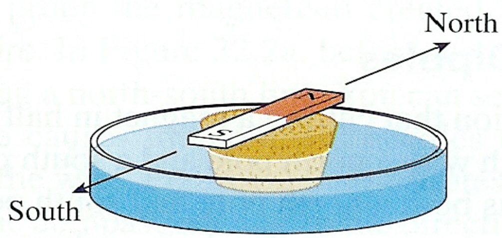
Lecture 14: Chapter 32 Beginning, October 20 2005

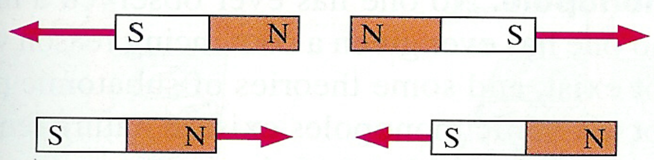
Magnetism is not the same as electricity: Electroscope and Compass

eriment 1

bar magnet is taped to a ce of cork and allowed to t in a dish of water, it ays turns to align itself in pproximate north-south ction. The end of a mag- that points north is called *north-seeking pole,* or ply, the **north pole.** The r end is the **south pole.**



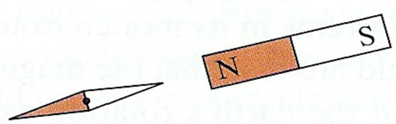
eriment 2



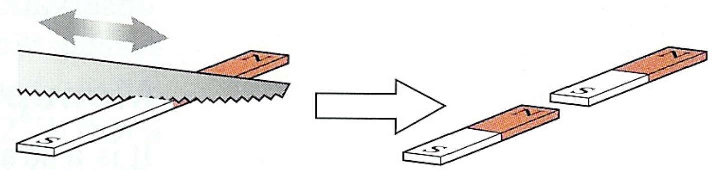
e north pole of one magnet is brought near the north pole of her magnet, they exert repulsive forces on each other. Two h poles also repel each other, but the north pole of one mag- xerts an attractive force on the south pole of another magnet.

riment 3

north pole of a bar magnet cts one end of a compass le and repels the other. rently the compass needle is a little bar magnet with th pole and a south pole.



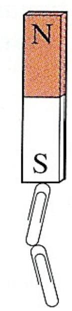
Experiment 4



Cutting a bar magnet in half produces two weaker but still complete magnets, each with a north pole and a south pole. No matter how small the magnets are cut, even down to microscopic sizes, each piece remains a complete magnet with two poles.

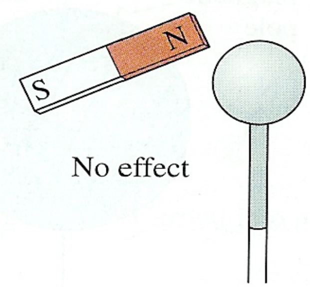
Experiment 5

Magnets can pick up some objects, such as paper clips, but not all. If an object is attracted to one end of a magnet, it is also attracted to the other end. Most materials, including copper, aluminum, glass, and plastic, experience no force from a magnet.



Experiment 6

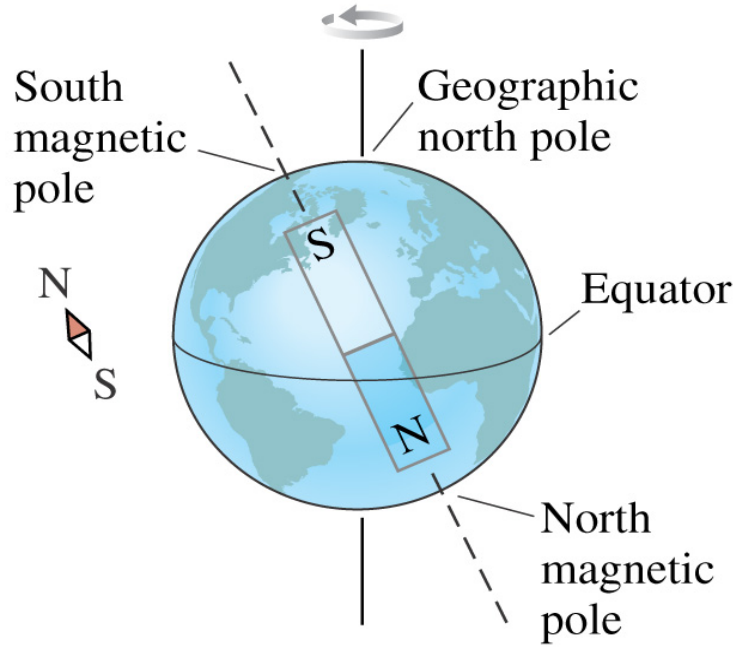
A magnet does not affect an electroscope. A charged rod exerts a weak *attractive* force on *both* ends of a magnet. However, the force is the same as the force on a metal bar that isn't a magnet, so it is simply a polarization force like the ones we studied in Chapter 25. Other than polarization forces, charges have *no effects* on magnets.



Properties of the Magnetic Field

Apparently the earth itself is a large magnet.

The origin – currents in its molten iron core

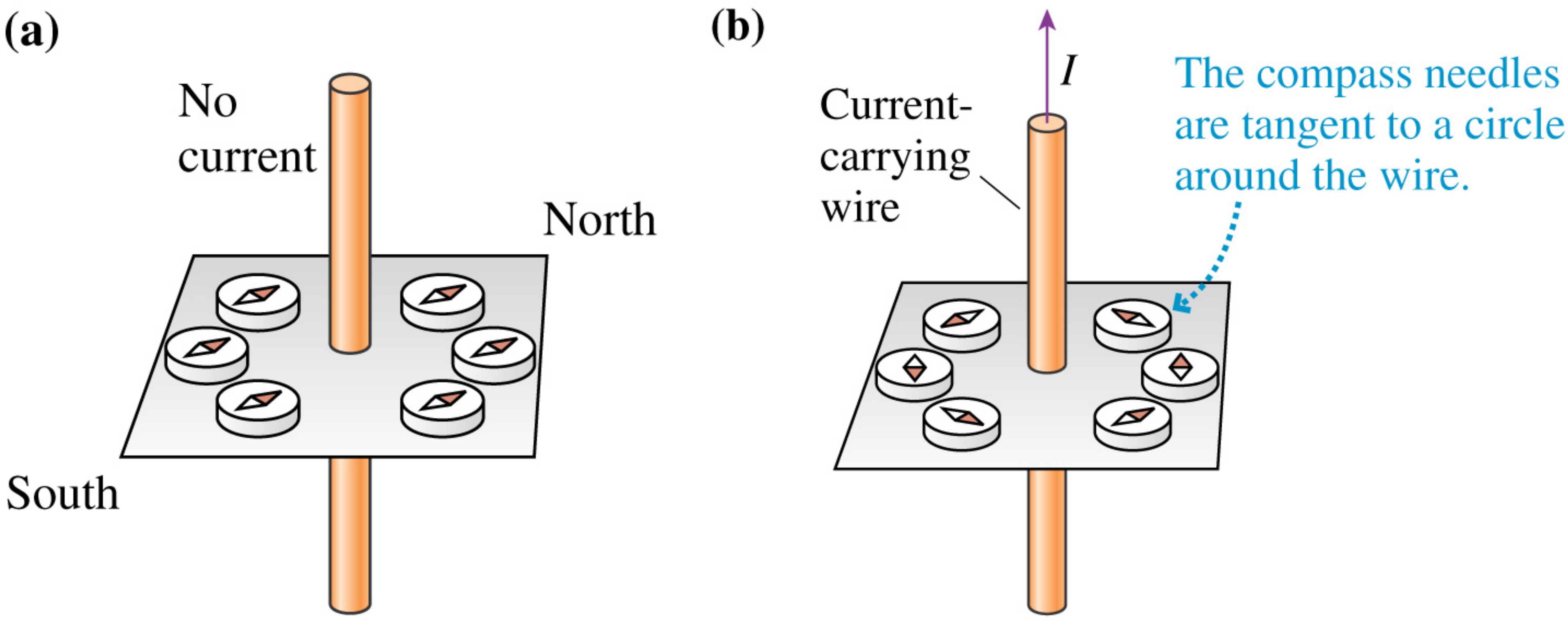


Magnetic monopole does not exist, whereas electric charges do exist separately from electric dipoles

- Magnetism is a long-range force.
- Magnets have two poles.
- The poles of a bar magnet can be identified by using a compass.
- Materials that are attracted to a magnet are called magnetic materials:

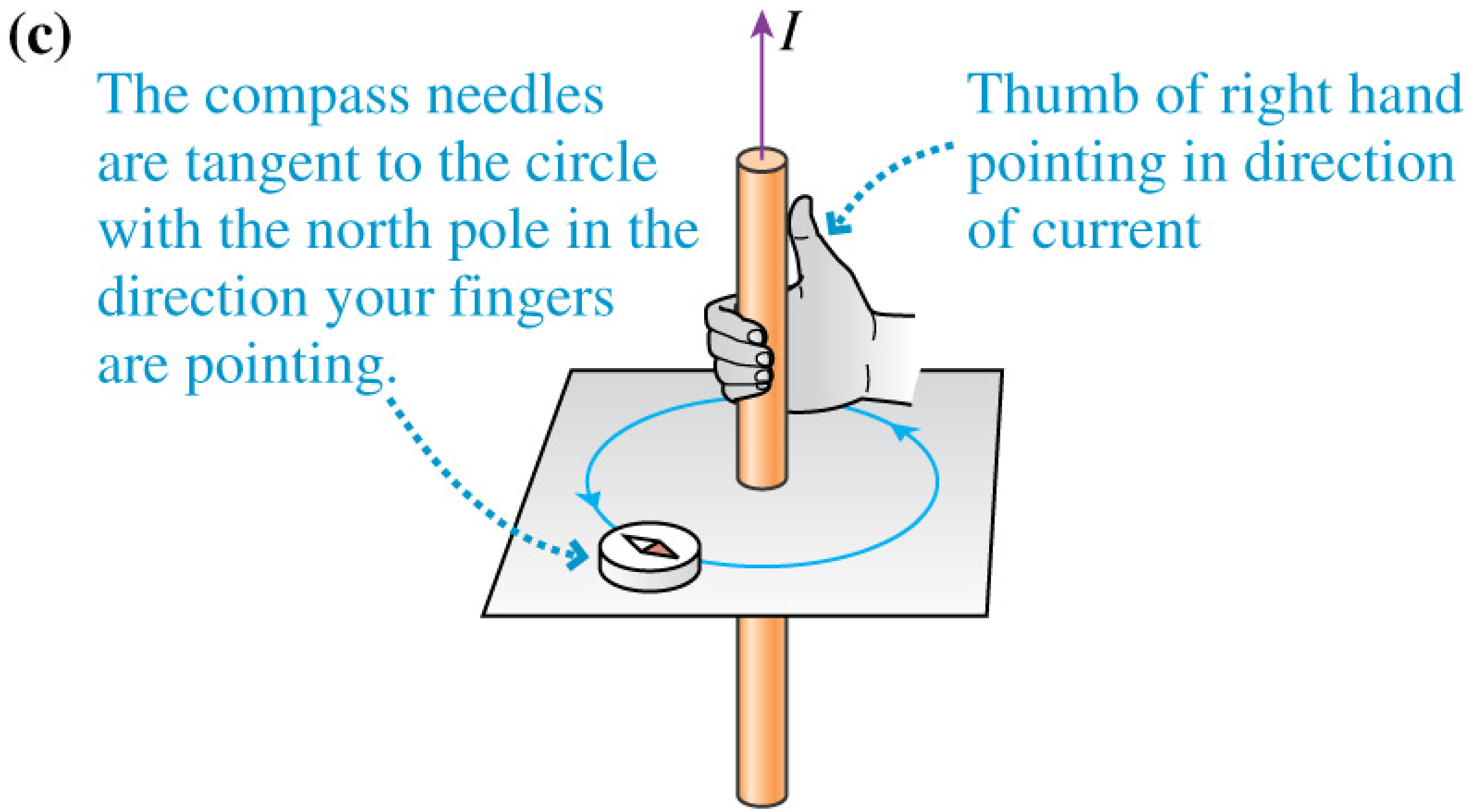
Iron, nickel, cobalt, etc.

The Discovery of the Magnetic Field

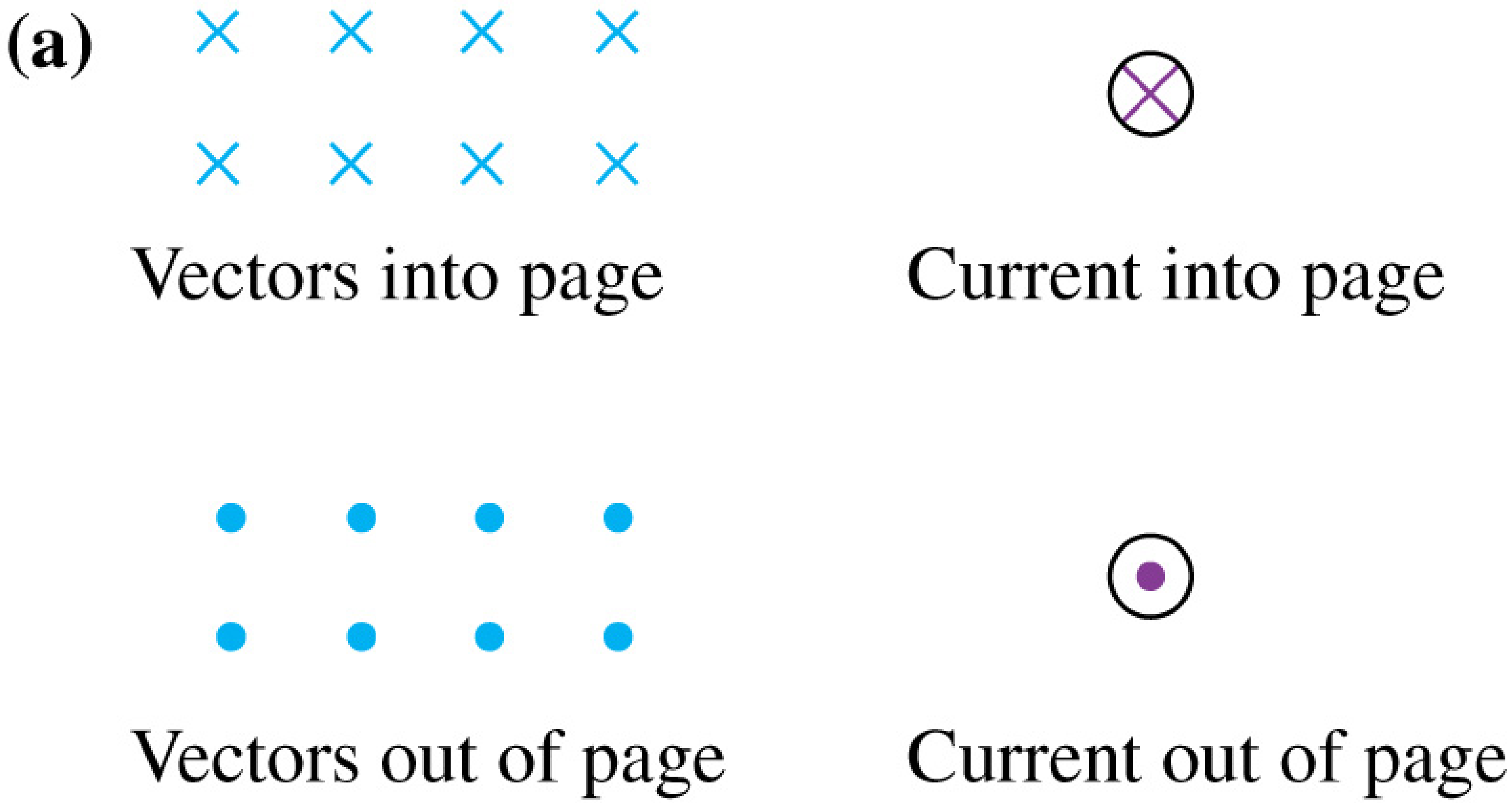


1819 by Hans Christian Oersted:
Magnetism is caused by an electric current

Right-hand rule



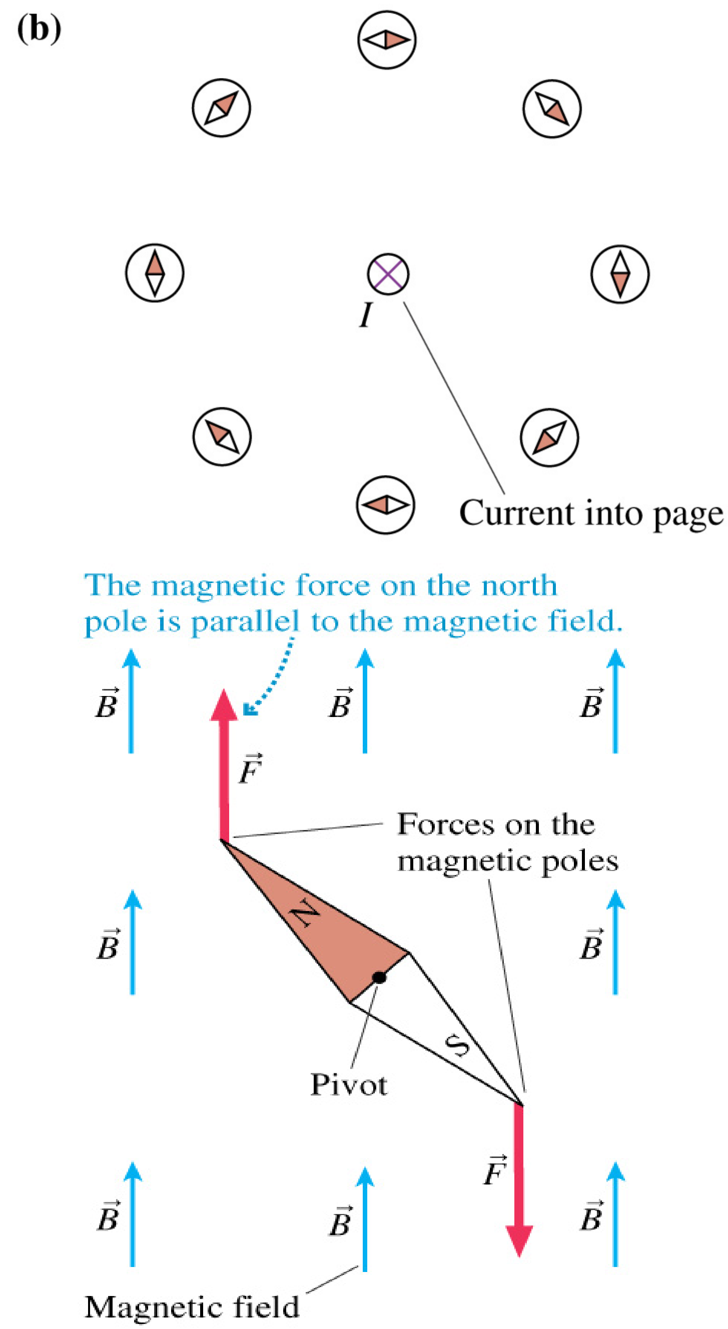
Notation


(a)
Vectors into page
Current into page
Vectors out of page
Current out of page

The Magnetic Field

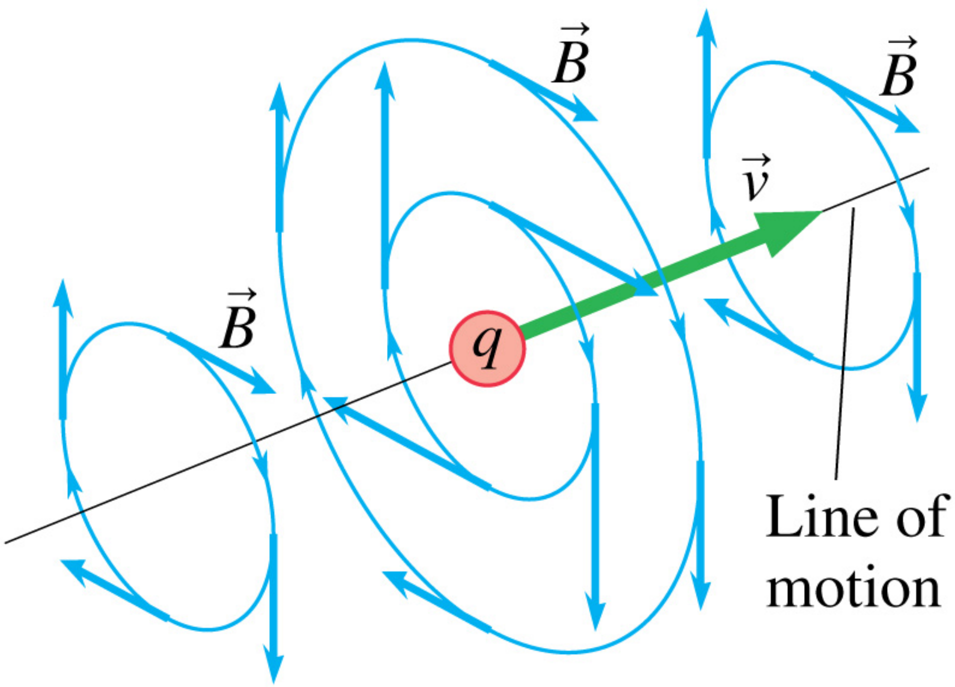
To explain ***long-range*** force let us introduce ***magnetic field B:***

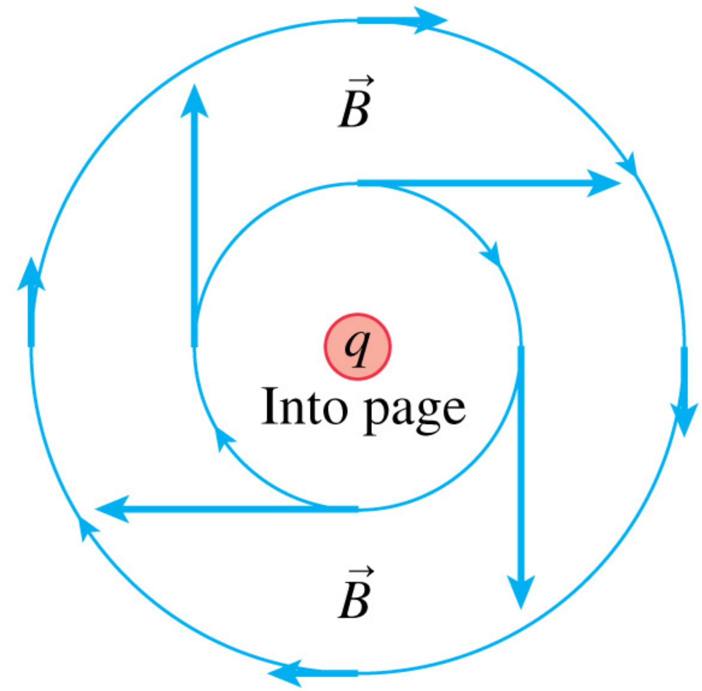
• A magnetic field created at all points in space
• The magnetic field is a vector. It exerts forces on magnetic dipoles:
The force on a north pole is parallel to B.
The force on a south pole is opposite to B.



The Magnetic Field

Basic geometry: Right Hand Rule

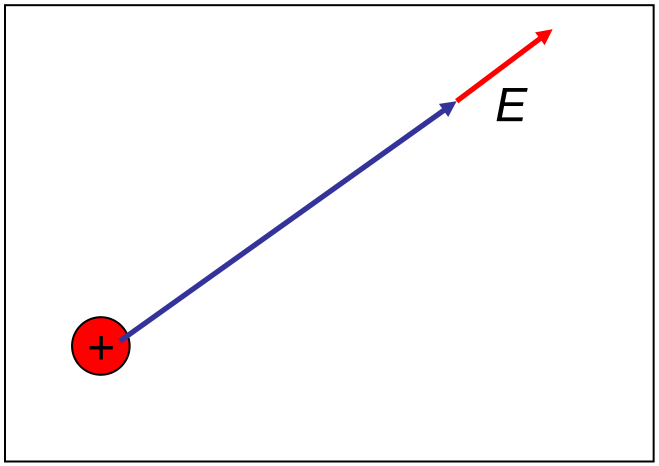




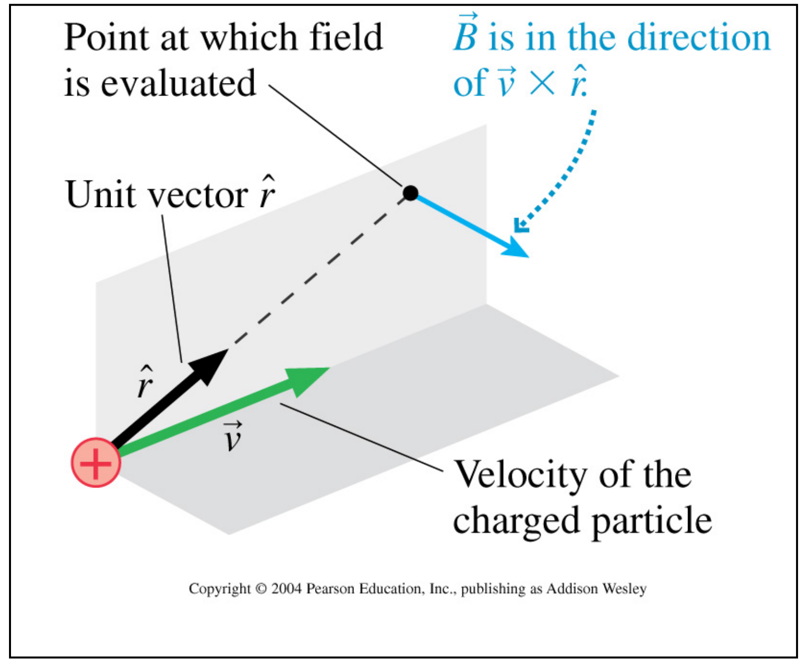
Magnetic forces cause a compass needle to become aligned parallel to a magnetic filed. What is the origin of ***B***? If it is a current, how can we describe ***B*** mathematically?

Let us compare electric and magnetic fields

Electric Field ***E***



Magnetic Field ***B***



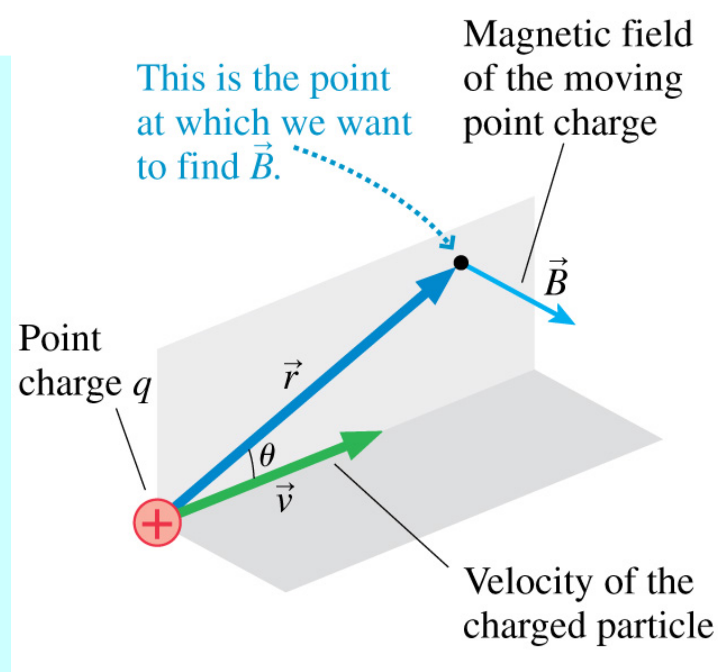
- ***E*** is created by fixed charges, ***B*** is created by moving charges
- The source of ***E*** is *q*, the source of ***B*** is ***qv***
- Both fields (***E*** and ***B***) have inverse square distance law ($\sim 1/r^2$)
- ***E*** is directed along line-of-sight, ***B*** has direction determined by *right hand rule.*

For $q>0$ it has direction of ($q\mathbf{v}\times\mathbf{r}$), for $q<0$ it has opposite direction

Coulomb and Biot-Savart Laws

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$ **Coulomb law**

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{\upsilon}\times\vec{r}}{r^2}$$ **Biot-Savart law**

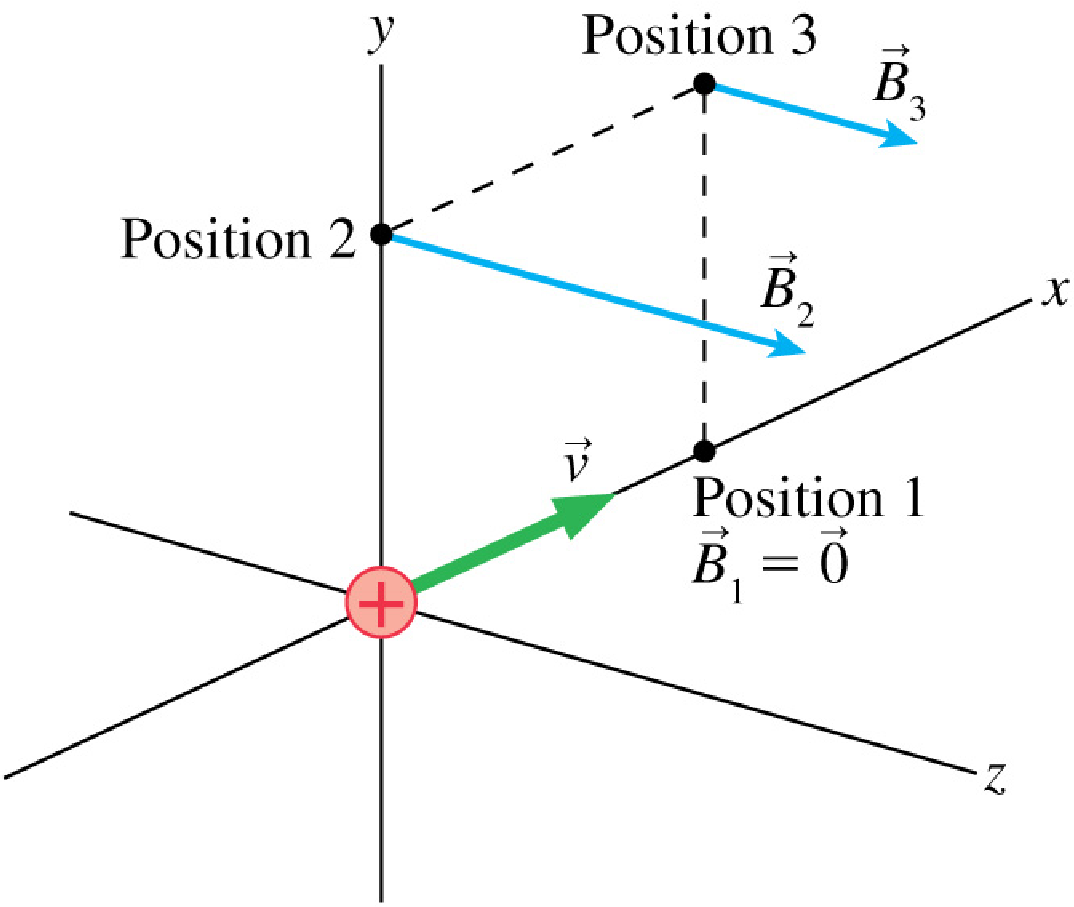


$$\vec{B} = \left(\frac{\mu_0}{4\pi}\frac{q\upsilon\sin\theta}{r^2}, direction:\_right\_hand\_rule\right)$$

The SI unit of magnetic field strength is ***tesla***, abbreviated as T:
1 tesla= 1T = 1 N/Am – see later
Magnetic permeability constant:
$\mu_0 = 4\pi \times 10^{-7}$ Tm/A = 1.257×10^{-6} Tm/A

Magnetic Field of a Proton

$$\vec{B} = \left(\frac{\mu_0}{4\pi} \frac{q\upsilon \sin\theta}{r^2}, direction: \_right\_hand\_rule \right)$$



Find B_1, B_2, and B_3. Express your answer quantitatively.

What is the force exerted on fixed charges at positions 1, 2, and 3?

End of Lecture 14
Reading: Chapter 32
HW7