CHAPTER 6

BASIC MAGNETISM

CHAPTER's Objectives

- To gain knowledge of basic magnetic phenomena
- To develop a dipole model of magnetism and discuss it similarity to charge model in electricity
- To study magnetic fields produced by current wires and loops
- To discuss the source of magnetism
- To discuss the atomic view of magnetism
- To learn and study more about the classification of materials according to their magnetic behavior
- To study electromagnetic induction and its application in generators and transformers

Magnetism is a property of matter like charge and mass, which determines its behavior in the presence of a magnet. This behavior depends on whether the material is magnetic or not. Iron, cobalt, nickel and alloys of them, are called magnetic materials. Others like gold, silver, water, and living things are not "appreciably" magnetic.

Magnetism is 2000 or so year's old concept and the name is associated with ***Magnesia***, an ancient city in Turkey. People observed that ***loadstone***, a rock contains oxide of iron (Fe_3O_4), could attract small pieces of iron; a behavior, which was explained as an art of magic and loadstone was recognized as the first natural magnet.

Interest in magnetic force grew up in Europe and Asia. Scientist found that this new force is not related to both gravitational and electrical forces. Observations showed that not all objects exhibit this force and neither a rubbed plastic nor pieces of papers were attracted to magnets. Yet, electricity and magnetism were found closely related.

Chinese were the first people who used loadstone compasses in navigation by the year 1000 A.D, followed by Europeans two hundred years later.

Today we use magnets everywhere; in recording media, in ATM, credit and debit cards, in electric motors and generators, in TV and computer monitors screen, to store information on computer disks, and in loudspeakers. In medicine, they are also used in magnetic resonance imaging to provide an image of the human interior. In research they are used to identify subatomic particles and in magnetic levitation trains. This is just few of a big list of uses.

6.1 Most common shapes of magnets

The three most common magnets are the bar magnet, the U and horse shoe-shaped magnet, and the disk-shaped and doughnut- shaped magnets. Figure (6.1) shows these magnets.

(a) (b) (c)

Figure6.1: (a) bar magnet, (b) U and horse shoe-shaped magnets, and (c) disk and doughnut-shaped magnets.

6.2 Magnetic phenomena

Consider these magnetic observations

1. When a bar magnet is freely suspended by a string or firmly fixed on a cork floated in a dish of water, it swings slightly around a vertical axis and then aligns itself in a North-South direction as illustrated in Figure 6.1

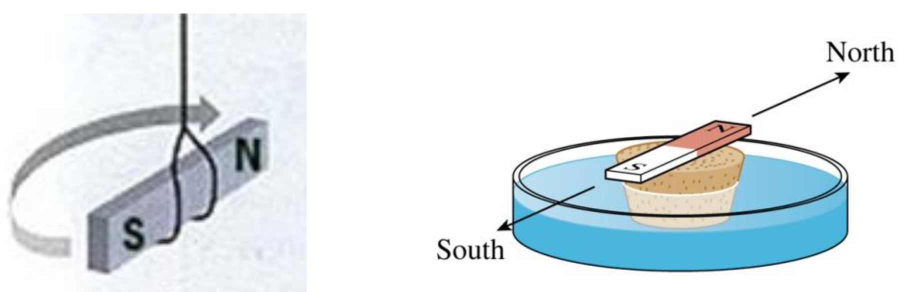


Figure 6.1: A free bar magnet aligns itself in a N-S direction. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

2. If two magnets are brought close to each other and in the manner shown in Figure 6.2, they exert repulsive and attractive forces on each other

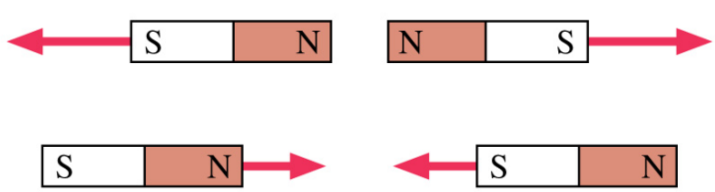


Figure 6.2: Two magnets exert forces of repulsions and attraction on each other. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

3. When we cut a bar magnet in half as shown in Figure 6.3, the result is two complete magnets similar but weaker than the original

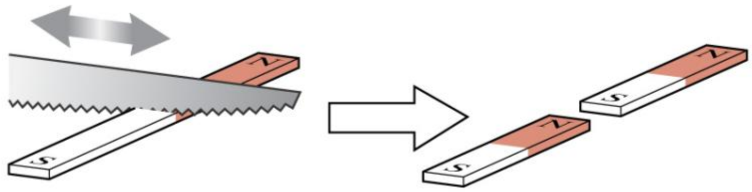


Figure 6.3: (a) Cutting a magnet in half produces two complete magnets. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

4. A magnet shows no effect on the electroscope as seen in Figure 6.4

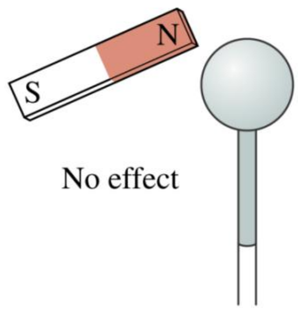


Figure 6.4: A magnet shows no effect a neutral or charged electroscope. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

From these observations, we conclude the following

- Figure 6.1 illustrates that a ***magnet has two poles***. The end that points toward the north is called North Pole (N). The opposite is called the South Pole (S)

- Figure 6.2 illustrates the basic fact, which states that: two like poles repel each other and two unlike (opposite) poles attract each other.

- Figure 6.3 demonstrates the fact that no matter how many times a magnet is being cut, two complete but weaker magnets are produced. Unlike electricity where charges can be isolated, this observation indicates that magnetic poles cannot be isolated, or simply there are no monopoles

- Figure 6.4 revels that a magnetism and electricity are different though electric charges and magnetic poles show similar behavior

6.2 The compass

A ***compass*** is an instrument that shows N, S, E, and W directions in a frame of reference that is stationary relative to the surface of the earth. As Figure 6.5 illustrates, the compass consists of a small magnetic needle with N and S poles mounted on a friction free pivot so that it can turns easily. The compass's

North Pole is red colored. When placed in the presence of another magnet, a magnetic force acts on the compass's needle and causing its north pole to align with the external field. It was invented by the Chinese around 247B.C, and was used for navigation by the 11th century. In scientific laboratories, the magnetic compass is usually used for detecting and mapping magnetic fields.

Figure 6.5: magnetic compass. A small magnetic needle mounted on a low friction pivot used for navigation and in detecting and mapping magnetic fields.

6.3 Magnetic field

Every magnet is surrounded by a space or a region in which the magnetic force acts. This space or region of force is called a ***magnetic field***. Like the electric field, the magnetic field is a vector and has a magnitude and direction at each point in space. The magnetic field lines, which are used to draw a picture of the field, have the following properties

- The direction of magnetic lines at any point is in the direction of magnetic force on the north pole of a magnetic compass as illustrated in Figure 6.6. Therefore, they leave the North Pole and enter the South Pole of the magnet forming continuous loops. Iron filings can also be used to map the field.

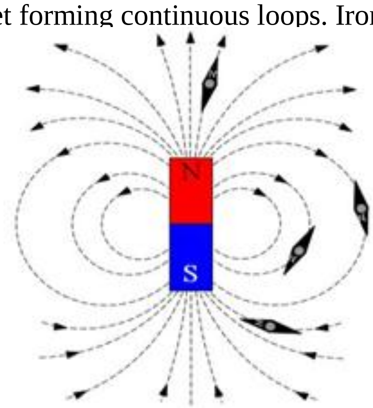


Figure 6.6: magnetic field lines of a bar magnet. The lines points in the direction of the magnetic force on a north magnetic pole of a compass.

- They form continuous loops; leaving N pole and reenter S pole as Figure6.6 shows
- The lines never intersect no matter how close they are. Their spacing measures the magnetic field strength. The space widen with distance from the magnet as Figure 6.6 shows
- The magnetic lines in the region between two like and unlike poles are illustrated in Figure 6.7

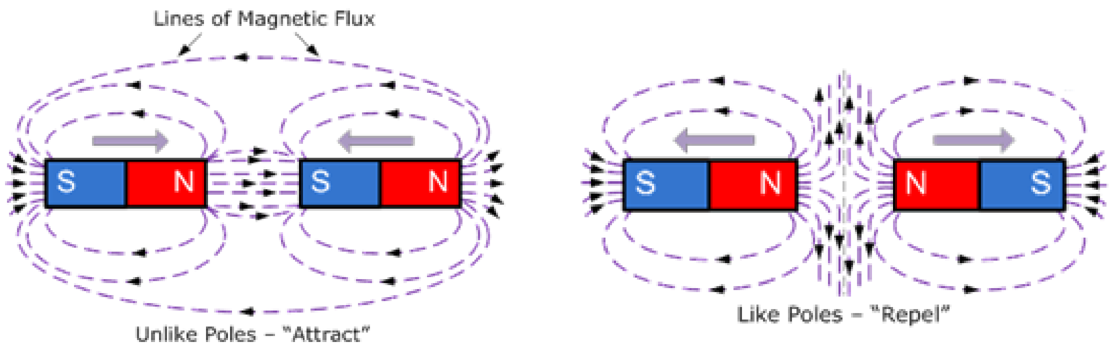


Figure 6.7: the magnetic lines between two unlike and like poles.

- The magnetic field lines for U and disk-shaped magnets are depicted in Figure 6.8

Figure 6.8: magnetic field lines of U and disk shaped magnets. It is left to the student to draw directions of these lines

6.3 The sources of magnetism

Magnetism is produced by two sources: electric current (electromagnet) and permanent magnets

6.3.1 Magnetism from electric currents

In 1820 the Danish scientist Hans Oersted discovered that when an electric current from a battery passes through a wire it produces a magnetic field around the wire as illustrated in Figure 6.10. The field acts on a compass near the wire and align it in its direction as depicted in Figure 6.10b. Usually a right hand rule (RHR) as Figure 6.10c shows is used to determine the field direction.

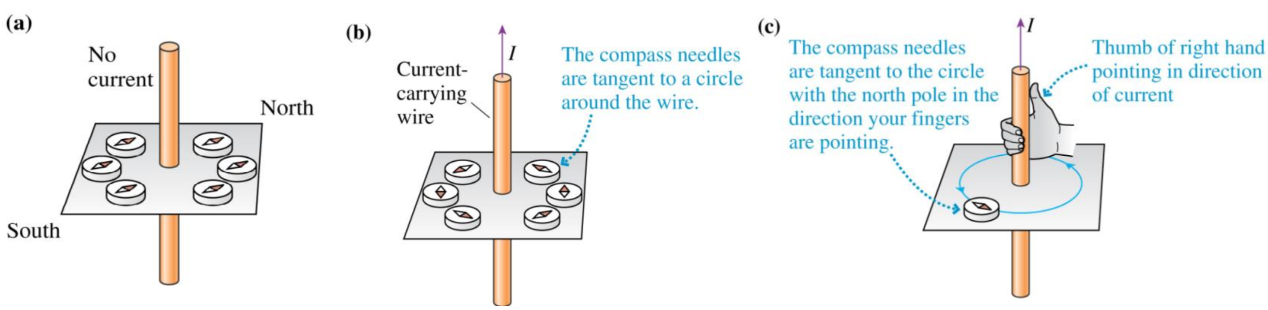
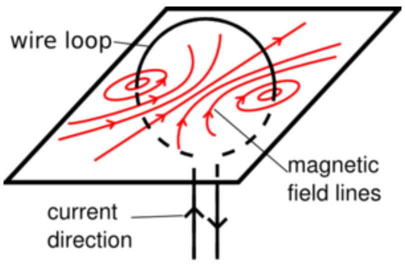


Figure 6.10: electric current in a wire creates a magnetic field. The compass and RHR draws the shape of the field. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

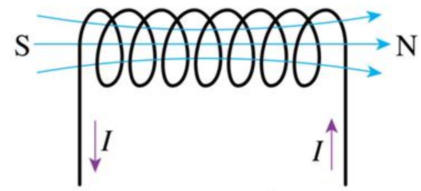
The magnetic field lines are concentric circles with center at the wire as lustrated in. The closer the circle to the wire, the stronger the field is.

Magnetic field of a loop: The solenoid

If the wire carrying current of Figure 6.10 is bent into a single loop as Figure 6.11a illustrates, the magnetic field lines become concentrated in the centre of the loop. Increasing the number of loops to form a coil increases the field intensity inside the loops even more. The produced field is similar to that of a bar magnet with north and south poles at its ends is determined by RHR as shown in Figure 6.12b.



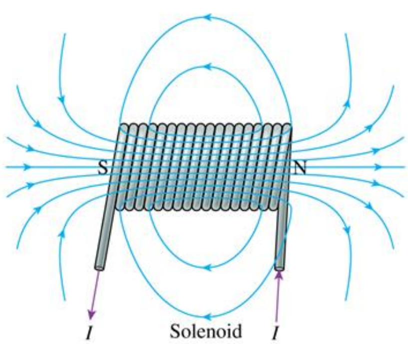
(a)



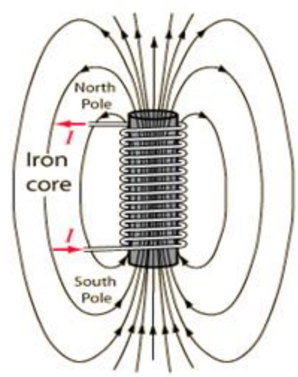
(b)

Figure 6.11: (a)magnetic field around a loop of wire current carrying wire. (b) Magnetic field of a coil. Credit **(b):** *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

A ***solenoid*** is a coil consists of many circular loops of wire wrapped tightly as illustrated in Figure 6.12(a). The magnetic field produced by solenoid is similar to that of a bar magnet. To increase the magnetic field intensity, possibly to 100 times or more, the loops are wrapped around an iron core as shown in Figure 6.12(b)



(a)



(b)

Figure 6.12: (a) the magnetic field of air solenoid. (b) Magnetic field of iron core solenoid. RHR was used to determine field direction. Credit (a): *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

The earth as a giant magnet

As we show in Figure 6.1 of magnetic phenomena, a freely suspended magnet always points in the North-South direction even in the absence of magnets nearby. This suggests that the earth itself behaves as a giant magnet with a magnetic field similar to that of a bar magnet as depicted in Figure 6.13.

The earth's axis of rotation *RR* specify the north and south geographic poles, while the magnetic axis *MM* determines the earth north and south magnetic poles. The earth's north magnetic pole lies in the northern hemisphere in Canada. The cause of earth's magnetic field is believed to be due to electric currents resulted from the movement of hot molten core of iron and nickel deposit in earth's center.

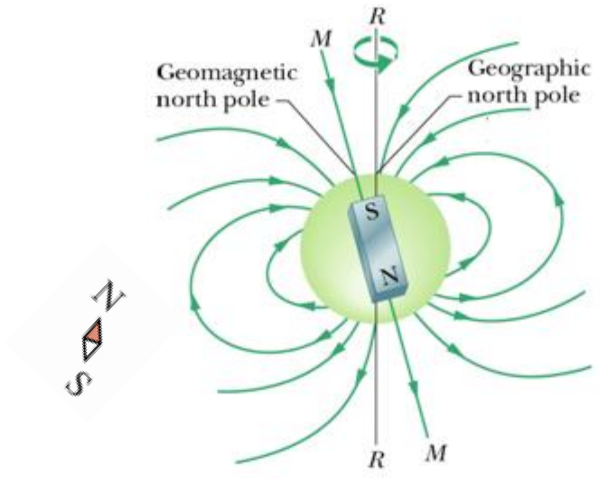


Figure 6.13: The earth is a giant bar magnet. Credit: *D. Halliday, R.Resnick, and J Walker"Fundamentals of Physics", John Wiley and Sons, Inc2001.*

A compass needle on the surface of the earth will always point along the magnetic field lines, towards the north magnetic pole. Because unlike poles attract each other, the earth's north magnetic pole is actually the earth's south magnetic pole as illustrated in Figure 6.14. Therefore, the lines of earth's magnetic field leave the southern hemisphere and enter the northern hemisphere.

The earth's magnetic field has a very interesting role of protecting earth from energetic charged particles like electrons and protons that enter earth atmosphere from the sun (solar wind). The field exerts a force on these particles and traps them along the field lines between the poles in helical paths as Figure 6.15 illustrates.

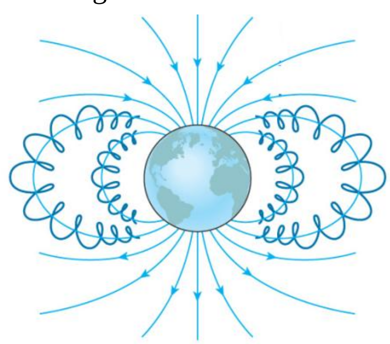
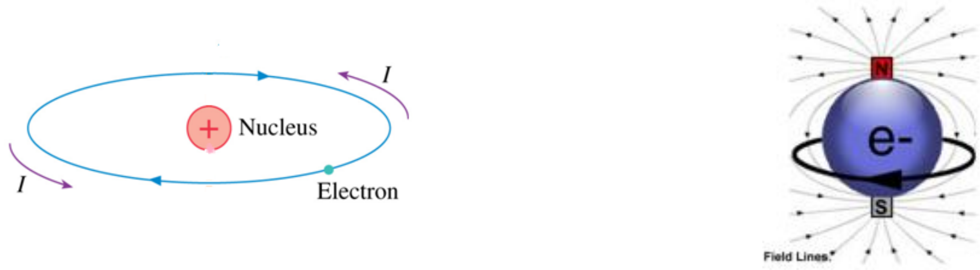


Figure 6.14: Charged particles trapped along helical paths around the magnetic field lines of earth. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

6.3.2 Magnetism from permanent magnets: Atomic magnetism

Why iron, nickel, and cobalt are attracted strongly to a magnet whereas other materials like silver, gold, aluminum, and humans are not? The answer to this question requires deep looking deep within the atoms of substances.

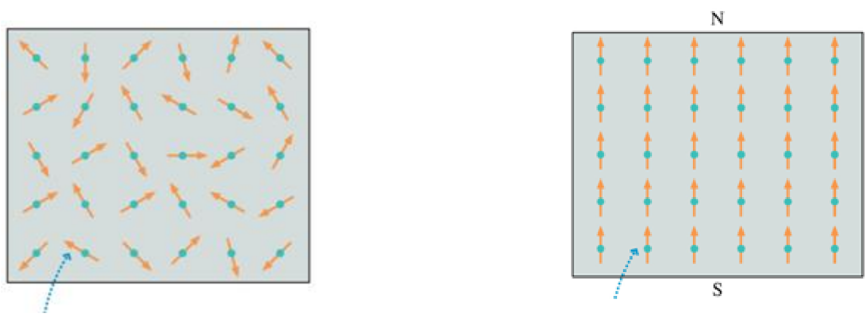
In every atom, the electron performs two motions; orbital motion around the positive nucleus and spin motion around its own axis. Each of these motions shown in Figure 6.15 is a current loop that generates a magnetic field. The two magnetic fields are combined to form a net field. Consequently, each electron is regarded as a tiny magnet with north and south poles.



(a) (b)

Figure 6.15: The electron within an atom is a tiny magnet. (a) Orbital motion and (b) spin around an axis

The magnetic fields of all electrons combine to form a net atomic magnetic field for the whole atom. For a piece of non magnetic material like gold or silver, these atomic magnets are oriented in random and often cancelling each other as Figure 6.16(a) illustrates. This leaves the material with zero or very small net magnetic field. For a piece of magnetic material such as iron, the magnetic atoms are lined up in a perfectly one direction causing their magnetic fields to add up producing as Figure 6.16(b) a field of N and S poles.



(a) (b)

Figure 6.16: Atoms as tiny magnets. (a) Random orientation cancels out atomic magnetisms. (b) Group of atoms lined up and enhances their magnetisms. The dotted line points on an atom. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

In solid iron, groups of atoms are grouped into small regions called ***magnetic domains***. In each domain atoms are perfectly lined up with arrows represent their net magnetic fields. Figure 6.17 shows magnetic domains. However, the domain fields are in random, which explains why a piece of iron like a paper clip is not a magnet.

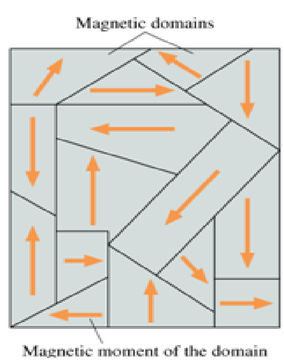


Figure 6.17: Magnetic domains in a piece of iron. The net magnetic field is nearly zero. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

Magnetic materials: magnetization by induction

What happens when we place different materials close to a magnet? The materials will respond and their behavior can be detected. According to their behavior, materials are classified into three groups:

1. ***Ferromagnetic materials*** (or iron-like): These materials are found strongly attracted to the magnet. The external magnetic field aligns their magnetic domains (arrows) in one direction and thus induces magnetism with N and S dipole. Figure 6.18 shows what happens to a ferromagnetic material near a magnet (solenoid).

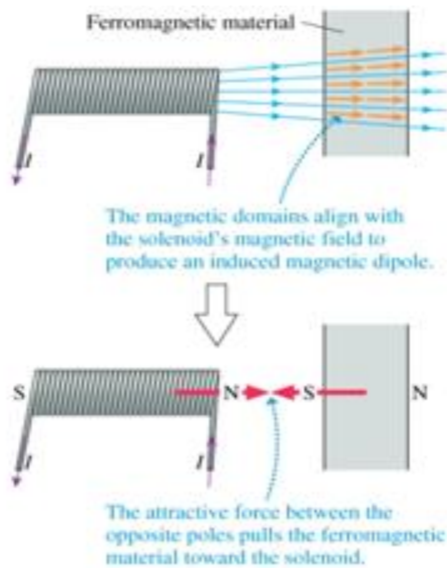


Figure 6.18: The magnetic field of a solenoid induces a magnetic dipole (N and S poles) in the iron. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

Examples of ferromagnetic materials are iron, nickel, cobalt, and their alloys (mixtures).

ferromagnetic materials can be further classified as soft and hard irons:

- ***Soft iron***, which can be magnetized, but loses its magnetism when the external magnet is removed. Examples are paper clips and steel nails. Figure 6.19 illustrates the magnetization of soft irons.

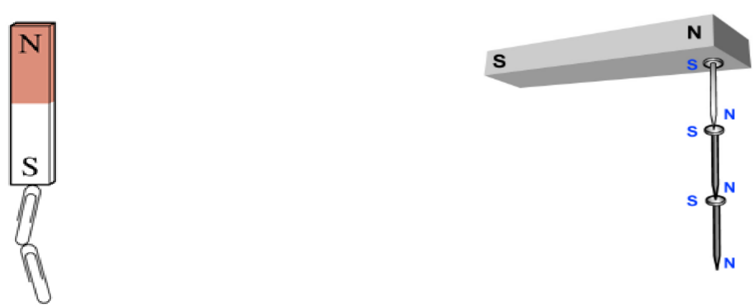


Figure 6.19: magnetization of some soft iron materials.

- ***Hard iron***, which can be magnetized and keeps its magnetism even when the external magnet is removed. Permanent magnets are made of hard irons. An alloy called alnico (**al**uminum, **ni**ckel, **co**balt) is an example of hard iron.

2. ***Paramagnetic materials***: These are materials whose atoms are tiny magnets, but their random orientation leaves them with zero or very small magnetism. When placed in an external magnetic field, the magnetic atoms align, but not in a perfectly fashion as in ferromagnetic materials. This improves their overall magnetism, but their induced field is 10^{-5} times weaker than that of ferromagnetic materials. Examples of paramagnetic materials are platinum, aluminum, oxygen, and all alkali and earth alkali metals. This behavior is illustrated in Figure 6.20.

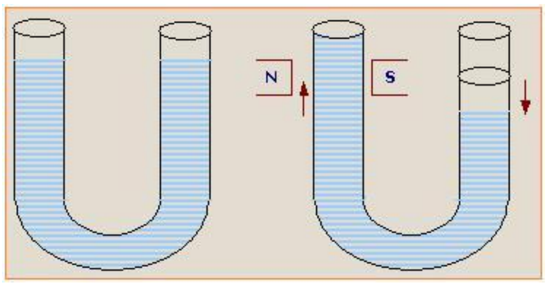


Figure 6.20: A paramagnetic liquid in U tube placed between two poles of a magnet is attracted.

Caution: strong magnetic field is required to display the paramagnetic effect

3. ***Diamagnetic materials***: These materials are found to develop a magnetic field that repels the external field. Most of gases except oxygen are diamagnetic and also carbon, copper, water, gold, silver, diamond, plastic, and many organic compounds. The behavior of a diamagnetic liquid in U-shaped glass is shown in Figure 6.21. This behavior makes diamagnetic materials .used in magnetic levitation.

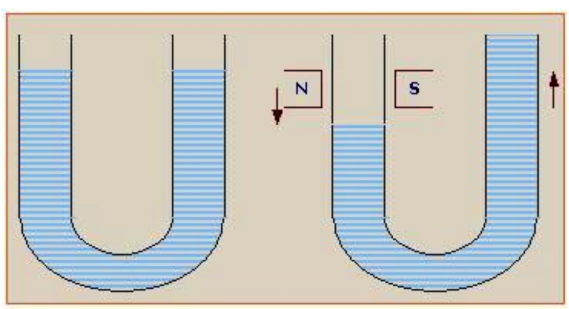


Figure 6.21: A diamagnetic liquid in a U shaped tube is depressed when subjected to a magnetic field.

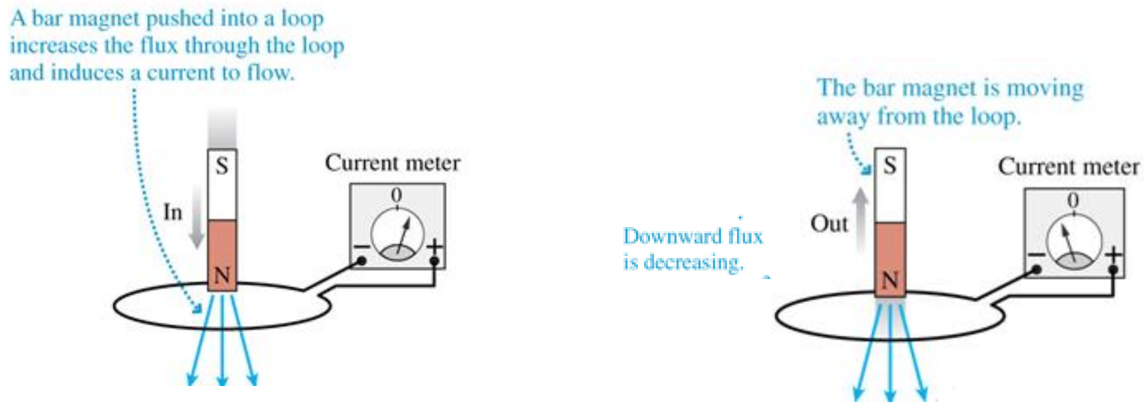
Caution: extremely strong magnetic field is required to display the diamagnetic effect

6.4 Electromagnetic induction

Can we get a current from magnetism? Yes through a process called ***Electromagnetic induction***. In this process, an electric current is generated across a conductor (wire) placed in a changing magnetic field. It is the basis of the operation of electric motors, generators, transformers, computer hard disks, metal detector, and cell phone. The key element in this process is a "changing magnetic field"

Changing a magnetic field can happen in three ways

1. By pushing a magnet inside a stationary loop of wire or pulling it out as illustrated in Figure6.22.



(a) (b)

Figure 6.22: (a) pushing a bar magnet toward a loop and (b) pulling it away from loop generates (induces) a current. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

2. By pushing a loop into a stationary magnet or pulling it out as illustrated in Figure 6.23.

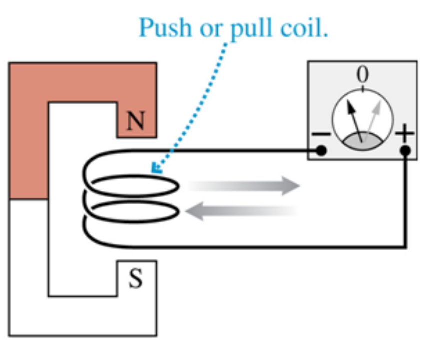


Figure 6.23: pushing a magnet in or pulling it out a loop generates current. Credit: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

These two observations imply the following

- Induced current is produced only if the magnetic field is changing, meaning that the number of magnetic lines that cross the wire changes

- If the magnetic field is increasing (lines increasing by pushing in), the induced current points in one direction

- If the magnetic field is decreasing (lines decreasing, by pulling out),, the induced current points in the opposite direction

3. By using an AC (changing) current through solenoid (primary coil). This would create a changing magnetic field. If the lines of this field are allowed to cross a secondary coil as Figure6.24 illustrates, an induced voltage is produced and recorded by a voltmeter.

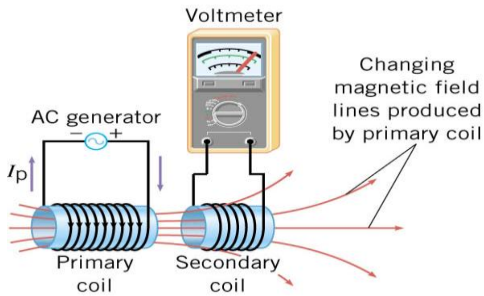


Figure 6.24: A changing magnetic field in the primary coil induces a voltage in the secondary coil.

Applications of electromagnetism:

The AC generator

The ***electric AC generator*** is a device that converts mechanical (kinetic) energy into electrical energy. A typical electric generator is shown in Figure 6.22. It consists of a magnet and a coil of wire rotating in a constant magnetic field. As the coil rotates, the magnetic field lines crossing it change continuously producing an induced voltage Ɛ, which generates an induced current. The current is then removed from brushes attached to the loop. The generator produces an AC voltage, therefore the current through the resistor *R* changes direction back and forth. The value of the induced voltage depends on the area of the loop, the speed of coil, and on the number of loops in the coil.

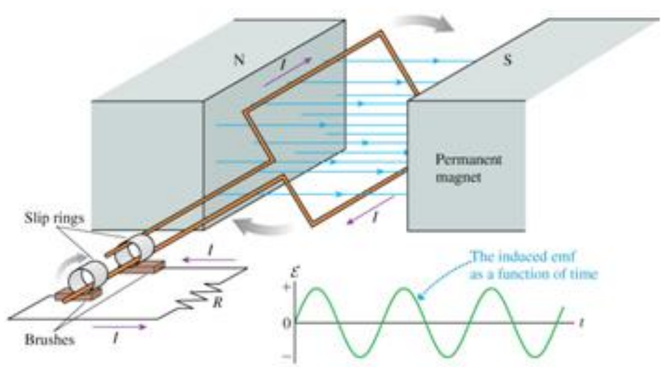


Figure 6.25: An Ac generator. Credit: *Randall D. Knight "Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

Transformers

A ***transformer*** is an electrical device that changes the voltage (raise or lower) in an AC circuit. It consists of two coils of wire wrapped on an iron core. Figure 6.26 shows a simple transformer. As an AC current passes through the primary, a changing magnetic field is established throughout the core, which induces a voltage in the secondary coil. The magnitude of the induced voltage is given as

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}, \quad or \quad V_s = V_p \frac{N_s}{N_p} \tag{6.1}$$

Where:
$$V_s = secondary\ voltage$$
$$V_p = primary\ voltage$$
$$N_s = number\ of\ secondary\ turns$$
$$N_p = number\ of\ primary turns$$

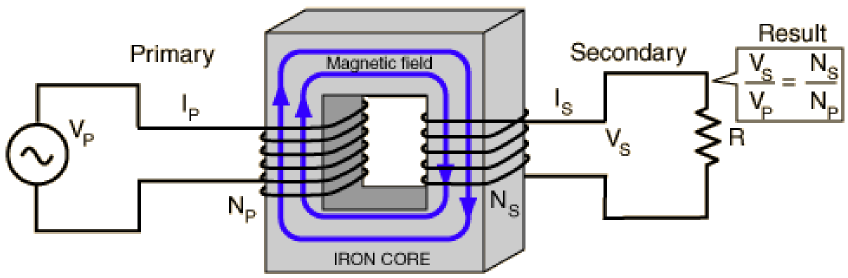


Figure 6.26: A simple transformer.

A transformer used to raise a voltage up is called ***step-up transformer***. In step-up transformer $V_s > V_p$. This can be done by having $N_s > N_p$. It is used when a high voltage is needed. A transformer used to lower a voltage is called ***step-down transformer***. In step-down transformer $V_s < V_p$. This can be achieved by having $N_s < V_p$. Practical uses of a transformer are in cell phone charger, TV, and computers.

Example 6.1

A step-up transformer on 115 *V* line provides a voltage of 2300 V. If the primary coils has 65 turns, how many turns does the secondary have?

Solution

$$Given: V_p = 115V, V_s = 3500V, N_p = 65, \quad wanted: N_s$$

$$\because \frac{V_s}{V_p} = \frac{N_s}{N_p}, \ or \ N_s = N_p\left(\frac{V_s}{V_p}\right), \quad \Rightarrow \therefore N_s = 65\left(\frac{2300}{115}\right) = 1300\, turns$$

Summary of Chapter 6

A ***magnet*** is a dipole (N and S poles) object, which produces a magnetic field even in the absence of other magnets nearby. ***Magnetism***, on the other hand, is a property of matter like mass or charge that describes the behavior of any material placed in the presence of a magnet. This behavior varies from a weak to strong respond. The source of magnetism in matter is due to electrical currents (electron movements) around the atomic nucleus and also to the electrons arrangement in orbits within atoms. Most common magnets in laboratories are the bar magnet, U and horse shoe magnets, and disk and doughnut- shaped magnets. Among these, the bar magnet is the simplest. Electrons and atoms are modeled as bar magnets. This is true even for solenoids and earth. Like poles repel and unlike poles attract. Unlike electricity, poles cannot be isolated; no matter how many times a magnet breaks it produces two complete magnets. Like the electrical force, the magnetic force is not a contact force (a push or pull), therefore it must be represented by a field. The ***magnetic field*** is an invisible space around a magnet where the magnetic force exists. It decreases with distance from the magnet. Materials are either magnetic or nonmagnetic in the presence of external magnetic field (magnet). According to their respond to the external field, materials are classified as ***ferromagnetic***, ***paramagnetic***, or ***diamagnetic*** materials. Ferromagnetic materials have ***magnetic domains***; magnetic regions of group of perfectly aligned atoms in such a way that each domain is a microscopic bar magnet. The domains are randomly oriented shown as arrows pointing at different directions. In the presence of an external field, these domains line themselves up and thus show strong attraction to the magnet. Mostly, this induced magnetism is not permanent where the domains become random again when the field id removed. Permanent magnets keep their induced magnetism for undefined time when the external field is removed. Paramagnetic materials have an overall zero or very small magnetic fields. In the presence of an external field they establish very weak and hard to detect magnetic field. Like paramagnetic materials, the diamagnetic materials have no overall magnetism. An interesting behavior is observed when these materials are brought close to an external magnet; they develop a negative or a repulsive magnetic field. This behavior allows them for the use in magnetic levitation. Electrical currents have magnetic effects. A wire carrying current produces a constant magnetic field in the shape of concentric circles around the wire. DC current produces steady and constant magnetic field and AC current produces a ***changing magnetic field***. A changing magnetic field induces electric currents. This is called ***electromagnetism***. Based on electromagnetism countless instruments and devices have been built including generators, motors, and transformers

.**Basic principles and facts**

- There are no monopoles in magnetism. Each magnet natural or manmade is a dipole
- Like poles repel and unlike poles attract
- Hard irons materials keep their magnetism even when the external magnet is removed
- Permanent magnets are made by mixing magnetic materials such as iron, nickel, and cobalt
- Currents produce magnetic field and a changing magnetic fields produce currents

Basic equations

Transformer equation: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

Chapter 6 worksheet

Part1: Multiple choices

1. A magnetic field in a region can be detected by
   A. A magnet
   B. A compass
   C. Iron filing
   D. All of the above

2. The alignment of a freely suspended magnet by a string in specific direction in the absence of any magnet nearby shows
   A. The magnetic field of the magnet itself
   B. The magnetic field of the sun
   C. The magnetic field of the earth
   D. All of the above

3. The deflection of a compass needle close a wire carrying current shows
   A. The magnetic field of the sun
   B. The magnetic field of the wire
   C. The direction of wind
   D. The electric field

4. Which of the following statements is not correct statement of the similarities between charges and magnets?
   A. There are attractive and repulsive forces between like and unlike charges and magnetic poles
   B. Both magnetic poles and charges develop fields
   C. Both exert non push or pull force
   D. Both electrical charges and magnetic poles can be separated (isolated)

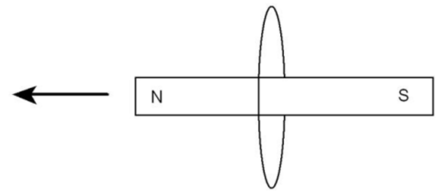
5. Bt which process a magnetic field can be produced
   A. By the motion of separated magnetic poles
   B. By the motion of electrons within atoms
   C. By the motions of protons and neutrons within the atomic nucleus
   D. By rubbing iron by a piece of cloth

6. Which of the following will strengthen the magnetic field in a solenoid
   A. By increasing the thickness of the iron core
   B. By increasing the thickness of the wire
   C. By reducing the number of loops
   D. By increasing the number of loops

7. What energy conversion is achieved by the electric generator?
   A. Mechanical energy to electrical energy
   B. Electrical energy to mechanical energy

C. Electrical energy to solar energy
D. Mechanical energy to nuclear energy

8. If you constantly push the bar magnet through the loop as shown below, then
A. constant current would flow in the loop
B. A changing current would flow in the loop
C. The magnet demagnetized
D. None of the above is correct



9. If you stopped the magnet (questions 8) midway through the loop, then
A. The current gradually dropped to zero
B. The current immediately dropped to zero
C. The magnet demagnetized
D. None of the above is correct

10. Which of the following would not be part of a generator?
A. Electromagnet
B. Permanent magnet
C. Wires
D. Battery

Part 2: True/False. If the answer is False then correct it

1. A compass is a magnet
A. True
B. False

2. The magnetic force is exerted by the north pole of a magnet only.
A. True
B. False

3. The magnetic force increases when the distance from a magnet increases
A. True
B. False

4. Before current from a power lines enter your house, it must be pass through a step-up transformer.
A. True
B. False

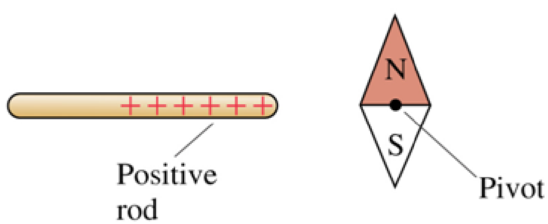
5. Generally, the strength of the solenoid magnetic field depends on both the current and number of turns
A. True
B. False

6. When a current pass through a wire an electric field generates around the wire.
   A. True
   B. False

7. A constant magnetic field induces electric current.
   A. True
   B. False

Part 3: Challenge questions

1. Explain why the needle of a compass points in a certain direction.
2. Discuss one major difference between electric field lines and magnetic lines.
3. Explain how you could identify the polarity of unknown magnet.
4. Explain what will happen if you spread iron filing near a magnet.
5. Suppose you have been given two physically identical magnets, then how can you determine which one is more powerful than the other?
6. If you stack two physically identical magnets together, does their magnetic force increases? Explain
7. You have been given two coils (solenoids), one with 10 turns and 20 turns for the other. Which will have a stronger magnetic field if same current passes through each?
8. If we put a lighted candle between the poles of U-shaped magnet, its flame is repelled by the field. Explain why.
9. You have been given a physically identical U-shaped and horseshoe magnets, which has the strongest magnetic field? Explain
10. Though the protons and neutrons move in a similar fashion like electrons within the atom, but they do not contribute to the atomic magnetism. Explain why.
11. How can you determine for sure whether a piece of steel is magnetized? How would you determine its polarity if magnetized?
12. Which is more fundamental, electricity or magnetism? Remember that magnetism is a property of charge in motion.
13. What is your justification that the theory of magnetic domain is true?
    Explain what will happen when a positively charged rod is brought close to a compass(Sketch was taken from: *Randall D. Knight* "*Physics for scientists and engineers a strategic approach*" by Pearson-Addison Wesley 2004.

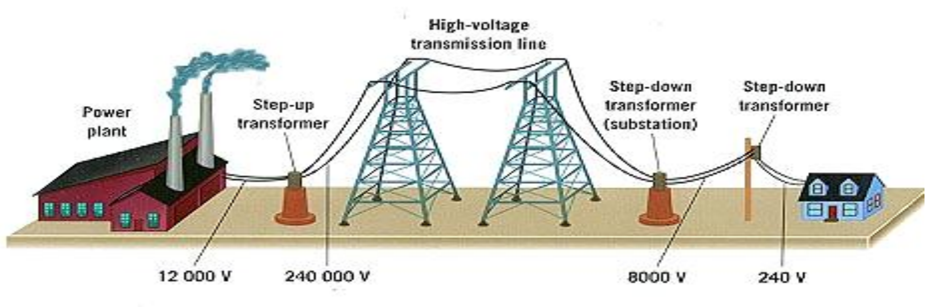


14. Why do you think that a human is considered as a diamagnetic material? Can a human be elevated? Scientists were successful to elevate a live frog. Suggest a proposal.

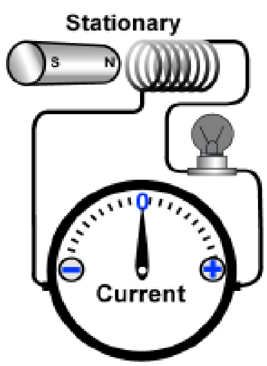
Part 4: learning from looking at sketches and diagrams

In few lines, explain in writing what these diagrams are demonstrating to you

1.



2.



3.

4.