2019 RiSE June Conference

Integrating Research & Practice: Strategies for interdisciplinary teaching and learning across the STEM+C disciplines

Workshop D (Tuesday, June 25, 10:20-11:50am)

Workshop on instruction and assessment in middle-school science: Useful comparisons with college-level instruction

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There is great potential for science learning in the middle-school and high school grades, but many challenges as well, some of which are often underappreciated. This workshop will address both the potential, and the challenge. I will describe how I have modified and adapted research-based instructional and assessment materials developed at the college level for use in K-12 classrooms. Workshop participants will have the opportunity to use some of the materials, and to work together to discuss how best to adapt and implement the materials within their own classroom setting. We will also break up into smaller groups to discuss some key issues, including (1) the appropriate amount of instructional time and effort needed to achieve significant learning outcomes at the middle-school level; (2) the degree to which mandated grade-level standards and expectations are matched to the realities of the science learning process; and (3) the nature of "decay" in middle-school student learning gains over time (e.g., from one grade to the next), and how that can and should impact the nature of instruction and assessment.

Sample Activities

For this activity sequence, we will start by having a student walk down a straight-line path at a constant speed while other students time her with stopwatches. Then, students will use carts, tracks, motion sensors, and data-loggers to create multiple, automatically plotted graphs representing the motions of carts that are moving with both constant and changing speed.

Activity #1; *Goals: (a) position-time graph; (b) best-fit line*

a. With a tape measure or meter sticks, lay out a 10-to-15-meter straight-line path, with chalk or masking-tape markings at every meter, starting from a position marked "0 meters" at one end.

b. Arrange at least five teams of students, 2-3 in each team and each equipped with a stopwatch, standing near the meter markings at 2, 4, 6, 8, and 10 meters. At the loud signal "3, 2, 1, Go!" from the starter, everyone starts their stopwatches and the student begins to walk at a slow, steady pace—neither speeding up nor slowing down—starting from the position marked "0 meters," until she reaches the end of the track. Each team member stops their stopwatches as the student walker passes their mark. All times are recorded. *Note:* Several practice runs should first be carried out.

c. Each team averages their recorded times and reports the average to the tabulator, who enters them into a table such as the one below. (Here, "meters" and "seconds" are known as *units of measure*.) Once completed, the full table is copied by each student group who then proceeds to answer the questions listed below.

Position (meters)	0	2	4	6	8	10
Time (seconds)						

Here we have an example of a variable quantity—the position—whose value depends on the value of another quantity—the time. Corresponding to each of the values in the "time" column, the "position" variable has a specific value; we describe this by saying that the position is a **function** of time. A table of values is one way to represent a function. Another way is to use a **line graph**.

➔ Can you think of another quantity that can be described as a function of something else?

1. Using graph paper, lay out two perpendicular lines in an "L" shape, labeled with "Position (meters)" along the vertical line and "Time (seconds)" along the horizontal line, with numbers along each line beginning with 0 (meters) and 0 (seconds) at the place where the lines meet. The vertical and horizontal lines are called **axes**, and the place where they meet is called the **origin**. The numbers are called the **scale**. Numbers should run from 0 to 15 or 20 along the vertical "position" axis, and from 0 to 10 along the horizontal "time" axis. Place a large dot at each grid point that matches up with a position-time pair from the table of values above; this process is called **plotting** the points representing our data. Since we only had a limited number of timing teams, we were not able to tabulate times for every possible position of the student walker, such as 3.4 meters, 6.7 meters, or 8.9 meters. However, we know that the walker did pass by all of those positions.

➔ Try to estimate the time at which the walker passed the 6.7-meter mark. Explain your reasoning.

2. Take a clear plastic ruler and lay it down on the graph so that its edge goes through the origin, and lies as close as possible to the points that were plotted; some points should lie slightly to one side of the edge, and other dots on the other side of the edge. With a pencil, draw a straight line along the ruler's edge. We say that this is a **line-graph** representation of position as a function of time, and we call the line that we have drawn a **best-fit line** for the data points.

3. Using your best-fit line, estimate the time at which the walker passed by the positions 3.4 meters and 6.7 meters. How close is the new estimate of the time for 6.7 meters to your previous estimate from #1 above?

Activity #2; *Goals: (a) slope; (b) magnitude of slope*

Repeat Activity #1, except that this time the person walking should walk at a significantly faster pace than that in Activity #1, although still without changing speed. Plot the best-fit line on the same sheet of graph paper, using the same axes, as was done for Activity #1. We now have two best-fit lines, corresponding to two different motions.

If you think of these lines as resembling a small hill or mountain, we could say that one of them is "steeper" than the other; that is, it makes a larger angle with the horizontal axis. The mathematical term for measure of steepness is called **slope**.

➔ Which of the two lines on your graph has a steeper slope? How can you tell? Try to describe a method that could be used for comparing the slopes of two lines.

1. It is possible to calculate a precise numerical value for the slope of a line, using the line graph. To do this, we must first choose two points that lie on the best-fit line; each point corresponds to a pair of values: a value of position and a value of time. We can designate these pairs of values as (t_0, P_0) and (t_1, P_1), where $t_0 < t_1$. The quantity ($P_1 - P_0$) is equal to the change of position P between time t_0 and time t_1; on the graph, it corresponds to a "rise" along the vertical axis from a smaller value to a larger value. Similarly, the quantity ($t_1 - t_0$) is equal to the change of time values, corresponding to an interval along the horizontal axis; this interval is called the "run." The slope is defined as the ratio of $\frac{rise}{run}$ or, using symbols from our graph, the ratio $\frac{P_1 - P_0}{t_1 - t_0}$. (In our case, the slope has units of meters/seconds or m/s, corresponding to the vertical-axis unit divided by the horizontal-axis unit.) We can use the letter m to represent slope in the general case, so for now we can write $m = \frac{P_1 - P_0}{t_1 - t_0}$.

➔ Calculate the slopes of the two lines you have plotted on your graph.

2. Since lines on a position-time graph represent the motions of objects, there should be an observable difference in the *motions* of objects that are represented by lines with different slopes. To observe the difference, let's experiment using the dynamics carts and tracks, along with the data-loggers.

   First, make sure that the track is level so that the cart, when placed at rest anywhere on the track, will not move one way or the other. Put the cart at one end of the track and give it a short, sharp "push" to get it moving. Using the motion sensors, create a position-time graph representing the motion of the cart as it rolls all the way down to the other end of the track. (Start the data-logger only *after* the cart has separated from your hand. First, do some practice runs until you can get a smooth line.) Use the function that allows multiple runs to be plotted on a single set of axes.

   Do a second trial which differs from the first by using a stronger, harder initial push. Plot a position-time graph for the motion of the cart so that this graph and the one from a moment ago appear on the same axes and can be easily compared. In which case did the cart move faster? How does the graph of the faster motion differ from the one in which the cart moved slower?

3. **We give a particular name to the slope of a line that plots position as a function of time: This slope is called the *velocity* (symbol: *v*) and has units of meters/seconds or m/s.**

   Determine the velocity corresponding to the two lines on your graph. Which line represents a motion with a larger velocity? In which case was the cart going faster? Something that is going faster is said to have greater speed. (Later, we will explore the relationship between "velocity" and "speed.")

Activity #3; *Goal: velocity-time graph*

We will now switch from displaying position-time graphs to displaying velocity-time graphs. To begin, click on the "position" label on the vertical axis and select "velocity" from the drop-down menu.

Then, as before, put the cart at one end of the track and give it a short, sharp "push" to get it moving. Using the motion sensors, create a velocity-time graph representing the motion of the cart as it rolls all the way down to the other end of the track. (Start the data-logger only *after* the cart has separated from your hand. First, do some practice runs until you can get a smooth line.) Use the function that allows multiple runs to be plotted on a single set of axes. Do a second trial which differs from the first by using a stronger, harder initial push. Plot a velocity-time graph for the motion of the cart so that this graph and the one from a moment ago appear on the same axes and can be easily compared. In which case did the cart move faster? How does the graph of the faster motion differ from the one in which the cart moved slower?

Activity #4; *Goals: (a) force and force measurement; (b) acceleration; (c) relation of acceleration to force and mass*

1. We will now investigate the effect of a pushing force on the motion of the cart. We will put the fan attachments on the cart to provide the pushing force. First, measure the strength of the force provided by the fan by attaching the 2.5-N spring scale to the cart with fan and allowing the cart to stretch the spring out while you hold the cart and prevent it from moving. You should see a fairly constant force registered on the scale, with magnitude less than 0.5 N. If it is possible to run the fan at a different speed, trying measuring the force at that different speed as well.
2. Hold the cart at one end of the track while the fan gets up to speed, then release the cart. After the cart has started moving and is free from your hand, click the computer to start the graph. Stop the graph before the cart crashes into the other end of the track. On the same set of axes, repeat the procedure, but this time using a different fan speed to provide a stronger or weaker force. Examine the two velocity-time graphs to see how they compare.
3. If time allows, set the fan at the highest speed and generate a velocity-time graph as before. Then, place a 250-g or 500-g mass on the cart and repeat the procedure, comparing the two velocity-time graphs corresponding to the different mass carts (both of which experienced the same magnitude of pushing force). How do the two graphs differ from each other?
4. The slope of the velocity-time graph is called the "acceleration," symbolized by the letter a. The magnitude of a is equal to the magnitude of the slope of the v-t graph. The magnitude of the force is symbolized by F and is measured by the spring scale. The mass of the cart is represented by the letter m.

   Which of the three following relationships best describes the results of your observations?

   $a = m \times F$

   $a = m/F$

   $a = F/m$

Density Activity; ***Goals: (a) measurements of mass and volume; (b) concept of density; (c) uncertainty in measurement; (d) sinking and floating***

We will examine several objects, some of which float in water and others of which sink. To try to find a pattern, we will examine the densities of the objects and compare them with the density of water.

First, determine the density of water (D = m/V where D = density, m = mass, and V = volume) by using the 250-ml graduated cylinder. (Note that 1 mL = 1 cm^3.) Use the large digital scale to determine the mass of the empty cylinder, and then the mass of the cylinder with a measured amount of water in it. Estimate the uncertainty of your volume measurement by noting the highest possible volume and the lowest possible volume of the water in the cylinder, according to your observations. Estimate the uncertainty in the mass measurement as well. Find the value of the density in units of g/cm^3.

The highest possible density would be given by the highest possible mass, divided by the lowest possible volume. The lowest possible density would be given by the lowest possible mass divided by the highest possible volume. You can assume the true density lies between those two values.

Perform the same sorts of measurements on the cubes of different materials. You can determine the volume of the cubes either by measuring length × width × height, or by submersing the cube in the cylinder of water to see how much change there is in the water level. In either case, estimate the uncertainty of your volume measurement.

Determine the mass of the cubes by placing them on the small digital scale. You can get readings to 0.01 g.

After all the density measurements have been done, determine which cubes float and which ones sink. If there is any pattern associated with the densities, explain what that pattern is.

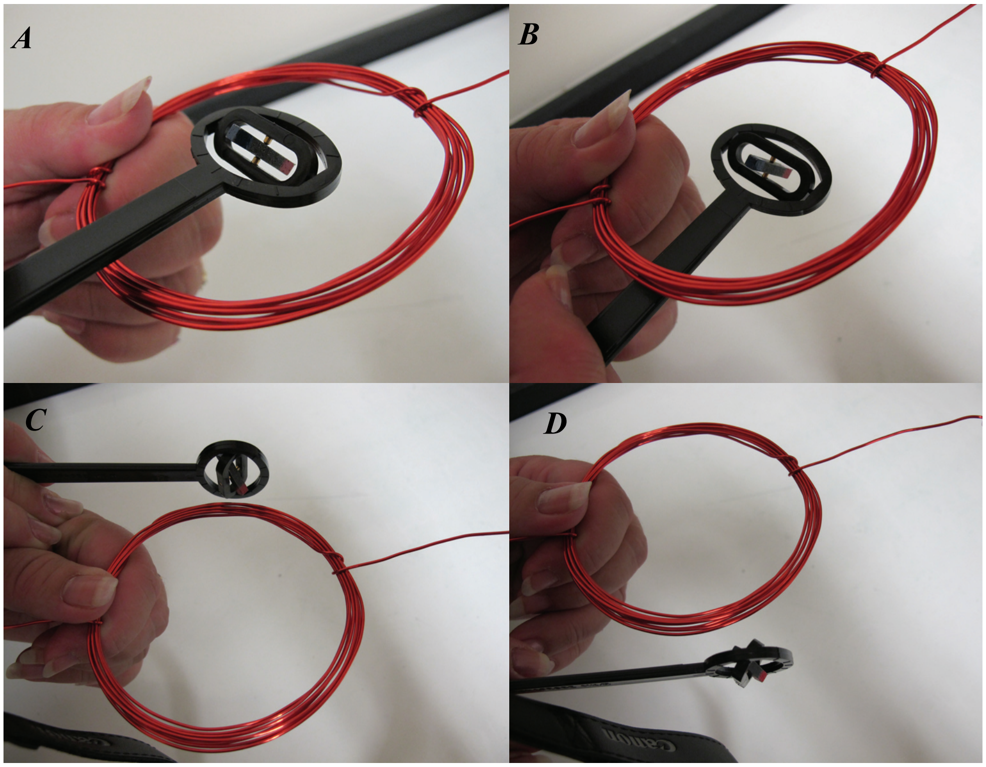
Field-Mapping Activity; ***Goal: magnetic field pattern of permanent magnet***

In the center of a blank sheet of paper, tape down a bar magnet and draw an outline of the magnet.

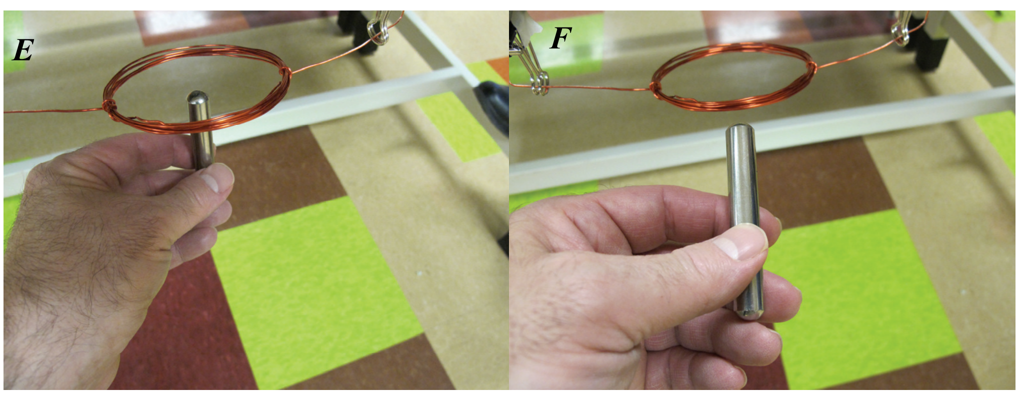
Place a small compass in contact with the magnet, and draw dots at the tip and tail of the compass needle. Remove the compass and draw an arrow to represent the direction of the needle. Place the compass on the paper again, so the tail of the needle is at the position of the *tip* of the first arrow; draw a second arrow as you did the first. Continue this process until you run off the page or back into the magnet.

Repeat this process at different points on the magnet.

Magnetic Field of the Flat Coil; ***Goals: (a) Explore magnetic field pattern of flat current-carrying coil; (b) interaction of current-carrying coil with permanent magnet***



Hold the Magnaprobe at different locations to check the direction of the magnetic field when the coil is connected to the battery (see photos above). Which way does the needle point when you hold it: (A) above the center of the coil; (B) below the center; (C) near one side; (D) near the other side? Where is the north pole of the coil? The south pole? How do your answers change when you reverse the connections to the battery terminals?



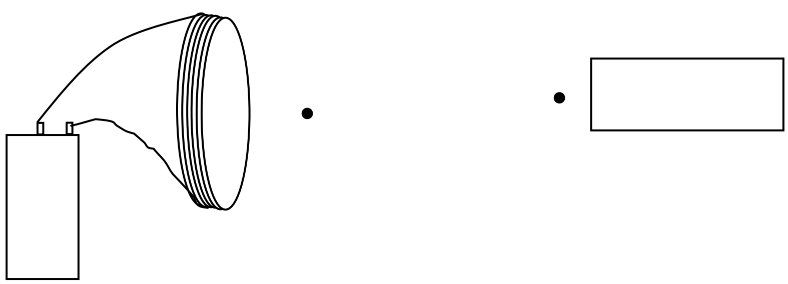
Try holding the magnet at different locations near the coil when the coil is connected to the battery: What happens to the coil when you hold the north pole of the magnet below the center of the coil as in photo *E* above? What happens when you hold it at the side of the coil (photo *F*)? How does this change when you flip the magnet around? How does it change when you reverse the connections to the battery terminals? See if you can make the coil spin around by holding the magnet in different positions while you repeatedly connect and disconnect the coil to the battery.

Goals: Understand properties of magnets and current-carrying coils

Grade 5/6 Science
Homework
April 14, 2011

1. Two magnets held near to each other are shown below. The arrows show the directions of compass needles held near the magnets. Would these magnets push each other apart, or would they pull each other together? Explain how you can tell.

2. The diagram shows a magnet, and a large flat coil connected to a battery. When you bring the magnet near to the coil, the coil and the magnet are pulled together, towards each other. Draw arrows at the positions of the two dots to indicate the direction of a compass needle held at those two points. Explain your answer. **IMPORTANT NOTE:** There is more than one correct answer for this question.



5/6 Homework
April 7

1. When you put the steel bolt through the center of the coil and connected the coil to the battery, what did you observe?

2.
a) When you connected the flat, hanging coil to the battery and brought the bar magnet near to it, what did you observe?

b) What happened when you turned the bar magnet around when it was near the hanging coil? Why do you think this happened?

Goals: Understand properties of magnets and current-carrying coils

Grade 5/6 Science Homework May 27, 2011

In the diagram below, five points are shown in the neighborhood of the magnet: points A, B, C, D, and E.

1. At which point is the magnetic field the *strongest* (strongest pull)? ___________

2. At which point is the magnetic field the *weakest*? (weakest pull)? ____________

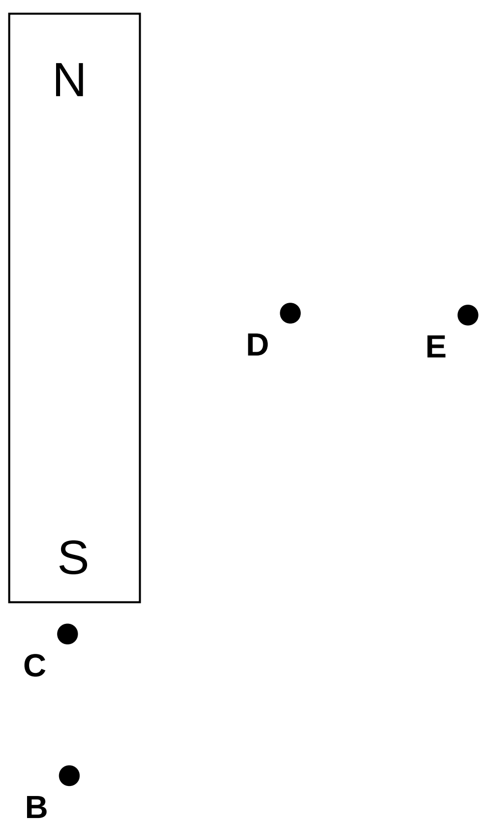
3. Where is the magnetic field stronger: at point B or at point C? ____________

Grade 5/6 Science April 6, 2011

In the middle of this page, draw a sketch of the wire coil and battery we used in last week's experiment; your diagram should show that the coil is connected to the battery. Write an "N" (for north pole) at one end of the coil (it doesn't matter which end), and write an "S" (for south pole) at the other end of the coil.

1. At the *top* of the coil, draw an arrow to represent the direction of a compass needle located at that point. At the *bottom* of the coil, draw another arrow to represent the direction of a compass needle located there.

2. At the *top* of the coil, draw a small diagram to represent the Magnaprobe needle when you hold it at that point. At the *bottom* of the coil, draw another small diagram to represent a Magnaprobe needle held there. Use the colored pencils or pens. Remember that one end of the Magnaprobe needle is red and the other is blue:  (blue end)



Magnetism and Electric Current Activity

Goals: (a) induction of current by changing magnetic field; (b) strength of induced current depends on rate of change of magnetic field

1. Connect the galvanometer to the flat coil. ***Without*** using the battery, but using the magnet, try to make the galvanometer needle deflect (move) either to the right or to the left. Do this ***without*** shaking or touching the galvanometer itself. Describe your method:

2. Once you have figured out how to make the galvanometer meter needle deflect, explain:

   a) how to make a *large* deflection, and how to make a *small* deflection.

   b) how to make a deflection to the left, and how to make a deflection to the right. Describe ***two methods*** for each.

      i) Deflection to the left:

      ii) Deflection to the right:

3. Construct an electromagnet using a steel bolt, wire, and battery. Connect the galvanometer to the flat coil or to the solenoid coil. Find a way to cause the galvanometer needle to deflect but ***without*** connecting the battery itself in the circuit containing the galvanometer.

   Never connect the battery in a circuit containing the galvanometer! It could severely damage the galvanometer.

   Describe your method:

4. Find one more method for causing a galvanometer needle deflection, *different* from the method you have been using up till now. This method should work without moving either the flat coil ***or*** the electromagnet. Describe your method. *Remember, do not connect the battery to the circuit containing the galvanometer.*

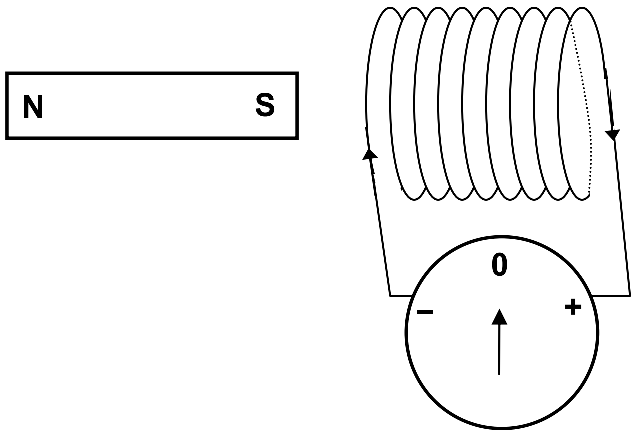
5. Try to come up with some kind of general rule, or several rules, about the methods that worked to cause a deflection of the galvanometer needle.

Grade 5/6 Science Homework May 19, 2011

Goal: Application of Faraday's law of inducent currents

Name: ______________________

This diagram shows a coil connected to a galvanometer, with a bar magnet held next to the coil right near the center of the coil. The galvanometer needle is shown at one particular moment.



a. At this moment, is the magnet *moving toward* the coil, *moving away* from the coil, or *not moving*?

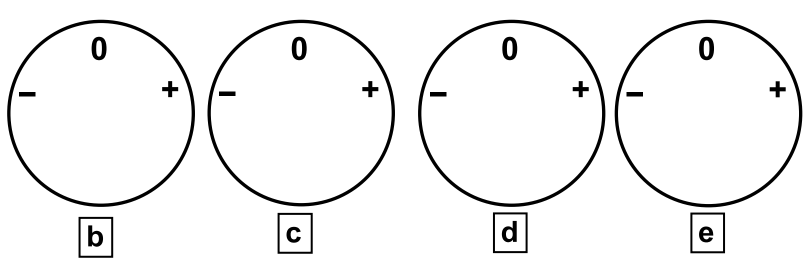
In b-e, draw the appropriate position of the galvanometer needle in the circles at the bottom of the page. Make sure that all of your drawings are consistent with ***each other****. Explain your answers to c and e.*

b. Suppose now the magnet is moving *toward* the coil. Draw the position of the galvanometer needle. *Note:* there is more than one possible response for this, but your answers to c-e must be consistent with it.

c. The magnet is held motionless inside the coil. *Explain your answer*.

d. The magnet is pulled out of the coil.

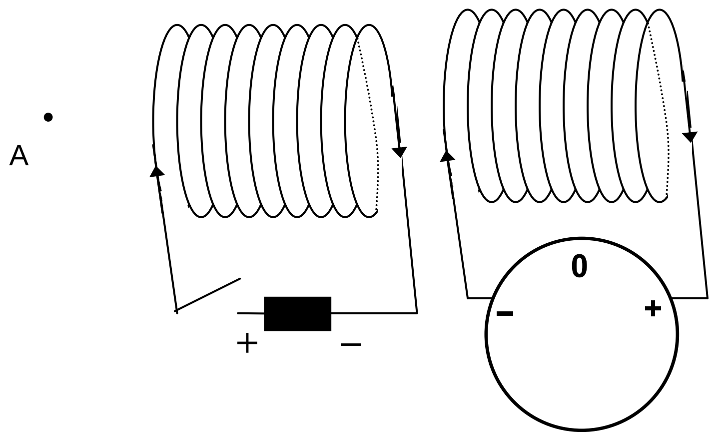
e. The magnet is pushed into the coil faster than it was in (b). *Explain your answer*.



Goal: Application of Faraday's law of inducent currents

Grade 5/6 Science
Coil and Galvanometer Activity
June 3, 2011

This diagram shows two identical coils next to each other. Point A is to the left, and a straight line could be drawn starting from point A through the exact middle of both coils. The left coil is connected to a battery through an open switch as shown. The arrow on the left coil shows the direction in which electric current flows through that coil.



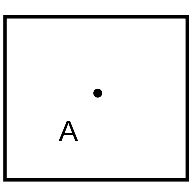
a. At the moment shown, draw the galvanometer needle with its correct position in the diagram above.

b. At a certain moment $t = 0$ seconds, the switch is closed. At the moment the switch is closed, draw an arrow in the box below to represent the direction of the magnetic field at point *A* that is due to the *left* coil. If there is no magnetic field, write “zero magnetic field.”

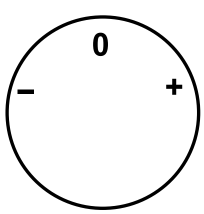
c. At the moment the switch is closed, draw (below) the *first* position to which the galvanometer needle moves. *Note:* There is more than one possible answer; however, it must be consistent with your other answers.

d. The switch is left closed for five seconds so the battery stays connected to the left coil during that period. Draw the approximate position of the galvanometer needle at $t = 3$ seconds.

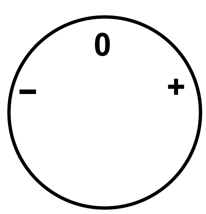
e. At $t = 5$ seconds the switch is opened. Draw the *first* position to which the galvanometer needle moves at that moment. *Explain your answer.*



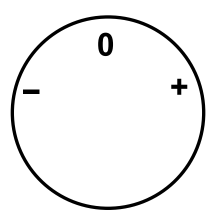
Magnetic field at point A at moment switch is closed.



Answer for *c*



Answer for *d*



Answer for *e*
Note: write explanation above