MAGNETIC FIELDS
USING RIGHT HAND RULES

OBJECTIVE
Students will practice drawing magnetic fields around permanent magnets and combinations of magnets. They will also become familiar with the conventions known as the *Right Hand Rules*.

NATIONAL STANDARDS
UCP.1, UCP.2, UCP.3 B.4

CONNECTIONS TO AP
III. Electricity and Magnetism, D. Magnetostatics, 1. forces on moving charges in magnetic fields, 2. Force on current-carrying wires, 3. Fields of long current-carrying wires

TIME FRAME
45-50 minutes plus a homework assignment

MATERIALS
Printed worksheets	rulers
Demonstration wire rod, one end red, one end white or black	

TEACHER NOTES
Magnetism and electricity are interlinked and the forces involved with both have been unified to show that they are different aspects of the same force. However, most students have had little instruction in magnetism other than a cursory introduction to making an electromagnet and the fact that like poles repel and unlike poles attract. This fact is often obscured with modern ceramic magnets such as refrigerator magnets which have multiple poles and will often stick to each other in multiple configurations.

Understanding both electricity and magnetism requires both a rigorous mathematical and conceptual approach using a combination of diagrams, demonstrations, labs and exercises.

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Understanding electricity and magnetism requires both a rigorous mathematical and conceptual approach using a combination of diagrams, demonstrations, labs and exercises.

This exercise is designed to introduce the concept and practice of what have become known as the Right Hand Rules. These are conventions first introduced by the British physicist Zachariah William Cole in the late 1800s for use in electromagnetism. Using the Right Hand Rules is essential in predicting the effects of a magnetic field on a moving charge or in determining the direction of a force on a current carrying wire in a magnetic field. In mathematics and physics, the **right-hand rule** is a common mnemonic for understanding notation conventions for vectors in 3 dimensions.

PURPOSE

To use the right hand rules to describe the interaction of magnetic fields, moving charges, electrical currents and electromagnetic forces.

MATERIALS

Printed worksheets	rulers

ILLUSTRATING MAGNETIC FIELDS AND CHARGE INTERACTIONS IN 3D

Magnetic field lines are usually described using arrows to show the direction of the field. Remember that, by convention, magnetic field lines emanate from North Poles and move outside the magnet to the South Pole and inside the magnet from South to North and exit as closed loops. Similarly, electric field lines radiate outward from + charges and terminate on – charges, but they do not circulate as do magnetic fields.

It is also important to understand other conventions that are used to represent magnetic fields and current flow in wires. The following descriptions show how these items may be represented:

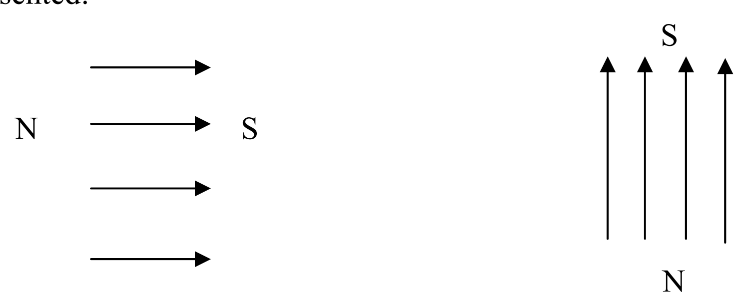

Figure 1: A magnetic field going to the right (+x) and one going up the page (+y)

A magnetic field may be represented as arrows to the left, right, up, or down. Remember, the head of the arrow always points toward the south magnetic pole, or the arrow points away from the north magnetic pole.

Fields, including magnetic fields (B fields), are three-dimensional and therefore exist in planes outside the plane of your paper. We need to be able to represent them in these planes. Figure 2 uses a "**X**" (the tail of an arrow) to represent a field going into the page and Figure 3 uses a "•" (the tip of an arrow) to represent a field coming out of the page.

X X X X X X X X
X X X X X X X X
X X X X X X X X
X X X X X X X X
X X X X X X X X
X X X X X X X X

Figure 2: Represents a magnetic field going into the page

. . . .

. . . .

. . . .

. . . .

. . . .

Figure 3: Represents a magnetic field coming out of the page

Because magnetic force, magnetic field and charge flow require a 3 dimensional analysis, making illustrations of these interactions involves using the two additional symbols to denote the directions of a current in a wire into and out of the page.

⊙ This symbol denotes the direction **OUT** of the page.

⊗ This symbol denotes the direction **INTO** the page.

THE RIGHT-HAND RULES

When using the Right-Hand Rules, it is important to remember that the rules assume charges move in a conventional current (the hypothetical flow of positive charges). In order to apply either Right-Hand Rule to a moving negative charge or an electron current, the velocity, *v*, of that charge must be reversed to represent the analogous conventional current.

Conventional or + Current

[1st] **Right Hand Rule** determines the direction of the magnetic field around a current-carrying wire and vice-versa

Using your right-hand:

1. Point your thumb in the direction of the conventional current.
2. Curl your fingers into a half-circle around the wire, they point in the direction of the magnetic field, B

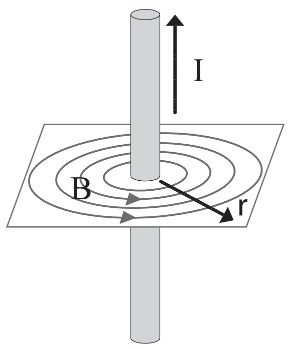

Figure 4

For a long, straight wire, the magnetic field, B circulates around the wire and is proportional to the inverse of the distance from the wire.

$$B \propto 1/r$$

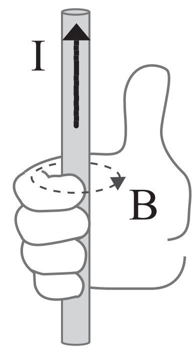

Figure 5

Remember the thumb points in the direction of the conventional current, from + toward -, and the fingers indicate the direction of the magnetic field..

[2nd] **Right Hand Rule** determines the direction of the magnetic field around a coil of wire or a solenoid. The first right hand rule can also be used for this purpose by simply grabbing one of the wires as it circles the core of the solenoid.

Place the fingers of the right hand in the direction that the conventional current is flowing in the coil of wire. The thumb of the right hand points in the direction of the magnetic field, or toward the north pole of the electromagnet.

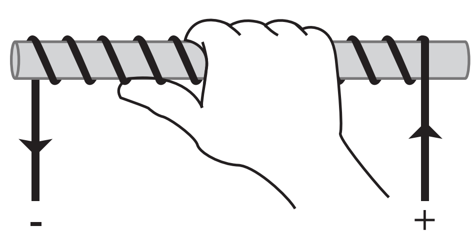

Figure 6

The force a magnetic field exerts on a moving charge or current bearing wire is described by the 3rd Right Hand Rule.

When a charge is placed in a magnetic field, that charge experiences a magnetic force when two conditions exist:

1. The charge is moving relative to the magnetic field.
2. The charge's velocity has a component perpendicular to the direction of the magnetic field.

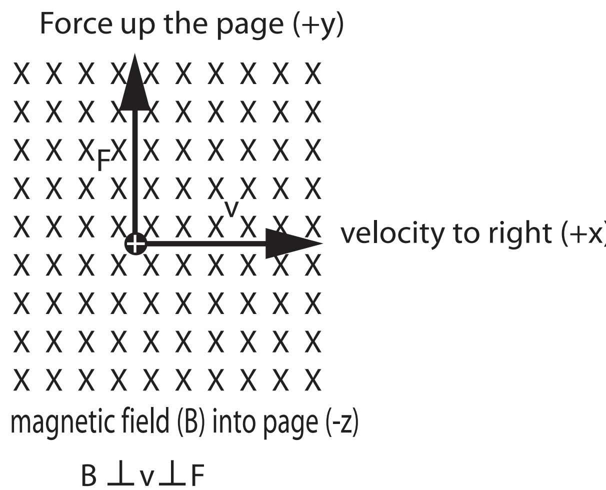

Figure 7

The Third Right-Hand Rule determines the directions of magnetic force, conventional current and the magnetic field. Given any two of these, the third can be found using your right-hand:

1. Point your index finger in the direction of the charge's velocity, *v*, or the direction of the conventional current.
2. Point your middle finger in the direction of the magnetic field, B.
3. Your thumb now points in the direction of the magnetic force, F_B.

Other ways to apply the 3rd Right Hand Rule:

1. Point your index fingers in the direction the magnetic field, B.
2. Point your thumb in the direction of the charge's velocity, *v*, or the direction of the conventional current.
3. The magnetic force F_B is directed out of the palm of your hand

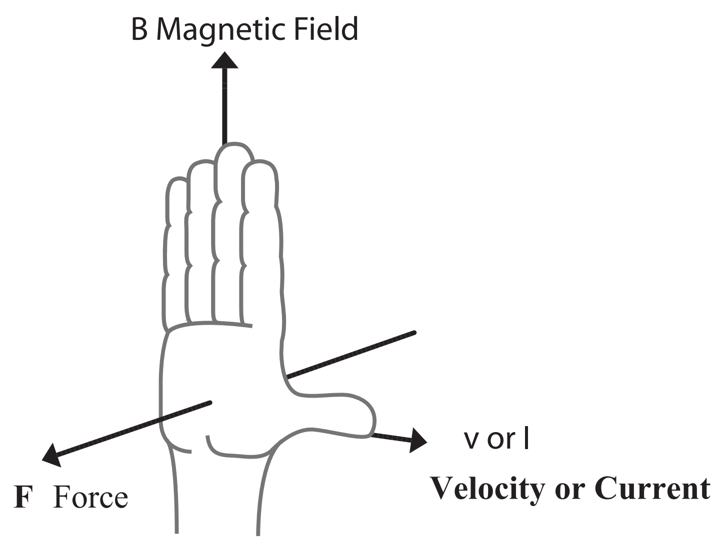

Figure 8

MAGNETIC FIELDS
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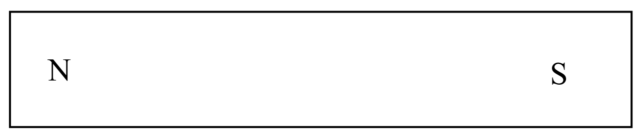
EXERCISES

1. Draw and describe the magnetic field around a permanent magnet. Make sure to indicate the direction of the magnetic field both outside and inside the magnet.



2. For a wire carrying a conventional current in the direction indicated, sketch the magnetic field produced. Be sure to indicate the direction of the field

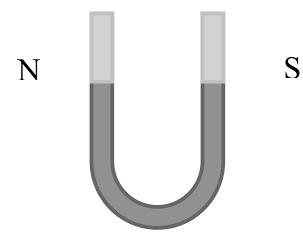
3. How do magnetic fields (**B**) differ from electric fields (**E**)?

4. A moving charge or a current-carrying wire may experience a force when placed in a magnetic field, how must the right hand rules be applied if you are given electron flow or a negative charge instead of conventional current or a positive charge?

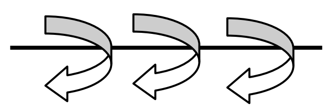
5. Draw the magnetic field present in the area of these two permanent magnets. Indicate the direction of the field.

6. Draw the magnetic field present in the area of these two permanent magnets. Indicate the direction of the field.

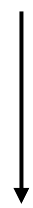
7. Draw the magnetic field present in the area of this horseshoe magnet. Indicate the direction of the field.



8. Indicate the conventional current flow: (current flow):

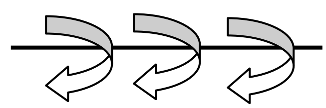


9. Indicate the magnetic field



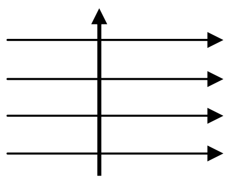
10. Indicate the magnetic field (electron flow)

11. Indicate the electron flow:



Indicate the direction of the force on the current carrying wire in 12-21 below: Draw a vector on the diagram indicating the direction of the force also indicate the direction in the blank provided below each diagram. Use +x (right) or – x (left), +y (toward the top of the page) or – y (toward the bottom of the page), +z (out of the page) or – z (into the page),.

12.



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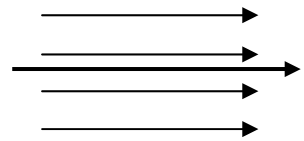

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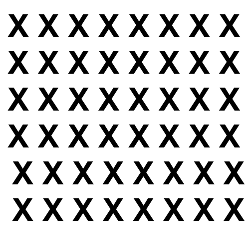

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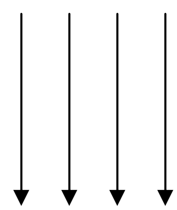

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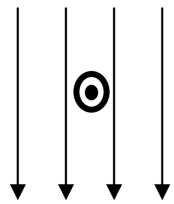

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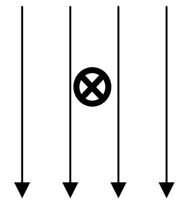

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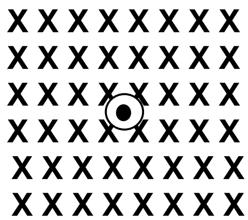

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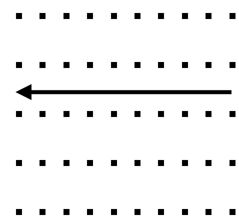

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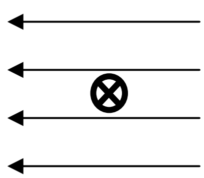

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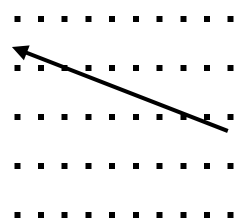
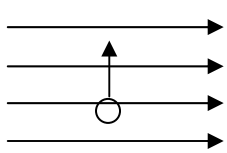


Questions 22–31: Use the line under each figure to specify the direction of the force and the resultant path on the charges moving in these magnetic fields:

This symbol represents a + charge ○
This symbol represents a – charge ●

22.



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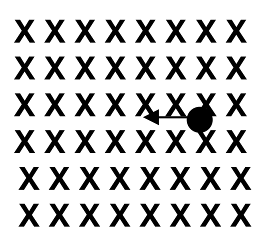

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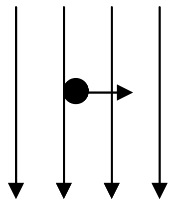

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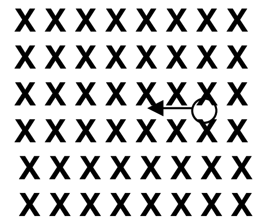

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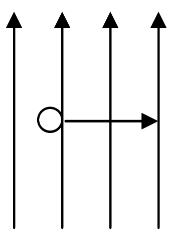

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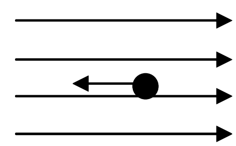

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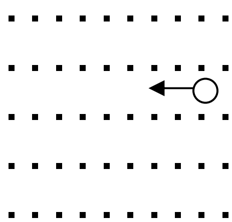

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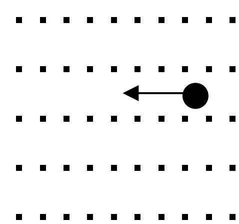

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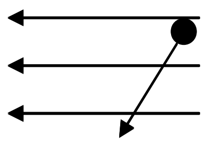

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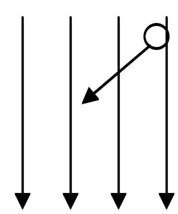
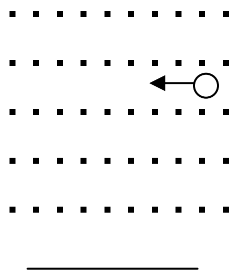


For 32-35 indicate the path of the charged particle.

32.



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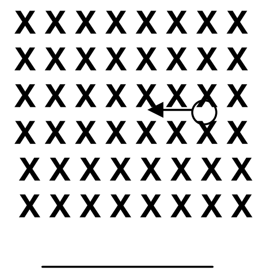

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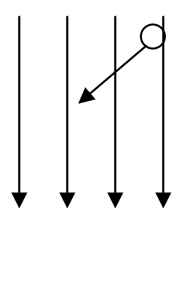

35.