# Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

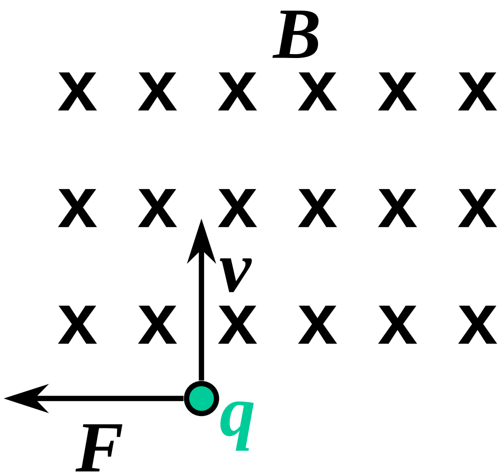
Notes for today:

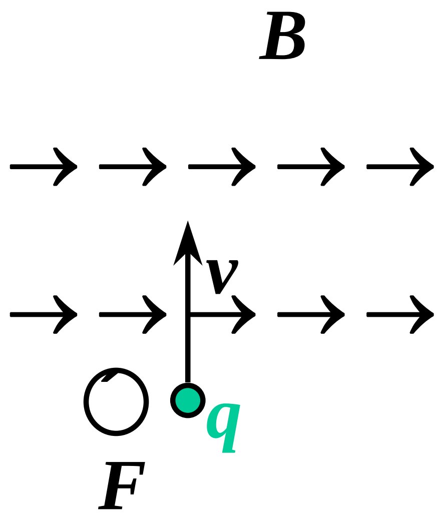
1) Assignment #6 due today
2) This week: Chap 27 (begin magnetism)
3) Need more DC circuit practice (Quiz 3)
4) Assignment 7 (Mastering Physics) online and separate, written problems due next Monday
5) Quiz 3 (redo) on Wednesday

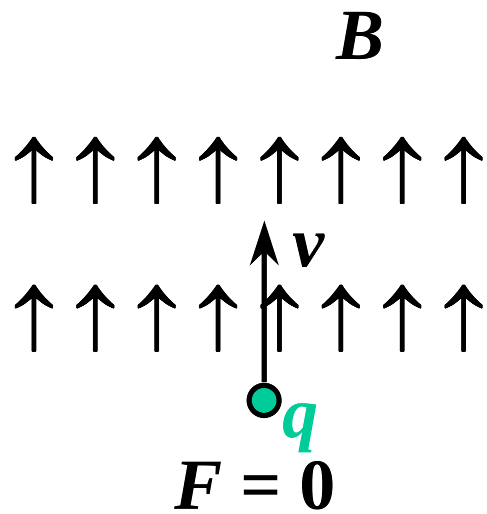
# Magnetism

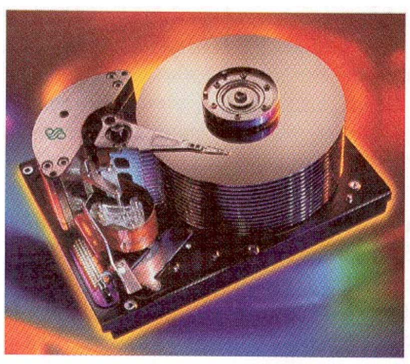
## The Magnetic Force

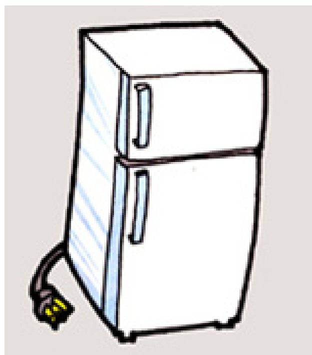
$$\boxed{\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}}$$





# A “bit” of history

IBM introduced the first hard disk in 1957, when data usually was stored on tapes. It consisted of 50 platters, 24 inch diameter, and was twice the size of a refrigerator.

It cost $35,000 annually in leasing fees (IBM would not sell it outright). It’s *total* storage capacity was 5 MB, a huge number for its time!

## History of Magnetic Fields

• Earliest mention (~800BC) of magnetic effects are from rocks, called lodestones, which were a natural occurring permanent magnet.

• Early seafarers used lodestones as compasses. The word, lode, means "way or course" in middle English, so lode+stone meant a "direction stone" for the sailors. In similar usage, is the "lodestar", which is Polaris north star used by sailor to know which direction was north.

• Lodestones contain magnetite. It is believed that iron ore became magnetized when the lightning struck the iron ore with high current and magnetized the iron, creating the magnetite.

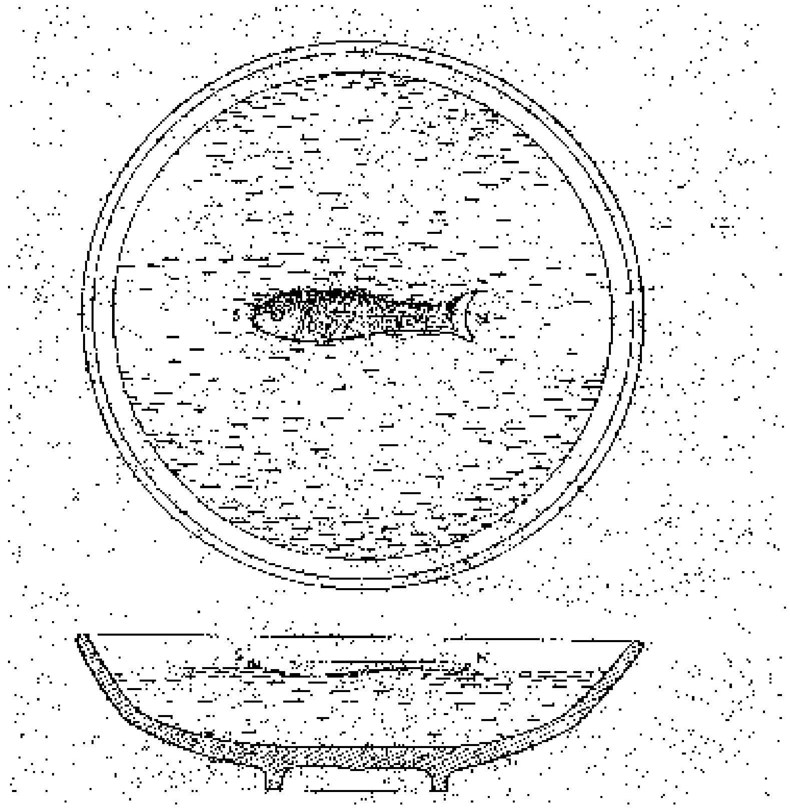
• Many superstition beliefs existed about lodestones

# Interesting superstitions about lodestones

*"Placed on the pillow of a guilty wife, it would make her confess her iniquities as she slept. It could be used for the treatment of many ailments, and as a contraceptive. There were curious beliefs that its effects could be countered by garlic or onions. It was said that sailors should be forbidden to eat these vegetables, in case their breath should demagnetise the needles."*

# Early Chinese Compass

A floating fish-shaped iron leaf, mentioned in the Wu Ching Tsung Yao which was written around 1040AD.



Lodestone (magnetite) floating in a dish of water, would point North

Modern compass with magnetic pointer in a liquid filled container, used by hikers

# Magnetic Properties

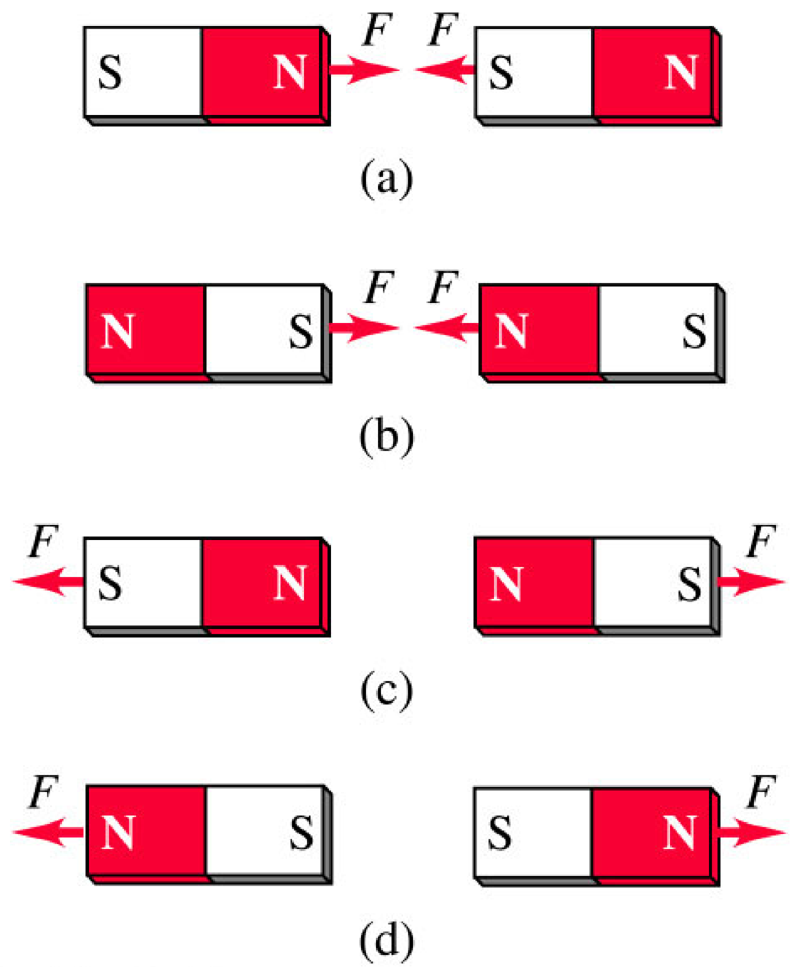
• All magnets are found to have a **PAIR** of points of attraction/repulsion,
called the NORTH and SOUTH poles.

• N & S poles attract

• N & N or S & S poles repel

• If the magnet is broken into two pieces, there are still a Pair of North & South poles.

• Mr. Coulomb actually measured the force and found the force is inversely proportional with distance.

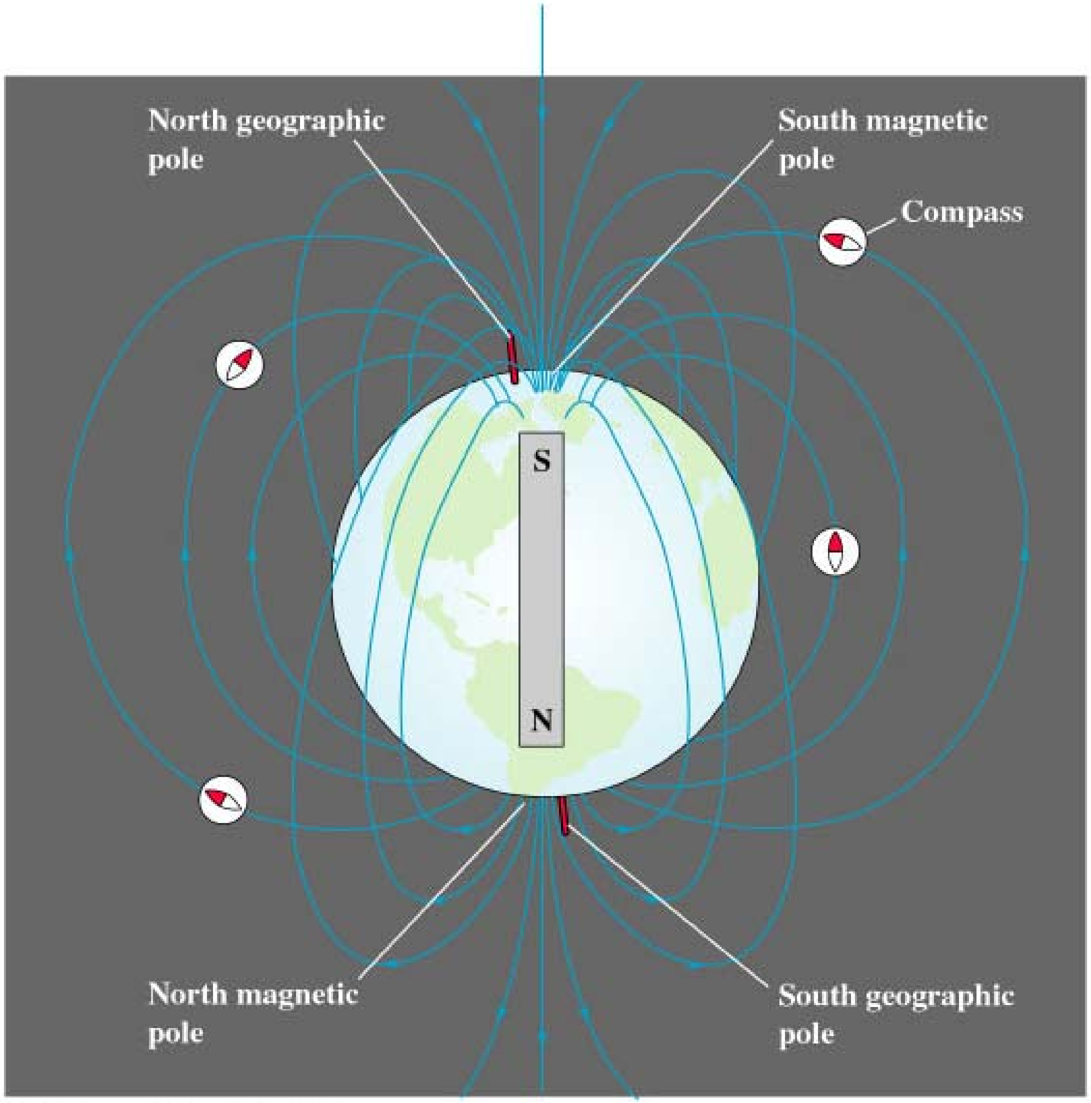


# Earth forms a large magnet

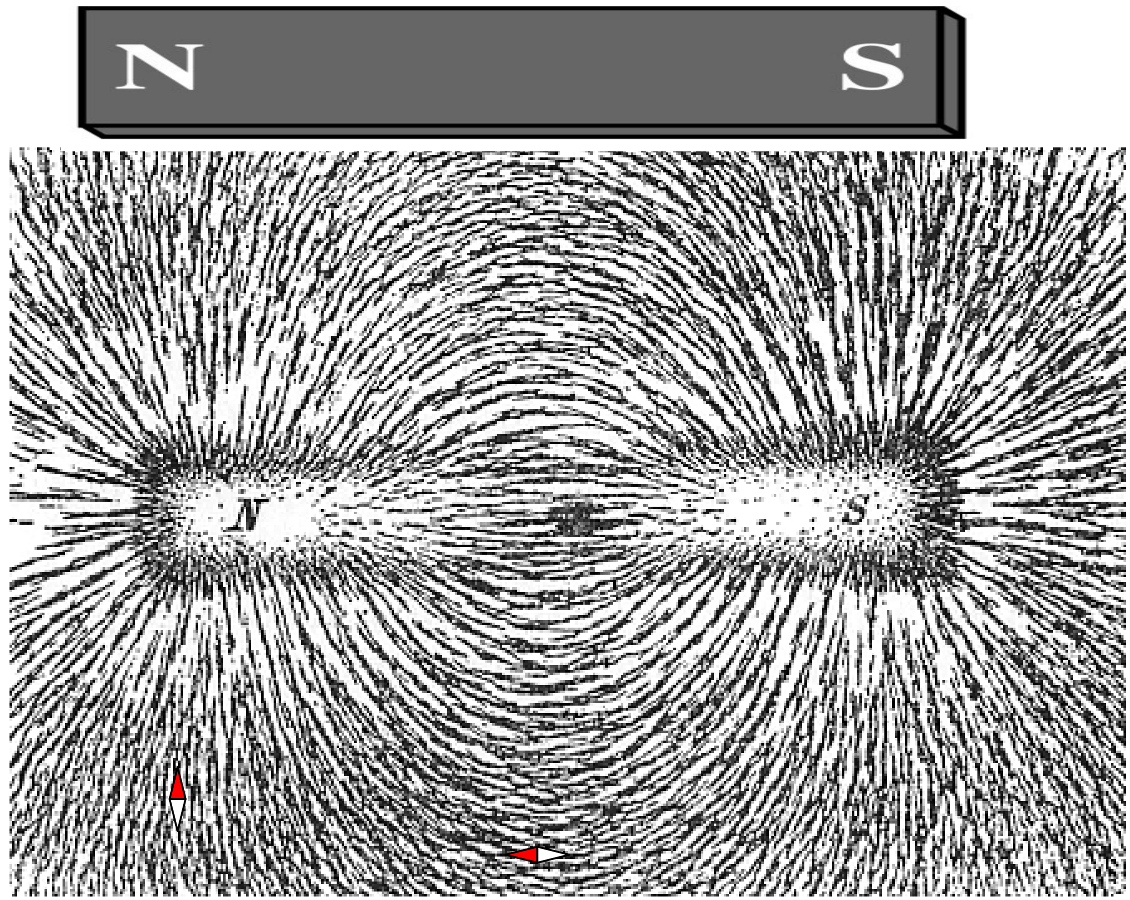
• Earth has a magnetic Field as drawn with blue lines.

• Compass, or free floating magnet, would align its N-pole direction along the earth's magnetic field line.

• Note the Earth's magnetic South-poles is at the Earth's geographic North pole

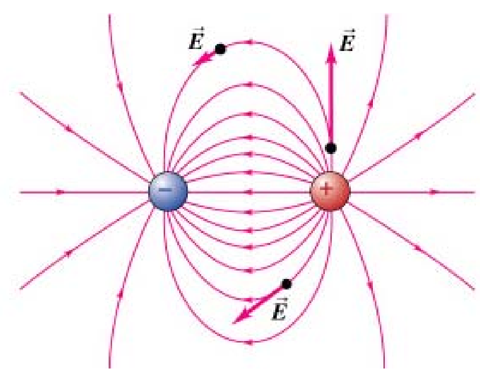


# Bar magnet sprinkled with iron filings



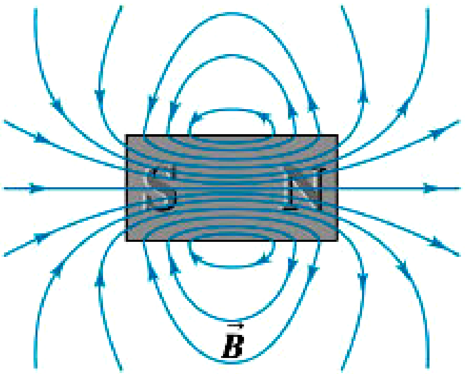

- If we place bar magnet underneath a paper and then sprinkle iron filings on the paper, the filings behave like tiny compasses and align themselves along magnetic field lines.

**Magnetic Field lines are similar in direction to Electric Field lines from an electric dipole**

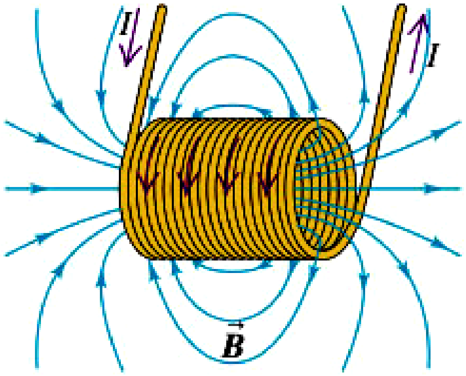


## Sources of Magnetic Fields, $\vec{B}$

• We study in detail the sources of magnetic fields in Chap 28, which are created from permanent magnets, currents and moving charges




(a) Magnetic field lines through the center of a permanent magnet




(b) Magnetic field lines through the center of a cylindrical current-carrying coil

• <u>For now (this week in Chap 27), lets assume there exist</u> vector magnetic fields. They will look similar to electric fields, that is at each position in space there are a field lines with direction and magnitude. The unit of the magnetic field is given in units of Tesla ("T"). We will mostly be concerned with constant magnetic field examples.

# Lorentz Force Law

• The force on a moving charged particle is given by,

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

Where q is the charge, $\vec{v}$ is the vector velocity and $\vec{B}$ is the magnetic Field in units of Tesla, T.

• NOTE if the particle is not moving, it has NO force from $\vec{B}$ field

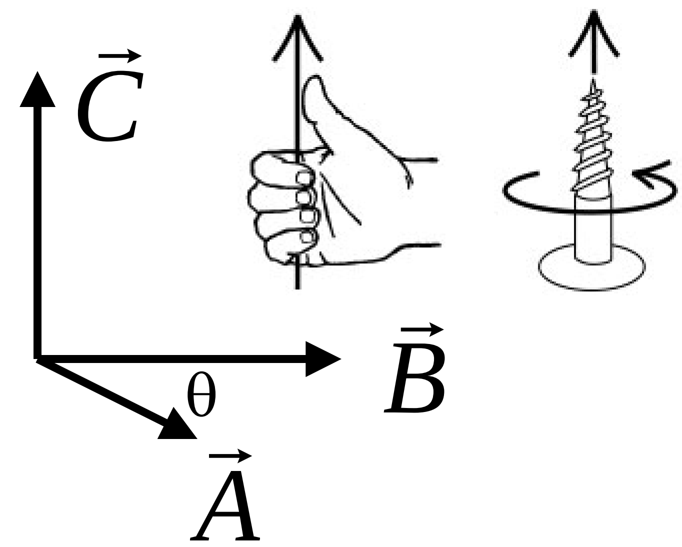
• NOTE the force is perpendicular to the velocity, hence the velocity magnitude does not change, but the direction changes. This is similar to Centripetal acceleration.

# Vector Cross Product

$$\vec{C} = \vec{A} \times \vec{B}$$

Use right hand rule to get vector C direction and ABsinθ to get magnitude

$$\left|\vec{C}\right| = \left|\vec{A}\right|\left|\vec{B}\right|\sin\theta$$




Rotate A into B with your finger tips. Thumb points into C direction

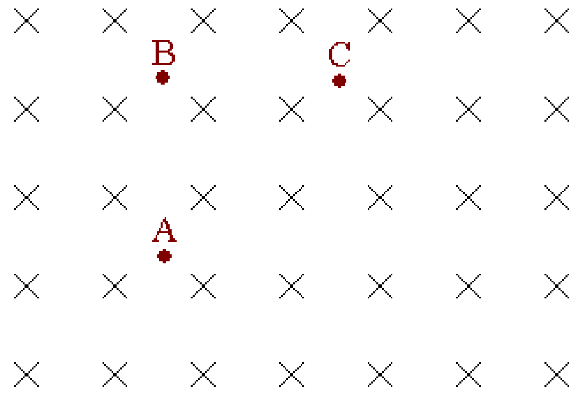
2nd Useful formula for vector cross product in component form

$$\vec{C} = \left(A_y B_z - A_z B_y\right)\hat{x} + \left(A_z B_x - A_x B_z\right)\hat{y} + \left(A_x B_y - A_y B_x\right)\hat{z}$$

Question 1:

Three points are arranged in a uniform magnetic field. The **B** field points into the screen.

Magnetic Force: $\vec{F} = q\vec{v} \times \vec{B}$




1) A positively charged particle is located at point A and is stationary. The direction of the magnetic force on the particle is:

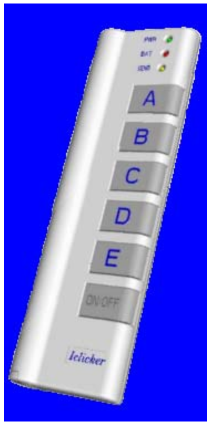
a) right

b) left

c) into the screen

d) out of the screen

e) zero



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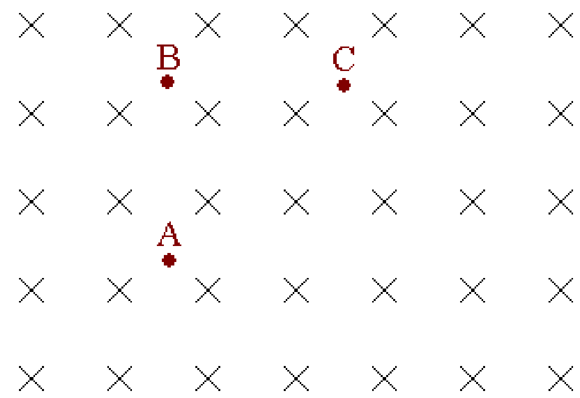


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1) A positively charged particle is located at point A and is stationary. The direction of the magnetic force on the particle is:

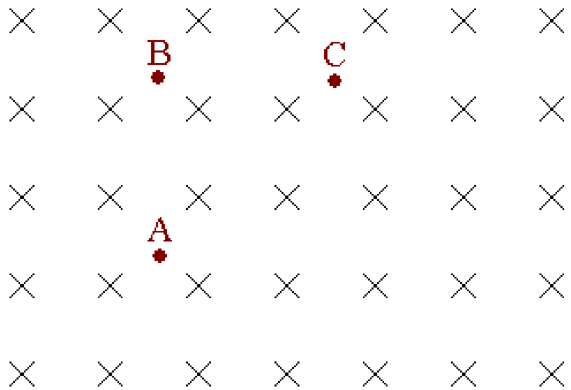
a) right b) left c) into the screen

d) out of the screen e) zero

If $v = 0 \Rightarrow F = 0$.

Question 2:

Three points are arranged in a uniform magnetic field. The **B** field points into the screen.

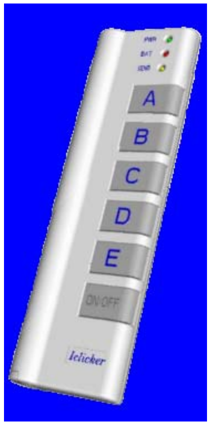



Magnetic Force: $\vec{F} = q\vec{v} \times \vec{B}$

2) The positive charge moves from point A toward B. The direction of the magnetic force on the particle is:

a) right b) left c) into the screen

d) out of the screen e) zero



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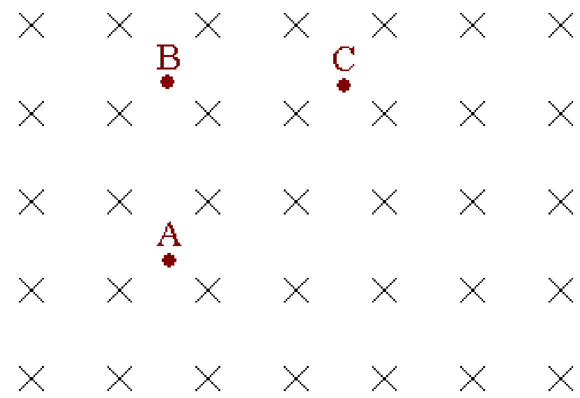



2) The positive charge moves from point A toward B. The direction of the magnetic force on the particle is:

If $\vec{v} \perp \vec{B}$ then $F = qvB$

a) right

b) left

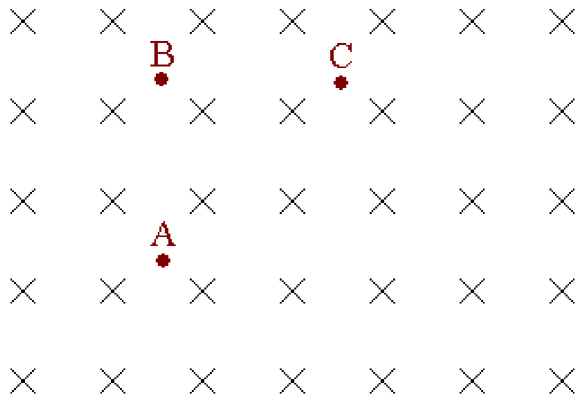
c) into the screen

d) out of the screen

e) zero

If $v$ is up, and $B$ is into the page, then $F$ is to the left.

Question 3:



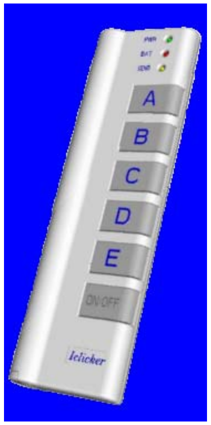

3) The positive charge moves from point A toward C. The direction of the magnetic force on the particle is:

a) up and right

b) up and left

c) down and right

d) down and left



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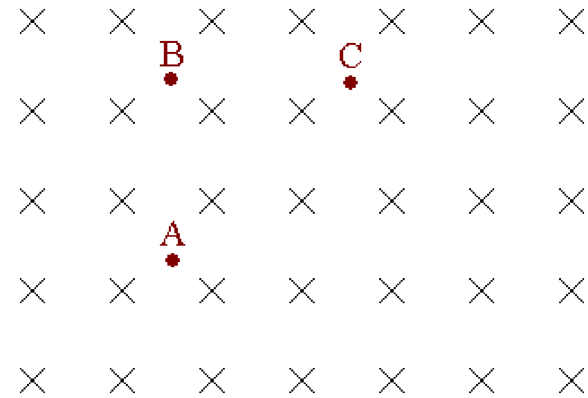



3) The positive charge moves from point A toward C. The direction of the magnetic force on the particle is:

a) up and right

b) up and left

c) down and right

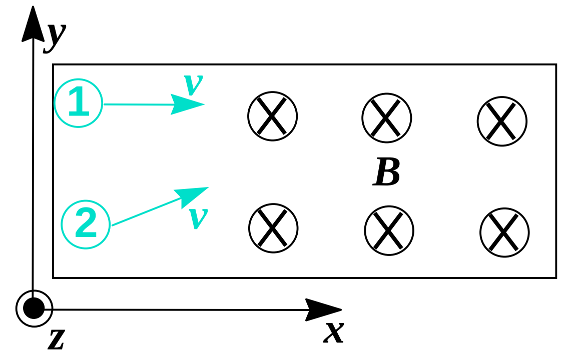
d) down and left

Magnetic Force: $\vec{F} = q\vec{v} \times \vec{B}$

If $v$ is up and to the right, it is still perpendicular to $B$, hence $F = qvB$ then and $F$ is up and to the left.

# Question 4a

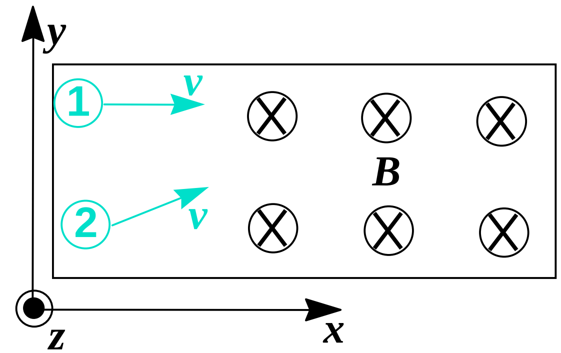
- Two protons each move at speed *v* (as shown in the diagram) in a region of space which contains a constant B field in the -*z*-direction. Ignore the interaction between the two protons.
  - What is the relation between the magnitudes of the forces on the two protons?




(a) $F_1 < F_2$ (b) $F_1 = F_2$ (c) $F_1 > F_2$

# Question 4a

- Two independent protons each move at speed *v* (as shown in the diagram) in a region of space which contains a constant B field in the -*z*-direction. Ignore the interaction between the two protons.




  – What is the relation between the magnitudes of the forces on the two protons?

(a) $F_1 < F_2$ (b) $\boxed{F_1 = F_2}$ (c) $F_1 > F_2$

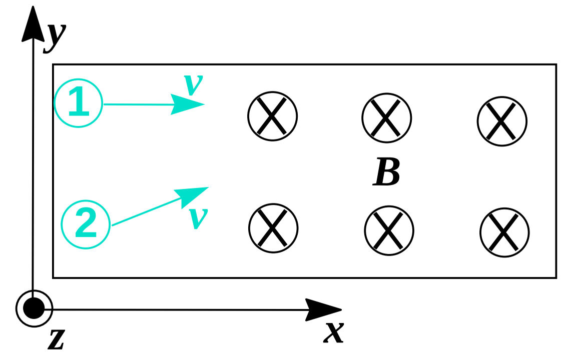
- **The magnetic force is given by:**

$$\vec{F} = q\vec{v} \times \vec{B} \Rightarrow |F| = qvB\sin\theta$$

- **In both cases the angle between** $v$ **and** $B$ **is 90°**
**Therefore** $F_1 = F_2$**.**

# Question 4b

- Two protons each move at speed $v$ (as shown in the diagram) in a region of space which contains a constant B field in the -$z$-direction. Ignore the interaction between the two protons.

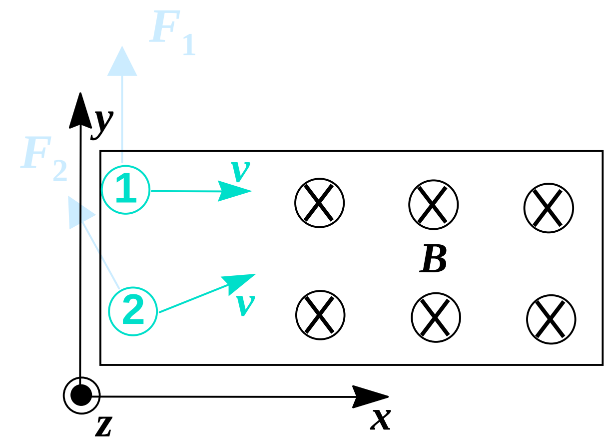



  – What is $F_{2x}$, the $x$-component of the force on the second proton?

(a) $F_{2x} < 0$ (b) $F_{2x} = 0$ (c) $F_{2x} > 0$

# Question 4b

- Two independent protons each move at speed $v$ (as shown in the diagram) in a region of space which contains a constant B field in the -$z$-direction. Ignore the interaction between the two protons.




  – What is $F_{2x}$, the x-component of the force on the second proton?

(a) $\boxed{F_{2x} < 0}$ (b) $F_{2x} = 0$ (c) $F_{2x} > 0$

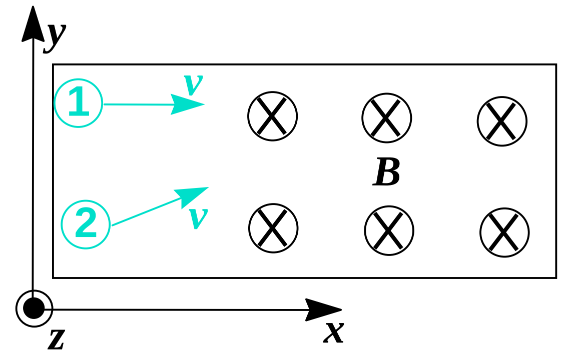
- **To determine the direction of the force, we use the right-hand rule.**

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

- **As shown in the diagram, $F_{2x} < 0$.**

# Question 4c

- Two protons each move at speed $v$ (as shown in the diagram) in a region of space which contains a constant B field in the -$z$-direction. Ignore the interaction between the two protons.

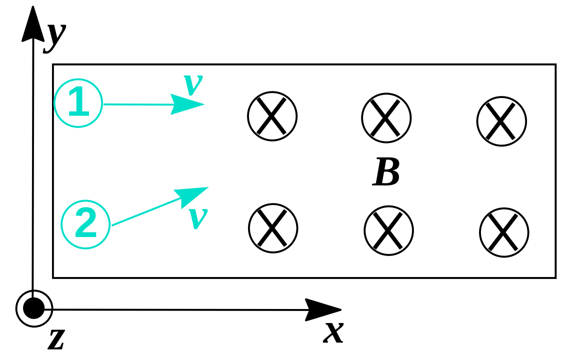



  - Inside the **B** field, the <u>speed</u> of each proton:

(a) **decreases** (b) **increases** (c) **stays the same**

# Question 4c

- Two protons each move at speed $v$ (as shown in the diagram) in a region of space which contains a constant B field in the -$z$-direction. Ignore the interaction between the two protons.
  - Inside the B field, the *speed* of each proton:



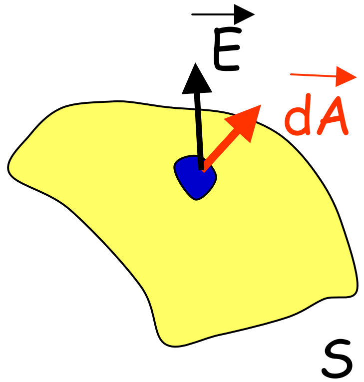

(a) **decreases** (b) **increases** $\boxed{\text{(c) stays the same}}$

**Although the proton does experience a force (which deflects it), this is *always* $\perp$ to $\vec{v}$ . Therefore, there is *no possibility to do work*, so kinetic energy is constant and $|\vec{v}|$ is constant.**

# Magnetic Flux

• Recall that we introduced the electric flux as the product of the electric field and the area

$$\Phi_E = \int_S \vec{E} \cdot d\vec{A}$$




and this resulted in Gauss' Law

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

• Lets introduce the analog, the magnetic flux as the product of the magnetic field and the area

$$\Phi_B = \int_S \vec{B} \cdot d\vec{A}$$

The units are Tesla·m², which are called a Weber (Wb)

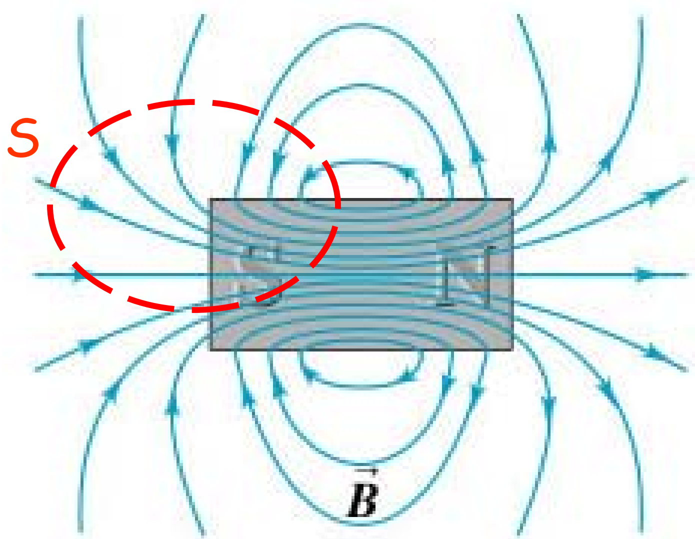
# Magnetic Flux Law

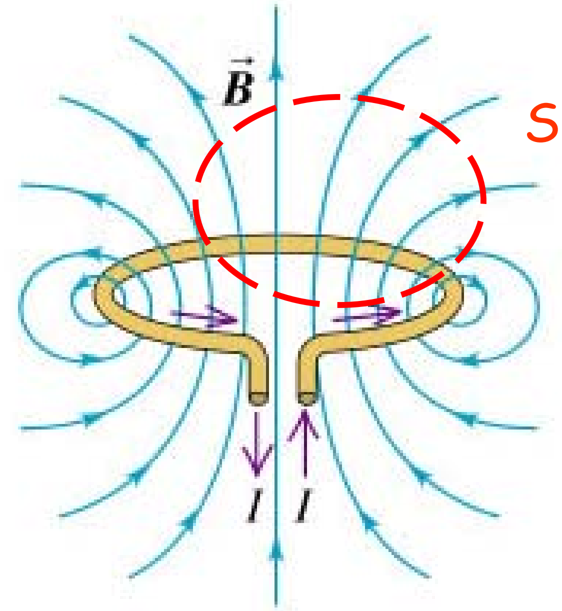
- We now state the magnetic flux law (analogous to Gauss' Law)

$$\Phi_M = \oint \vec{B} \cdot d\vec{A} = 0$$

- The net magnetic flux through any enclosed surface is always ZERO

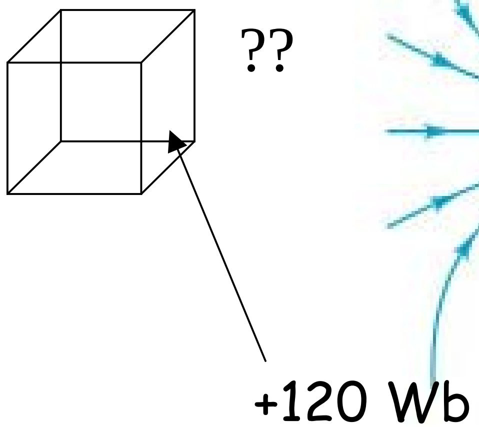
This might be interpreted as non-existence of magnetic charges and the fact that all magnetic lines form a loop (do not start/end on a charge).

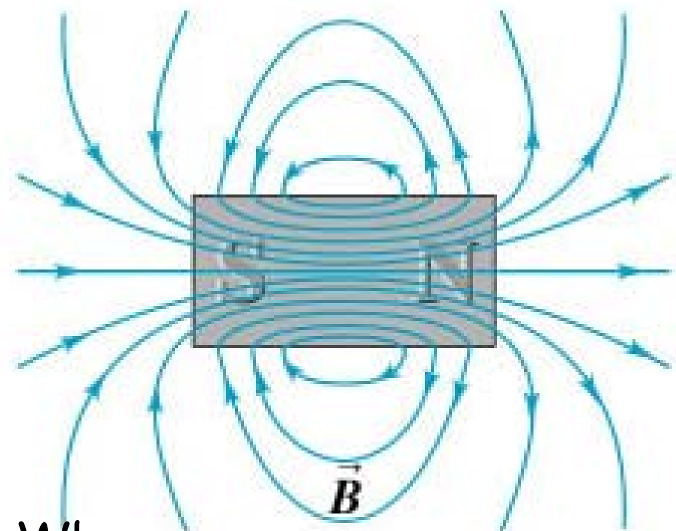


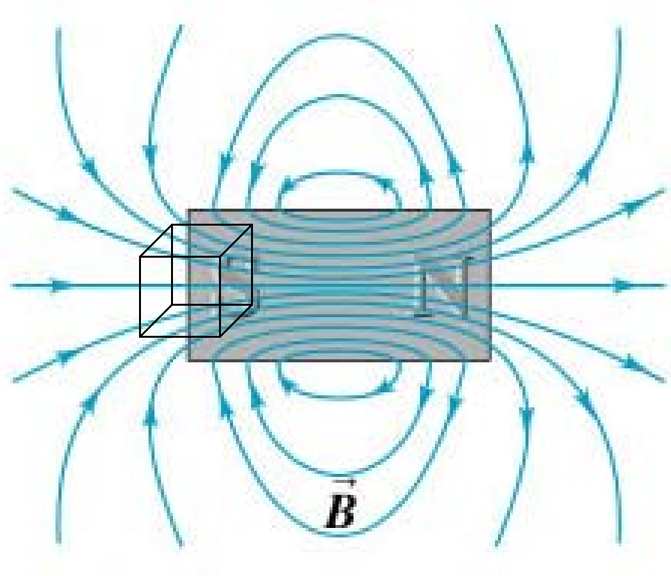

Any enclosed surface will have net magnetic flux = zero
above are B fields from bar magnet and current loop

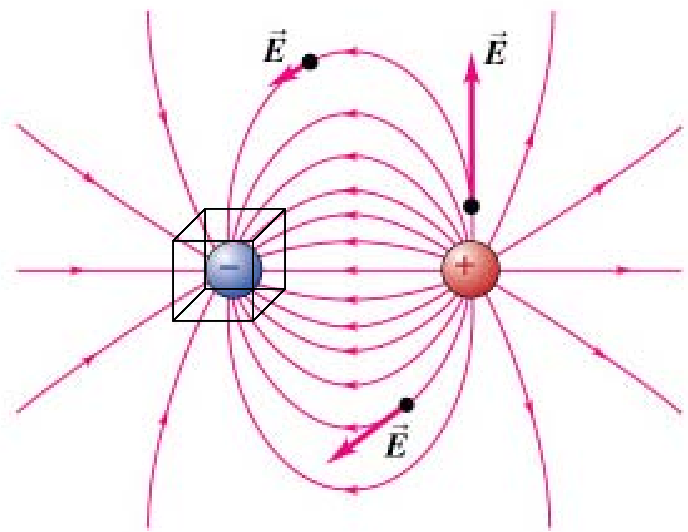
Example: Y&F problem 27.10
The magnetic flux through one face of a cube is +120Wb
A) What must the total magnetic flux through the other five faces of the cube be?
B) Why did you not need to know the dimensions of the cube in order to answer part A)?
C) Suppose the magnetic flux is due to a permanent magnet, show Where the cube in part (A) might be be located



# Comparison between bar magnet & E-dipole




The magnetic lines form closed loops. The electric fields start on the +charge and end on the –charge. So if we place a closed Gaussian box around a charge, we get non-zero electric flux. If we place a closed box anywhere in the bar magnet case, we always get zero magnetic flux. There are NO such things in nature such as free "magnetic charges". These hypothetical particles are called "magnetic monopoles".

Example: Y&F 21.12

The magnetic field B in a certain region is 0.128 T, and its direction is that of the *z*-axis in the figure.

A) What is the magnetic flux across the surface *abcd* in the figure?

B) What is the magnetic flux across the surface *befc*?

C) What is the magnetic flux across the surface *aefd*?

D) What is the net flux through all five surfaces that enclose the shaded volume?

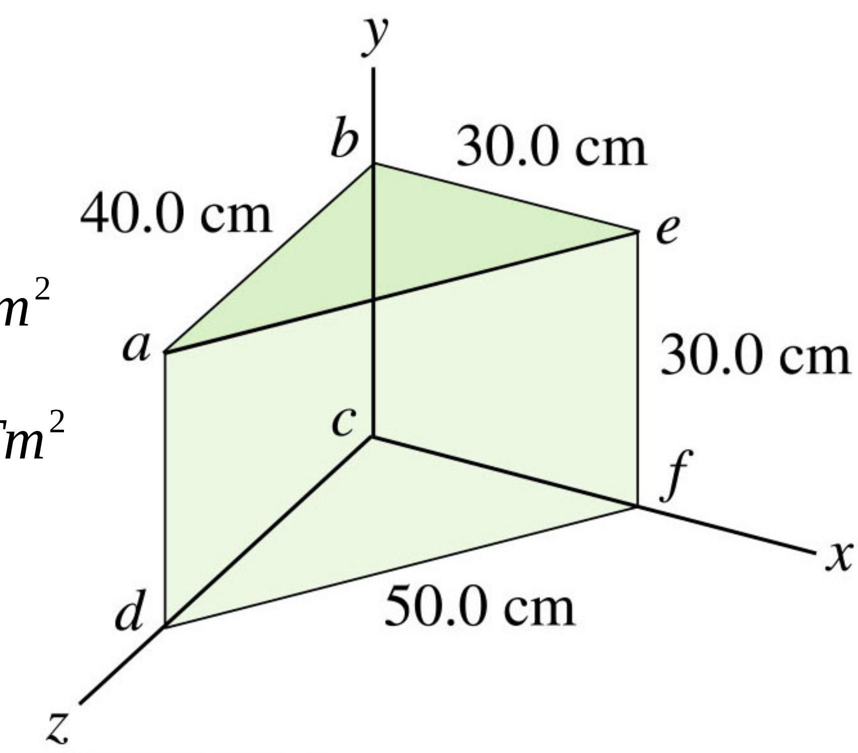
$$\Phi = \vec{B} \bullet d\vec{A} = B\,dA\cos\theta$$

$$\Phi_{abcd} = 0$$

$$\Phi_{befc} = -(0.128T)(0.09m^2) = -0.0115Tm^2$$

$$\Phi_{aefd} = (0.128T)(0.15m^2)(\frac{3}{5}) = 0.0115Tm^2$$

$$\sum \Phi = 0$$



# PH272 Half Time Remark

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

The above two equations are TWO of the FOUR fundamental equations from Maxwell, called Maxwell's Eqns.

➔ Maxwell's Eqns. predict and govern all of the physics of electricity and magnetism. We're HALF-way through understanding all of electromagnetic science.

# For next time

- HW #7 Assigned → due next Monday

- Quiz #3 (anon) on Wednesday

- Leaving Electricity → read up on Magnetism (they are actually the same force – the electro-magnetic force)