EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING

Revised for

ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
MAGNETIC FORCES

AN ACADEMIC SKILLS MANUAL
for
The Precision Machining And Tooling Trades

This trade group includes the following trades:
General Machinist, Tool & Die Maker,
Mould Maker, Pattern Maker, and
Machine-Tool Builder Integrator

Workplace Support Services Branch
Ontario Ministry of Training, Colleges and Universities

Revised April 2011

In preparing these Academic Skills Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual.

This trade related material is not intended to instruct you in your trade. It is used only to demonstrate how understanding an academic skill will help you find and use the information you need.

SCIENCE SKILLS
MAGNETIC FORCES

An academic skill required for the study of the
Precision Machining and Tooling Trades

INTRODUCTION

The effect of magnetic force is easily observed in a magnetic compass needle. The north-seeking pole of a compass magnet is attracted to the earth's North Magnetic Pole and points in that direction.

Less visible are the effects of the magnets used in the electronic devices that are used to run industrial equipment. They are necessary for the alternating electrical current that runs electronic devices for industrial equipment, like alternators and generators.

In fact, the relationship between magnetic and electrical forces has played a part in all the major technical developments of the last one hundred years. Magnets play a role the creation of alternating current. Alternating current allows electricity to be provided in an efficient safe way. Magnets also play a crucial role in computer and electronic technologies which are rapidly working their way into the all of the trades.

Magnets play an important role in the electrical energy used by the modern world. An understanding of the basic properties of magnets can help explain how generation of electrical energy takes place.

This skill manual looks at the following aspects of magnetic forces:

- Magnetism
- Polarity
- Electromagnetism and induced current
- Uses of electromagnets

MAGNETISM

Magnetism, like gravity and atomic charge, is one of the basic forces of nature. Magnets generate a force of attraction or repulsion similar to the force generated by the positive and negative charges on protons and electrons. Magnetic force has an effect on other natural magnets and substances such as steel are attracted to magnets. Magnetic force is felt by these substances as a push away from or a pull towards the magnet. This force can cause a responsive object to move.

Magnetism is generated by the spin of electrons:

- When electrons spin, they act like tiny magnets.
- In the atoms of most elements, the spinning electrons form pairs. Each electron in a pair spins in the opposite direction to the other so they cancel each other's magnetic effect.
- In naturally occurring magnetic substances, unpaired electrons spin in the same direction. This causes the substance to act as a magnet.
- A type of iron called magnetite has this property. Pieces of magnetite form *permanent magnets*

Substances which are strongly attracted to magnets are called *ferromagnetic*. Iron and steel are ferromagnetic substances.

Induced Magnetism

When a ferromagnetic substance is brought in contact with the magnetic field of a natural magnet, it becomes a *temporary magnet*. This is called ***induced magnetism***.

- When an object such as a nail is picked up by a magnet, it becomes a small magnet. It can attract and pick up other ferromagnetic objects.
- If the original magnet is withdrawn, most of the induced magnetism will be lost. When the nail is removed from the magnet, it quickly loses its magnetic properties.

Steel and steel alloys containing iron, cobalt and nickel tend to keep their molecules aligned in the same direction when they are made into magnets. They tend to stay magnetized and so can be used as permanent magnets.

Magnetic Fields

All magnets possess a ***magnetic field*** of force that surrounds them. The magnetic field indicates the area in which a magnet can influence another substance with ferromagnetic properties.

- ♦ A magnetic field is created because every magnet has two poles with differing properties of attraction and repulsion.
- ♦ These poles are called the ***north pole*** and the ***south pole***.
- ♦ The force of attraction between the poles of a magnet creates invisible field lines of magnetism that run from the ***north to the south pole***.

In diagrams like Figure 1, the magnetic field is represented by ***lines of flux***. The magnetic attraction, and thus the magnetic field, is strongest at the north and south poles where the lines of flux are closest together.

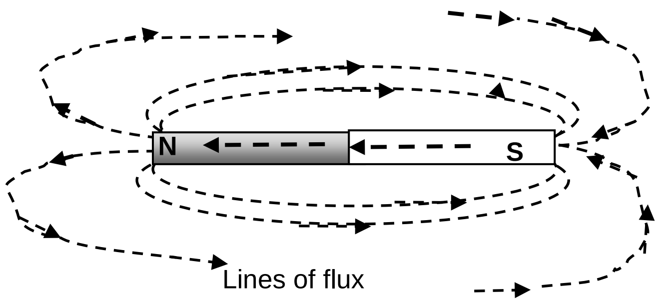


FIGURE 1: Magnetic Field Around A Bar Magnet

A bar magnet has a narrow rectangular shape. The core of the earth is considered to be like a bar magnet. In a bar magnet, lines of flux have a specific direction. In general, they

- run through the bar from the south pole to the north pole,
- exit at the north pole, and
- curve back in a circular pattern to enter the magnet again at the south pole.

POLARITY

Because the lines of force enter through one pole and exit through the other, the two poles have different properties of attraction and repulsion. These opposite magnetic forces give a magnet the property called ***polarity***. All magnets have polarity.

If a magnet is freely suspended, its north pole will be pushed away if the north pole of another magnet is brought close to it. See Figure 2.

- Likewise, if the south poles of two magnets are placed close together, they will move away from each other.
- Two similar poles repel each other.

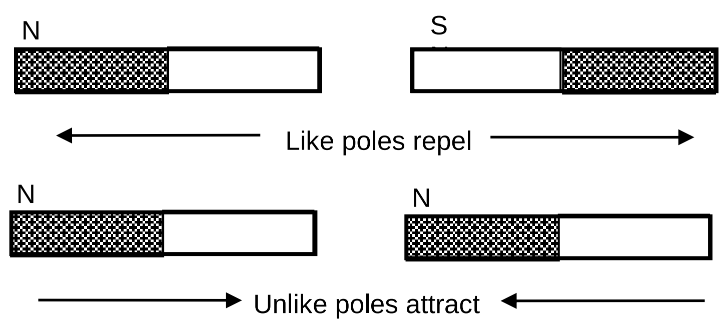


FIGURE 2: Polarity In A Magnet – like poles repel each other, unlike poles attract each other

At the same time, the north pole of a magnet will be strongly attracted to another magnet's south pole.

- If they are placed close together, they will move to contact each other.
- Two opposite poles attract each other.

We say that ***like poles repel; unlike poles attract.***

T he magnetic force that results from the two different poles is similar the electric force that results from differently charged electrons and protons. In an atom:

- Two positively charged protons repel each other.
- Two negatively charged electrons also repel each other.
- An electron and a proton attract each other because they have opposite charges.

In a similar way:

- Two north poles or two south poles repel each other and move apart if possible.
- A north pole and a south pole attract each other and move together as close as possible.
- The strength of the force of attraction or repulsion between two magnets depends on the strength of the magnetic fields generated by each magnet.

The core of the earth is like a large bar magnet. Its poles are called the north and south poles. Although we call the poles on other magnets the north and south poles, we really mean the *north-seeking* and *south-seeking* poles. During the long history of the earth, the south and north poles have flipped around and changed places several times. Geologists are able to interpret these changes by reading the ancient patterns of magnetic attraction in the rocks.

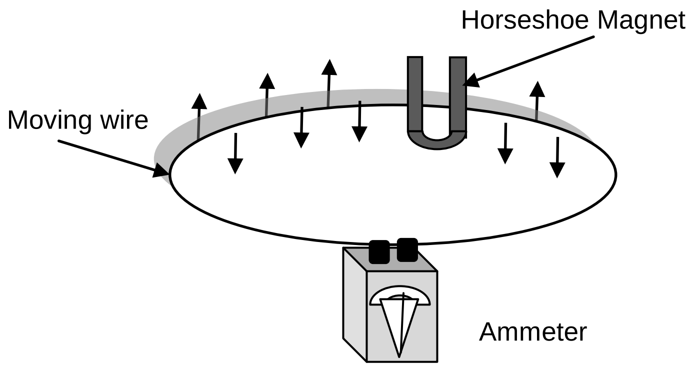
Not all magnets are shaped like a bar magnet. The poles of a horseshoe magnet, which is shaped like a horseshoe, are close together. This generates a very strong magnetic field across its narrow gap. Horse-shoe magnets are important in the electromagnetic generation of current.

ELECTROMAGNETISM AND INDUCED CURRENT

An electrical current occurs when electrons, which have a negative charge, are free to flow through a conducting wire towards an area with positive charge. The current is created by the force of attraction between negative electrons and positive protons.

There is a close relationship between magnetism and electricity. If a conducting wire is moved between the ends of a horseshoe magnet, a current starts to flow in the wire. See Figure 3.

- The magnetic force provides the energy to create the current.
- A current will flow if either the conducting wire moves or if the magnet moves over the conductor.
- If the wire or magnet stops moving, the current stops flowing.



When a wire moves through a magnetic field, an electric current flows in the wire.

FIGURE 3: Magnetically Induced Current In A Conductor

A current created by moving a conducting wire through a magnetic field is called an ***induced current***. The process is also called ***electromagnetic induction***.

A magnetic field can cause an induced current to flow. Conversely, a current flowing through a wire will produce a ***magnetic field*** around the wire. A magnetic field produced by a current is called ***electromagnetism***.

An electrically generated magnetic field consists of lines of force that flow in one direction. See Figure 4.

- The direction of the lines of force in the field depends on the direction of the current.
- The strength of the magnetic field varies directly with the strength of the current.
- When the current is turned off, the magnetism disappears.

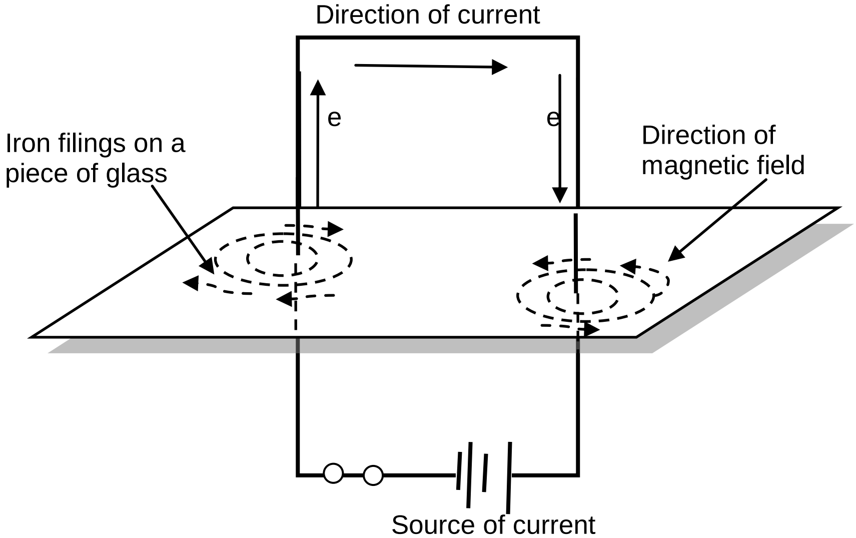


FIGURE 4: Magnetic Field Created By A Current

USES OF ELECTROMAGNETS

The close relationship between electricity and magnetism was used in the development of electric motors, generators, switches, alternators and transformers. Recall that:

- Moving electric charges create a magnetic field.
- Moving magnetic field causes charged electrons to move, creating an electric current.

These reactions are used in electric motors and in generators.

- In an electric motor, magnetic fields generated by electric current force a shaft to rotate.
- In a generator, a rotating shaft moves a magnetic field, causing a current to flow in a wire.
- An electric motor and a generator are basically the same device, except the cause and the effect are reversed in them.

What happens if a loop, or a coil, is made in a conductor?

- A strong magnetic field will be created inside the loop.
- If many loops are made in the conductor, a magnetic field becomes even stronger.
- The strength of the electromagnet depends on the number of coils in the wire and the magnitude of the current flowing through the wire.
- This type of magnet is called a ***solenoid*** when there is air in the core inside the coil.

The strength of an electromagnet depends on the number of coils in the wire and the magnitude of the current flowing in it.

- To increase the strength of the magnetic field, an iron bar can be inserted inside the coil. The magnet created by looping a conductor around an iron core is called an ***electromagnet.*** It has a north and south pole. The polarity is determined by the direction the current flows.
- To reverse the polarity, the direction of the current is reversed.

Alternating Current

To further increase the strength of the magnetic field, an iron bar can be inserted inside the coil. The polarity of the magnet created by looping a conductor around an iron core is determined by the direction the current flows. To reverse the polarity, the direction of the current is reversed.

A current flowing through a rotating coil forms the basis of generating an alternating current:

- When a coil rotates through a magnetic field, the current generated is strongest when the coil is at right angles to the lines of force.
- When the coil is parallel to the lines of force, no current is generated.
- During the next half turn of the coil, the current flows in the opposite direction.
- So when a coil rotates through a stationary magnetic field, there is a constant fluctuation in the voltage of the current and the direction of the current changes every half turn.

Transformers

The relationship between magnetism and electricity in a coil of wire is used in designing a transformer. A transformer changes the voltage of a current so that it can be made larger or smaller, depending on what kind of voltage is required. This is called stepping the voltage up or down.

In a transformer, wire is wrapped around a U-shaped piece of iron.

- One arm of the iron core has a large number of windings, while the other arm has many fewer windings.
- The current comes into one arm, called the primary coil.
- This produces a magnetic field.
- The core transfers the magnetic field to the other arm, called the secondary arm.
- The magnetic field generates a current in the secondary coil which then leaves the transformer as an output current.
- If there are more windings in the primary coil, the voltage is stepped down.
- If there are more windings in the secondary coil, the voltage is stepped up.

CONCLUSION

Magnetism and electricity are closely connected. A magnetic field creates a current in a conducting wire moving through the field. This is called an induced current. It varies directly with the strength of the field. When a current flows in a wire, it generates a magnetic field around the wire. When the conducting wire is made into a coil, the magnet that is created inside the coil is called an electromagnet. Electromagnets are used as switches in electronic devices because the magnetic field can be turned off and on by turning the current off and on.

As a coil rotates through a magnetic field, it produces a varying voltage. The voltage is at a maximum when the coil is at right angles to the field. The voltage becomes zero and no current flows when the coil is parallel to the field. The rotation of the coil also causes the current to change direction every half turn. The voltage of a current can be stepped up or down depending on the number of windings in two connected coils.

The close connection between magnetism and electricity is used in most of the machines that are part of the electrical industry, from electric motors to the varying electrical signals that are used to send sound or information through wires and cables.

Answer the following questions by putting the correct word in the blank spaces. Answers are at the end of the skills manual.

polarity repel lines of flux attract electromagnet induced magnetism induced current

1. When a north pole and a south pole of two magnets are close together, they are pulled towards each other. We say that unlike poles __________________ .

2. When two south poles are brought near each other, they try to move way. This is because like poles _____________ .

3. Lines of flux run out of the north pole and re-enter the magnet at the south pole, giving the two poles different properties. Because of this, all magnets have _________________ .

4. The flow of a magnetic field is represented by ______________ ___ _____________ .

5. A conducting wire that is moved through a magnetic field generates an electrical current. This is called an ________________ __________________ .

6. When a ferromagnetic material is brought into contact with a natural magnet, it becomes a temporary magnet. This is called ___________________ ___________________ .

7. When a magnetic field is created by an electric current flowing through a conductor, the resulting magnet is called an _______________________ .

Answer the following questions by writing true or false in the blanks:

8. The magnetic attraction is strongest at the poles because that is where the lines of flux are closest together. ____________

9. There is a close relationship between magnetism and electricity. ____________

10. The lines of a magnetic field run from south to north. _____________

11. All magnets have polarity. This means that the two poles have different properties of attraction and repulsion. ____________

12. The north poles of two freely suspended magnets are brought close together. The magnets will move closer together. ____________

13. If a wire moves through a magnetic field, an electric current is generated. _____________

14. All magnets are permanently magnetic. ____________

15. A current flowing through a wire produces a magnetic field around the wire. ____________

16. The more times the conducting wire is coiled, the weaker the magnetic field produced. ______________

17. A coil with an iron core produces a stronger magnet than a coil with a core of air. ______________

18. If the current generating an electromagnet is turned off, the electromagnet stays permanently magnetized. ______________

19. When a coil rotates through a magnetic field, the current produced has a voltage that does not vary in strength. ______________

20. An electromagnet is used as a switch in electronic devices because the magnetic field can be turned off and on by turning the current off and on. _____________

ANSWER PAGE

1. attract
2. repel
3. polarity
4. lines of flux
5. induced current
6. induced magnetism
7. electromagnet
8. true
9. true
10. false See page 2, Magnetic Fields.
11. true
12. false
13. true
14. false
15. true
16. false
17. true
18. false
19. false
20. true