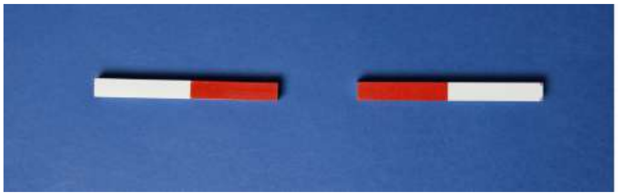
Chapter 20

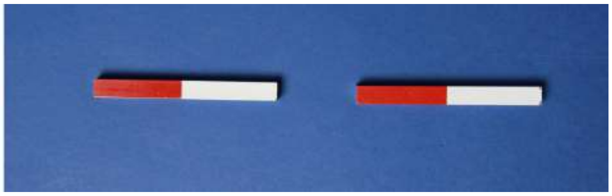
Magnetism

20.1 Magnetic interactions

OALG 20.1.1 Observe and find a pattern

In the following video 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?

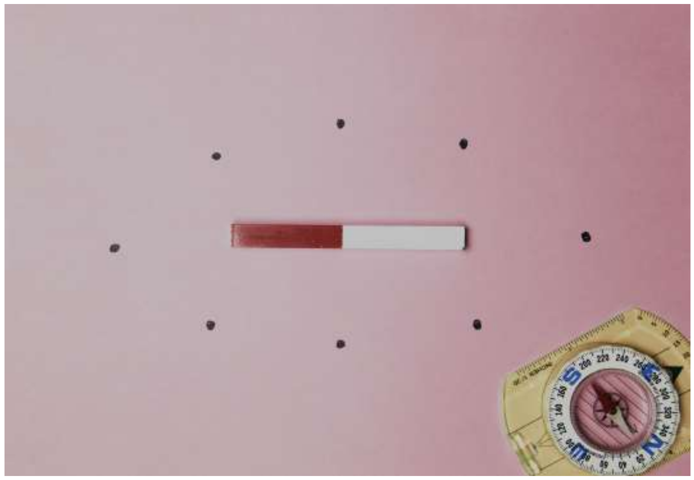
OALG 20.1.2 Observe and find a pattern

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.

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

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

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

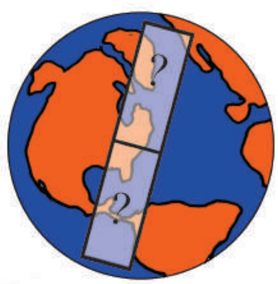


OALG 20.1.3 Reason

Equipment: bar magnet, compass, string.

You may already know that on Earth a compass points in a northward direction as long as no other magnets are nearby. The end of the compass that points in the northward direction is called the *north pole* of the compass and the other end is called the *south pole*.

a. If Earth were a magnet, would its magnetic north pole be in a northern direction or a southern direction?



b. If you have a bar magnet and hang it by wrapping the string around its center so the magnet is horizontal. Investigate its orientation when it is hanging freely. Explain your findings.

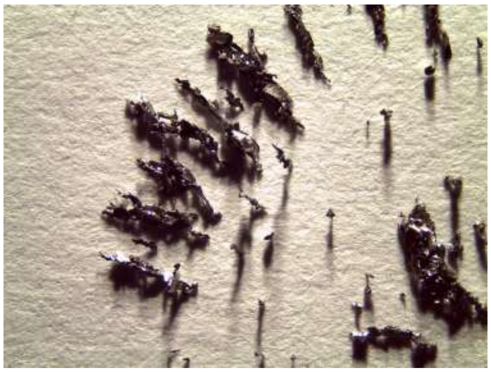
OALG 20.1.3 Read and interrogate

Read and interrogate Section 20.1 and answer Review Question 20.1.

20.2 Magnetic field

OALG 20.2.1 Observe and explain

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.



OALG 20.2.2 Read and interrogate

Read and interrogate material on 618 in the textbook and answer the following questions:

a. How does a compass indicate the direction of the $\vec{B}$ field and how does the compass indicate its magnitude?

b. How does the orientation of a compass at a particular location relate to the direction of the $\vec{B}$ field vector?

OALG 20.2.3 Observe and find a pattern

a. Several experiments are described below.

Experiment 1. The north pole of a bar magnet always attracts the south pole of another bar magnet and repels the other bar magnet's north pole.

Experiment 2. Neither the north pole nor the south pole of a magnet exerts a notable force on a small aluminum ball hanging at the end of a thin, non-conducting thread.

Experiment 3. A foam tube is rubbed with a fur and becomes negatively charged. A glass tube is rubbed with a silk and becomes positively charged. You find that *both* tubes attract the north pole of a bar magnet and both attract the south pole.

For each experiment above, compare and contrast magnetic poles with the behavior of positively or negatively electrically charged objects.

b. Explain the results of experiment 3 in part **a**. above. Start by drawing a picture of the charge distribution inside the magnet when the positively charged tube is near the magnet's N pole and again when the negatively charged tube is near the magnet's N pole.

OALG 20.2.4 Observe and explain

In the following set of experiments https://youtu.be/BY90UvvJuaw we investigated whether current carrying wires produce magnetic fields. Your task is to watch the video and answer the following questions (if you are having trouble, consult Observational Experiment Table 20.1 on page 619 in the textbook).

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?

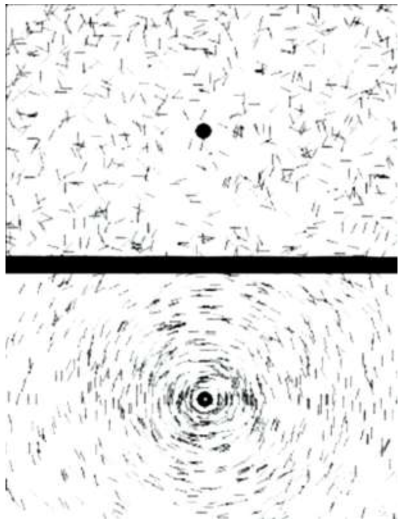
d. What can you say about the magnetic field of the current-carrying wire based on these two experiments? Compare your answer to figure 20.9 on Page 620 in the textbook.

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.)

OALG 20.2.5 Observe and explain

Imagine that a wire passes perpendicularly into the page you are reading. Iron filings are sprinkled on the page. We can think of the iron filings as small compasses. The upper picture below shows the filings when there is no current in the wire. The lower picture is the arrangement of the filings when there is a significant current in the wire.

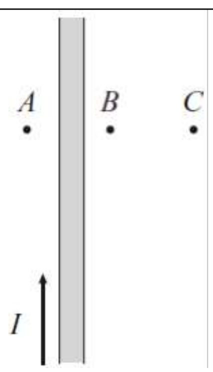
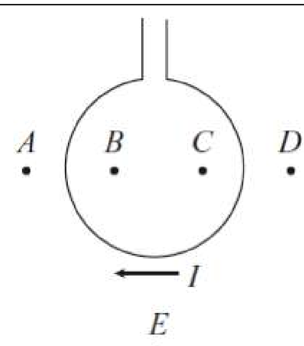
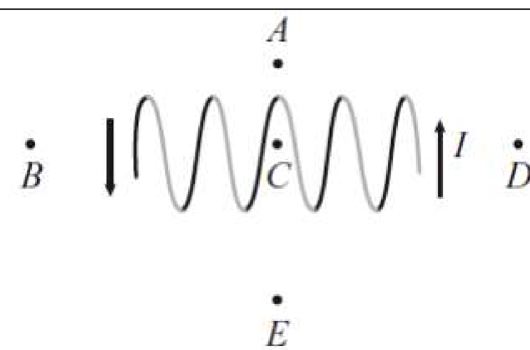
a. Is the lower picture consistent with the results of the experiment in Activity 20.2.4? Explain your answer.



b. Draw a sketch that you think represents the orientation of $\vec{B}$ field vectors for the magnetic field produced by the electric current in the wire at five different points. (*Hint:* Choose the direction of the current as coming out of the page and use your findings in Activity 20.2.4.)

OALG 20.2.6 Represent and reason

There is current in each of the wires shown in the illustration below (the battery and the rest of the circuit are not shown). In cases **a**. and **b**., the current-carrying wires are in the plane of the paper. Case **c**. shows a solenoid (parts of wires that are further from you are black and those closer to you are gray). Determine the direction of the $\vec{B}$ field created by the current at the points indicated and draw it with an arrow, a dot (out of the page), or a cross (into the page).

a.	**b.**	**c.**
		

OALG 20.2.7 Read and interrogate

Read and interrogate the remainder of Section 20.2 in the textbook and answer Review Question 20.2.

OALG 20.2.8 Practice

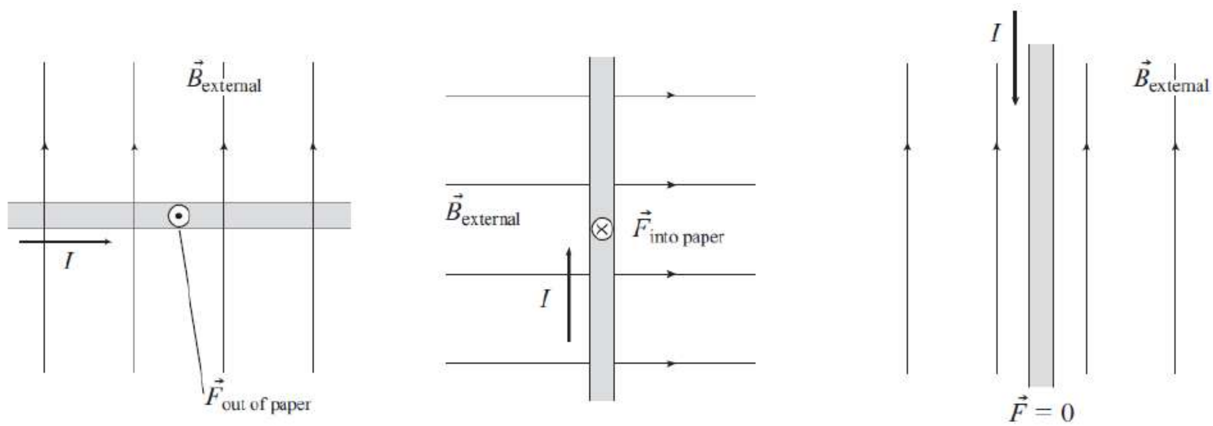
Answer Questions 1, 4, 5, 11, 13, and 13 on page 643 and solve Problems 1 – 5 on page 644.

20.3 Magnetic force exerted by the magnetic field on a current-carrying wire

OALG 20.3.1 Find a pattern

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.

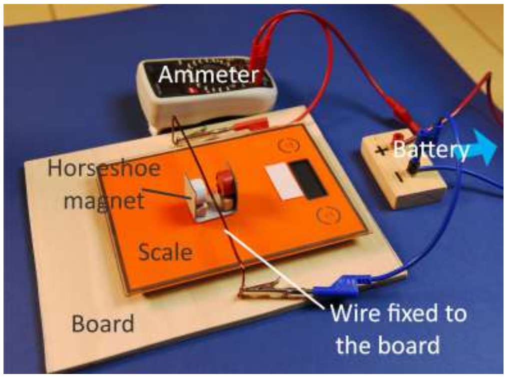
a. Invent a rule that relates the directions of the magnetic force $\vec{F}_{\vec{B}\text{ on wire}}$, the directions of $\vec{B}_{\text{external}}$, and the directions of the current I in the wire.

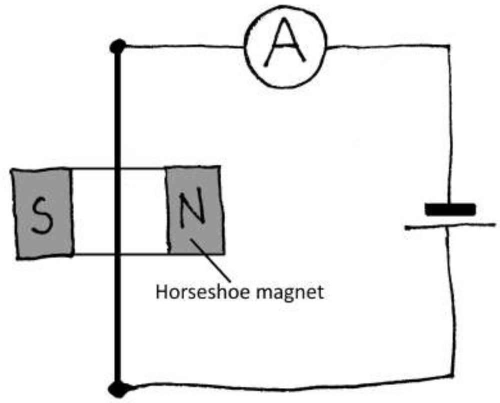


b. Does your rule account for the outcomes of the experiments in the following video? [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-42]. Explain.

OALG 20.3.2 Test your idea

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.

OALG 20.3.3 Find a pattern

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.

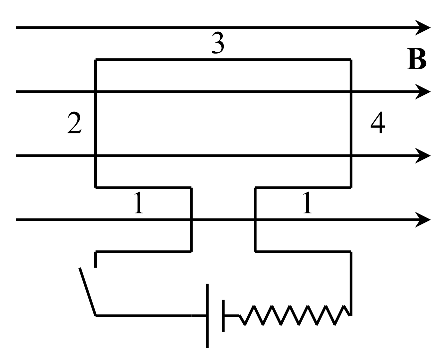
Magnitude of the magnetic field $\vec{B}$ (T)	**Current *I* in the wire (A)**	**Length *L* of the wire (m)**	**Angle θ between current**	**Magnitude of the magnetic force**

			direction and $\vec{B}$ field	**$\vec{F}_{\vec{B}\text{ on W}}$ 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. Compare the rule that you devised to Eq. 20.3 on page 625 in the textbook. How are they the same? How are they different?

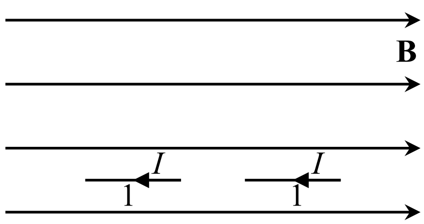
c. Use the set-up in Activity 20.3.2 to test the rule you just invented. Here are some additional measurements: the length of the wire inside the magnet is about 20 mm; the magnitude of the $\vec{B}$ field at the location of the wire is 0.33 T. Using these data (and the value of the electric current 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?



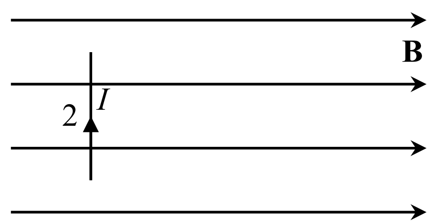
OALG 20.3.4 Represent and reason

A rigid wire in the shape of a rectangular loop is shown in the figure to the right. When the switch in the circuit is closed, current flows around the loop in a clockwise direction. The loop resides in a uniform external magnetic field. Figure out the direction of the force exerted by the magnetic field on each side of the rectangular loop shown in the figures below.

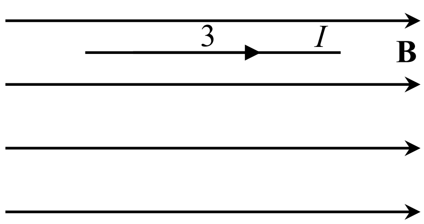
a. Force exerted by $\vec{B}$ on side 1



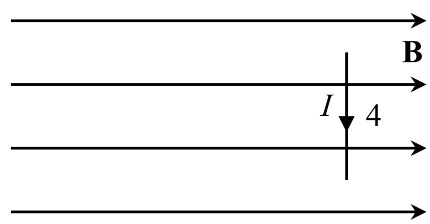
b. Force exerted by $\vec{B}$ on side 2



c. Force exerted by $\vec{B}$ on side 3



d. Force exerted by $\vec{B}$ on side 4



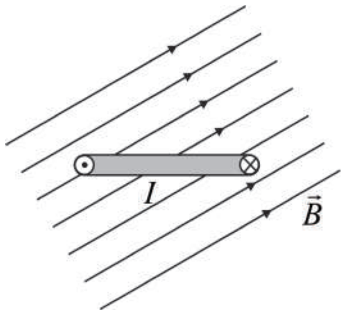
e. Does the magnetic field exert a net nonzero magnetic force on the loop? If so, what is the direction of the net force?

f. Does the field exert a net nonzero magnetic torque on the loop? If so, how does this torque tend to cause the orientation of the loop to change (assuming it is initially at rest)?

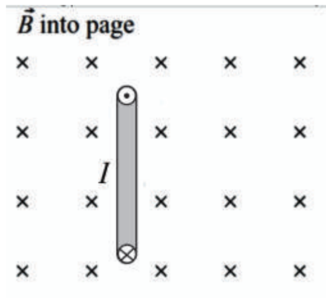
OALG 20.3.5 Represent and reason

Decide whether the magnetic field exerts a nonzero torque on the current loop in each case pictured below. If so, and if the loop is initially at rest, which way would the magnetic torque cause the loop to start turning? For each case, draw in the forces on two opposite sides of the loop and show the direction of the net torque. (Current loops in parts **a**., **b**., and **d**. are perpendicular to the page.)

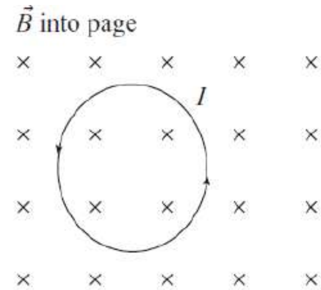
a.



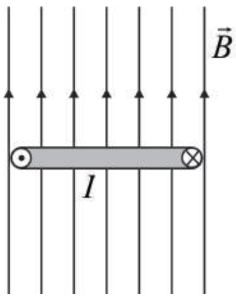
b.



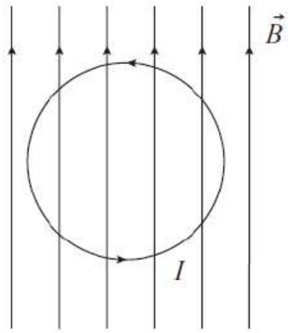
c.



d.

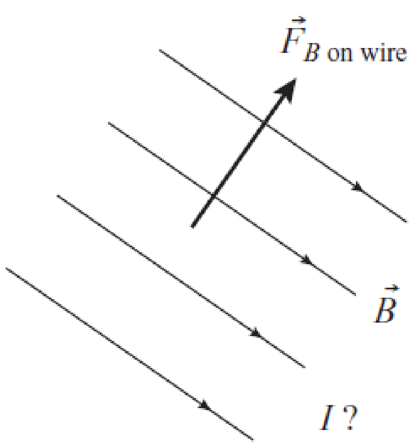
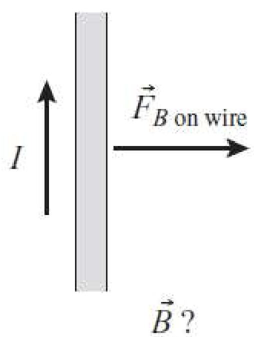
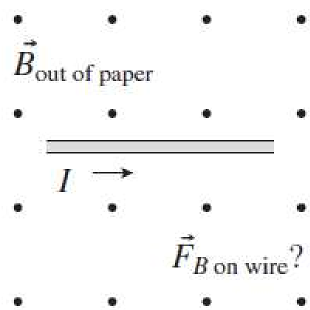


e.



OALG 20.3.6 Practice

For each situation depicted in the table that follows, find the direction of the unknown physical quantity. Draw in the directions in the figures.

Situation 1	Situation 2	Situation 3
		

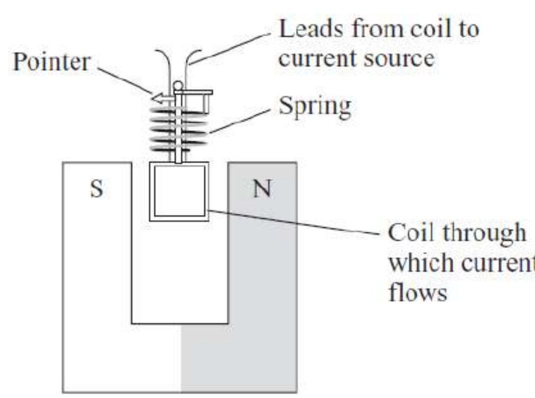
OALG 20.3.7 Represent and reason

Two wires are parallel to each other. Wire 1 has electric current going into the page and wire 2 has electric current coming out of the page. Figure out what wires 1 and 2 do to each other. Use the questions in the table that follows to guide your reasoning. They emphasize the importance of choosing a source of a field and a system on which the field exerts a force.

a. Draw in magnetic field lines $\vec{B}_1$ produced by the current I_1 in wire 1 (the source of the field). Be sure to include a line passing through wire 2. 1 $\otimes$ I_1 in 2 $\odot$ $\vec{B}_1$?	Noting the field $\vec{B}_1$ passing through wire 2, draw the direction of the magnetic force $\vec{F}_{1\text{ on }2}$ that wire 1's magnetic field $\vec{B}_1$ exerts on wire 2 (the system). 1 $\otimes$ I_2 out 2 $\odot$ $\vec{F}_{\vec{B}_1\text{ on }I_2}$?
b. Draw in magnetic field lines $\vec{B}_2$ produced by the current I_2 in wire 2 (the source of the field). Be sure to include a line passing through wire 1. 1 $\otimes$ $\vec{B}_2$? 2 $\odot$ I_2 out	Noting the field $\vec{B}_2$ passing through wire 1, draw the direction of the magnetic force $\vec{F}_{2\text{ on }1}$ that wire 2's magnetic field $\vec{B}_2$ exerts on wire 1 (the system). 1 $\otimes$ I_1 in $\vec{F}_{\vec{B}_2\text{ on }I_1}$? 2 $\odot$

OALG 20.3.8 Reason

An old-fashioned galvanometer is a device that serves as a basis for an ammeter and a voltmeter. The galvanometer consists of a coil hanging between the poles of a horseshoe magnet. The coil is supported by a rod that can turn in a ball joint. A spring opposes its turning. A needle, attached to the rod, changes its orientation as the rod turns. The greater the current flowing through the coil, the greater the torque exerted on it by the magnetic field of the magnet, and the more the needle deflects. How can you make an ammeter and a voltmeter out of the same galvanometer? Imagine that you have resistors of different resistances.



OALG 20.3.9 Read and interrogate

Read and interrogate Section 20.3 in the textbook and answer Review Question 20.3.

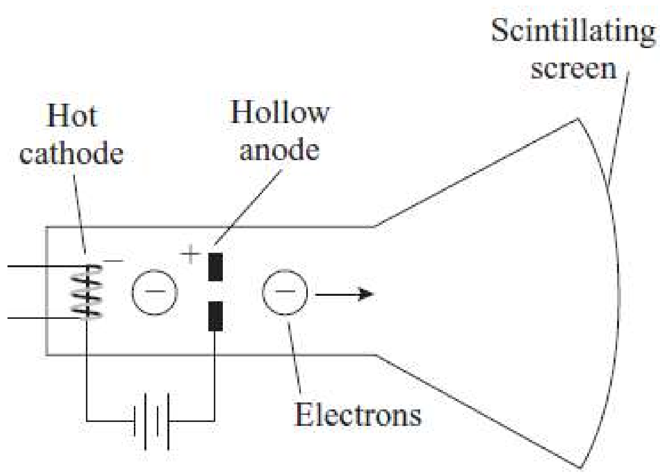
OALG 20.3.10 Practice

Answer Question 17 on page 643 and solve Problems 8 – 12, and 18 on pages 644 -645.

20.4 Magnetic force exerted on a single moving charged particle

OALG 20.4.1 Observe and find a pattern

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.



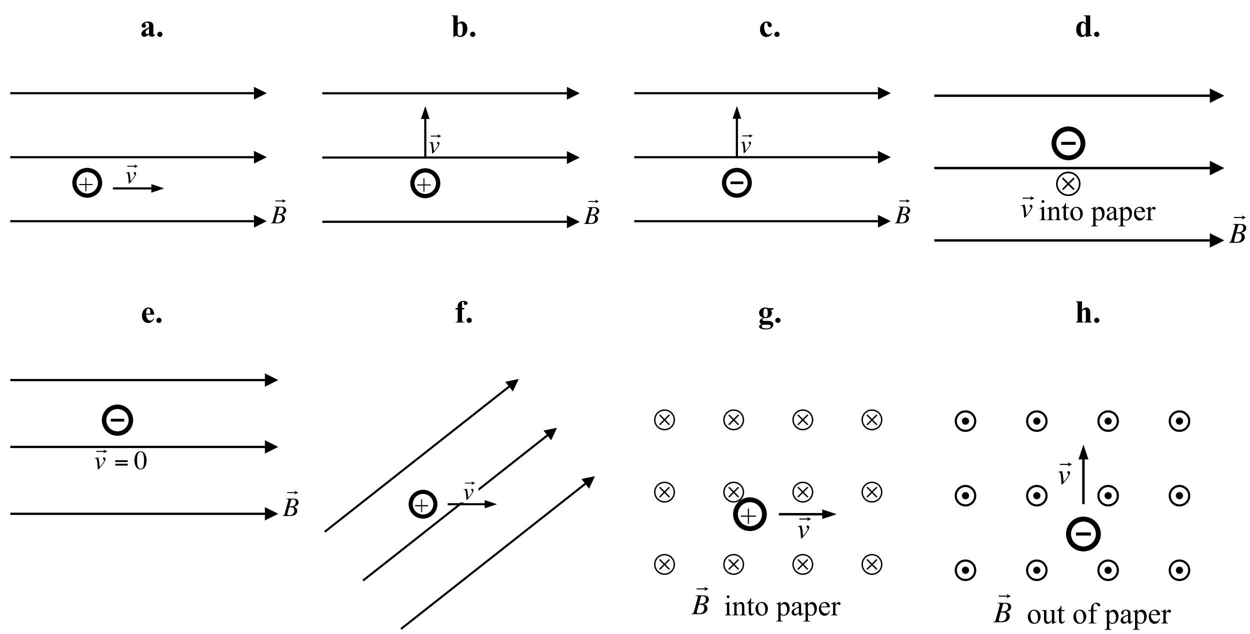
a. Watch the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-20-4-1] and devise a rule for the direction of the force $\vec{F}_{\vec{B}\text{ on }e}$ that the magnet exerts on the moving electrons relative to the direction of their velocity $\vec{v}$ and the direction 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?

OALG 20.4.2 Represent and reason

For each situation below, decide whether a nonzero magnetic force is exerted on the moving electric charge (test object). If the force is not zero, draw in the direction of the magnetic force on the figures that follow.



OALG 20.4.3 Find a pattern

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.

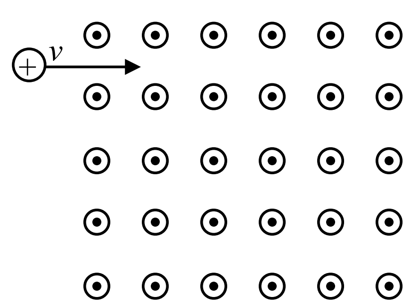
Magnitude of the magnetic field $\vec{B}$ (T)	**Charge of the moving particle**	**Speed v of the moving particle (m/s)**	**Angle θ between the velocity $\vec{v}$ and the $\vec{B}$ field**	**Magnitude of the magnetic force $F_{\vec{B}\text{ on P}}$ exerted on the particle (N)**
B	q	v	90°	F
$2B$	q	v	90°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

Compare the rule you devised to Eq. 20.5 on page 629 in the textbook. How are they the same and how are they different?

OALG 20.4.4 Represent and reason

A positively charged object (mass m, initial velocity $\vec{v}$) enters a region of magnetic field as shown in the figure at right. (To make life easier, don't worry about gravitational interactions for now.) Use your understanding of how magnetic fields interact with moving charged objects to draw the trajectory of the object. Pick 4 different points on the trajectory. Draw the velocity of the object and draw the force exerted by the magnetic field on the charged object.

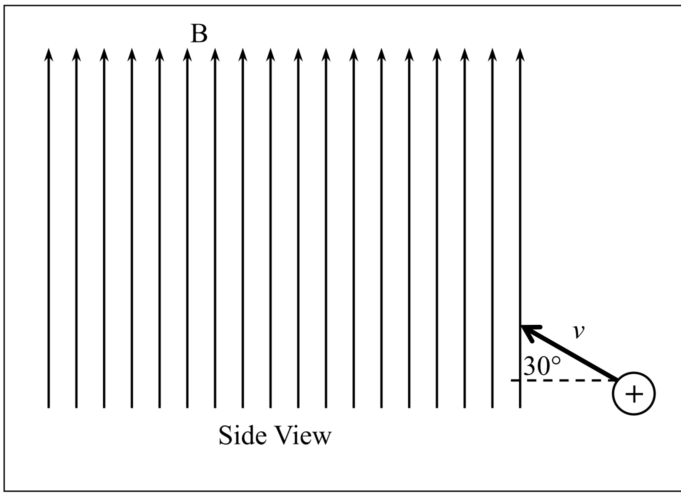


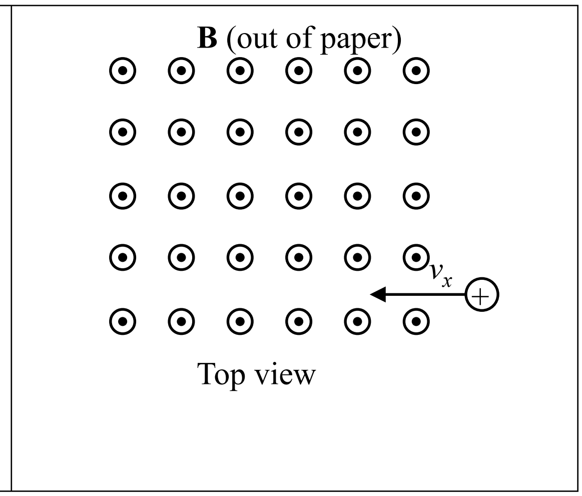
B (out of paper)

Does this look like a familiar pattern you saw last semester? What is it? If you had a sufficiently large region of magnetic field, what sort of motion would you expect to see? Sketch it in your notes.

OALG 20.4.5 Represent and reason

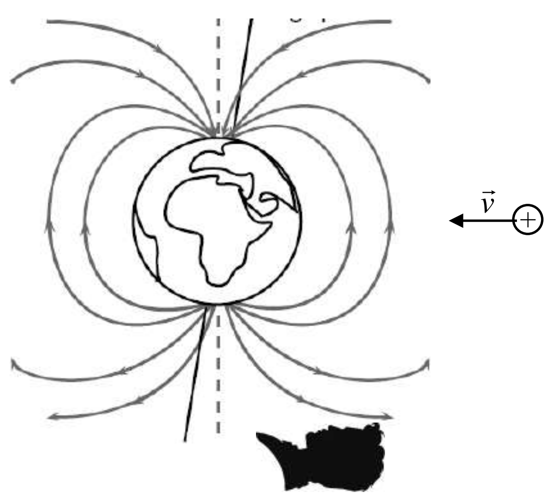
A positively charged object (mass m, initial speed v) enters a region of magnetic field as shown in the figures below. (To make life easier, don't worry about gravitational interactions for now.) Use your understanding of how magnetic fields interact with moving charged objects to draw and describe the trajectory of the object. *Hints*: 1. Pay particular attention to the angle at which the charged object enters the magnetic field. 2. Remember that motion in two perpendicular directions can be analyzed separately.





OALG 20.4.6 Reason

A positively charged proton is ejected into space during a supernova - an explosion that occurs during the gravitational collapse of a large star near the end of its life. The proton travels through space for millions of years and finally reaches the magnetic field that surrounds Earth; we call the proton a *cosmic ray*. Sketch the path of the proton as it travels in the Earth's magnetic field. Show its path as it might be seen from



below Earth (see the viewpoint of the person in the figure).

OALG 20.4.7 Read and interrogate

Read and interrogate Section 20.4 in the textbook and answer Review Question 20.4.

OALG 20.1.3 Reason

Answer Questions 2, 8, 18 and 19 and solve Problems 20, 24, 25, and 26 on pages 645-646.

20.5 Magnetic fields produced by electric currents

OALG 20.5.1 Read and interrogate

Read and interrogate Section 20.5 in the textbook and answer Review Question 20.5.

OALG 20.5.2 Practice

Solve Problems 28, 31 and 32 on page 646.

20.6 Skills for analyzing magnetic processes

OALG 20.6.1 Regular problem

Use the steps below to solve the problem, then compare your solution to the solution in Example 20.6 in the textbook.

A horizontal metal wire of mass 5.0 g and length 0.20 m is supported at its ends by two very light conducting threads. The wire hangs in a 49-mT magnetic field, which points perpendicular to the wire and out of the page. The maximum force each thread can exert on the wire before breaking is 39 mN. What is the minimum current through the wire that will cause the threads to break?

Sketch and translate • Sketch the process described in the problem. Label the known and unknown quantities. • Choose the system of interest. • Show the direction of the $\vec{B}$ field and the direction of the electric current (or the velocity of a charged particle) if known. • Decide whether the problem asks to find a $\vec{B}$ field	

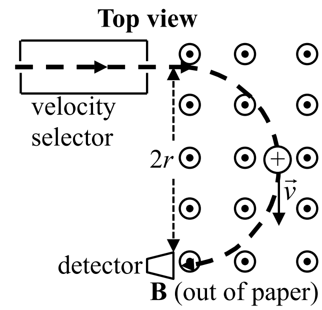
produced by an electric current or to find a magnetic force exerted by an external field on a moving charged particle or wire with electric current.	
Simplify and diagram • Decide whether the $\vec{B}$ field can be considered uniform in the region of interest. • Draw a force diagram for the system (the object in the field region) if necessary. Use the right-hand rule for the magnetic force to find an unknown force, current, velocity, or field direction if needed. • Use the right-hand rule for the $\vec{B}$ field if the problem is about the field of a known source.	
Represent mathematically • Describe the situation mathematically using the expressions for magnetic force exerted on a current or charged particle and the expressions for the $\vec{B}$ field produced by currents. • If necessary, use Newton's second law in component form and/or kinematics.	
Solve and evaluate • Use the mathematical representation of the process to determine the unknown quantity. • Evaluate the results—units, magnitude, and limiting cases—to make sure they are reasonable.	

OALG 20.6.2 Regular problem

You wonder if you could support your clothesline by running an electric current through it while it resides in the 0.5×10^{-4} T magnetic field due to Earth. We'll assume that you are in Costa Rica near the equator, where the field is parallel to Earth's surface. The line is to be 10 m long. You estimate that, with the clothes attached, its mass is 2.0 kg. What direction should you orient the line and what electric current is needed to support the line? Finally, does this seem like a promising way to support a clothesline? Explain.

OALG 20.6.3 Represent and reason

The mass-detecting part of a mass spectrometer is described below. Devise a mathematical expression for the ion's mass based on its speed, the strength of the magnetic field, and the radius of the circle that it makes in that field.

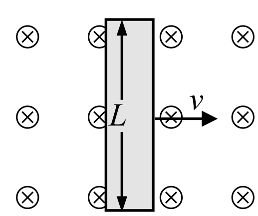
An ion with mass m and charge $+e$ leaves a velocity selector moving at speed v. It then moves in a half circle in a magnetic field that is perpendicular to the plane of its motion. At the end of this trip, it is detected. The radius of the circle can be used to determine the mass of the ion.	

a. Draw a force diagram for the ion at any point in its motion.

b. Represent the process mathematically by applying Newton's second law for circular motion.

c. Solve for the mass of the ion.

OALG 20.6.4 Represent and reason

Answer the questions below. A metal bar of length L moves at constant velocity $\vec{v}$ through a magnetic field $\vec{B}$ that points into the paper (as shown by the crosses in the figure at right).	

a. Indicate on the bar (redraw it in your notes) how the charges in the bar are redistributed due to the force that the magnetic field exerts on them.

b. This charge redistribution from part **a**. produces an electric field inside the bar that prevents further charge redistribution. Draw the $\vec{E}$ field lines inside the bar.

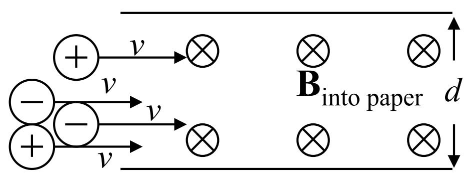
c. Apply Newton's second law to a charge in the middle of the bar—now it is in an electric field and in a magnetic field, and it is in equilibrium.

d. Use the expression that relates the $\vec{E}$ field magnitude component E_y (direction perpendicular to the velocity of the bar) and the potential difference over a distance $\Delta V/L$ with the previous results to determine an expression for the potential difference between the ends of the bar.

OALG 20.6.5 Real-life application

First, solve the previous activity. It will help you to understand how a magnetic flow meter works (you will need to identify the analogous parts by yourself).

A major artery has a diameter d of 1 cm. A magnetic flow meter clamped around the artery sets up a region of magnetic field $B = 0.20$ T. The flow meter measures a potential difference of 2×10^{-3} V between opposite sides of the artery. Positive and negative ions flow through the artery at a speed v as shown in the diagram. Estimate the speed of the blood flowing through the the artery.



a. Draw the force exerted on a + ion and on a – ion flowing in the blood by the external magnetic field.

b. Draw a charge diagram showing how the + and – ions accumulate on the walls of the artery.

c. Draw a force diagram for a + ion that travels straight through the artery because $F_{\text{E on q}}$ balances $F_{\text{B on q}}$.

d. Start with an equation relating $F_{\text{E on q}}$ to $F_{\text{B on q}}$ and solve for E.

e. Use the expression that relates $\vec{E}$ field magnitude E and the potential difference over the diameter of the artery $\Delta V/d$ with the previous results to determine an expression for the speed v of the ions in the artery.

OALG 20.6.6 Regular problem

What happens to a cosmic-ray proton flying into Earth's atmosphere at a speed of about 10^7 m/s? The magnitude of Earth's $\vec{B}$ field is approximately 5×10^{-5} T. The mass m of a proton is approximately 10^{-27} kg. Consider three cases: The proton enters Earth's atmosphere parallel to the $\vec{B}$ field, perpendicular to the field, and at a 30° angle. Represent the processes in different ways in your notes and decide what interesting or relevant quantities you can calculate from the given information.

OALG 20.6.7 Equation jeopardy

Two processes are represented mathematically below. Represent each process with

a. a force diagram,

b. a sketch, and

c. a word problem for which the given mathematical representation is the solution.

Process 1: $(1.6 \times 10^{-19}\ \text{C})(2.0 \times 10^{7}\ \text{m/s})B = (1.67 \times 10^{-27}\ \text{kg})\left(\dfrac{(2.0 \times 10^{7}\ \text{m/s})^2}{6000\ \text{m}}\right)$

Process 2: $0.020\ \text{N} = (0.020\ \text{A})(0.10\ \text{T})(20\ \text{m})(0.50)$

OALG 20.6.8 Evaluate

You work in the complaints office of an auto manufacturer. A customer makes a complaint. Describe the process in other ways and decide how you will respond to the customer:

The customer says that while driving through Earth's magnetic field, a potential difference developed from one end of her car to the other. The car discharged, causing her to lose control and run off the highway into a ditch. Decide the action you should take. Be sure to use your physics knowledge to help complete the recommendation—people have much more confidence in decisions based on physics, don't they?

a. Sketch the situation.

b. Construct a mathematical representation.

c. Evaluate the argument and provide a recommendation.

OALG 20.6.9 Read and interrogate

Read and interrogate Section 20.6 in the textbook and answer Review Question 20.6.

OALG 20.6.10 Practice

Solve Problems 33-36, 41, and 45 on pages 646-647.

20.7 Magnetic properties of materials

OALG 20.7.1 Read and interrogate

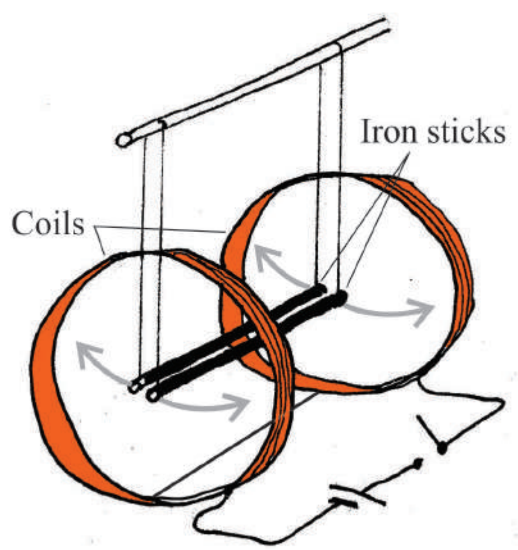
Read and interrogate Section 20.7 in the textbook, watch the videos and answer the Review Question 20.7. Then answer Question 9 on page 643.

OALG 20.7.2 Explain

Using the knowledge you developed working with Section 20.7, explain the experiment in the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-20-7-2].

OALG 20.7.3. Explain

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.

