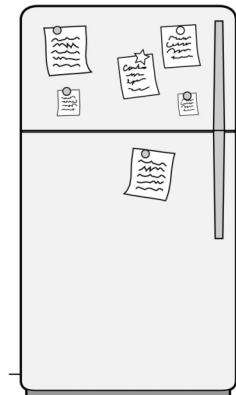


In this lab, you will focus on the concepts of magnetism and magnetic fields and the interaction between flowing charges (electric current) and magnetic fields. You will find this material in Chapter 19 of Serway and Faughn. It is a good idea to read all of the steps in each part before you start.



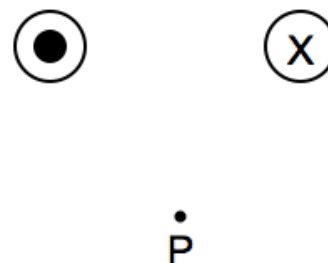
Pre-Lab Questions

1. The magnetic field a distance 5.0 cm from a long straight current-carrying wire is 5.6×10^{-5} T. What is the current in the wire? What is the magnetic field at a distance of 20.0 cm from the wire?

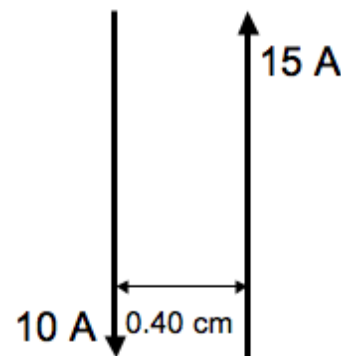
2. Two wires lie perpendicular to the plane of the paper, and equal electric currents pass through the paper in the directions shown. Point P is equidistant from the two wires.

a) Construct a vector diagram showing the direction of the resultant magnetic field at point P. Explain your reasoning.

b) If the currents in both wires were instead directed out of the plane of the page (such that the current moved toward us), show the resultant magnetic field at point P.



3. Two long straight wires are parallel and carry current in opposite directions (as shown in the figure to the right). The currents are 10 Amps and 15 Amps and the wires are separated by 0.40 cm. What is the magnetic field (magnitude and direction) due these currents at a point midway between the wires?



Experiment A: Interactions between Magnets

- Take two bar magnets, and bring them towards each other slowly. Do they exert a force on each other? Which parts (ends, middle) exert or feel forces from which other parts?
- Attach the magnets to the wheeled carts so they repel each other. Put the carts close together then release them from rest. What happens? Is the force on cart 1 equal and opposite to the force on cart 2?
- The carts start with no kinetic energy, but they gain KE when released. Where does the KE come from?
- Can magnets interact without touching?
- How does one magnet know the other one is there?

Experiment B: Interactions between magnets and compasses

NOTE: Do not allow the compass to get close to a strong magnet as this will magnetize them and destroy their accuracy!!

Whenever a magnet is allowed to rotate freely, and without another magnet nearby, one end will always end up pointing (approximately) towards the geographical North pole of the Earth. By mutual agreement, scientists **define** this end of the magnet as the **North pole** of the magnet. The opposite end of the magnet, by definition, is called the **South pole**.

- Place a compass at different places on the lab bench when all the other magnets are kept far away (at the front or back table).
- Mark with tape and an arrow the direction to magnetic North inside the lab room. (Be sure to remove the tape when you finish the lab). Add small labels to S, E and W.
- Use the bar magnet to investigate the field of influence of the magnet on a compass.
- Does the effect of the magnet on the compass depend on distance?
- Does it depend on which pole of magnet is used?
- Label the poles of your bar magnet as N or S using tape. Please be sure to remove the tape at the end of the lab.
- Place the bar magnet at the center of a sheet of white paper. Trace the outline of the magnet onto the paper and label the poles. Use the compass to record the direction of the magnetic field of the bar magnet.
- Connect “magnetic field lines” and put arrows on them. Remember the field lines show the direction of the force on a “N pole”.

Experiment C: What kinds of materials are attracted to magnets?

- Before you make any tests, record your predictions for the interaction between the materials provided (they include wood, glass, copper, a PVC pipe that can be charged with wool, and a spoon) and the magnet. Discuss your predictions with your lab group.
- If these materials are not themselves magnets can they be repelled from magnets?
- Try the objects provided and any other items you find of interest. Record your observations in a table. Are any objects repelled?

Scientists call materials that are attracted to a magnet *ferromagnetic materials*. Magnets are also made of ferromagnetic materials. Iron is the most common ferromagnetic material, and objects that include iron in them (like steel) are ferromagnetic. (Nickel and cobalt are also examples of

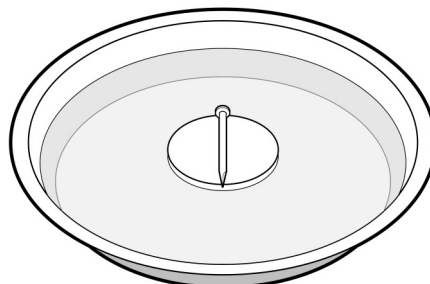
ferromagnetic materials.) For the remainder of this activity, you will use iron (or steel) nails to explore some important properties of the magnetic interaction.

Experiment D: What happens when a nail is rubbed with a magnet?

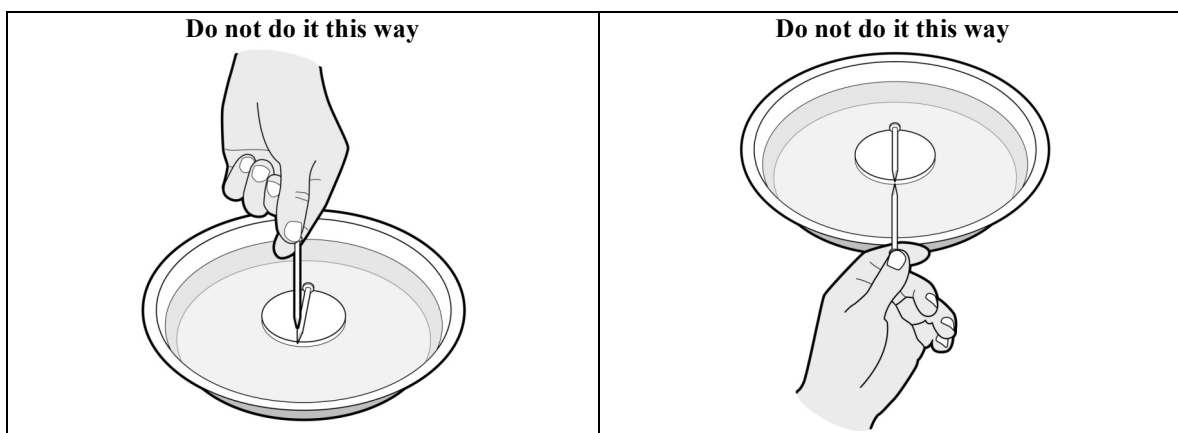
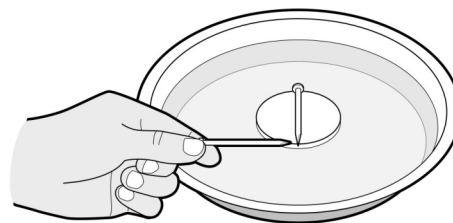
Your group will need a magnet, three nails, a small styrofoam float, an aluminum pie tin, a beaker to carry water and some water from the tap. In this experiment you will distinguish between two types of nails: those that are rubbed with a magnet (called *rubbed*), and those that are not rubbed with a magnet (called *unrubbed*).

Note: Keep the magnets far away from the nails. Once you rub a nail, it is no longer “unrubbed.” Please do not rub the nails until you are asked to do so.

D1. Use the beaker to pour some water into the aluminum pie pan. Lay an **unrubbed** nail on a small, flat piece of Styrofoam and float it in the water. This will give a very sensitive test arrangement. Check that your aluminum pan is not sitting over a piece of metal under the table, and that there are no large metallic objects nearby. Try to keep it away from the edges of the pan.

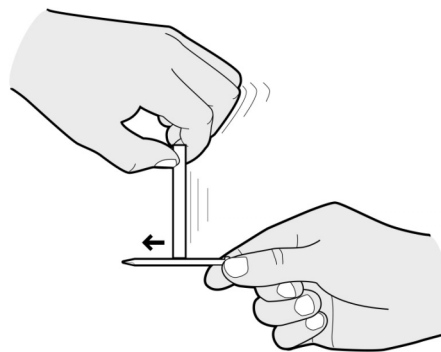


D2. We first want you to investigate whether an unrubbed nail can affect another unrubbed nail. To determine this, take a second unrubbed nail, hold it horizontally, and bring its tip **close to** (but not touching) the floating nail. See picture to the right showing that the held nail should be at right angles to the floating nail. Always test held and floating nails this way. Do not bring the held nail from above (picture below to the left), nor bring it parallel to the floating nail (see picture below to the right).



- What, if anything, happens to the floating nail when the held unrubbed nail is brought nearby?

D3. Make a **rubbed** nail as follows. Place one end (use the N pole) of the bar magnet over one end (start at the head end) of an unrubbed nail and rub in **one direction only (head to tip) to the other end**. Then lift the magnet away from the nail and repeat the process a few times, always rubbing in the **same** direction.



D4. Now we will investigate the interactions between a **rubbed** and an **unrubbed** nail.

- Using the same procedure as described in step D2, bring the tip of a held **rubbed** nail near the tip of the **floating unrubbed** nail. What, if anything, happens to the tip of the floating unrubbed nail?
- Bring the tip of the held rubbed nail near the head of the floating unrubbed nail. What, if anything, happens to the head of the floating nail?
- Turn the held **rubbed** nail around and bring its head near the tip and head of the floating nail.
- Summarize what happens, if anything, to the tip and head of the floating **unrubbed** nail.

D5. Lay the rubbed nail aside for a moment. *Imagine* that you removed the floating nail, rubbed it with the magnet in the same way you rubbed the other nail, then floated it again. You would then have two rubbed nails—one held and one floating. (Don't do it yet!)

- Predict what you think will happen if you were to bring the tip of the held **rubbed** nail near the tip of the floating **rubbed** nail.
- Predict what you think would happen if you were to bring the tip of the held **rubbed** nail near the head of the floating **rubbed** nail?

D6. Now remove the floating nail, rub it with the magnet the same way as in D3, and replace it on the floater. Then test your predictions.

- What actually happens when you bring the tip of the held rubbed nail near the tip of the floating rubbed nail?
- What actually happens when you bring the tip of the held rubbed nail near the head of the floating rubbed nail?
- What happens when you bring the head of the held rubbed nail near the tip and head of the floating rubbed nail?

D7. The direction of magnetization of the nail:

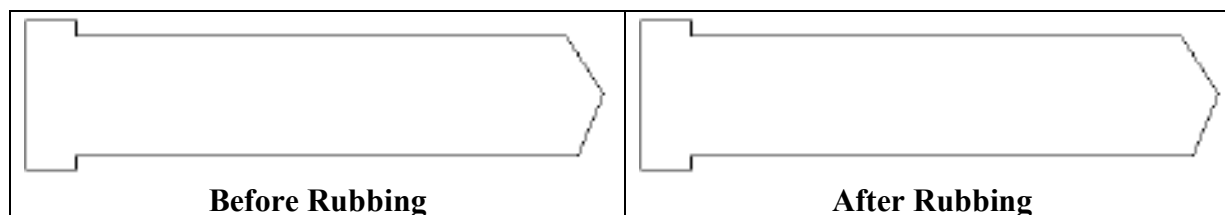
- Establish and record which end (head or tip) of the two rubbed nails is the N pole.
- Describe at least two ways to magnetize a nail in the **opposite** sense.
- Try one of your techniques on a third nail and test the result.

Summarize your observations for Experiment D by answering these questions.

- What happens when the tip of an **unrubbed** nail is brought near the tip of another **unrubbed** nail?
- What happens when the head of an **unrubbed** nail is brought near the tip of another **unrubbed** nail?
- What happens when the tip of a **rubbed** nail is brought near the tip of an **unrubbed** nail?
- What happens when the head of a **rubbed** nail is brought near the tip of an **unrubbed** nail?
- Make a 2x2 table to show this information more clearly
- Based on your observations, would you claim that a rubbed nail behaves like a magnet or like a ferromagnetic material that is not itself a magnet? What is your evidence?

Experiment E: Models for magnetism

E1. What do you think is happening **INSIDE** the nail when it is rubbed with a magnet? Copy a figure like this into your notebook and show as much detail as you can about your ideas.



- From your model predict what will happen if you cut a rubbed nail in half and put one half on the floater then bring an uncut rubbed nail close to the floating piece. Record your prediction.
- Do the experiment and record your observations.
- What other tests could you do to check your model?

E2. Make a **physical model**. Use the test tube half-full of iron filings, shake it up and hold it horizontally with the iron filings spread uniformly along the tube.

- Stroke the test tube slowly several times with a bar magnet's N pole, starting at the stopper and finishing at the tip (rounded end). Watch what happens to the iron filings.
- Float the rubbed nail again, bring the test tube close, rounded end to nail tip, then to nail head. Is the test tube like a rubbed or an unrubbed nail?
- Shake test tube and test it with the floating nail again, has it changed? Why?
- If you hammered on a magnetized nail would you be able to change its properties? Try it. What happens inside the hammered nail? An alternate procedure is to drop the nail to the floor many times. The nail has a hard landing which simulates hammering.

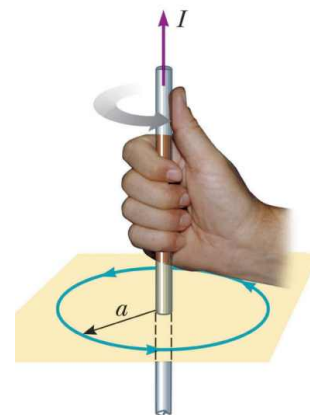
PLEASE discard all magnetized nails into the box on the front table.

Experiment F: Magnetic Effects of an Electric Current in a Straight Wire

The purpose of this experiment is to investigate the nature of the magnetic field generated by an electric current flowing in a straight wire. Before you start please be sure all magnets are at the far end of your bench. To get an effect measurable with a compass, we would like to be able to provide a large current through the straight wire to be able to make magnetic fields larger than the earth's field. However, practical considerations restrict the current to about 2.0 A. To overcome this we have five wires running parallel to each other, each carrying about 2.0 A. This is equivalent of a single wire carrying 10 A. This setup also has a platform where you can place a sheet of paper and a compass. You can mark the angle of the compass needle on the paper.

Before you connect the loops of wire to the power supply, set the current limit of the supply to its maximum value, and set the voltage to 2.5 V. Then switch the supply to read current, and turn the power supply off. Cut a sheet of paper to fit around the wire and rest on the platform to record the direction of the magnetic field. Set up the circuit so that the "conventional" current is flowing upwards. Review section 19.7 if you need to review magnetic fields of straight wires.

1. Test your setup: turn the power supply on and verify that you get a current of about 2.0 A. Do not leave the supply on for more than 10 seconds to avoid overheating. Note the current and the number of wires in your setup.
2. Using a compass observe and record the direction of the magnetic field at several points near the wire *when the current is zero*. Does this agree with the measurements you made in experiment B?
3. BEFORE you close the switch, predict what you expect to see when the current is not zero. Explain the figure on the right. Which way does the thumb point? Which way do the fingers point? Why is it useful?
4. Now close the switch, and record the magnetic field direction near the wires. Start with the compass north of the wires. Also note the field direction with the compass E, S, and W of the wires.
5. Is the direction and shape of the magnetic field you observe consistent with predictions made with the right hand rule?
6. Change the direction of the current through the straight wire. Is the magnetic field still consistent with the RH rule?
7. At what position relative to the wires is the magnetic field of the current perpendicular to the earth's magnetic field? (Choose N, S, E, W). Set the compass at this position. Turn on the power supply and reduce the current in the wires until the compass settles at 45° to the NS direction of the earth's field. Measure the current.
8. Calculate the magnitude and direction of the magnetic field from the current at the compass position. (Remember there are five loops of wire.)
9. Show the vector diagram of the two magnetic fields and the resultant field. (Hint: you know the size and direction of the field from the wires, and the angles of the earth's field and the resultant field.) What is the earth's field from your measurements?



BEFORE YOU LEAVE THE LAB: please remove all tape from tables, magnets, compasses etc. Place used tape in the trash and leave the lab as you would hope to find it.