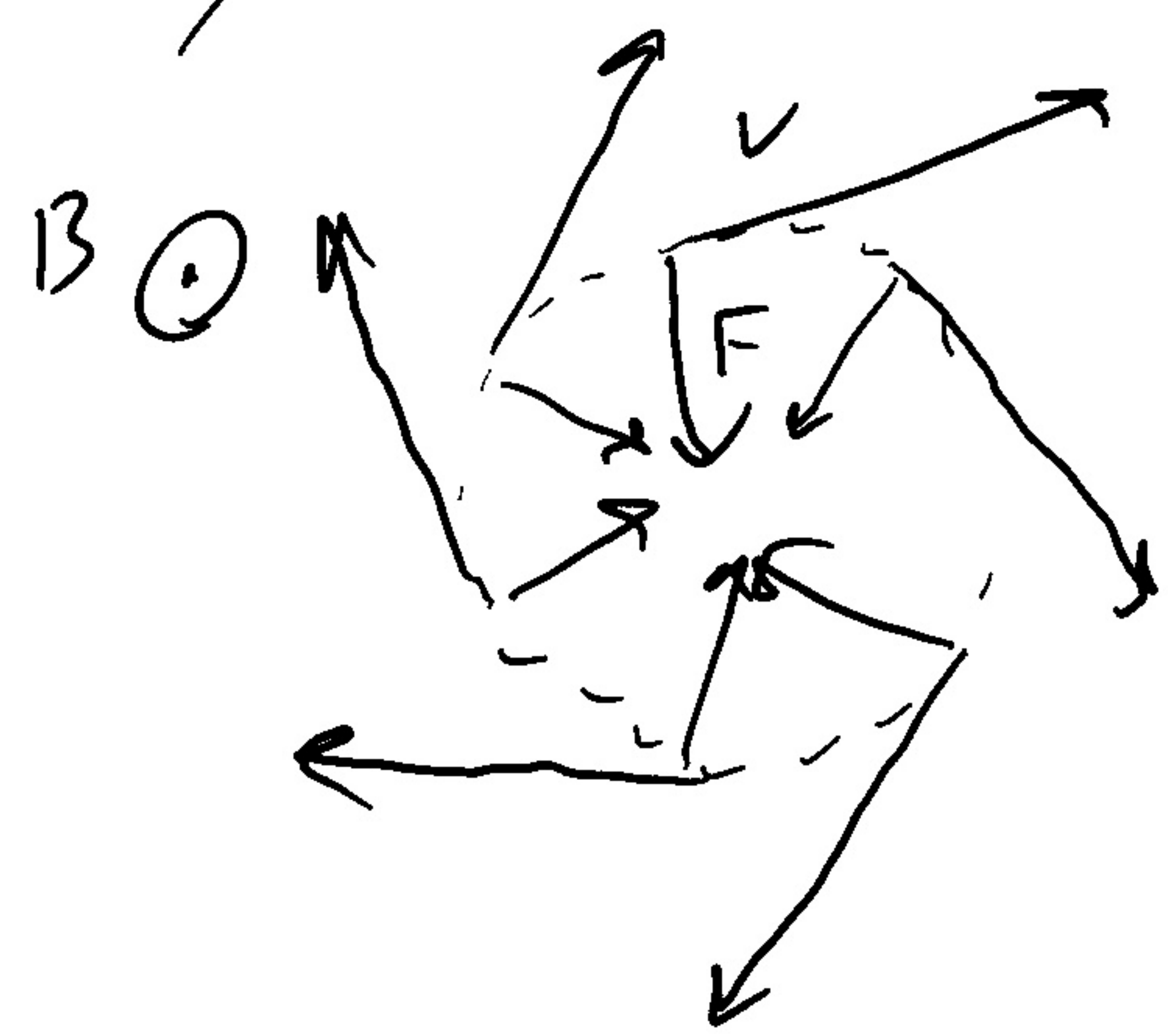
Charged Particle Motion in B



Particle Moves in Circle

$$qvB = mv^2/r$$

Charged particles in magnetic field.



Ion goes in circle clockwise around B "Left-handed"

Electron goes CCW "Right-handed"

What is radius?

$$mv^2/r = qvB$$

$$r = mv/qB$$

- Bigger mass ⇒ bigger circles
- Bigger B ⇒ smaller circles

What about lots of charges?

$$I = dQ/dt \longrightarrow = Q/\Delta t = Q \frac{\Delta x}{\Delta t} \cdot \frac{1}{\Delta x}$$
$$= Qv/L$$

w/ Q = total charge
v = velocity of charge carriers
L = length of wire

$$\vec{F} = Q\vec{v} \times \vec{B}$$
$$= \frac{IL}{v} \vec{v} \times \vec{B}$$
$$= IL\hat{v} \times \vec{B}$$
$$= I\vec{L} \times \vec{B}$$

$\vec{L}$ = vector along wire w/ length L

Electromagnetic Force

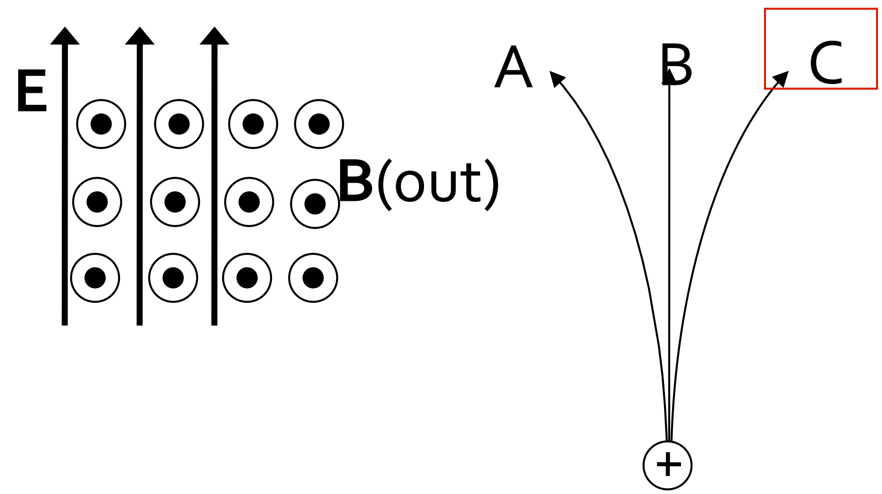
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Electric force

Magnetic force

Concept Check

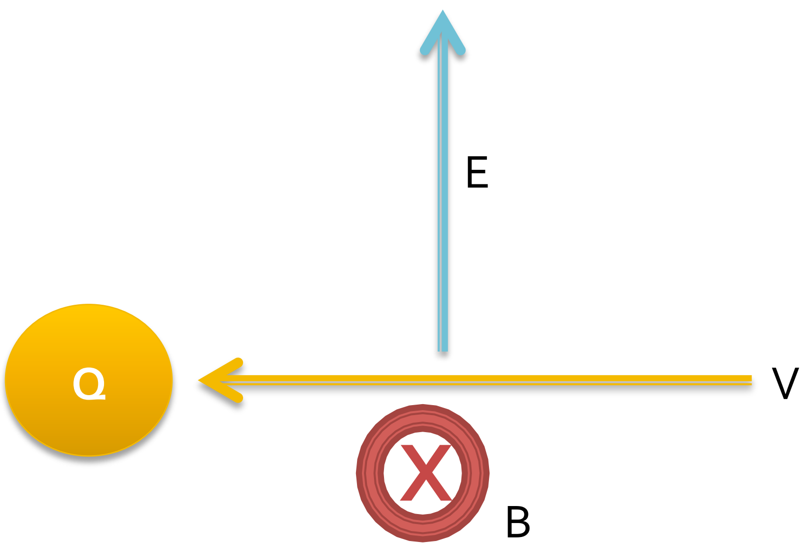
A positive particle is released from rest in a region of space where there is constant, uniform, electric field and a constant, uniform magnetic field. The electric field points up and the magnetic field points out of the page in the diagram below. <u>Which path will the positive particle follow?</u> (All paths shown are in plane of the page.)



D: it will not move

Can You Balance E and B Forces?

- Yes, but only for one velocity



Note the same V works for either +Q or –Q!

Useful Thing to Remember

- Electric fields are created by charges
- Electric fields exert a force on charges

- Magnetic fields are created by moving charges [currents]
- Magnetic fields exert a force on moving charges