Prep Notes for Lab #6 – Current Balance

Magnets

There are two types (just like charges) and they are called “Poles”. There are “North” and “South” poles. Some people use “Positive” and “Negative” poles, but that is incorrect. Here, we are trying to differentiate between charges and magnets. We don’t want to use the same terms for different subjects.

Characters of Poles:

Like poles repel and opposite poles attract. (similar to charges)

Poles always come with a pair. There is no mono-pole. (Big difference between charges and magnets) – Mono-pole fans - shut up! Argue this when you take graduate E&M. I am very happy to discuss with you, but not in 231.

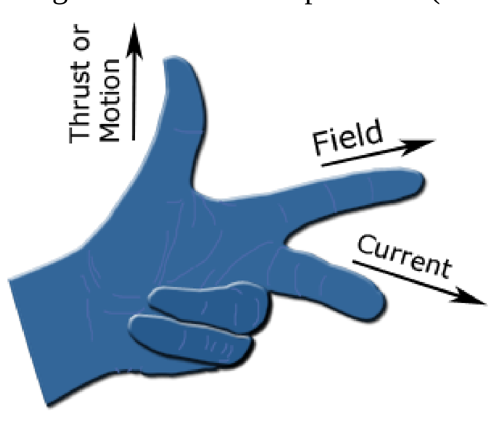
Forces acting on a charge:

Electrostatic (stationary charge) – Electric field (create by other charge(s)) influences the charge (Coulomb Force). Thus, $\vec{F}_{elect} = q\vec{E}$. Note: the direction of the force is along the E-filed.

Electrodynamic (moving charge) – Both electric field and magnetic field (create by other means) influence the charge. $\sum \vec{F}_{net} = \vec{F}_{elect} + \vec{F}_{magnet} = q\vec{E} + q\ (\vec{v} \times \vec{B})$ Note: The direction of the magnetic force is perpendicular to the plane made by velocity and magnetic field vectors, not along either v or B.

Magnetic Field (B) – Somehow, the magnetic field is noted as “B” and I don’t know why. The only thing I can tell is that any letter from the word “magnetic” has been used for other things. That’s why? It should be called “Bagnetic Field”. The direction of the magnetic field is from “N to S” (outside) and “S to N” if it is a physical magnet. For a current, we will use (second) right-hand-rule. This is discussed later.

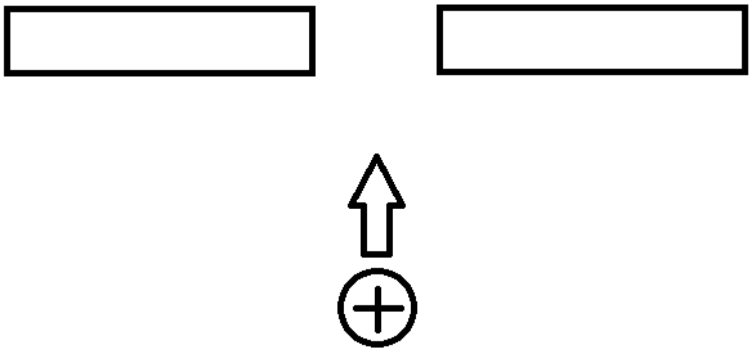
So, the direction of Coulomb force is easy. It is just along the E field vector. However, the direction of the magnetic force is not. It is perpendicular to both v and B. You can find the direction by using the right hand rule (regular vector cross product rule) or Fleming’s Law, also known as the Left Hand Rule. I personally recommend using this because this is more versatile. I was gonna draw a picture for you, but thought it would be easier if I just stole a diagram on the net. So, here it is. Look at the diagram below. The key is to make your **LEFT HAND’s** thumb (F), forefinger (B), and middle finger (I) perpendicular to each other. This is a cute rule (and very helpful rule), because as you can see, it seems like you are making a gun with your left hand, and calling “FBI” from the top. If two (two from F, B, and I) are given and you can align your fingers correctly, you can find the direction of the third component easily.



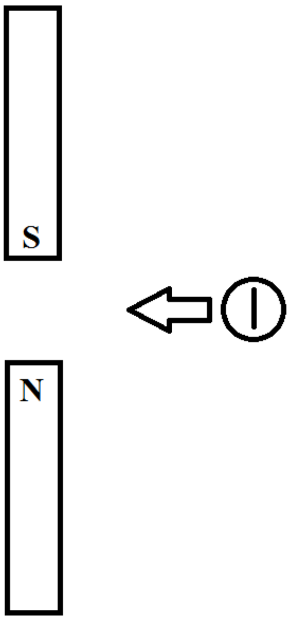
I noticed that there aren’t many schools teaching this rule in the U.S., but they teach this in other countries (all of the foreign students I talked to said that they had learned the left hand rule in their countries.) I think they don’t teach this in this country because somehow, American students can’t tell right and left (I ain’t kidding.) Some 231 students use their right hands for the left hand rule every semester. Why is it so difficult to tell? I don’t know. Let me give you a helpful hint: For right-handed people, the hand you use chopsticks is the right hand and the hand you hold a rice-bowl is the left hand. For left-handed people, it is reversed. Here, I said it. So, I don’t want to see 231 students making mistakes ever again.

Left-Hand-Rule Practice

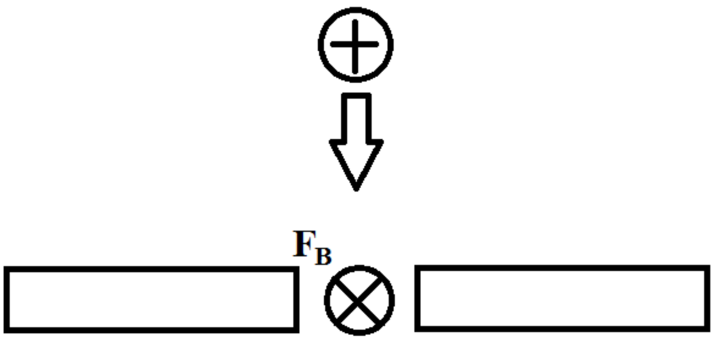
Ex.1 Direction of the force (F_B) Pick "N" and "S" first.



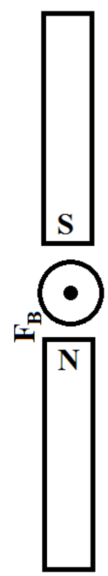
Ex. 2



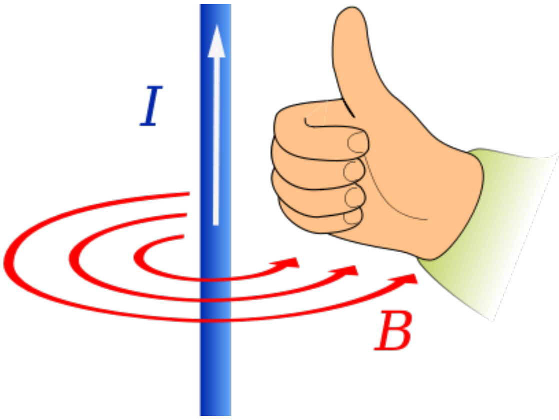
Ex. 3 Indicate "N" and "S"



Ex. 4 Indicate the direction of electron motion



Why is a moving charge influenced by an existing magnetic field? It is found that a moving charge creates “magnetic field” around it. Now, we have two magnets and they influence each other. The direction of magnetic field created by the moving charge is found by using the (second) “Right-Hand-Rule”. Once again, the diagram came from the web.

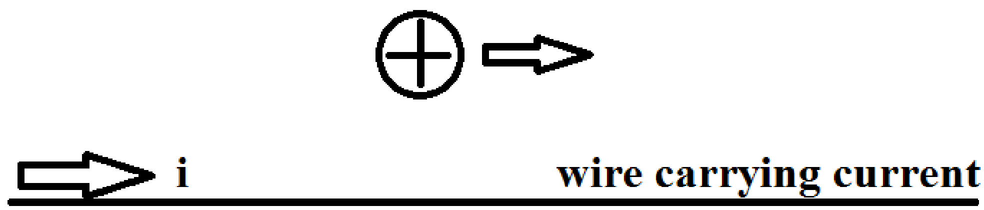


Your (right) thumb is the direction of “current” and other fingers show the direction of B-field (can I start using B instead of spelling out “magnetic”? Actually, this was not a question. You have to get used to. You ain’t got no choice!)

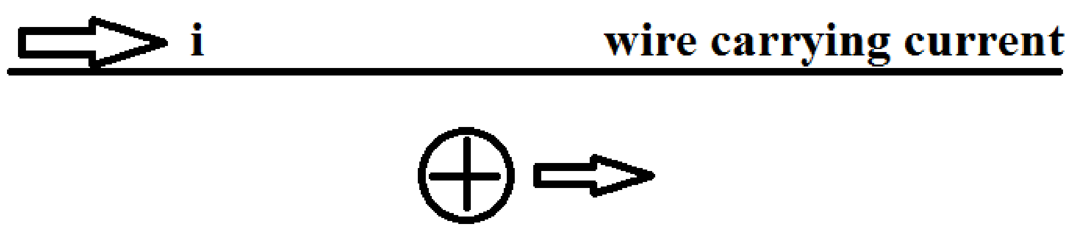
Notice that in this case, there is no starting point or ending point for the B-field. It just circulates. However, if you pick a point, the direction of the B-field is always tangent (Just like a velocity vector for a circular motion is tangent to a circle). Another thing that I want you to be careful is that the B-field created by a moving charge exists only **AROUND** the charge and **NEVER THROUGH** it. I am emphasizing this because this is a typical mistake students make. If B-field (created by the moving charge) exists where the moving charging is located, the charge will be deflected by its own magnetic field. If this is possible, you should be able to lift yourself by pulling up your hair. **The key is to identify who creates “B-field” and who gets “F_B”.**

Find the direction of F_B

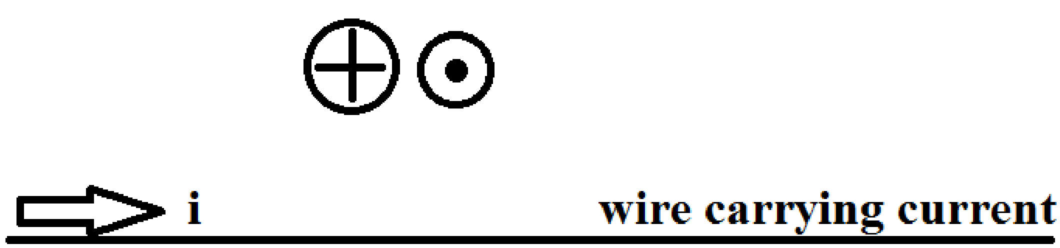
Case 1



Case 2



Case 3



Actual Lab part: Refer the lab manual:

d: The distance from the center of the top rod to the center of the bottom rod.

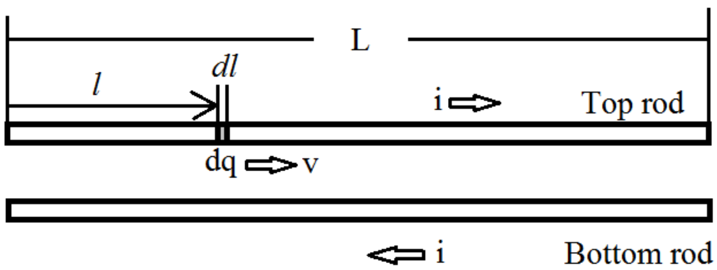
$d = (D_{top} + D_{bottom}) \div 2 + (|Reading_{initial} - Reading_{final}| \div 2) \times ratio$

a: The distance from the mirror to the center of the top rod

L: The distance from the center of the right rod to the center of the left rod (where effective current runs)

Measure the distance from outside edge of the side rod to the other outside edge. Use a caliper to measure diameters of the side rods to calculate L.

Derivation of $F_B = iLB$ for rod (make sure to understand which i is responsible for what.)



Focus on a small chunk of the top rod, *dl*.

B created by the bottom rod at *dl* is into the page (right hand rule). Hence the force acting on dq (in *dl*) is up (left hand rule).

$\therefore\ d\vec{F}_B = (dq)\,\vec{v} \times \vec{B}_{\text{by the bottom rod}}$

For the total force acting on the top rod is:

$$F_{B,net} = \int (dq)\,\vec{v} \times \vec{B}$$

$$= \int (i\,dt)\left(\frac{dl}{dt}\right)B, \qquad \text{since } i = \frac{dq}{dt},\ v \perp B,\ v = \frac{dl}{dt}$$

$$= \int_0^L i\,dl\,B$$

$$= i_{top} L B_{bottom}$$

B_{bottom} will be derived in the class (with both hard way and easy way). Here it is give as $B_{bottom} = \frac{\mu_0 i_{bottom}}{2\pi r}$, where r = d in this case. ($\mu_0 = 4\pi \text{ X } 10^{-7}$) Combining the two, we get

$F_{B,net} = i_{top} L\left(\frac{4\pi \text{ X } 10^{-7} i_{bottom}}{2\pi d}\right)$, because $i_{top} = i_{bottom}$ (only in this case)

$$= 2 \times 10^{-7} \frac{L}{d} i^2$$