Magnetic Fields -- Conceptual Solutions

1.) What is the symbol for a magnetic field? What are its units? Also, what are magnetic fields, really?

Solution: As a vector, the symbol for a magnetic field is ***B***. Its units are *teslas*. In reality, magnetic forces are relativistic effects brought on by the interaction of charge in motion with charge in motion. This phenomenon was observed before Einstein's relativity existed. As a consequence, the observers attributed to the phenomenon a new, special vector field. They called that vector field a *magnetic field*.

2.) What are magnetic forces? That is, how do magnetic forces act; what do they act on; what, in general, do they do?

Solution: Within the context of what has become known as *the classical theory of magnetism*, magnetic fields create forces on charges whose motion cuts across magnetic field lines. That is, magnetic fields are associated with magnetic forces, but they aren't modified force fields the way electric fields are. Magnetic forces accelerate moving charge centripetally according to the relationship $\boldsymbol{F} = q\boldsymbol{v}x\boldsymbol{B}$, where q is the size of the charge moving with velocity $\boldsymbol{v}$ through the magnetic field $\boldsymbol{B}$.

3.) Give two ways you can tell if a magnetic field exists in a region of space.

Solution: The easiest way to detect a magnetic field is with a compass. A more obscure way is to shoot a charged particle through the region. If its path arcs, assuming the change of direction can't be attributed to gravity, you probably have a magnetic field in the region.

4.) The direction of an electric field line is defined as the direction a positive test charge would accelerate if put in the field at the point of interest. How are magnetic field lines defined?

Solution: The direction of a magnetic field line at a particular point is defined as the direction a compass would point if put at that point.

5.) What does the magnitude of the magnetic field tell you?

Solution: The magnitude of a magnetic field tells you the amount of *magnetic flux per unit area* associated with a particular point. Magnetic flux has the units of *webers*, so the units for the magnetic field are technically *webers per square meter*.

6.) What kind of forces do magnetic fields produce?

Solution: A magnetic force will not change the magnitude of a charged particle's velocity. What it will change is the *direction* of a moving, charged particle's velocity. That is, magnetic forces act centripetally.

7.) You put a stationary positive charge in a magnetic field whose direction is upward toward the top of the page. Ignoring gravity:

a.) What will the charge do when released?

Solution: A stationary charge in a magnetic field will do absolutely nothing. ELECTRIC FIELDS are modified force fields. Release a stationary charge in an electric field and the field will change the charge's velocity--the charge will accelerate along the line of the field. Magnetic fields are *not* modified force fields. Magnetic fields affect charges only if the charge is in motion, and only then if there is a component of the motion that cuts across magnetic field lines. In short, a charge released from rest in a magnetic field will just sit there.

b.) How would the answer to *Part 7a* change if the charge had been negative?

Solution: Generally, negative charges do exactly the opposite of positive charges. In this particular case, given the fact that a positive charge would do nothing in the magnetic field, one would expect that a negative charge would also do nothing.

c.) In what direction would the charge have to move to feel a magnetically produced force *into the page*? If allowed to move freely, would the charge continue to feel that force into the page?

Solution: The direction of the magnetic field is toward the top of the page. To determine the direction of a magnetic force on a moving charge, you need to evaluate ***vxB*** (i.e., you need to use the *right hand rule*). The direction of that *cross product* will give you the direction of that force. You know the direction of that force--it's into the page--and you know the direction of ***B***--it's toward the top of the page. In other words, the question becomes, *in what direction would you have to extend your hand (i.e., in what direction is **v**?--this is what you are looking for) so that when you curl your fingers toward the top of the page (i.e., in the direction of **B**), your thumb extends into the page (i.e., in the direction of the magnetic force)*? The velocity direction that satisfies this question points *to the left*. Note that, as always with a *cross product*, the direction of the *cross product* (i.e., the direction of ***F***) is perpendicular to the plane defined by the two vectors (i.e., ***v*** and ***B***). As to whether that force would be felt continuously in that direction, the answer is *no*! As the charge begins to move into the page, motivated by the original magnetic force, the direction of the charge's velocity vector would change, the direction of the *cross product* ***vxB*** would change, and the direction of the magnetic force ***F*** would change. In short, the charge would *circle* into the page motivated by a magnetic force that was always *perpendicular* to the charge's motion. So, the force *wouldn't* always be directed *into the page*.

d.) How would the answer to *Part 7c* change if the charge had been negative?

Solution: Negative charges do the exact opposite of positive charges. In this case, a negative charge would have to move *to the right* to feel a force *into the page* due to a magnetic field directed upward toward the top of the page.

e.) The positive charge is given an initial velocity of 2 m/s directed upward toward the top of the page. How will its velocity change with time?

Solution: A moving charge has to *cross* magnetic field lines before a magnetic force is felt. As this charge is traveling *along* the magnetic field lines, there is *no force* on the charge and its motion will continue unchanged.

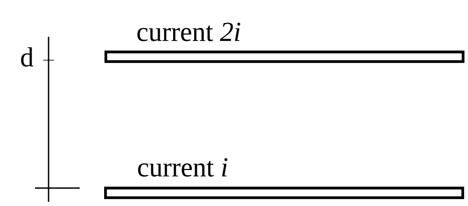
8.) In what direction is the magnetic field associated with a wire whose current is coming *out of the page*?

Solution: Magnetic field lines circulate around a current-carrying wire. The sense of the circulation (i.e., clockwise or counterclockwise as viewed from the end of the wire) depends upon the current's direction. The easiest way to determine this is with the *right thumb rule*. Point the thumb of your right hand in the direction of current flow. The direction your fingers curl gives the sense of circulation of the field. In this case, a right thumb pointing out of the page produces fingers that curl counterclockwise. (Note that you now have two rules connected with the right hand. What has been called *the right hand rule*, associated with cross products, gives you the direction of the MAGNETIC FORCE on either a moving charge ($\boldsymbol{F} = q\boldsymbol{v}x\boldsymbol{B}$) or a current-carrying wire ($\boldsymbol{F} = i\boldsymbol{L}x\boldsymbol{B}$) in a magnetic field. The *right thumb rule* is associated with determining the SENSE OF CIRCULATION of a magnetic field around a field-producing, current-carrying wire.)

9.) You have two current-carrying wires, one on the left and one on the right, positioned perpendicularly to the page. The magnitude of the current in each is the same. You are told that the current flow in the wire on the left is *into* the page. If you are additionally told that there is *no place* between the wires where the magnetic field is zero, in what direction is the current in the wire on the right?

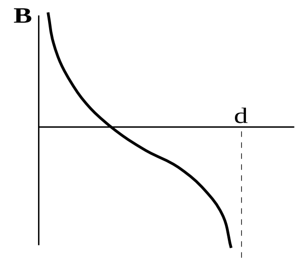
Solution: This is a job for the *right thumb rule*. Between the wires, the magnetic field due to the left wire is oriented toward the bottom of the page. That is, if you orient your right thumb so that it is directed into the page in the direction of the left wire's current, the fingers of the right hand . . . and the circulation of the magnetic field . . . is clockwise. In between the wires, that means the magnetic field is oriented downward. That means that to insure the field will not be zero anywhere between the wires, the field due to the right wire must *not* be upward--it must also be downward. That would mean the current in the right hand wire must produce a counterclockwise magnetic field. The thumb orientation that produces a counterclockwise rotation is oriented out of the page. That is the direction of the current in the wire to the right.

10.) You have two current-carrying wires in the plane of the page. The magnitude of the current in the upper wire is twice the magnitude of the current in the lower wire. Do a quick sketch of the magnetic field between the wires if:



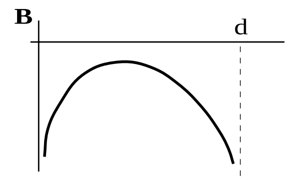
a.) Both currents are to the right.

Solution: Assume the distance between the wires is d, and that our coordinate origin (i.e., $y = 0$) is located at the bottom wire. Using the *right thumb rule*, the magnetic field due to the lower wire will be *out of* the page between the wires (we'll take *out of the page* to be the positive direction), and the magnetic field due to the upper wire will be *into* the page. With the lower wire having the smaller current, it will dominate the net field direction only for small values of y. At some point $y < d/2$, the field will add to zero. On the other side of this zero will be a field *into the page*. We could use the magnetic field expression for a wire to determine exactly where this zero occurs, but all we were asked for was a sketch, so that's all we'll do. In any case, the field will look something like the field shown.

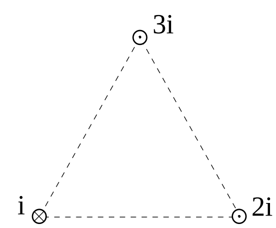


b.) The top current is to the right while the bottom current is to the left.

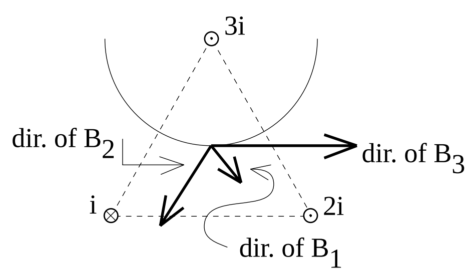
<u>Solution</u>: Using the *right thumb rule* again, the magnetic field due to the upper wire will still be *into* the page between the wires (we'll still call this *negative*), but the magnetic field due to the lower wire will now also be *into* the page. That means there will be no place where the net field will be zero. In fact, the field will go to infinity at the wires with the turn-around point being at the same point where the *zero point* was in *Part 10a*. The sketch is shown to the right.



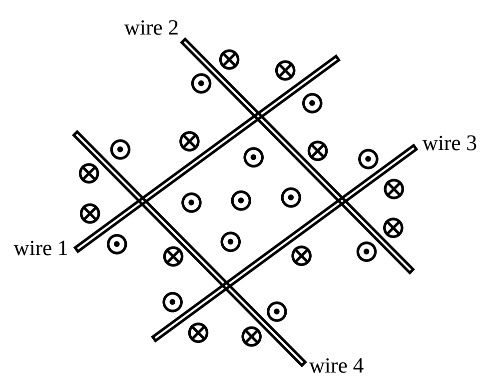
11.) Three wires with different currents as shown are perpendicular to the page as depicted in the sketch. In what direction is the magnetic field at the center of the triangle?



<u>Solution</u>: If you want to determine the direction of the magnetic field due to a single current-carrying wire, the easiest way to do so is to visualize a circle passing through the point of interest that is additionally centered on the current-carrying wire. The magnetic field due to the wire will be *tangent to that circle*. That is, magnetic fields *circulate* around current-carrying wires. Using the *right thumb rule* allows you to determine in which direction the field is circulating. For the *3i* current, the *right thumb rule* maintains that its magnetic field circulates counterclockwise. At the center of the triangle, this translates into a magnetic field direction that is to the right (see the sketch). The other fields are also shown in the sketch. The net field would be the vector sum of the parts.



12.) A group of current-carrying wires is shown to the right. The current is the same in each wire and the direction of the magnetic field is shown at various places in the configuration. From what you have been told, identify the direction of each wire's current.



Solution: To get a sense of the direction of current flow in a particular wire, the best thing to do is to look to see what the magnetic field looks like close to the wire. The right thumb rule should do the rest. That is, for wire 1, the magnetic field is into the page above the wire and out of the page below the wire. A right thumb directed in that direction will produce a finger-curl that moves into the page above the wire and out of the page below the wire. This suggests that the current is downward toward the left. Wire 2's current is directed upward and to the left; wire 3's current is directed upward and to the right; wire 4's current is directed downward and to the right.

13.) A coil sits so that its central axis is perpendicular to the plane of the page. From that perspective, current passes clockwise through the coil.

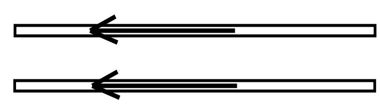
a.) Is there much of a magnetic field out far from the coil (i.e., at *Point P*)?

Solution: There is very little magnetic field outside the coil. The field that is there is produced by the current-carrying sections that are farthest from P (these, according to the right-thumb rule, will produce a magnetic field that is *into* the page) coupled with the current-carrying sections that are nearest P (they produce a field that is *out of* the page). Assuming the *distance to P* is a lot larger than the radius of the coil, these two fields will come very close to adding to zero.

b.) In general, *where* and *in what direction* is the coil's actual magnetic field?

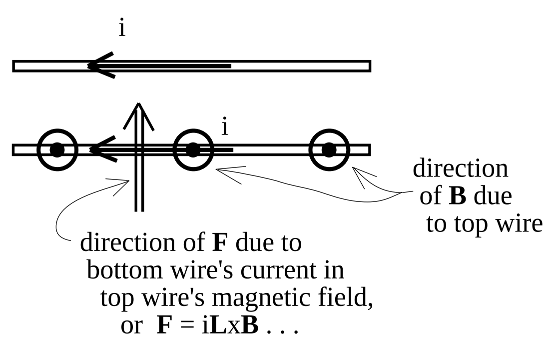
Solution: The main magnetic field exists down the axis of the coil. Again, using the right-thumb rule, the direction of that field in this case will be *into the page* down the axis.

14.) Two parallel wires have equal currents passing through them. The currents are toward the left. The top wire's current produces a magnetic field which, impinging upon the current-carrying bottom wire, produces a force on the bottom wire. The bottom wire produces a similar force on the top wire.



a.) Draw on the sketch the direction of both forces.

Solution: See sketch.



b.) Are the two forces alluded to in *Part 14a* N.T.L. force couples? Explain.

Solution: Yes. One way to see if a pair of forces are N.T.L. couples is to see if the force expression for one is identical to the force expression for the other. The force in this case is $i_1 LB$ (the angle between $\boldsymbol{L}$ and $\boldsymbol{B}$ is 90^o, so the sine is *one*), where i_1 is the current in the wire that is feeling the force (we'll take that to be the bottom wire). The magnetic field produced by the current (i_2) in the field-producing wire (that would be the bottom wire in this case) will equal $(\mu_o i_2)/(2\pi r)$. Putting it all together yields $i_1 L(\mu_o i_2)/(2\pi r)$. If we looked at the expression for the force on the top wire due to the presence of the bottom wire, the i terms would switch places but the net force would be the same. These are, indeed, force couples.

c.) If you doubled the distance between the wires, how would the magnitude of the force on the bottom wire change?

Solution: The magnitude of the force is $iLB = iL(\mu_o i)/(2\pi r)$. If you double the distance between the wires, the magnetic field halves. According to the relationships shown, that means this force will also halve.

15.) A negative charge passes through a magnetic field. The charge follows the path shown in the sketch.

a.) In what direction is the field?

Solution: If the charge had been positive, it would have curved upward. That is, if we can determine the direction of ***B*** that produces an upward force on a *positive charge*, we will have the direction of ***B*** that will send a negative charge on the downward path we were given. The field expression for the force on a positive charge is $q\mathbf{v}x\mathbf{B}$. The right-hand rule maintains that when the length of your right hand moves in the direction of ***v*** with the fingers of that hand curling in the direction of ***B***, the direction of the right thumb must be upward and to the right (again, we are assuming a positive charge is in motion). Given the velocity and force directions required, the direction of ***B*** must be *out of* the page.

b.) In what direction would a positive charge take in the field?

Solution: As was pointed out above, the direction of the force on a positive charge in this ***B*** *field* will be opposite the direction of the force on a negative charge. In short, a positive charge would curve upward.

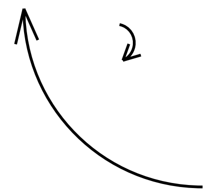
c.) If the size of the magnetic field had been doubled, how would the radius of the motion have changed?

Solution: The point of order here is that magnetic forces are centripetal. Assuming that ***v*** and ***B*** are perpendicular to one another, we can write $qvB = mv^2/r$, where r is the radius of the arc upon which the body moves. From this, doubling the magnetic field while keeping everything else constant will halve the radius.

d.) If the magnitude of the velocity had been doubled, how would the radius of the motion have changed?

Solution: Again, we can write $qvB = mv^2/r$, where r is the radius of the arc upon which the body moves and v the magnitude of the body's velocity. Manipulating this, we get $qB = mv/r$. Doubling the velocity while keeping everything else constant will double the radius.

16.) Two charges move through a given magnetic field as shown.



a.) If we assume the velocities and masses are the same, which charge must be larger?

Solution: As was the case in *Problem 15*, the force on a charge moving in a magnetic field is $qvB = mv^2/r$, where r is the radius of the arc upon which the body moves and v the magnitude of the body's velocity. With all else constant, this means that the charge will be proportional to $1/r$. That is, the smaller the radius, the larger the charge.

b.) If we assume the charges and masses are the same, which charge must have the larger velocity?

Solution: The force on a charge moving in a magnetic field is $qvB = mv^2/r$, or $qB = mv/r$. With all else held constant, this means that the velocity will be proportional to r. That is, the smaller the radius, the smaller the velocity.

c.) If the magnetic field is oriented out of the page, what is the sign of each charge (i.e., positive or negative)?

Solution: Using the right-hand rule, the direction of the force on a *positive charge* moving in a magnetic field is consistent with the direction the charges are actually curving through. Both charges are positive.

17.) An electric field E is oriented toward the bottom of the page. In the same space is a magnetic field B. A negative charge passes straight through the region moving in the *+x direction*. As a consequence of both fields, the negative charge moves through the region *without changing its direction of motion*. Ignoring gravity:

a.) What is the direction of the magnetic force in this case?

Solution: For the charge to continue on in a straight line in the magnetic field, the field either has to be oriented along the line of motion, or there must be a second force in the system to counteract the magnetic force. As there is an electric field in the system, the latter situation must be the case. The negative charge will feel a force upward due to the presence of the downward electric field. To counteract that force, there must be a magnetic force that is oriented downward.

b.) What is the direction of the magnetic field in this case?

Solution: The charge is moving in the *+x direction*. The magnetic field must produce a force that is *downward* on a negative charge (it would produce a force that was *upward* on a positive charge). How do you determine this? You should know by now! Mess with the right-hand rule until $\boldsymbol{v}\mathrm{x}\boldsymbol{B}$ orients your thumb in the appropriate direction (a downward force on a negative charge will produce an upward force on a positive charge--as the $\boldsymbol{v}\mathrm{x}\boldsymbol{B}$ technique is for positive charge, you are looking for $\boldsymbol{B}$ such that $\boldsymbol{v}\mathrm{x}\boldsymbol{B}$ is upward). In this case, that will be a direction that is *into* the page.

18.) Is there a Gauss's Law counterpart to magnetic fields? If so, how do the two approaches compare?

Solution: The magnetic field counterpart to Gauss's Law is called Ampere's Law. With its use, if you are clever, you can generate an expression for the magnetic field produced by certain kinds of symmetric, current-carrying wire configurations. To compare Ampere's Law to Gauss's Law, we need to do a quick review. Gauss's Law suggests the following: Create an imaginary *closed surface* in the region of an electric field. Identify a differential area on the surface, then make a differential surface area vector (i.e., $d\boldsymbol{S}$) out of it. Determine the differential electric flux through that differential surface by executing the operation $\boldsymbol{E}\cdot d\boldsymbol{S}$. Summing that quantity over the entire surface (i.e., doing $\int\boldsymbol{E}\cdot d\boldsymbol{S}$) yields the net electric flux through the overall surface. According to Gauss, that net flux will be proportional to the *charge enclosed* within the surface. Ampere's Law suggests the following: Create an imaginary, *closed path* in the region of a magnetic field. Identify a differential length on the path, then create a differential vector (i.e., $d\boldsymbol{l}$) out of it. Determine the magnitude of the product of the *component of* $\boldsymbol{B}$ *along the line of* $d\boldsymbol{l}$ and $d\boldsymbol{l}$ (i.e., execute $\boldsymbol{B}\cdot d\boldsymbol{l}$). Do this operation for all the $d\boldsymbol{l}$*'s* around the path, then sum over the entire path (i.e., execute $\int\boldsymbol{B}\cdot d\boldsymbol{l}$) to determine the *circulation of* $\boldsymbol{B}$ around the entire closed path. According to Ampere, that magnetic circulation will be proportional to the amount of current that passes *through the face of the path*. Just as Gauss's Law is useful when symmetry exists, Ampere's Law is also symmetry bound. Just as charge outside a Gaussian surface produces no net electric flux through the surface (the *flux in* equals the *flux out*), the magnetic circulation around any closed path will add to zero if the field-producing current-carrying wire doesn't pass through the face of the path (the sum of the $\boldsymbol{B}\cdot d\boldsymbol{l}$*'s* on one side of the path will be equal and opposite the sum of the $\boldsymbol{B}\cdot d\boldsymbol{l}$*'s* on the other side). And just as the ideal situation for Gauss's Law is one in which the magnitude of $\boldsymbol{E}$ is the same over the entire Gaussian surface, the ideal situation for Ampere's Law is one in which the magnitude of $\boldsymbol{B}$ is the same over the entire Amperian path.

19.) What can you say about the magnetic circulation around a closed path in a magnetic field?

Solution: If there is no current passing through the face of the path, there will be no net magnetic circulation around the path.

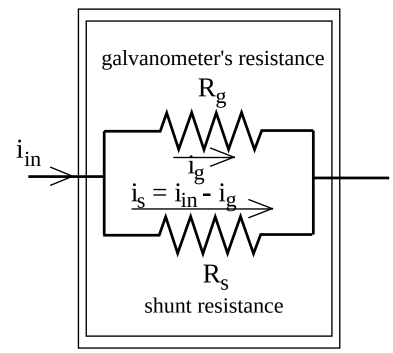
20.) When using Ampere's Law, you are looking for a path that has one of two characteristics. What are those characteristics?

Solution: You want symmetry that insures that $\boldsymbol{B}$*'s* magnitude will be the same over the entire path, and you want $\boldsymbol{B}$ to be either along the line of $d\boldsymbol{l}$ or perpendicular to the line of $d\boldsymbol{l}$ (in this latter case, $\int\boldsymbol{B}\cdot d\boldsymbol{l} = 0$), Like Gauss's Law, you need symmetry to make this approach useful.

21.) Galvanometers are based on what principle?

Solution: A current-carrying coil in a magnetic field can, if oriented correctly, feel a torque that motivates the coil to rotate. Attach a needle to the coil and add a spring designed to provide a restoring torque, and you have the makings of a current-measuring meter. This is how galvanometers are constructed. All galvanometers are made so that a current of .5 mA (that's 5×10^{-4} amps) will send the needle full deflection. (Note: This works well for small currents, but for large currents this basic design isn't enough. In such cases, you have to use a ready-made galvanometer in a clever way . . . see the next question.)

22.) An ammeter can be built using a galvanometer and what kind of circuit? How do you determine the value for any extra resistors used in the circuit (i.e., extra beyond the resistance of the galvanometer)?

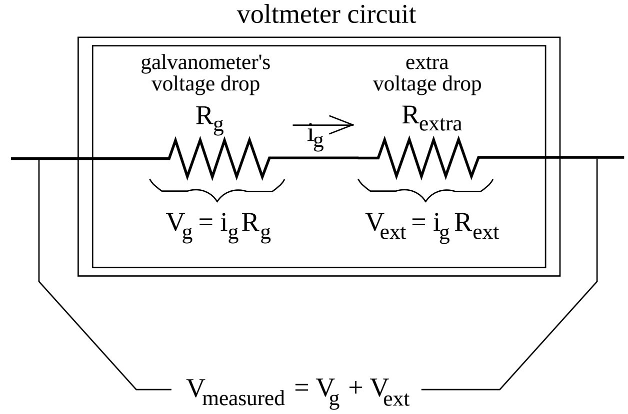


ammeter circuit

Solution: The general circuit is shown to the right. As for numbers, you have to realize that a galvanometer's needle will move full deflection when $5\text{x}10^{-4}$ amps passes through the galvanometer. You can use a galvanometer to measure a larger current if you are clever. Specifically, let's assume you want to create a 1 amp ammeter (i.e., a meter that executes full deflection when 1 amp passes through it). The trick is to create a situation in which a 1 amp input moves $5\text{x}10^{-4}$ amps through a galvanometer in the system with the rest of the current going somewhere else. This can be done by placing the galvanometer in parallel with a second, shunt resistor, as shown in the sketch to the right. To get the appropriate value for this shunt resistor, note that the voltage across the galvanometer (i.e., $V_g = i_g R_g = (5x10^{-4}\ amps)(R_g)$ . . . where the resistance R_g of the galvanometer must be known) will equal the voltage across the shunt resistor (i.e., $V_s = i_s R_s = (1 - 5x10^{-4})(R_s)$). Equating the two will allow you to determine R_s.

23.) A voltmeter can be built using a galvanometer and what kind of circuit? How do you determine the value for any extra resistor(s) used in the circuit (i.e., extra beyond the resistance of the galvanometer)?

voltmeter circuit



Solution: The circuit is shown to the right. As was mentioned in *Problem 22*, a galvanometer's needle will move full deflection when $5\text{x}10^{-4}$ amps passes through the galvanometer. And again, if you are clever, you can use the needle swing of a galvanometer to measure the voltage difference across a circuit element. Specifically, let's assume you want to create a 5 volt voltmeter (i.e., a meter that executes full deflection when 5 volts is placed across it),. The trick is to realize that at full deflection, the voltage drop across the galvanometer will be its *maximum deflection current* times its *known resistance*, or $(5x10^{-4}\ amps)(R_g)$. Let's say the galvanometer's resistance is 20 ohms. The voltage across the galvanometer at full deflection will, therefore, be 10^{-2} volts. Unfortunately, we want the galvanometer's needle to move full deflection when *5 volts* is placed across the meter. So how do we insure that this will happen? By placing just the right sized secondary resistor in series with the galvanometer, the sum of the voltage drops across the galvanometer and this second resistor can be made to equal *5 volts*. To get the value of this extra resistor, the galvanometer's voltage plus the resistor's voltage must equal the maximum deflection voltage (i.e., *5 volts* in this case). Remembering that the current through both elements will be the same in the series combination, the algebraic expression for this relationship becomes $V_g + V_{extra} = V_{max.for\ meter} = (10^{-2}\ volts) - (5x10^{-4}\ amps)(R_{extra}) = (5\ volt)$. Solving for R_{extra} finishes the problem.

24.) You are given two 200 meter strands of identical copper wire. With one strand you create a coil whose radius is 2 cm. With the second strand you create a 4 cm coil. Assuming the current is the same in both, which coil will have the greater *B field* down its axis?

Solution: It turns out that the magnetic field expression for a coil is $\mu_o in$, where μ_o is a constant and n is the number of turns *per unit length* in the coil. You might expect that ***B*** would have something to do with the coil's radius. After all, a bigger radius would mean more distance between the wire in the coil and the axis. But a bigger radius also means more length of wire per loop for the current to pass through, and the two parameters counteract one another. In any case, the magnetic fields should be the same.

25.) A straight, isolated wire of length L is hooked up to a 1 volt battery. A second situation differs only in that its wire is twice as thick. If you test the magnetic fields one meter from each wire, which wire will produce the larger *B field*?

Solution: Current in a wire is proportional to the area of the wire (i.e., πR^2, where R is the radius of the wire). Double the thickness and the area goes up by a factor of four. The resistance is inversely proportional to the area, and the current is inversely proportional to the resistance . . . or directly proportional to the area. In short, the current in the larger wire will be four times larger than the current in the smaller wire. As the magnitude of the magnetic field ***B*** set up by a current-carrying wire is equal to $(\mu_o i)/(2\pi r)$, where r is the distance between the wire and the point of interest ($r = 1$ *meter* in this problem), the magnetic field should also be four times larger for the larger wire.

26.) Why would you not expect the existence of a magnetic monopole?

Solution: It is possible to have a single electron or single proton in nature, so *electric* monopoles exist. Magnetic fields (at least, those generated by ferromagnetic materials), on the other hand, are produced at the atomic level by the spin of electrons. That means that each iron atom is a magnet unto itself . . . complete with a north and south pole. As such, it isn't possible to produce one pole without the other, hence the belief (at least in the Classical Theory of Magnetism) that magnetic monopoles can't exist within nature. (In fact, there are respectable theories that predict that magnetic monopoles should exist, but to date their existence hasn't been found in nature.)

27.) How can one piece of iron be magnetized while a second piece is not?

Solution: Domains are regions within a ferromagnetic material where the magnetic fields of all of the atoms making up that region are in alignment. The problem is that one domain will not necessarily be aligned with the domains on its perimeter. When such an alignment exists, we observe a net magnetic field from the material. When such an alignment is scrambled, we observe no magnetic field.

28.) What does the earth's magnetic field really look like, and why?

Solution: Solar winds (charged and uncharged subatomic particles ejected at high speeds from the sun) constantly buffet the earth. On the sun-side of the earth, their presence pushes the earth's magnetic field *in closer to the earth*. On the night-side of the earth, their presence pushes the earth's magnetic field *out away from the earth*.

29.) *Magnet A* is a light, weak, bar magnet. *Magnet C* is a heavy, strong, bar magnet. You place *magnet A* on a table so that it can move freely.

a.) If you pick up *magnet C* and approach *magnet A* so that C's north pole comes close to A's south pole, what will happen and why?

Solution: Remember, *unlike* magnetic poles attract. At some point in the approach, the attraction between the opposite magnetic poles will overcome friction between *magnet A* and the surface upon which it sits, and *magnet A* will be attracted to *magnet C* . . . most probably accelerating toward *magnet C* suddenly.

b.) If you pick up *magnet C* and approach *magnet A* so that C's south pole comes close to A's south pole, what would you expect to happen and why?

Solution: Remember, *like* magnetic poles repulse. At some point in the approach, the repulsion between the like magnetic poles will overcome friction between *magnet A* and the surface upon which it sits, and *magnet A* will move away from *magnet C*. At least, that is what you would expect.

c.) If you said the magnets would repulse one another for *Part 29b*, you could be wrong. In fact, there is a good chance that if you actually tried this, the two magnets would attract. THIS DOESN'T MEAN *LIKE POLES ATTRACT*! What does it mean?

Solution: If *magnet A* were sitting on a frictionless surface, it would respond to *magnet C* by repulsing as expected, moving away as expected. But if the friction between *magnet A* and the surface upon which it sits is large enough, *magnet C* might be able to get close enough to *magnet A* to literally rearrange *magnet A*'s domain alignment, thereby switching *magnet A*'s magnetic polarity. In other words, you could re-magnetize *magnet A* so that the end labeled "N" would become a south pole . . . and vice versa. In that case, the newly opposite poles would attract and the two magnets would come together, doing something in the process that would be, on the surface, totally unexpected.