Physics 122 – Class #27 – (4/21/15)

- Announcements
- Magnetism
    - Force on a charge
    - Force on a current
    - Field of a straight wire
    - Torque on a current loop
    - Summary of Chapter 32
    - Magnetic moment

Schedule for rest of term

Today – Magnetic Fields and Force
Motors, Magnetic Fields and Force
Thursday 4/23 – Exam #3
    Ch. 28, 29, 30, 31
        (thru this week's assignment)
Tuesday 4/28
  – Magnetic Induction – Ch. 33
Thursday 4/30 – Magnetic Induction

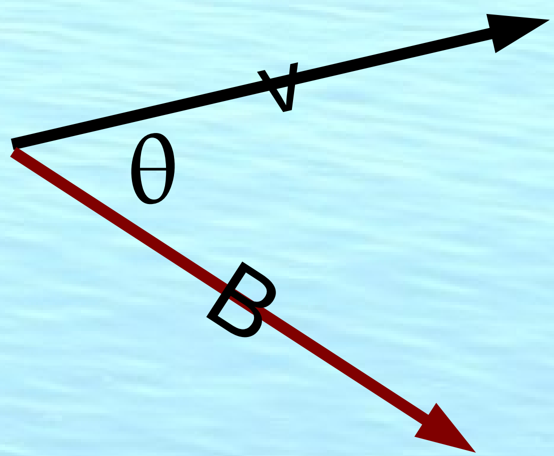
Announcements

- Go to lab this week … skip the write-up. Get a sense of induction
- Read all of Chapter 32 this week (you may permanently omit 32.10)
- Read Chapter 33. Omit 33.9 and 33.10, skim 33.8
- Written Homework 31.45, 31.60, 31.70 (due Thurs)
- Test #3 is Thursday
  - Ch. 28, 29, 30, 31
- Homework #12 – Due a week from today at midnight Problem 32.33, 34, 35, 36, 37, 38, 39, 40, 49, 50

Find the magnitude of the magnetic force on a proton moving at $v = 2.5 \times 10^5 \, m/s$ at 30 degrees to a 0.5 T magnetic field.

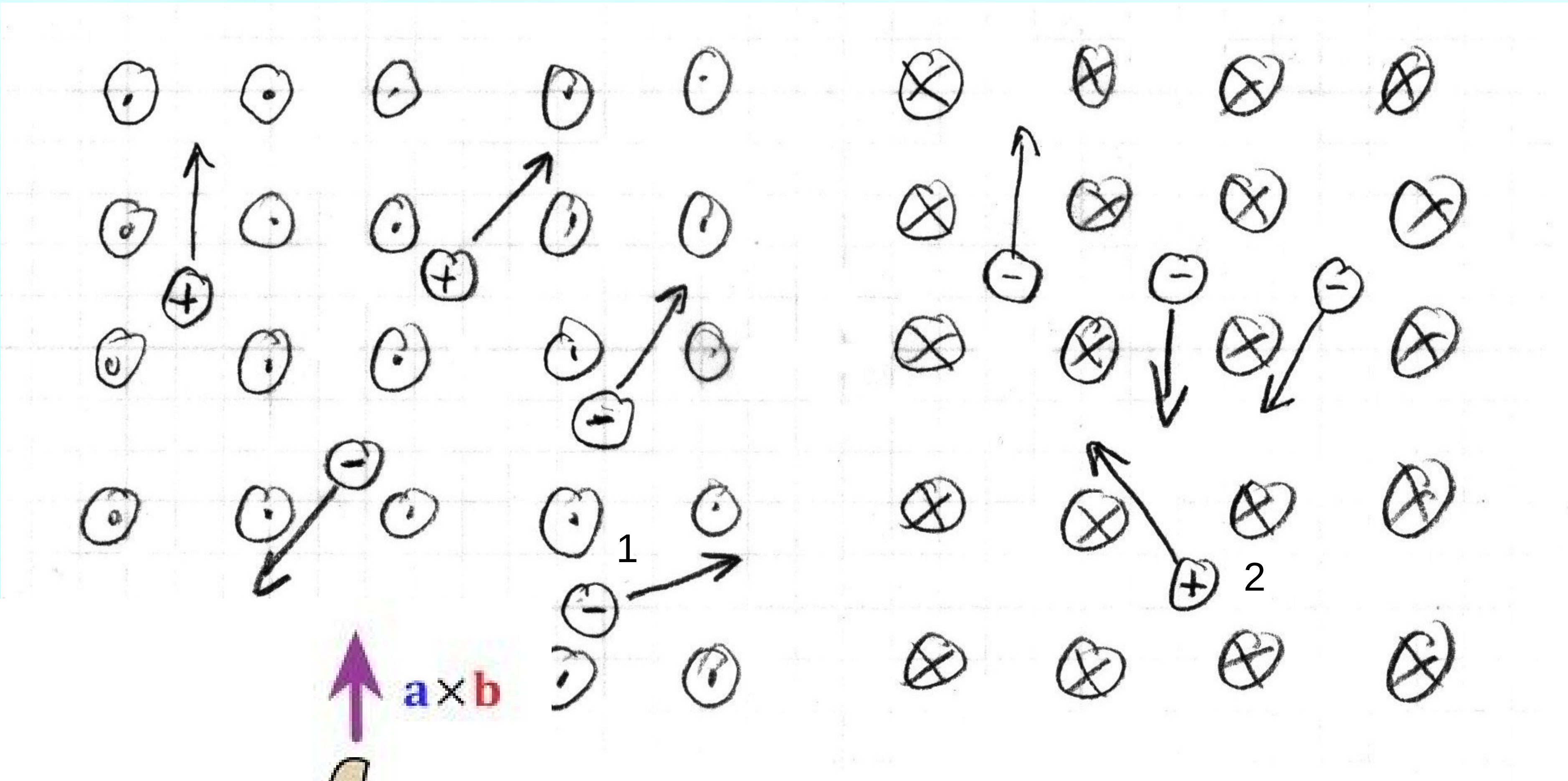
Magnetic force on a charge ---> $\vec{F} = q \vec{v} \times \vec{B}$

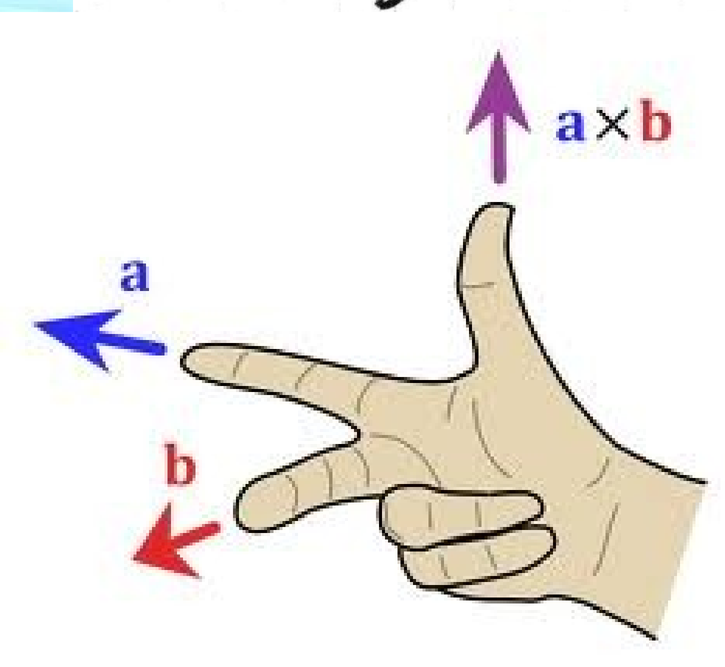
$F = q v B \sin(\theta)$



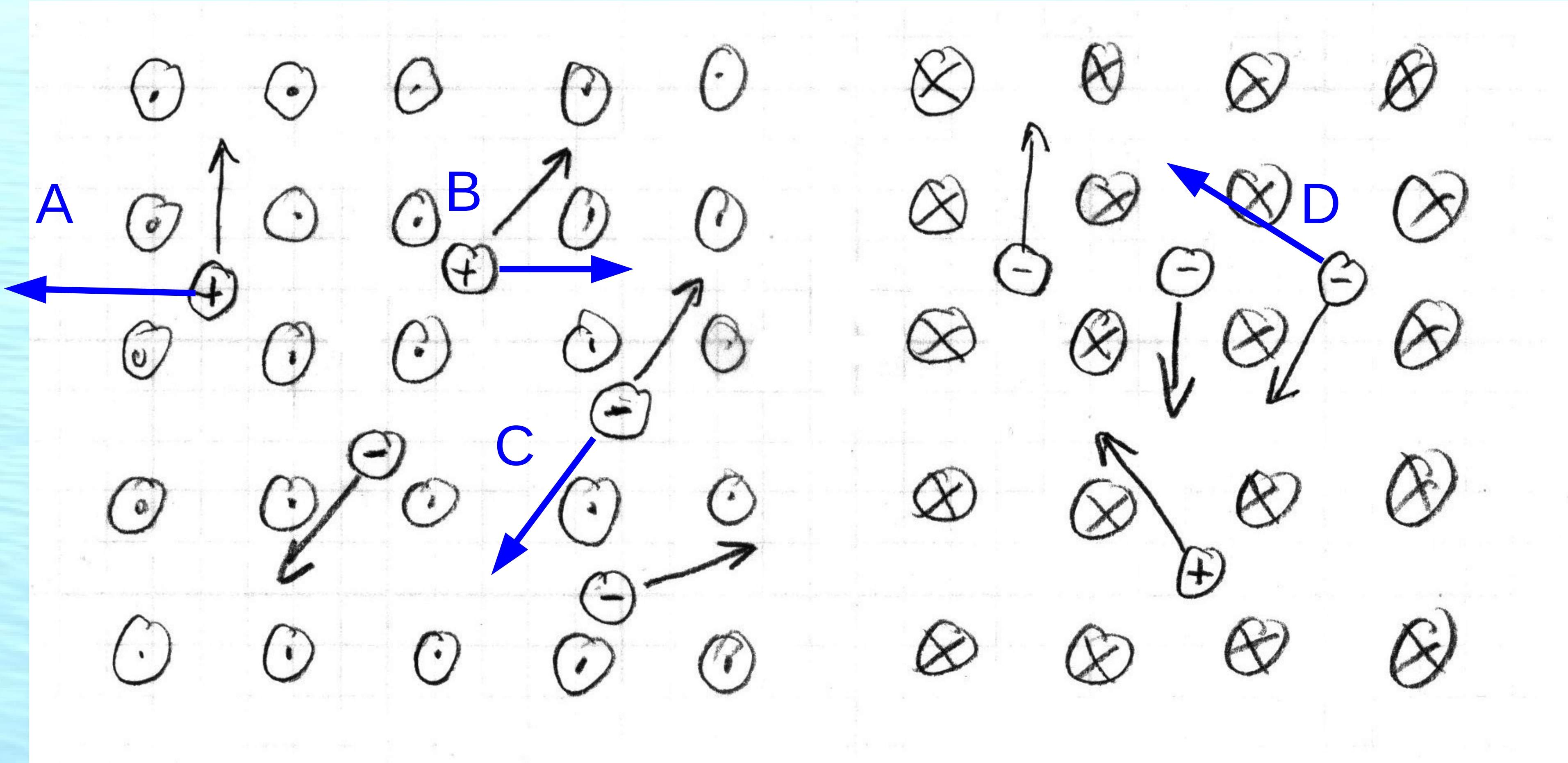
$$F = (1.6 \times 10^{-19} \text{ C})(2.5 \times 10^3 \text{ m/s})(0.5 \text{ T})(\sin(30))$$

Right-hand rule practice! $\vec{F} = q\,\vec{v} \times \vec{B}$





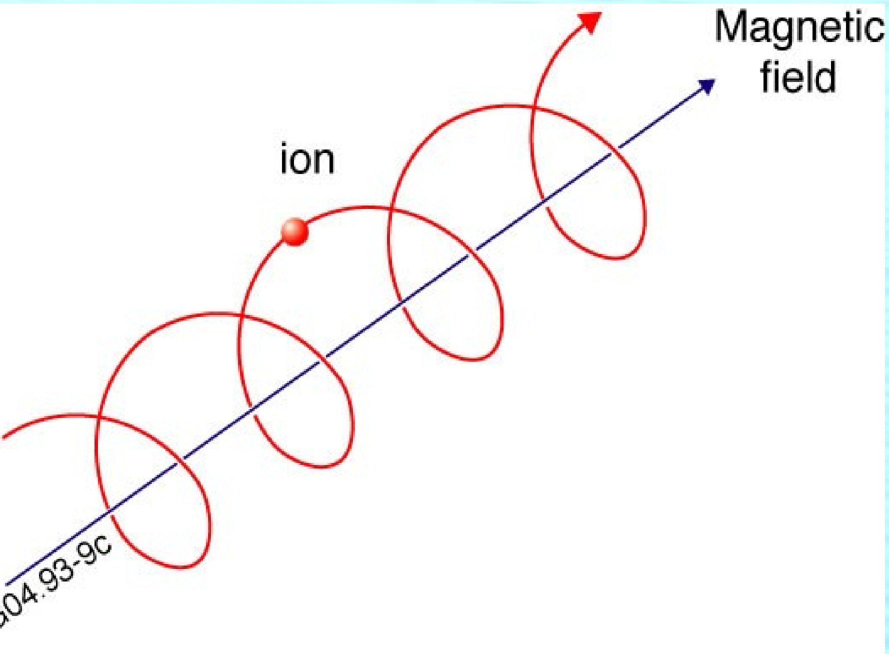
Right-hand rule practice! $\vec{F} = q\,\vec{v} \times \vec{B}$



Which of the four Force vectors are correct for v and B shown?

Helical motion of ion in a magnetic field

$$\vec{F} = q\,\vec{v} \times \vec{B}$$

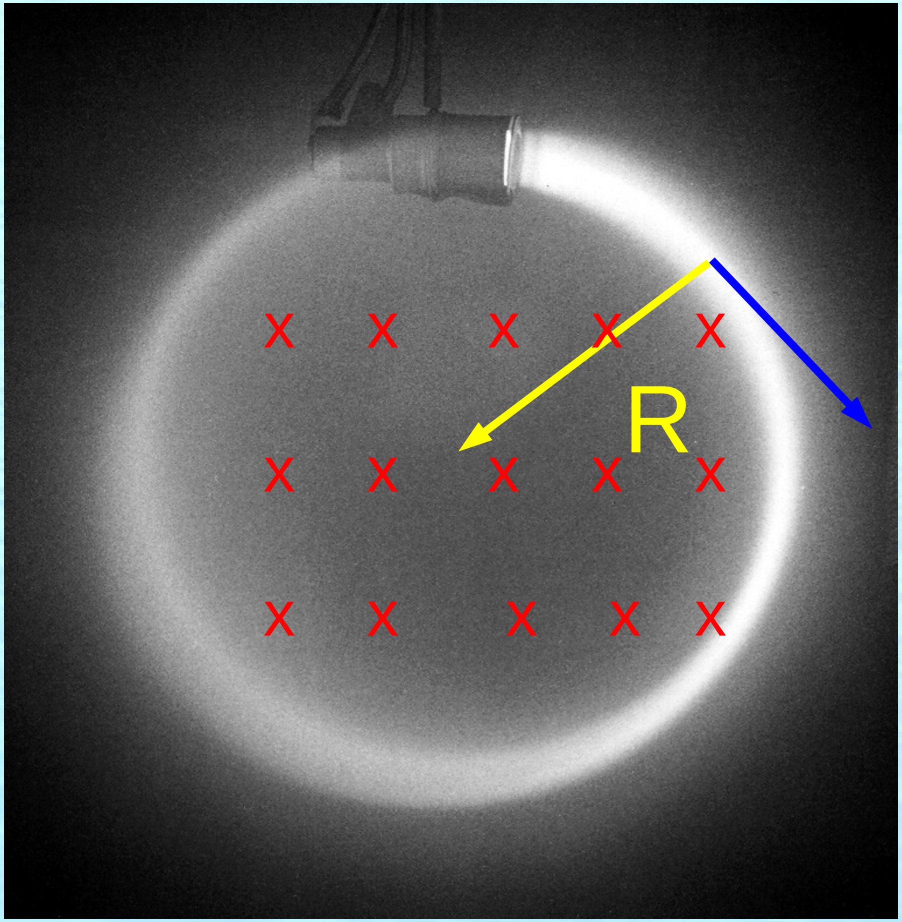


Force on component of velocity in direction of B is zero.

Force on component at right angles to B is always radial toward field line.

So trajectory is helical.

Radius of orbit of electron in Magnetic field



$$\vec{F} = q\,\vec{v} \times \vec{B} = q\,v_{perp}\,B$$

$$F_{centripetal} = \frac{m\,v^2}{R}$$

$$\frac{m\,v^2}{R} = qvB \qquad \frac{m\,v}{qB} = R$$

100 eV electron $v = 6 \times 10^6$ m/s

$$B = 5\ G(\text{Gauss}) = 5 \times 10^{-4}\ T$$

$$m_e = 9.0 \times 10^{-28}\ g \qquad q = 1.6 \times 10^{-19}\ C$$

$$R = 0.0675\ m$$

Radius of orbit of solar wind proton in Earth's Magnetic field

$$\frac{m v^2}{R} = qvB \qquad \frac{m v}{qB} = R$$

$$m_p = 1.6 \times 10^{-27} \text{ kg} \qquad v = 400 \text{ km/s}$$

Solar wind a million mph (400 km/s)

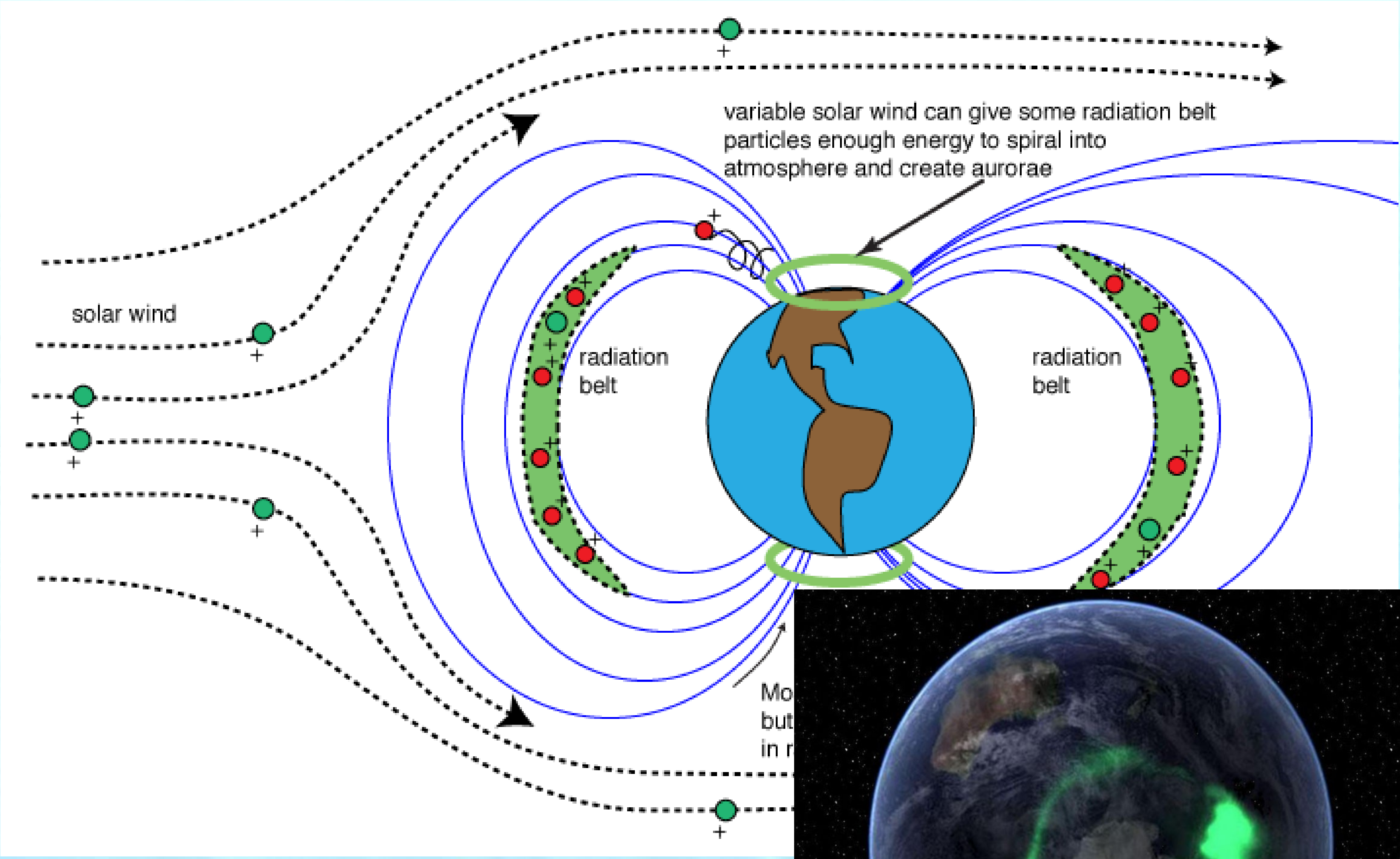
$$B_{Earth} = 0.5 \text{ G}\left(\text{Gauss}\right) \qquad q = 1.6 \times 10^{-19} \text{ C}$$

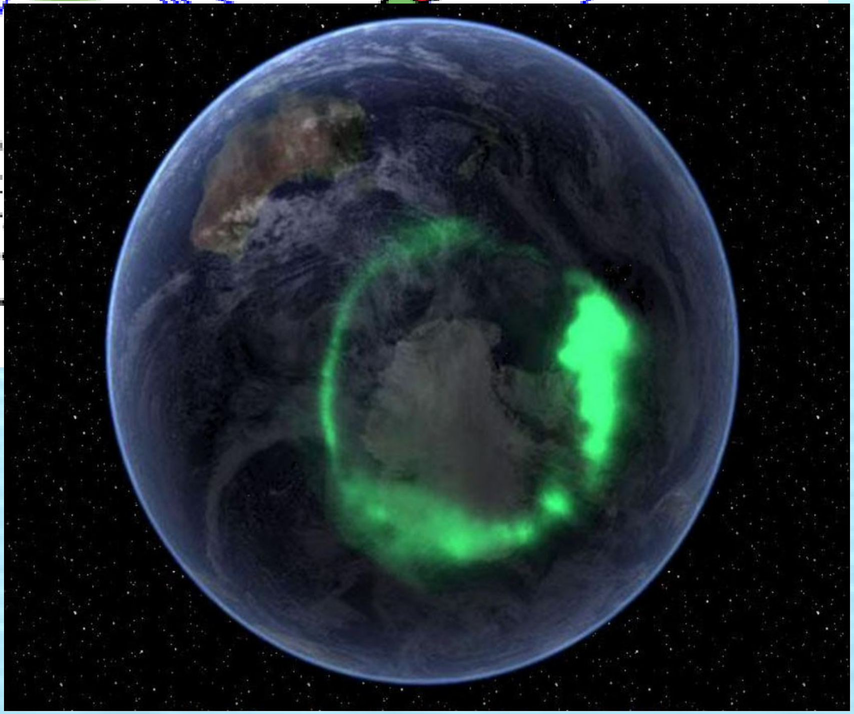
$[A]\ R = 80 \text{ m}$

$[B]\ R = 0.008 \text{ m}$

$[C]\ R = 8 \times 10^{-6} \text{ m}$

$[D]\ R = 0.08 \text{ m}$





http://tinyurl.com/aurora-sonnenfeld

Magnetic Permeability ---> $\mu_0 = 4\pi \times 10^{-7}$

Electric Permeability ---> $\epsilon_0 = 8.86 \times 10^{-12}$

http://phet.colorado.edu/en/simulation/magnets-and-electromagnets

Ampere's Law ---> $\int \vec{B} \cdot d\vec{s} = \mu_0 I_{encircled}$

Magnetic force on a charge ---> $\vec{F} = q\vec{v} \times \vec{B}$

Magnetic force on a current ---> $\vec{F} = nALq\vec{v}_d \times \vec{B}$

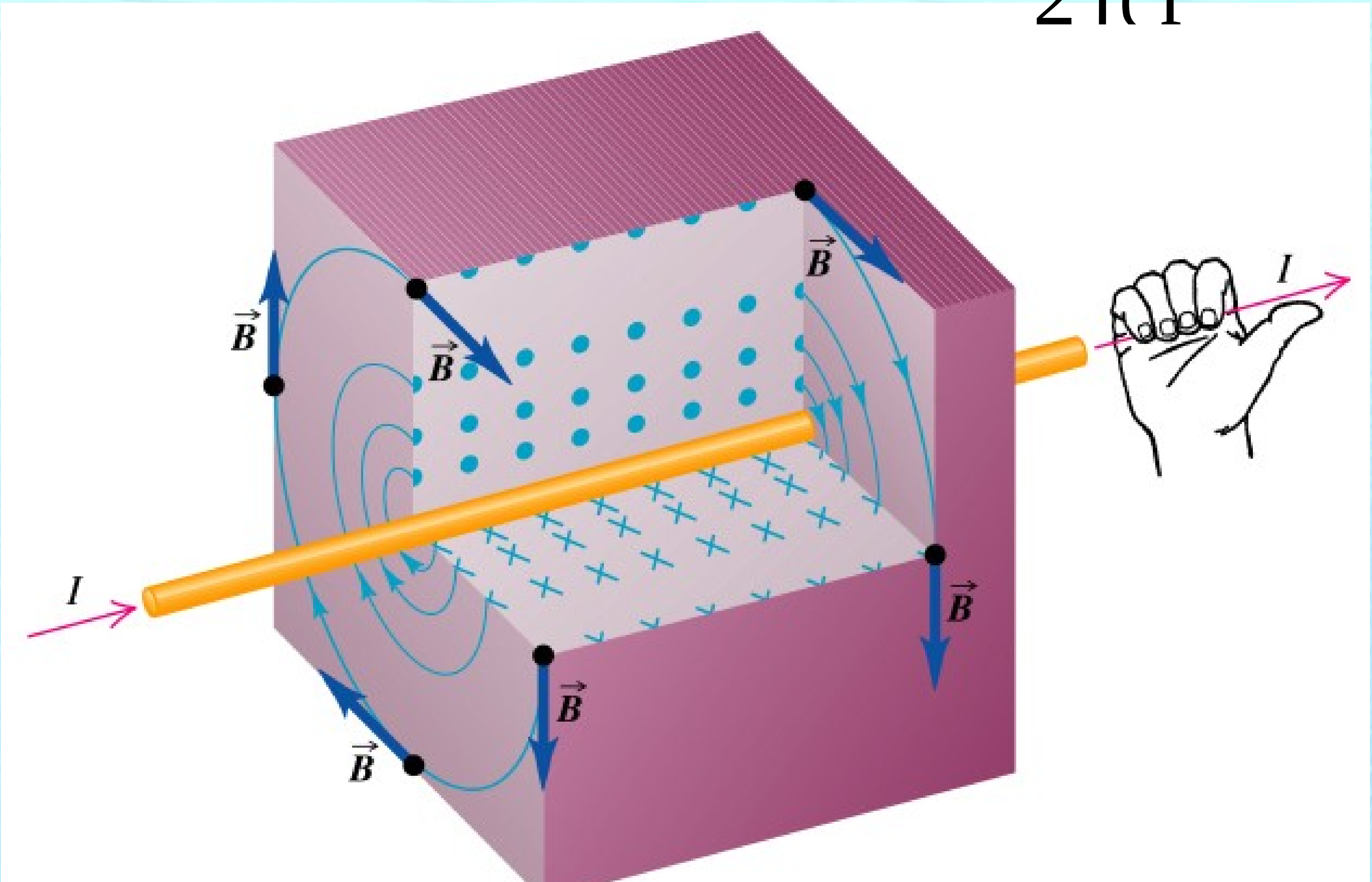
$\vec{F} = I\vec{L} \times \vec{B}$

Biot-Savart law –> Current loops, computers

Ampere's law --> Straight wires, current sheets, solenoids

Magnetic field of a wire encircles the current.

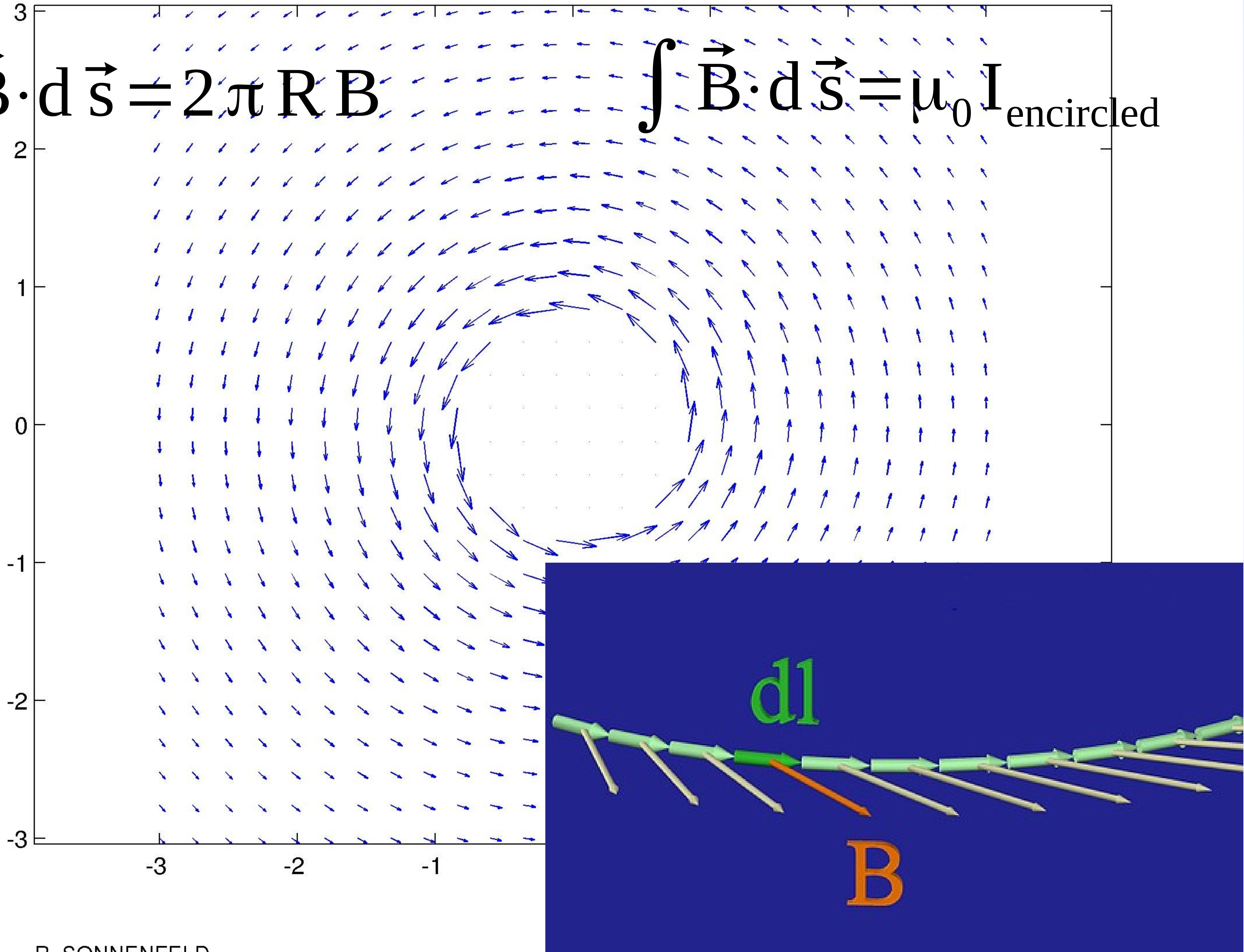
For infinitely long wire --> $B = \frac{\mu_0 I}{2\pi r}$



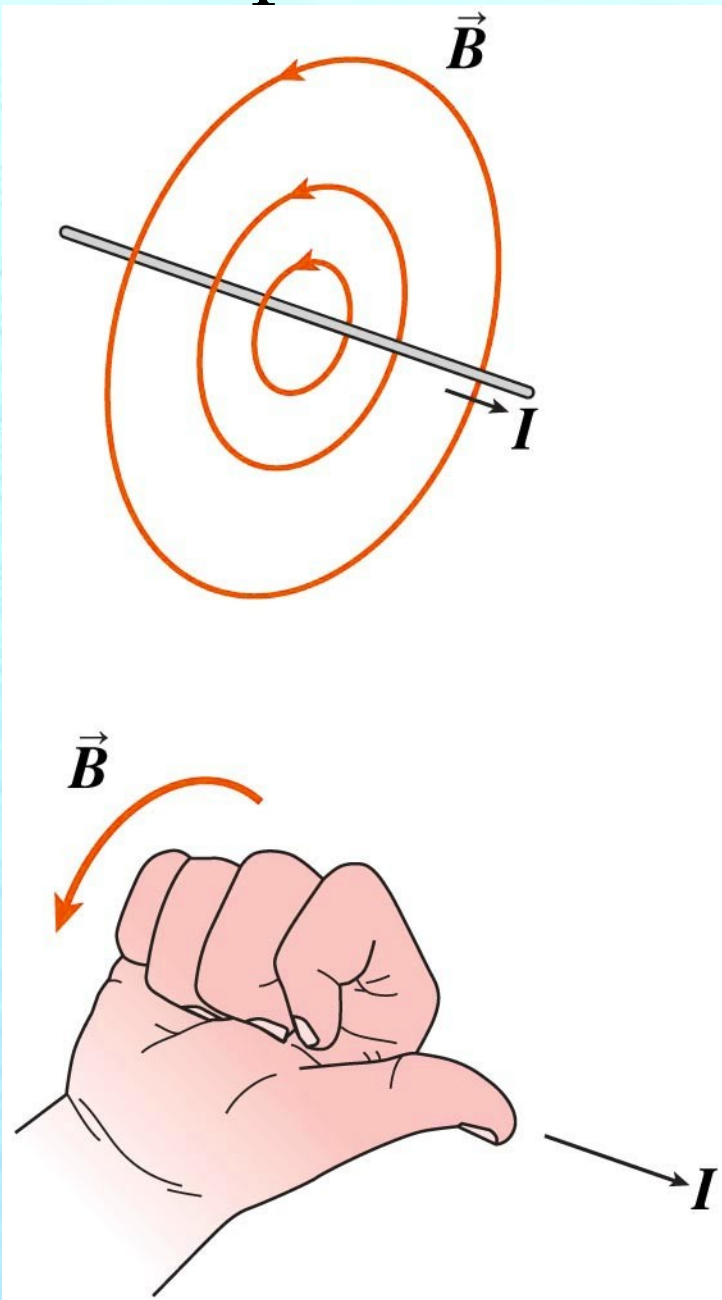
B-Field Around A Wire

$$\int \vec{B}\cdot d\vec{s} = 2\pi R B$$

$$\int \vec{B}\cdot d\vec{s} = \mu_0 I_{encircled}$$



Ampere's Law ---> $\int \vec{B} \cdot d\vec{s} = \mu_0 I_{encircled}$

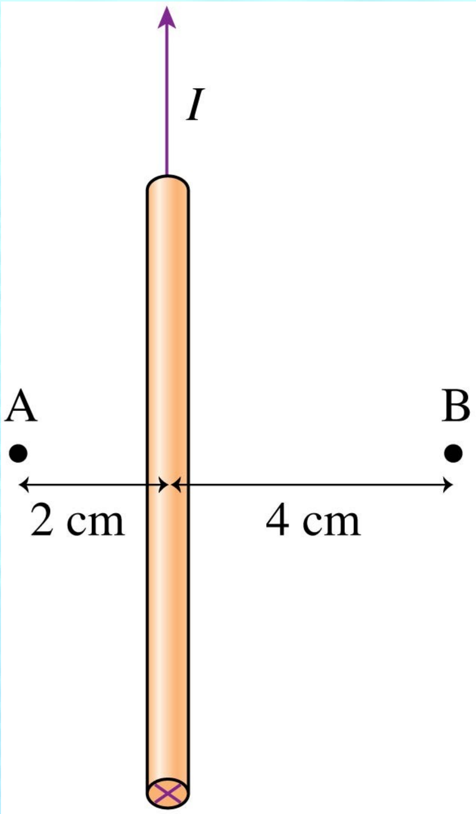


Use Ampere's law to Calculate B-field around a Straight wire.

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

Clicker

Compared to the magnetic field at point A, the magnetic field at point B is



A. Half as strong, same direction.
B. Half as strong, opposite direction.
C. One-quarter as strong, same direction.
D. One-quarter as strong, opposite direction.
E. Can't compare without knowing I.

In standard household wiring, parallel wires about 1 cm apart carry currents of about 15 A.

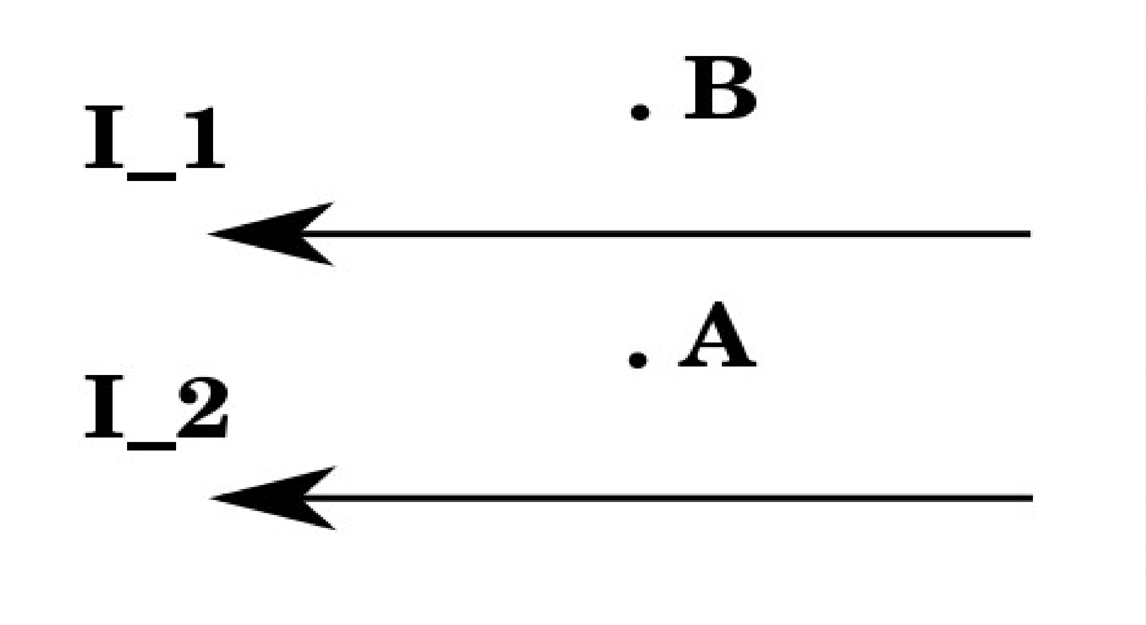
What is the magnetic field at 1 cm?

What is the magnitude of the force per Unit length between the wires?

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

$$\vec{F} = I\,\vec{L} \times \vec{B}$$

Equal currents
Are directed as
Shown.



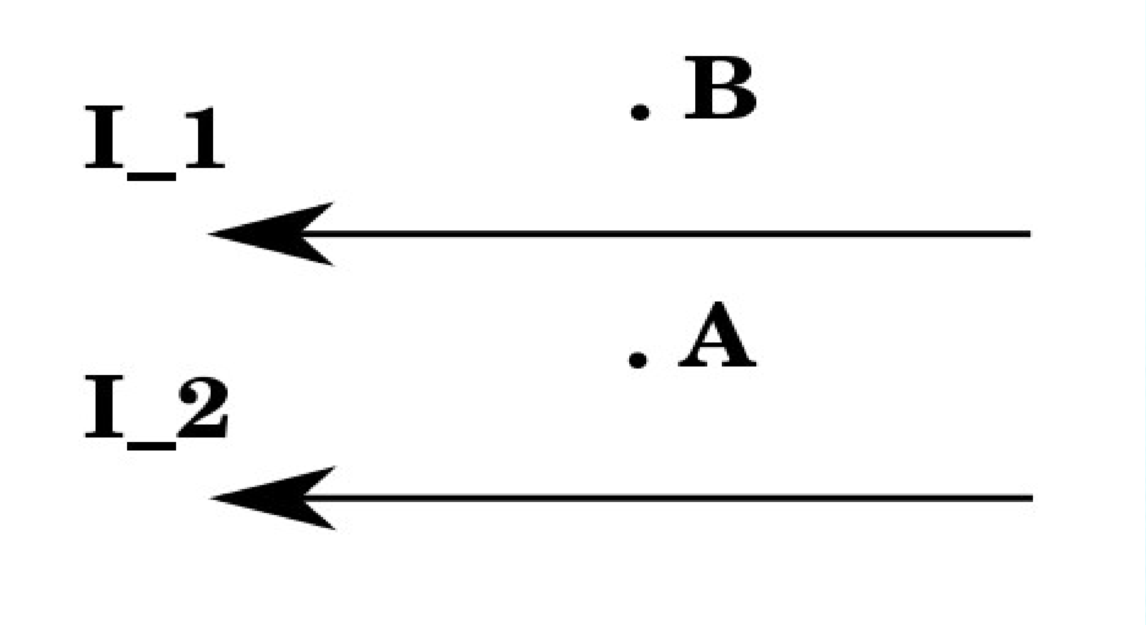
The magnetic force
On wire 1
Is:

(A) Directed downward
(B) Directed upward
(C) Directed into the page
(D) Directed out of the page
(E) zero

A 2.2 m long wire carrying 3.5 A is wound into a tight, loop-shaped coil 5.0 cm
In diameter. What is the magnetic field at the Center?

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

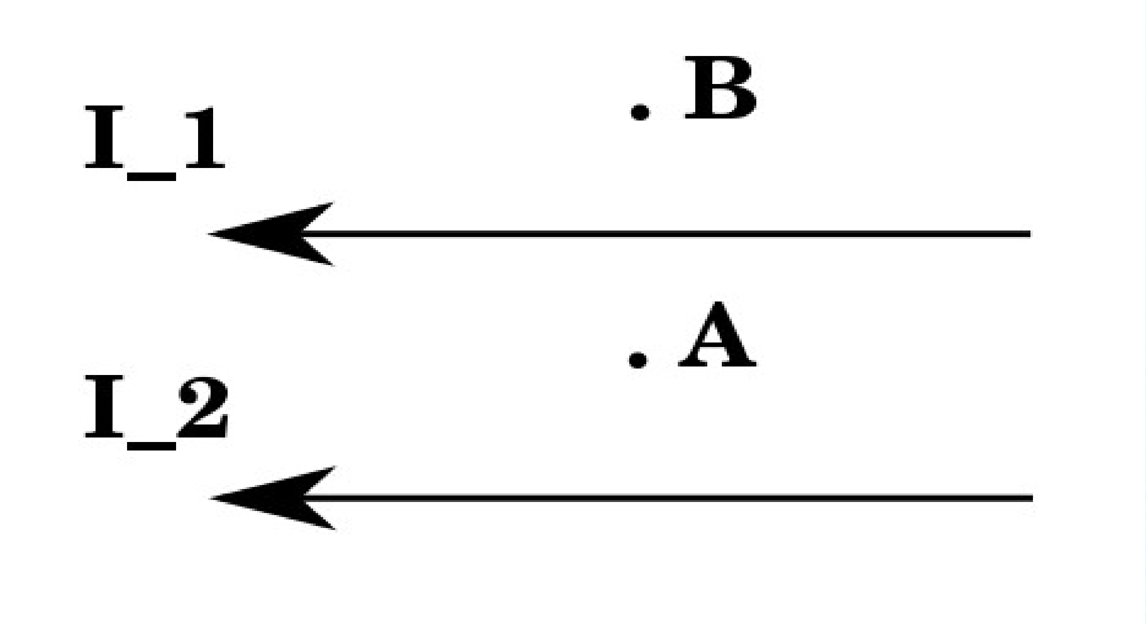
Equal currents
Are directed as
Shown.



At Point “A” the
Total magnetic field
Is:

(A) Directed downward
(B) Directed upward
(C) Directed into the page
(D) Directed out of the page
(E) zero

Equal currents
Are directed as
Shown.



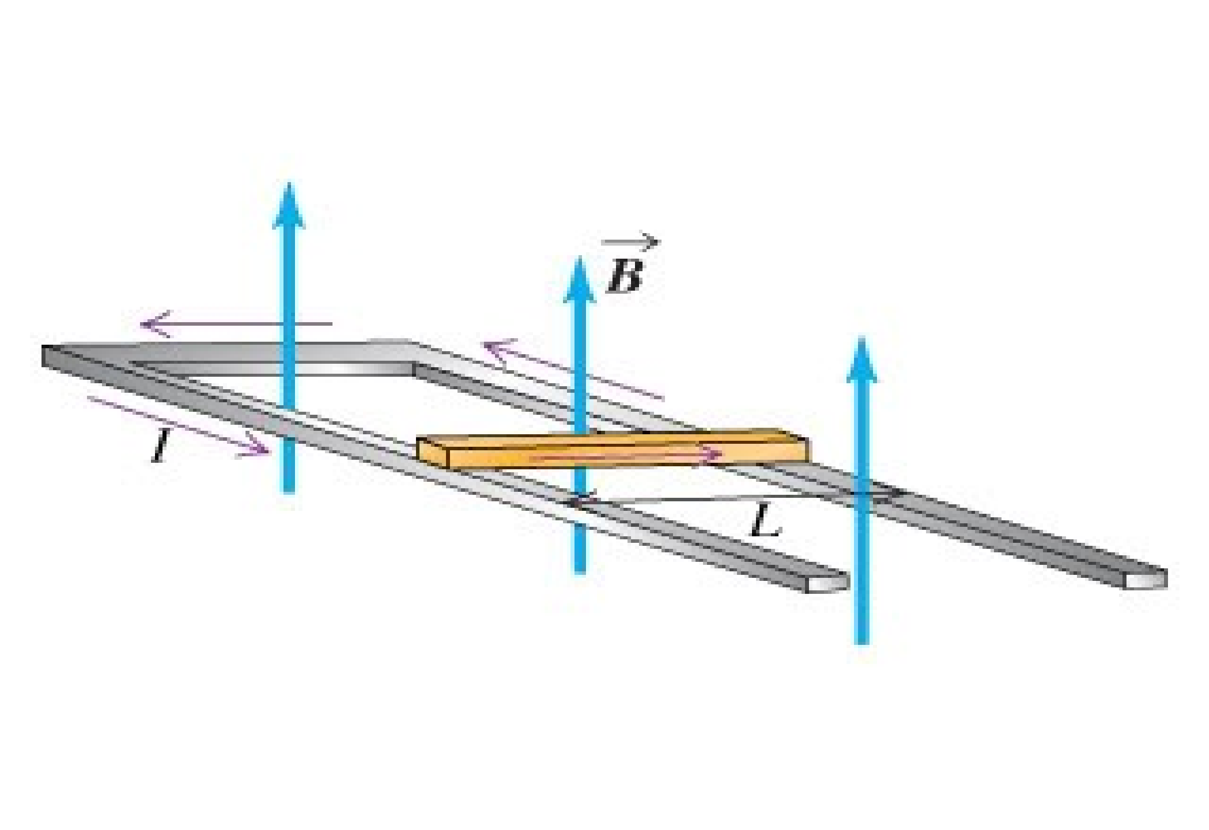
At Point "B" the
Total magnetic field
Is:

(A) Directed downward
(B) Directed upward
(C) Directed into the page
(D) Directed out of the page
(E) zero

Railgun

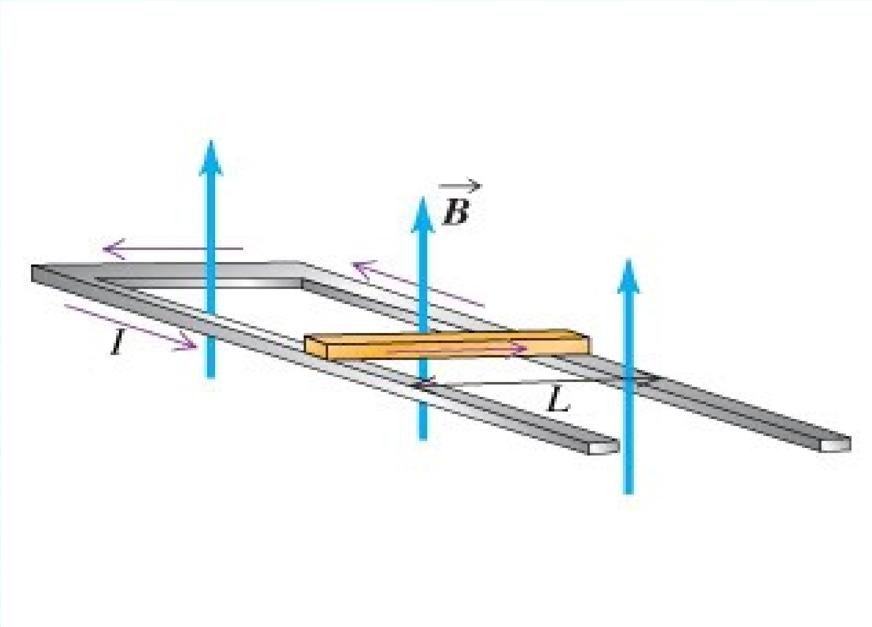
$$\vec{F} = I\,\vec{L} \times \vec{B}$$

Given a 1 cm x 1 cm Copper wire bent into a 10 meter long by 10 cm across "U" and generating 2 Tesla of "B", what is the speed of A crossbar-projectile launched as shown?



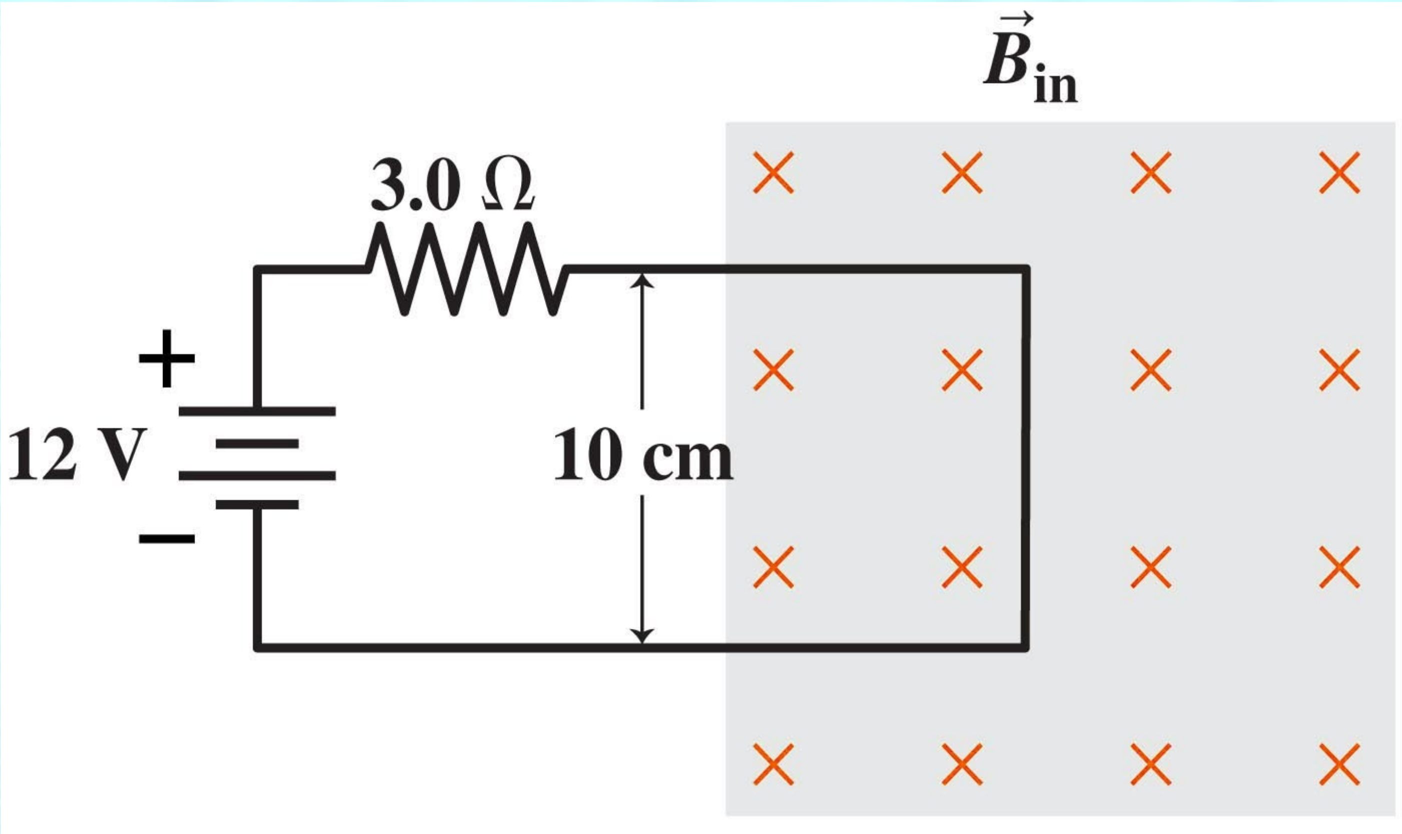
(Youtube Mach 10 railgun test by BAE)

Railgun $\vec{F} = I\,\vec{L} \times \vec{B}$



Given a magnetic field of 2 Tesla, what is the net force on the circuit shown?

$$\vec{F} = I\,\vec{L} \times \vec{B}$$



[A] F=4 A

[B] F=0.4 N

[C] F=8.0 T

[D] F=8.0 N

[E] F=0.8 N

Why is magnetic dipole moment a useful concept?

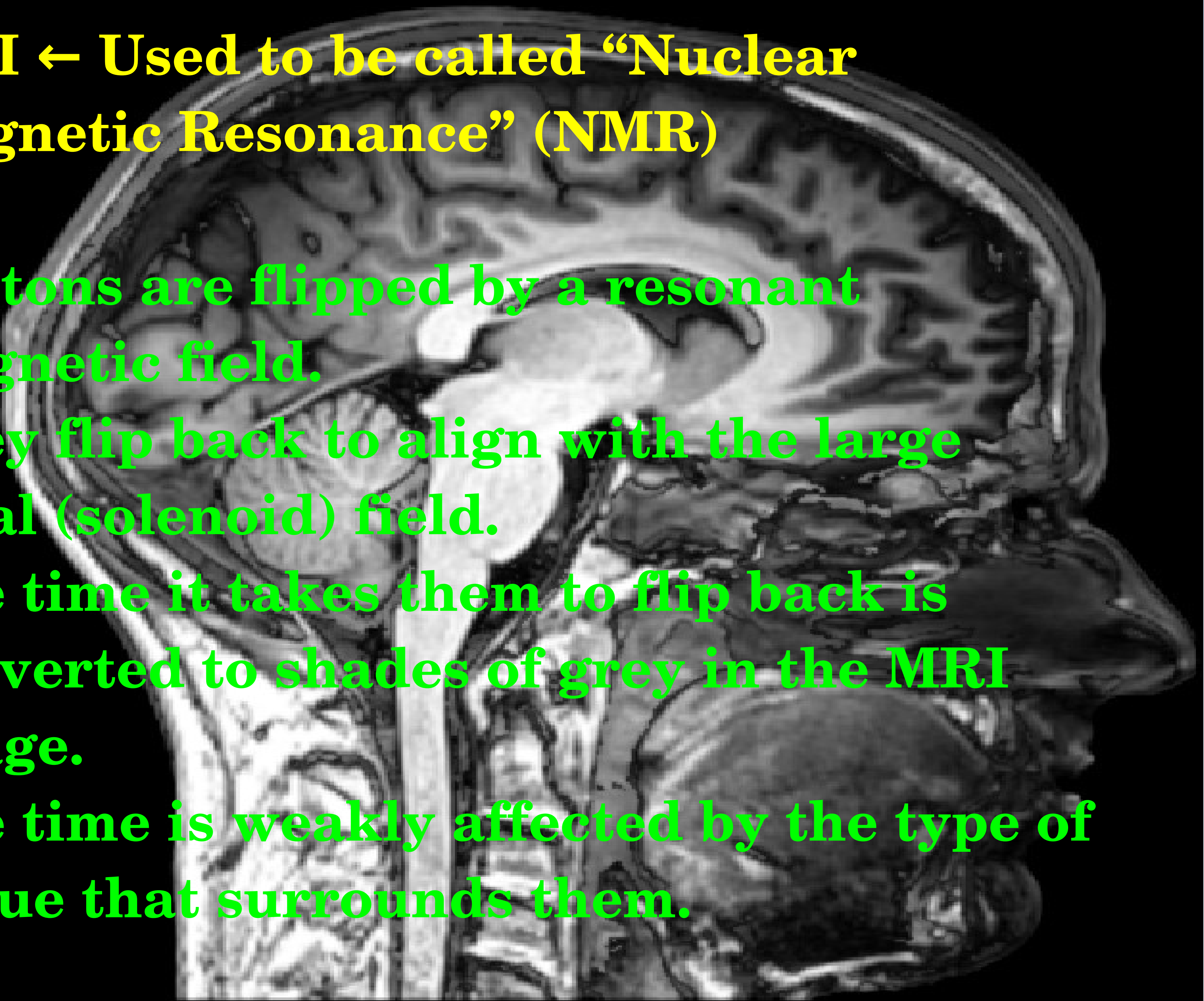
It's good for understanding motors.

Protons and electrons have dipole moments.

This is particularly surprising since electrons have zero size.

Even at the quantum level, particles act like spinning balls of charge!

MRI works by flipping over every proton in the Water-molecules in your body!



MRI ← Used to be called "Nuclear Magnetic Resonance" (NMR)

Protons are flipped by a resonant magnetic field.

They flip back to align with the large axial (solenoid) field.

The time it takes them to flip back is converted to shades of grey in the MRI image.

The time is weakly affected by the type of tissue that surrounds them.