

16 Magnetism / 17 Electromagnetism

Worksheet: Concepts & Calculations

Name _____

AP Physics B

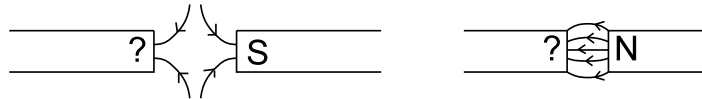
UNIT 16: MAGNETISM

1. An iron bar is placed between two magnets as shown below, which makes the iron a temporary magnet. Sketch the magnetic field (the lines of flux) between the permanent magnets and the nearest end of iron bar.



In the space to the left, write the letter of the answer to each question.

- _____ 2. Which phrase is a possible characteristic of a permanent magnet?
 A) all electrons are paired with opposing spins
 B) unpaired electrons with aligned spins
 C) unpaired electrons without aligned spins
 D) repels temporary magnets
- _____ 3. Lines of flux by convention point from the magnetic _____ pole to the magnetic _____ pole.
 A) north to south. B) south to north. C) north to north. D) south to south.
- _____ 4. What pole of the bar magnet below is nearest the compass?
 A) north B) south
- Magnet ?
- _____ 5. In the cases below, the poles of the left magnets are _____ respectively.
 A) N,N B) N,S C) S,N D) S,S



- _____ 6. The south pole of a compass points towards what *physicists* consider the Earth's magnetic north pole in the...
 A) center of Earth. B) Arctic C) Antarctic D) upper atmosphere.

Fill in each blank with the appropriate word.

7. Attraction or repulsion of charges depends on their *signs*: positive or negative. Attraction or repulsion of magnets depends on their magnetic _____: _____ or _____.
8. Opposite poles _____; like poles _____.
9. If you bang a magnet on something and it loses its field, you have destroyed the alignment of the electron _____.

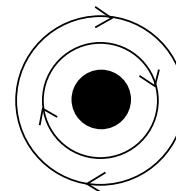
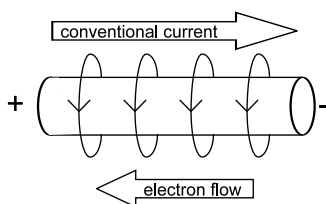
UNIT 17: ELECTROMAGNETISM

In the space to the left, write the letter of the answer to each question.

10. You have an electromagnet that is not quite strong enough. What are three changes you could make to increase the strength?
- A) _____
- B) _____
- C) _____

WIRE RULE

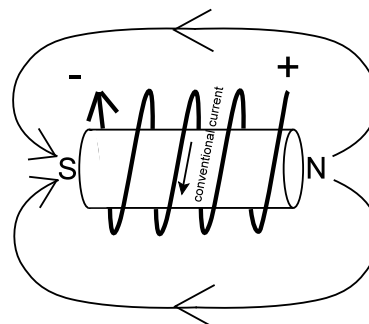
A straight current-carrying wire creates a radial magnetic field. To determine its orientation, point your right thumb in the direction of the conventional current (from + to - along the length of the wire). Your fingers will curl around the wire the same way the magnetic field does.



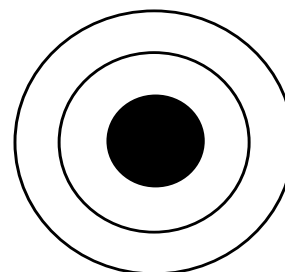
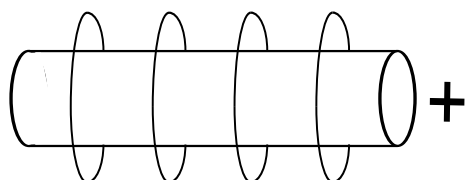
Wire in cross-section, conventional current flowing through the wire into the page, creating a clockwise field.

COIL RULE

A current-carrying wire coiled around a core will create a magnetic field resembling that of a bar magnet, with distinct north and south poles at the ends of the coil. To determine which end of the coil is which, curl your right fingers around the coil so that they follow the conventional current. Your extended thumb will point to the coil's north pole.

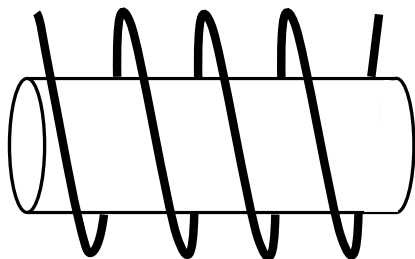


PRACTICE with the coil and wire rules:
(answers at bottom)

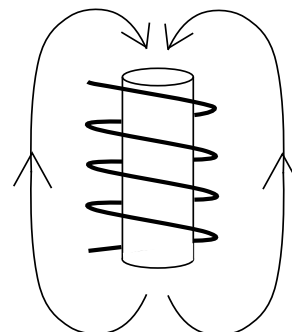


- A. A wire is shown with a radial magnetic field emanating from it. If the right end is positive, does the magnetic flux along the front side of the wire point upwards or downwards?

+



- B. A wire is shown in cross-section with its radial field around it. If conventional current flows out of the page (as shown by the dot in the center of the wire), is the field clockwise or counterclockwise?

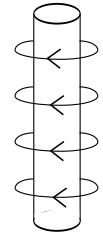


- C. A coil wrapped around a core is shown above, with the left end of the coil positive and the wire wrapped as indicated. Which end of the coil is its north magnetic pole?

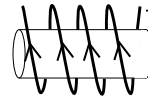
- D. A coil is wrapped around a core as shown above, with its lines of flux. Which end of the coil is positive?

Answers: A. upwards B. counterclockwise C. right D. bottom

11. In the diagram at right, the magnetic field around a wire is shown. Which end of the wire is connected to the + terminal of the source?
 A) top B) bottom C) it is impossible to tell
12. Which end of the electromagnet drawn below is the south pole?
 A) left end B) right end



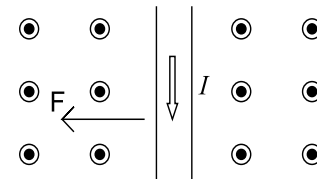
13. Sketch the magnetic field lines (lines of flux) around the coil shown at right from question 12. Include arrowheads on each line of flux indicating the direction of the magnetic field.



MOTOR RULE

A charged particle moving perpendicularly through a magnetic field will experience a force that is perpendicular to both its velocity and the field. The same effect can also push a current-carrying wire. This is called a *deflecting force*.

To predict the direction of the force, extend your right thumb and flatten your fingers. Point your thumb in the direction of conventional current (or the direction a positive charge is moving), point your fingers in the direction of the magnetic field (follow the lines of flux from north to south), and your palm will press in the direction of the force.



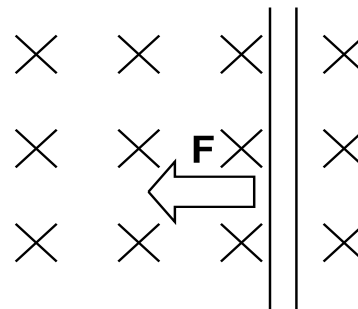
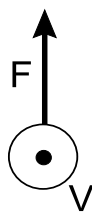
The wire carries conventional current down the page through a magnetic field pointing out of the page. This will create a force F that pushes conventional + charges in the wire, and thus the entire wire itself, to the left as shown.

Motor Rule Math for Charged Particles

The motor rule applied to a single particle of charge q is expressed mathematically as the cross product $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$ or, in scalar form, as $F = qvB(\sin \theta)$ where q is the charge in coulombs, v is the speed of the particle in m/s, and B is the magnetic field strength in teslas. As we saw in torque, the θ is the angle between the tails of the velocity vector and the magnetic field vector. Since $\sin 90^\circ = 1$, the force F is maximized when the particle moves perpendicular to the magnetic field lines. But since $\sin 0^\circ = 0$, the force disappears if the particle moves parallel to the magnetic field lines.

$$F = qvB(\sin \theta)$$


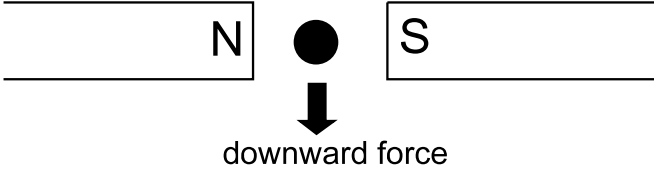
PRACTICE with the motor rule (answers at bottom):



- E. In a region of space there is a uniform magnetic field in the plane of the page but no electric field. A positively charged particle already moving with a velocity v directed out of the page experiences a deflecting force F as shown above. What is the direction of the magnetic field B ?

- F. A wire is immersed in a magnetic field that points into the page. Which direction must conventional current flow through the wire to cause the wire to be deflected to the left as shown?

Answers: E. the magnetic field is to the right F. the conventional current flows up the page

14. An electric charge moving perpendicular to the magnetic flux is deflected in a direction that is _____ to its direction of travel.
 A) opposite B) perpendicular C) at a 45° angle
15. What is the direction of the force on the current-carrying wire in the magnetic field shown in the diagram? (It is hooked to a dry cell and carries conventional current into the page.)
- 
16. The current flowing in the wire shown below creates a downward force on the wire. Show the direction of the conventional current flow. (Use a dot for out of the page and an X for into the page.)
- 

Show your work on the following problems, including all equations and units.

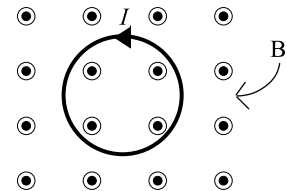
17. A proton ($q=1.60 \times 10^{-19}$ C, $m=1.60 \times 10^{-27}$ kg) in the solar wind travels perpendicularly at 3.00×10^5 m/s across the Earth's magnetic field lines. The field at that location is 0.0000100 T.
- A) Use the motor rule equation for a particle to determine the magnitude of the deflecting force on the particle. $N \cdot 61 \cdot 0I \times 08 \cdot t$
- B) The motor rule predicts that this force will act as a centripetal force, causing the proton to have a corkscrew circular motion. Calculate the radius of the circles it begins to make. $m \cdot 00 \cdot t$
18. A neutron and an electron are shot between the poles of a U magnet which generates a uniform B field across their paths of magnitude 0.600 T.
- A) One of the particles flies straight through the magnet's field lines without any deflection. Is that particle the neutron or the electron? Briefly explain how you know.
- B) The other particle is deflected by a force of 4.00×10^{-15} N. Determine the speed at which the particle was moving through the magnetic field.

Motor Rule Math for Current-Carrying Wires

The motor rule applied to a current-carrying wire is expressed mathematically as the cross product $\mathbf{F} = \ell(\mathbf{I} \times \mathbf{B})$ or, in scalar form, as $F = BI\ell(\sin \theta)$ where B is the magnetic field strength in teslas, I is the current in amperes, and ℓ is the length of the wire exposed to the field. As we saw in torque, the θ is the angle between the tails of the current vector and the magnetic field vector. Since $\sin 90^\circ = 1$, the force F is maximized when the current moves perpendicular to the magnetic field lines. But since $\sin 0^\circ = 0$, the force disappears if the current moves parallel to the magnetic field lines.

$$F = BI\ell(\sin \theta)$$

19. There is a counter-clockwise conventional current I in a circular loop of wire. The loop is situated in an external magnetic field \mathbf{B} directed out of the page as shown at right. The effect of the forces that act on this current is to make the loop...
- A) expand in size.
 - B) contract in size.
 - C) rotate about an axis perpendicular to the page.
 - D) accelerate into the page.



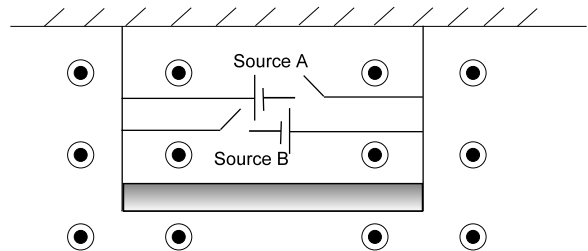
Show your work on the following problems, including all equations and units.

20. A simple motor consists of a straight wire 0.500 m long lying at 90° across a uniform magnetic field of 0.300 T. The motor will be used to accelerate a 5.00 gram mass at 3.00 m/s^2 . What is the smallest current that could be used?

$$F = 0.01 \text{ N}$$

21. A conductor of mass 40.0 grams per meter is hung by two wires in a 3.60 T field directed out of the page as shown.

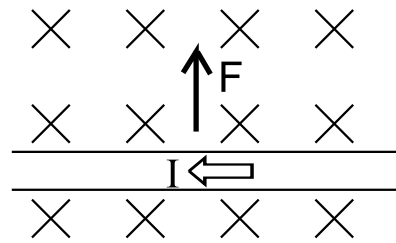
- A) Which source, A or B, should be switched on so that the magnetic field will deflect the wire upward, helping balance the conductor's weight?
- B) How much current from the source would be needed so that the conductor would levitate, reducing the tension in the wires to zero?



ELECTROMAGNETIC INDUCTION / GENERATOR RULE

We have seen that a charge moving across magnetic field lines will experience a deflecting force. We can use this property to create or "induce" electric current when wires and coils are *mechanically* moved through magnetic fields. The charges in the wires and coils are then deflected so that they flow down the wire – we say that an electrical current has been *induced*. This is the principle behind the electric generator, as first discovered by Michael Faraday.

So if you mechanically spin a coil of wire in a magnetic field (such as the armature of a motor), current will then be produced and you have a generator. Since a generator is a motor in reverse, you reverse the motor rule to use it for generators. This is done by using the **left** hand and then following the motor rule procedure:



The wire is immersed in a magnetic field that points into the page. As the wire is *mechanically* pushed up the page, a conventional current is induced that flows to the left.

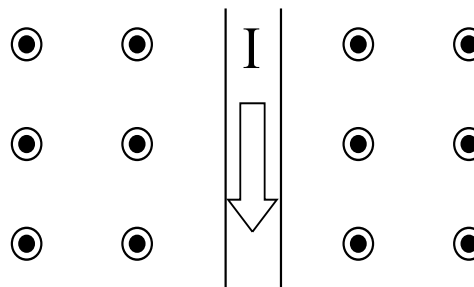
Extend your **left** thumb and flatten your fingers. Point your fingers to follow the direction of the magnetic field (follow the lines of flux from north to south) and rotate your hand until your palm will press in the direction of the mechanical force on the wire shoving it through the field. Your extended **left** thumb will then point in the direction of the **induced** conventional current, or the direction a positive charge would be deflected.

Generator Rule Math (Electromagnetic Induction)

The induced voltage that creates an induced current is directly proportional to the strength of the magnetic field, the length of wire moving through the field, and the speed at which the wire moves through the field. That induced voltage is sometimes called the “electromotive force” or “emf” and given the symbol ϵ , which should not be confused with the electric field E .

$$\epsilon = V = Blv$$

PRACTICE with the generator rule:



- G. A wire is immersed in a magnetic field that points out of the page. Which way must the wire be pushed to induce a conventional current that flows down the page as shown?

Answer: G. to the right

- _____ 22. In which diagram below would electricity be produced? The diagrams show magnetic fields as arrows and a wire in cross-section as a circle with an arrow indicating its movement.
- A) B)
- _____ 23. In the diagram you selected above, which way does the induced conventional current flow?
 A) out of the page B) into the page

24. A simple generator consists of a 2.00 m long copper wire that is suspended in a perpendicular magnetic field and moved at right angles to the lines of flux. The resistance of the wire is 3.00 Ω and the current induced in the wire is 0.0600 A. If the wire moves at 0.150 m/s, what is the magnitude of the magnetic field?

J 009'0

25. A rod is perpendicular to a magnetic field of 0.450 T and is moved at right angles to the flux at the rate of 30.0 cm/s. If the emf induced across the rod is 0.0200 V, what is the length of the rod?