On-line activities for magnetism (electromagnetic induction is not included in this file)

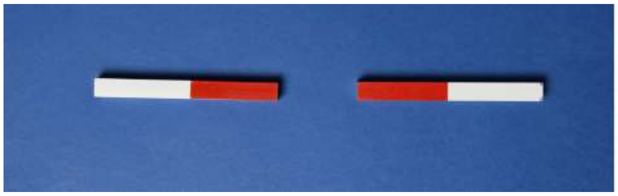
Below is the list of experiments (real, video based, simulations-based, and data-based) that students can perform as labs for magnetism. For each experiment we provide goals, equipment and rubrics for self-assessment. Rubrics can be found at https://sites.google.com/site/scientificabilities/rubrics

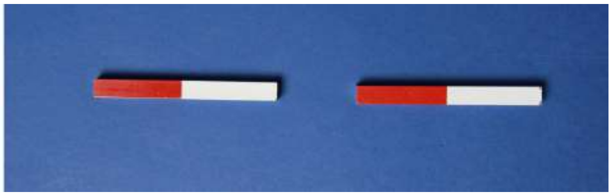
1. Observational experiment

Goals: to investigate interactions of magnets and the space surrounding them.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5 and B7.

Part I: In the following experiment https://youtu.be/x3a0AmPx3WM notice the markings on the ends of the bar magnets. (We used magnets that are marked with red (N) and white (S), but you may find other combinations such as brown (N) and white (S), red (N) and blue (S) and more.)





a. Describe your observations and record the patterns you found.

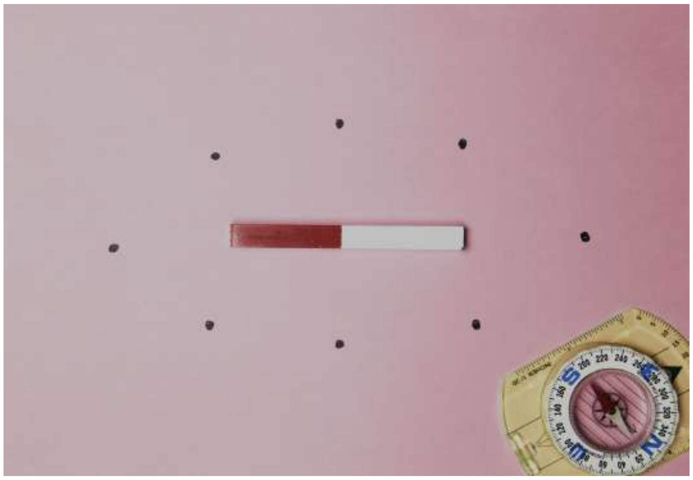
b. What other objects can interact at a distance in a similar way to magnets? What are the similarities and differences between these interactions and interactions of magnets?

Part II: In the following video https://youtu.be/rZBkxVt3_ZI the compass was placed on a table near the magnet and moved on the table around the magnet.

c. Draw pictures of the compass needle orientations for the locations marked in the figure below with points.

d. What are the patterns in the orientations of the compass needle?

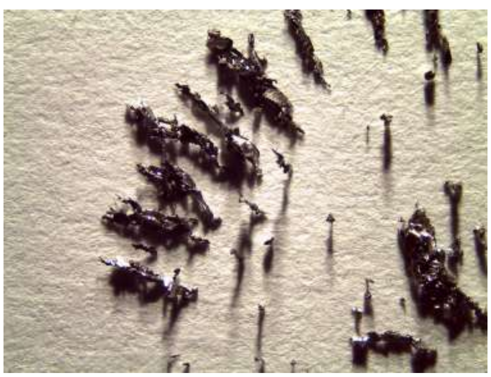
e. What can you say about the space surrounding the magnet (based on the behavior of the compass needle)?



2. Application experiment

Goals: To apply knowledge of magnets and compasses to explain a new phenomenon.

In the following video https://youtu.be/bG582AbFHsY the experimenter placed a sheet of white paper over the magnets and sprinkled iron filings on the sheet. A magnified image of the filings is pasted below. Draw what happens to the filings for several different arrangements of the bar magnets. Explain why the fillings might arrange the way they do.



3. Observational experiment

Goal: to investigate magnetic properties of a current carrying wire.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5 and B7.

In the following set of experiments https://youtu.be/BY90UvvJuaw we investigated whether current carrying wires produce magnetic fields.

a. Why are both compasses oriented the same way before the current is turned on in the circuit? What is their orientation? Watch carefully to find N and S of the compasses.

b. What can you say about the orientations of the compasses after the current is turned on in the first experiment? Do they turn in the same direction? Opposite?

c. How does the direction of each change in the second experiment?

d. What can you say about the magnetic field of the current-carrying wire based on these two experiments? Compare your answer to figure 20.9 on Page 620 in the textbook.

e. Notice that the compass needles are not exactly perpendicular to the current carrying wire. Why could that be? (Hint: think of the magnetic field of Earth.)

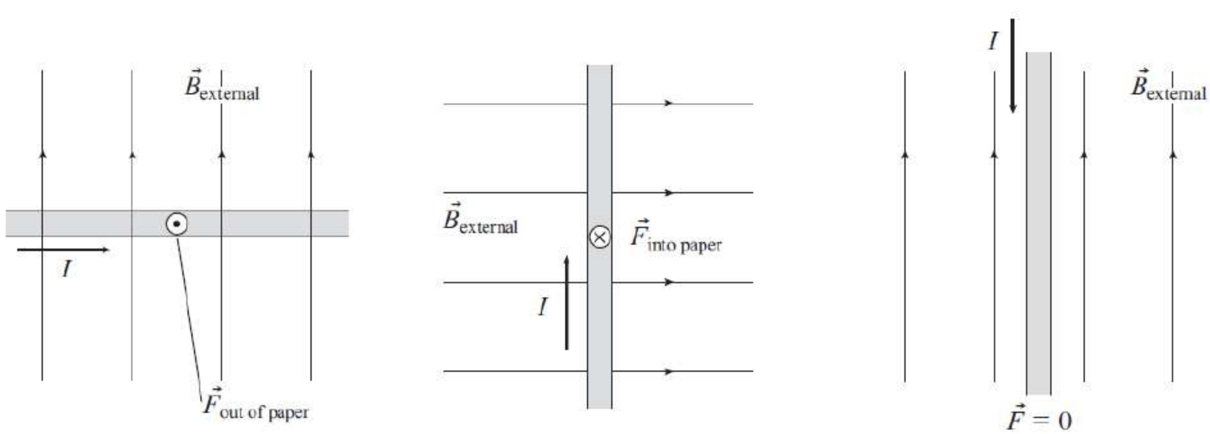
4. Observational experiment

Goal: to invent a rule that relates the directions of the magnetic force $\vec{F}_{\vec{B}\text{ on wire}}$, the directions of $\vec{B}_{\text{external}}$, and the directions of the current I in the wire.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5 and B7.

A current-carrying wire is placed between the poles of an electromagnet. The direction of the $\vec{B}$ field lines produced by the magnet $\vec{B}_{\text{external}}$, is shown in the figure.

a. Invent a rule that relates the directions of the magnetic force $\vec{F}_{\vec{B}\text{ on wire}}$, the directions of $\vec{B}_{\text{external}}$, and the directions of the current I in the wire.



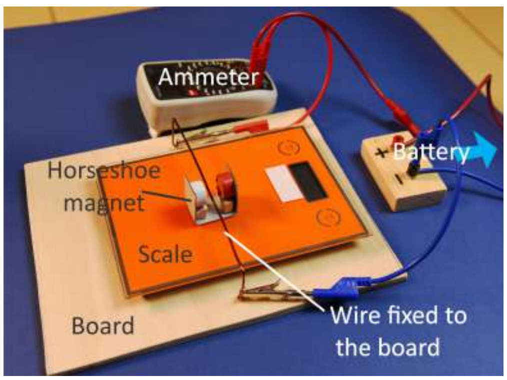
b. Does your rule account for the outcomes of the experiments in the following video? [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-42]. Explain.

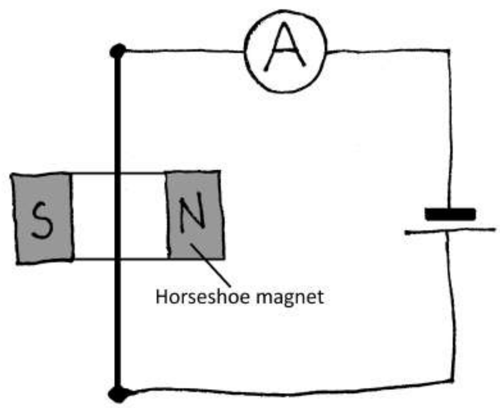
5. Testing experiment

Goal: to test the rule invented in Experiment 4.

Rubrics for self-assessment. Ability to conduct a testing experiment: C1, C4, C7 and C8.

Brainstorm about how you can use the equipment below to test the rule you developed for the direction of the force exerted by the magnetic field on a current-carrying wire. Using the set-up below, how do you expect the scale to respond when you turn on the power supply?





a. Consider the available equipment and how you could use it to test the right-hand rule. Write down your potential experiments. Think ahead about what you will measure and how you will measure it.

b. Describe the experimental procedure you have chosen. The description should contain a labeled sketch of your experimental set-up, an outline of what you plan to do, what you will measure, and how you will measure it.

c. Use the hypothesis you are testing to make a *qualitative* prediction for your particular experiment. Show the reasoning used to make the prediction, including force diagrams as appropriate.

d. Watch the following video of the experiment we conducted https://youtu.be/TUQtrs3zKfE. Does it support or reject the rule for the force that you invented in Activity 20.3.1? How do you know?

f. Compare your rule to the right-hand rule for the force discussed on page 622 in the textbook.

6. Observational experiment

Goal: To invent a rule for the magnitude of the magnetic force that the field exerts on a current carrying wire.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5, B7, and B8.

The table below provides data concerning the magnitude of the magnetic force $\vec{F}_{\vec{B}\text{ on W}}$ exerted on a segment of a current-carrying wire by an external magnetic field as the following quantities are changed: (1) the magnitude of the external magnetic field $\vec{B}$, (2) the magnitude of the electric current I, (3) the length of the segment of the current-carrying wire L, and (4) the direction of the electric current relative to the direction of the magnetic field.

Magnitude of the magnetic field $\vec{B}$ (T)	**Current I in the wire (A)**	**Length L of the wire (m)**	**Angle θ between current direction and $\vec{B}$ field**	**Magnitude of the magnetic force $\vec{F}_{\vec{B}\text{ on W}}$ exerted on the wire (N)**
$1B$	I	L	90°	F
$2B$	I	L	90°	$2F$
$3B$	I	L	90°	$3F$
B	I	L	90°	F
B	$2I$	L	90°	$2F$
B	$3I$	L	90°	$3F$
B	I	L	90°	F
B	I	$2L$	90°	$2F$
B	I	$3L$	90°	$3F$
B	I	L	0°	0
B	I	L	30°	$0.5F$
B	I	L	90°	F

a. Devise a mathematical rule relating the magnitude of the magnetic force $\vec{F}_{\vec{B}\text{ on W}}$ to these quantities.

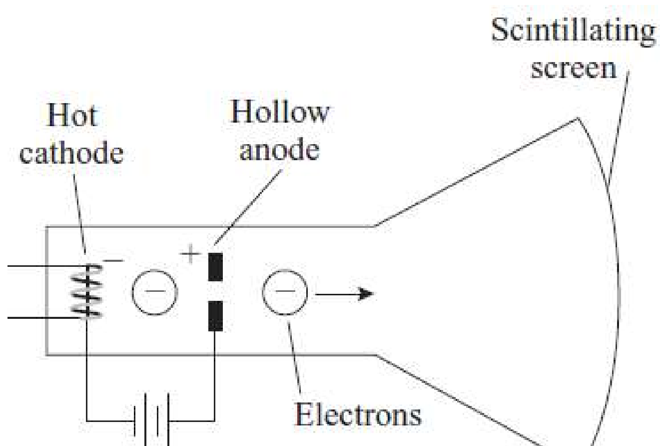
b. Use the set-up in Experiment 5 to test the rule you just invented. Here are some additional measurements: the length of the wire inside the magnet is about 20 mm; the magnitude of the $\vec{B}$ field at the location of the wire is 0.33 T. Using these data (and the value of the electric current from the video you can calculate the magnitude of the magnetic force exerted on the wire. Use the value of the magnetic force and other data from the video to predict the reading of the scale when there is current through the wire. Compare your prediction to the actual reading. Do you need to revise your reasoning?

7. Observational experiment

Goal: to find a pattern in the direction of the force exerted by the magnetic field on a moving charged particle.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5 and B7.

A cathode-ray tube (CRT) is part of a traditional television set or of an oscilloscope. Electrons "evaporate" from a hot filament called the *cathode*. They accelerate across a potential difference and then move at high speed toward a scintillating screen. The electrons form a bright spot on the screen at the point at which they hit it. A magnet held near the CRT sometimes causes the electron beam to deflect.



a. Watch the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-20-4-1] and devise a rule for the direction of the force $\vec{F}_{\vec{B}\text{ on }e}$ that the magnet exerts on the moving electrons relative to the direction of their velocity $\vec{v}$ and the direction of the magnetic field $\vec{B}$ produced by the magnet. Make sure your rule encompasses all the different scenarios you observe in the video.

b. Compare the rule that you devised in part **a** to the right-hand rule for the magnetic force devised earlier. How are they the same and how are they different?

c. Your friend says that the beam of electrons is deflected by the magnet because the electrons are charged particles and the magnet is made of iron. How can you convince your friend that she is mistaken?

8. Observational experiment

Goal: to find a pattern in the magnitude of the force exerted by the magnetic field on a moving charged particle.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5, B7, and B8.

The table below provides data concerning the magnitude of the magnetic force exerted on a moving charged particle by a magnetic field as the following quantities are changed: (1) the particle's speed, (2) the magnitude of the magnetic field, and (3) the direction of the particle velocity relative to the magnetic field.

Magnitude of the magnetic field $\vec{B}$ (T)	**Charge of the moving particle**	**Speed v of the moving particle (m/s)**	**Angle θ between the velocity $\vec{v}$ and the $\vec{B}$ field**	**Magnitude of the magnetic force $F_{\vec{B}\text{ on P}}$ exerted on the particle (N)**
B	q	v	90°	F
$2B$	q	v	90°	$2F$
$3B$	q	v	90°	$3F$
B	q	v	90°	F
B	$2q$	v	90°	$2F$
B	$3q$	v	90°	$3F$
B	q	v	90°	F
B	q	$2v$	90°	$2F$
B	q	$3v$	90°	$3F$
B	q	v	0°	0
B	q	v	30°	$0.5F$
B	q	v	90°	F

Devise a rule relating the magnitude of the force to these quantities.

9. Observational experiment

Goal: to learn how different materials behave in external magnetic field.

Rubrics for self-assessment. Ability to conduct an observational experiment: B5 and B7.

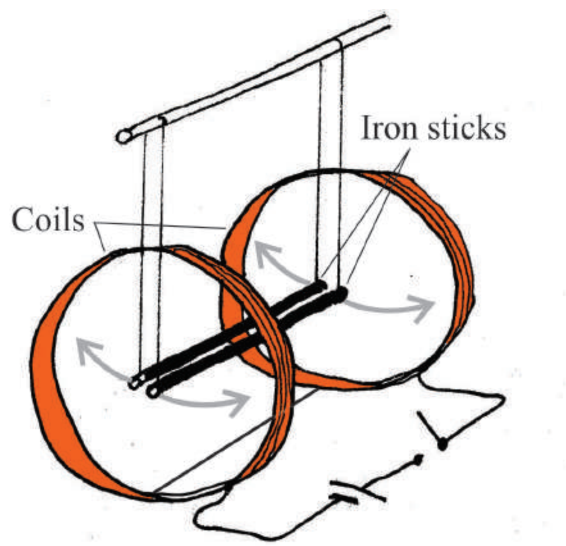
a. Observe the following experiments https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-egv2e-magnetic-properties-of-matter and describe the patterns that you observed.

b. Use available resources to find the names for three different types of materials shown in the video.

c. Using the knowledge you developed working answering part **b**, explain the experiment in the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-20-7-2].

10. Application experiment

Goal: to apply the knowledge of ferromagnetic materials to explain the outcome of the experiment.



Two iron rods hanging on non-conductive strings are placed in the area between two coils that are connected in series with a switch and a battery. The rods are initially close to each other (see the figure on the right). When you switch on the current through the coils, the rods move apart (as indicated by arrows) and stay apart while the current remains on. When you switch off the current, the rods move closer together, but they don't quite go quite back into their initial position. The current through the coils produces an almost uniform magnetic field in the space where the iron rods are hanging.

a. Explain why the iron rods repel each other after the current is turned on.

b. Explain why the iron rods continue to repel even after the current in the coils is turned off.

c. Can you make the iron rods go back into their initial positions by only manipulating the current through the coils? Explain.