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Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Science

Quarter 2 – Module 6
Electricity and Magnetism

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City of Good Character
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What I Need to Know

The purpose of this module is to help you understand and explain the working principle behind electric motors and generators. The module contains one lesson: The Phenomena of Electricity and Magnetism.

After going through this module, you are expected to **explain the operation of a simple electric motor and generator. S10FE-IIj- 54**

Specifically, you are expected to:

- define the magnetic field, magnetic force, electric field, and electric force;
- differentiate an electric motor from an electric generator;
- explain the working principles of a simple electric motor and generator; and
- explain how electromagnetic induction is applied to an electric generator.

What I Know

Read each question carefully and encircle the letter of the correct answer.

1. Which are TRUE about an electric motor?
   I. It uses magnets to create a circular motion.
   II. It uses magnets to create rotational motion.
   III. It converts electrical energy into mechanical energy
   IV. It depends on the interaction of magnetic and electric fields.
   A. I and II   B. II and III   C. I and III   D. II and IV

2. An electric generator converts energy from _______________ to ________________.
   A. chemical to electrical   C. electrical to mechanical
   B. electrical to chemical   D. mechanical to electrical

3. Which principle works with an electric motor and generator respectively?
   A. Faraday's Law and Ampere's Law
   B. Fleming's Right-Hand Rule and Electromagnetic induction
   C. current-carrying conductor inducing a magnetic field and electromagnetic induction
   D. electromagnetic induction and current-carrying conductor inducing a magnetic field

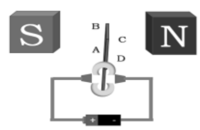
4. In which part of an electric motor is electric current supplied to create magnetic force?
   A. armature B. brushes C. commutator D. stator

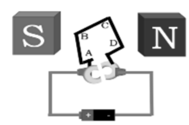
5. In which part of an electric generator is an electric current produced due to the induced electromotive force (emf) or voltage?
   A. armature B. brushes C. commutator D. stator

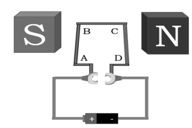
6. Which part of an electric motor provides a magnetic field, allowing the inner coil wire within to rotate as the electric current passes through.
   A. armature
   B. brushes
   C. field magnet
   D. terminal of the source

7. In which position does an electric motor experience a strong magnetic force?

A. 

B. 

C. 

D. 

(illustrated by Noreen Mabbagu)

8. Which part of an electric generator induces voltage difference and converts direct current (DC) into alternating current (AC)?
   A. armature B. brushes C. commutator D. stator

9. Based on the principle of electromagnetic induction as applied to generators, which setup produces the greatest amount of electric current as a magnet is inserted into a coil of wire? Consider the same strength of the magnet.
   A. A magnet is inserted into a coil with 50 turns of wire.
   B. A magnet is inserted into a coil with 100 turns of wire.
   C. A magnet is inserted into a coil with 200 turns of wire.
   D. A magnet is inserted into a coil with 250 turns of wire.

10. According to Fleming's Left-Hand Rule, in which orientation does current-carrying wire receive no force of the magnetic field?
   A. A current-carrying wire oriented at 40^{o} to the magnetic field.
   B. A current-carrying wire oriented parallel to the magnetic field
   C. A current-carrying wire oriented at the right angle to the magnetic field.
   D. A current-carrying wire oriented at an oblique position to the magnetic Field

Lesson	The Phenomena of Electricity and Magnetism

What's In

Identify the truth in each statement below based on the highlighted word. Shade the box with **BLUE** color if the statement is a "FACT" and **RED** color if "BLUFF" then correct it by writing the real answer.

NO.	STATEMENT/S	FACT	BLUFF	Correct Answer for Bluff Choices
1	According to **André-Marie Ampère**, a magnetic field was created when there is a passage of electric current in a conductor. This led to the beginning of electromagnetism			
2	**Michael Faraday** discovered that a changing magnetic field could induce electricity.			
3	The direction of the magnetic force, magnetic field, and an electric current was introduced by **Alexander Fleming.**			
4	The idea that the direction of induced electric current is related to the change in magnetic flux was explained in law by **Heinrich Friedrich Lenz.**			
5	**Hans Christian Oersted** had demonstrated the generation of the magnetic field between two parallel current-carrying wires.			
6	The **magnetic field** is the force experiences around a magnet.			
7	The imaginary space or region around an electrical charge is known as the **electric field.**			
8	If electrical charges move, there is the presence of **electrical resistance.**			
9	The space around the magnet is called **magnetic force.**			
10	Any material that can attract metals like iron is called **a magnet.**			

What's New

Activity 1: Analyzing the Current-Carrying Wire and The Electric Motor
Objective: Investigate the induction of magnetism out of electricity
You Will Need: a diagram of a current-carrying wire circuit (Fig.1)
Procedure:

Figure 1 shows an illustration of a loop of wire attached to a source and was exposed to the magnetic field of the surrounding magnets. The flow of electric current is conventional. Examine the circuit in Figure 1 and answer the following questions.

Guide Questions:

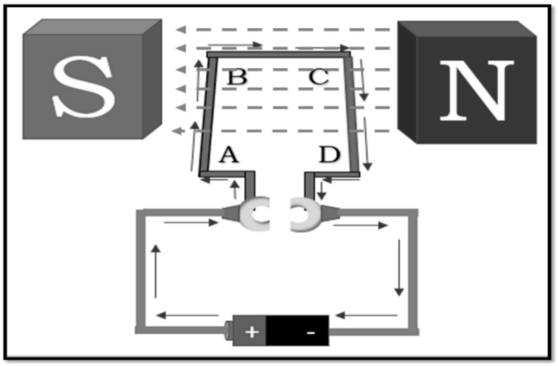


Fig. 1: Current-Carrying Wire Circuit
(Illustrated by Noreen Mabbagu)

1. Is the circuit closed-switch or open-switch?
2. Do electrons flow throughout the circuit? In what direction?
3. Magnets are not directly connected to the loop of wire. Do they still provide magnetism? How?
4. As the electrons move around the loop of the wire, the electric force induces magnetism on the wire. The wire loop is also affected by the magnetic field of the magnets around it. If that is so, what will be the behavior of the wire loop?
5. How will you compare the direction of electric current to that of the magnetic field provided by the magnets at the following points of the wire loop:
   a. AB = ______________________________ c. CD = __________________________
   b. BC = ______________________________ d. AD = __________________________

Activity 2: The Magic of a Magnet in a Generator
Objective: Investigate the induction of electricity out of magnetism
You Will Need: a diagram of a generator

Procedure:

Figure 2 shows an illustration of a loop of wire attached to an axle or shaft and was exposed to the magnetic field of the surrounding magnets as shown in Fig. 2.

The flow of electric current is conventional. Analyze the circuit and answer the following questions.

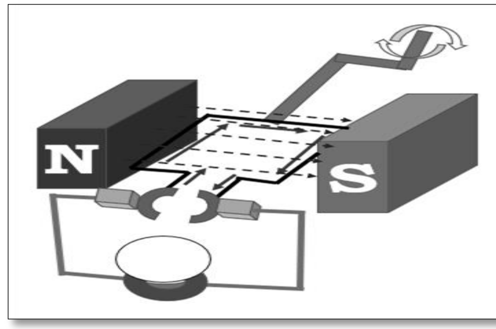


Fig. 2: A simple generator
(Illustrated by Noreen Mabbagu)

1. What happens to the magnetic field provided by the magnets as you rotate the axle or shaft?

2. As the loop of wire rotates, it cuts the magnetic field. Electrons in the wire will be disturbed. Why?

3. What will happen to the induced currents in the wire loop as it flows in one direction?

4. If the induced current flows, will the bulb be lighted? Explain your answer.

What Is It

Whenever people go to new places, one of the favorite items bought for a souvenir is what we commonly called a “ref magnet”. Have you seen one? How does it look like? Oh yes, you are correct! A “ref magnet” commonly displays pictures of a place through the use of a non-adhesive material, usually flat and round in form, called “magnets”.

Magnets affect any materials around them in a region of space known as the **magnetic field** where the **magnetic force** acts. Such force could either be attractive or repulsive depending on the orientation of the poles. Following the law of magnetism, “like poles repel while unlike poles attract” as shown in Fig. 3. The lines of force indicate the direction of how the force acts on different

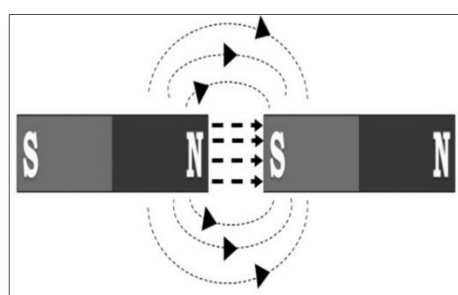


Fig. 3: Magnetic Field and lines of force
(Illustrated by Noreen Mabbagu)

poles of the magnets, thus, from the north to the south pole. In the case of electromagnets, magnetism manifests if electric charges flow in a conductor by electricity. Electric charges, either positive or negative, are acted upon by **electric forces** in a region of space around it called an **electric field**.

Electromagnetism

In the early centuries, electricity and magnetism had been regarded and observed as two different phenomena. However, in the 19th century, brought about by curiosity, hard work, and perseverance of different known scientists, electricity, and magnetism were found out to be interrelated. The relationship that exists between these phenomena were elaborately explained in an area of classical physics known as ***"Electromagnetism".***

One of the unexpected initial discovery that involves electromagnetism comes from the work of a Danish scientist Hans Christian Oersted in 1820. He observed the deflection of the compass needle around a conductor when switching on the circuit and at right angles with the wire. Oersted had thought that the presence of moving electric charges could induce the creation of a magnetic field, but clueless on where the magnetic field is directed.

Such discovery of Oersted was expressed quantitatively by a French physicist Andre-Marie Ampere in 1820. He showed that the attraction or repulsion might happen between two current-carrying wires. If the electric current moves in the same direction, the two wires are attracted. But if the current flows in the opposite direction, the wires repelled each other. With this, Ampere initially expresses the direction of the magnetic force on electric current in a magnetic field through the *right-hand rule.*

A year after Oersted's discovery of electromagnetism, an English physicist Michael Faraday had proven his work by using the set-up in Fig. 4. In his work, he observed that the wire continuously rotated around the magnet as the switch is on and put into a stop when off. He called his setup as the first **simple electric motor** – a device that converts electrical energy into a mechanical one.

Fig. 4: Simple Electric Motor
https://nationalmaglab.org/education/magnet-academy/history-of-electricity-magnetism/museum/faraday-motor-

The phenomena that happened in Activity No. 1 is like what has been discovered by Faraday in applying Oersted's principles of current-carrying wire in his electric motor. In the activity, you will notice that in a current-carrying wire circuit as shown in Fig.1, the circuit is closed allowing the passage of electrons. Thus, electric current flows throughout the circuit. As the electrons flow, it exerted an electrical force on a region of space around it called an electric field. The electrons around the loop of wire exerted another force due to its motion. This force is known as the magnetic force which is due to charges motion and interaction among each other. Thus, magnetism was induced or created around the wire and magnetic field build-up. Because of this, the loop of wire's magnetism interacts with the magnet's magnetic field. Thus, a twisting or turning effect is known as "torque" that has been created allowing the loop of wire to rotate in a half cycle and cut the presence of a magnetic field for some time.

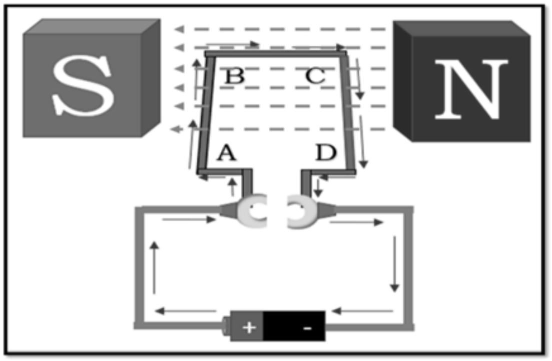


Fig. 1: Current-Carrying Wire Circuit
(Illustrated by Noreen Mabbagu)

However, there are portions around the loop of wire where the action of the magnetic force is said to be negligible. This happens when the wire is positioned parallel with the magnetic field of the surrounding magnet. In the case of Fig. 1, where the loop is oriented horizontally, the magnetic force is significantly experienced at points AB and CD, and negligible at point BC and AD. But what will happen when the loop of wire is oriented vertically? Yes, you are correct! No current will run through the half rings. So, what do you think will happen?

Proving the works of Oersted with his invention, the electric motor, Faraday became curious about the possibility that electricity could be created out of magnetism. After a decade of hard work, Faraday introduced another phenomenon that relates electricity to magnetism in a reversed process. He called this "electromagnetic induction".

Electromagnetic Induction

In 1831, Faraday's hard work of experimentation and investigation of this concept became fruitful when he found out that moving permanent magnet in and out of loops of wire, an electromotive force (emf) was induced and hereby allowing electric


Fig. 5: The First Generator

https://www.timetoast.com/timelines/electromagnetismo-79f60ba8-7fe4-

charges to flow. Such a phenomenon induces or creates electricity out of magnetism. He published his findings as Faraday's *Law of Electromagnetic Induction.* In the same year, with his discovered principle, he created the **first generator** (Fig. 5) – a device that converts mechanical energy into an electrical one.

This principle of converting magnetism to electricity is being illustrated in Fig. 2 as the rotating loop of wire cuts off the magnetic field provided by the magnets. This is made possible through the rotation of the axle. Due to the motion of the wire loop, electrons exerted magnetic force, disturbed, and moved in one direction until it reaches the two-half rings.

The collection of induced current was obtained by a component attached to the connecting wire and provide it to the load in the circuit.

The phenomenon that exists between electricity and magnetism could better be understood by knowing the relationship between magnetic force, magnetic field, electric field, and electric force. With this, an English electronics pioneer John Ambrose Fleming devised a mnemonic that was initially used by his students in the late 19th century. He called this Fleming's Left-Hand Rule (Fig. 6) and Right-Hand Rule (Fig. 7). Such hand rules were also used to clearly explained the underlying principle behind simple motor and generator.

In using Fleming's mnemonic, keep the following in mind to follow the conventional flow of electric current.

- **Thumb** – shows the direction of motion of the conductor (for the right-hand rule) and the direction of magnetic force (for the left-hand rule)
- **Forefinger** – shows the direction of the magnetic field (for both left- and right-hand rule)
- **Middle finger** – shows the direction of electric current (for both left- and right-hand rule)

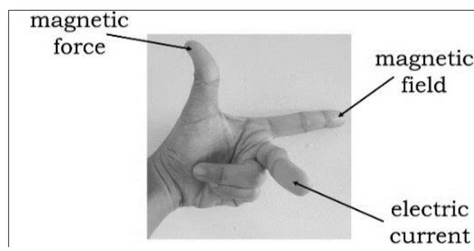


Fig. 6: Fleming's Left-Hand Rule

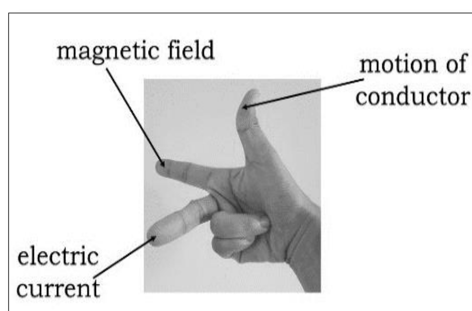
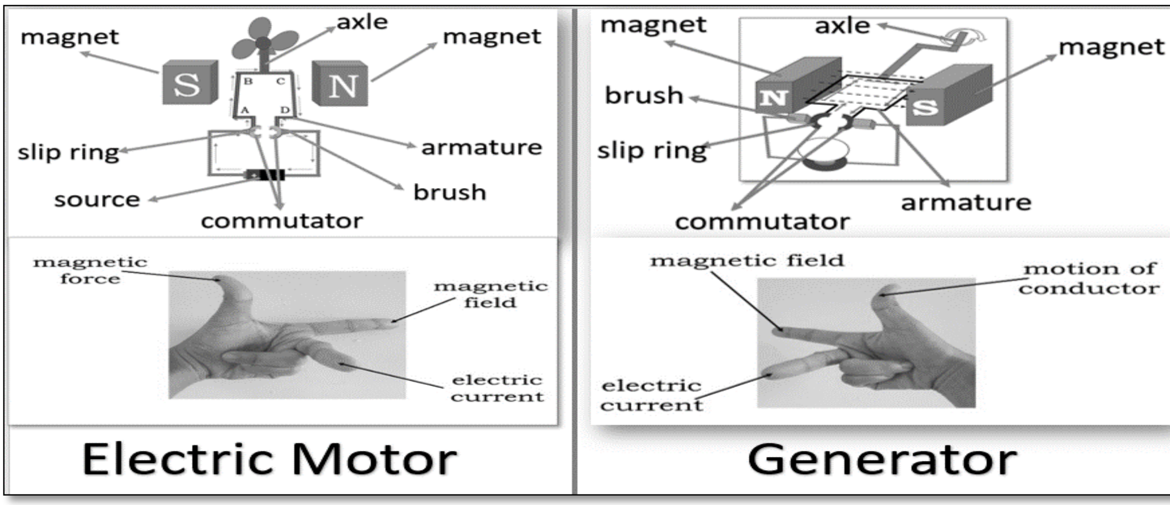


Fig. 7: Fleming's Right-Hand Rule
(Photograph by Noreen Mabbagu)

To better explain the underlying principle in electric motor and generator, you will be using Fleming's Left- and Right-Hand Rule in the next activity, respectively.

What's More

Activity 3: Electric Motor Vs. Generator
Objective: Compare the electric motor and generator
You Will Need: a picture of the electric motor and generator



Procedure: Complete the Venn Diagram below based on the similarities and differences of a simple electric motor and generator as shown in the given illustration.

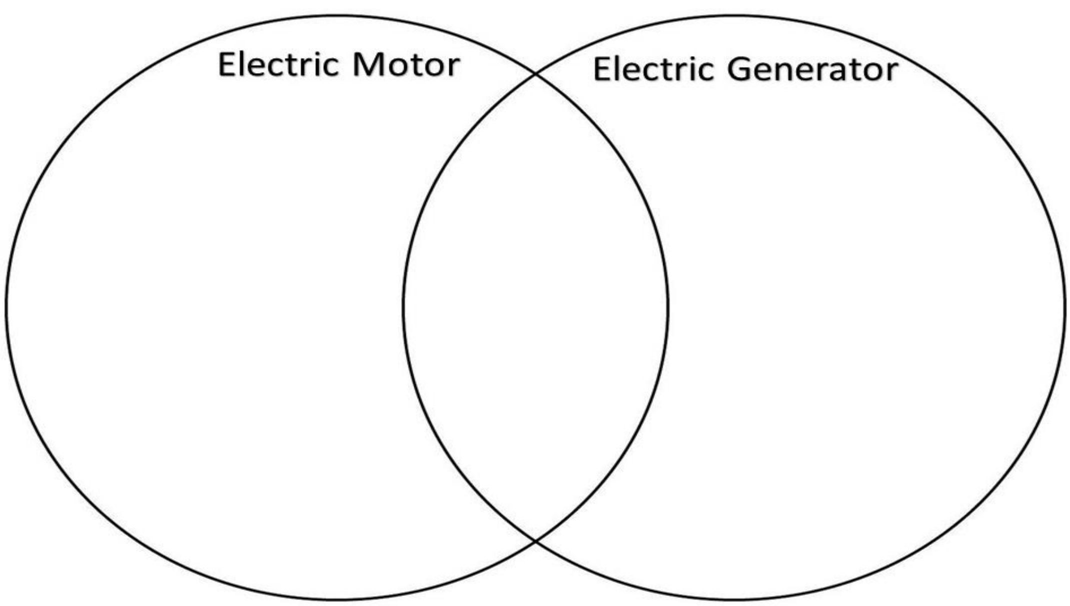


Fig. 8: Electric Motor VS. Generator

Guide Questions:

1. The following describes the functions of the parts of a motor or generator. Identify the part being described.
   _______a. turns DC to AC for generators
   _______b. receives electric charges from brushes and sources
   _______c. produces electric current due to the induced electromotive force (emf) or voltage
   _______d. conducts electric charge from sources for electric motor and receives AC current from commutator
   _______e. provides mechanical energy for generator and helps armature to start rotating around the magnet
2. Explain the difference between an electric motor and a generator.

Activity 4: Principle Behind Electric Motor
Objective: Explain the working principle behind a simple electric motor.
You Will Need: Picture of a Simple Electric Motor
Direction: Explain how an electric motor works when the conventional flow of electric current flows through the circuit by numbering the following statements using 1-5 in proper order.

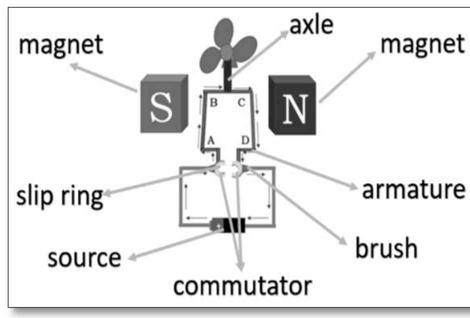


Fig. 9: A Simple Electric Motor
(Illustrated by Noreen Mabbagu)

_____ External electric current was supplied in the armature by the commutator.
_____ As the switch is turned on, electric charges flow to the brushes through the connecting wire.
_____ The commutator reverses the current direction each half cycle between the armature and the external circuit and keep the torque turning.
_____ When the electric current passes through the armature in the magnetic field between the stationary magnets, torque is produced by the presence of magnetic force in the coil.
_____ The continuous turning torque of the armature through the commutator allows the motor to do mechanical work. Hence, the flow of electric energy in the system in the presence of a magnetic field was converted into mechanical energy.

Guide Questions:
1. Using Fleming's Left-Hand rule, what will be the direction of the magnetic force as electric current flows through the side of the armature CD near the South pole of a stationary magnet? How about on the left side of AB?

2. Concerning the presence of the magnetic field of a stationary magnet, in what position of the armature through the commutator will the motor do great mechanical output? Why?

3. What principle in electromagnetism applies to an electric motor? Why?

Activity 5: Principle Behind Generator
Objective: Explain the working principle behind a simple electric generator
You Will Need: Picture of a Simple Generator
Direction: Explain how an electric generator works when the conventional flow of electric current flows through the circuit by numbering the following statements using 1-5 in proper order.

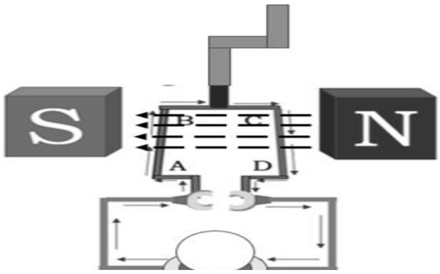


Fig. 10: Diagram of a Simple Motor
(Illustrated by Noreen Mabbagu)

_____ The brushes collect the induced current through the commutator.
_____ Electricity was generated and can be used to power up electrical devices.
_____ The armature converts DC current to AC current through the commutator.
_____ The armature cuts the magnetic field between the field magnets as the axle is rotated.
_____ As the magnetic field is cut, it will interfere with the electrons in the coil of the armature. Thus, an electromotive force (emf) was induced allowing the flow of electrical charges.

Guide Questions:
1. Using Fleming's Right-Hand rule, what will be the direction of the magnetic force on the armature coil as an electric current was induced whenever the magnetic field had been cut due to the rotation of the axle?
2. Concerning the presence of a magnetic field of a stationary magnet, what position of the armature through the commutator will the generator induce a great amount of electric current?
3. Which principle in electromagnetism applies to an electric generator? Why?

What I Have Learned

Match the description in column A to the terms in column B. Write the letter of your answer on a separate sheet of paper.

COLUMN A	COLUMN B
1. explains the direction of magnetic force, magnetic field, and electric current	_____A. electric motor
2. converts electrical energy to mechanical energy and works with the principle of current-carrying wire conductor	_____B. armature
3. explains the direction of the conductor's motion, magnetic field, and electric current	_____C. generator
4. transforms mechanical energy to electrical energy and works under the principle of electromagnetic induction	_____D. Fleming's Left-Hand Rule
5. cuts the magnetic field in the generator as the axle is rotated continuously	_____E. Fleming's Right-Hand Rule

What I Can Do

With the knowledge that you have acquired about electromagnetism, solve the following problems.

1. Gabby was playing his TAMIYA when suddenly it stopped. The battery was still in good condition. What could be the possible cause for this?

2. A small island community in the Northern part of our country does not have electricity. However, the wind in such a place blows strongly. Supposed you are an engineer; in what way you can help for the generation of electricity using the available strong wind? Kindly draw your invention and explain why you chose it.

Assessment

Look at the first pair of words and analyze how they are related to each other. Then supply the best word/s on the blanks for the second pair to show the same relationship as the first pair.

1. generator: electromagnetic induction;

   electric motor: _________________

2. mechanical to electrical: generator;

   ___________________ : electric motor

3. Right-Hand Rule: generator;

   Left-Hand Rule: __________

4. armature created turning effect: electric motor;

   __________________________: generator

5. brushes transmit DC to commutator: electric motor;

   ______________________________: generator

Additional Activities

Activity 6: DIY Flashlight
Objective: Develop a flashlight using the principles of electric motors or generators.
You Will Need: recycled, reusable, or indigenous materials
Procedure:

Using the knowledge acquired in studying electromagnetism, develop a flashlight that can be used in the absence of electricity. Create your plan, illustrate your model, and explain the principle of electromagnetism that you applied for it. Be ready to share your output in the class.

Posttest

Read each question carefully and encircle the letter of the correct answer.

1. Which is/are TRUE about an electric motor?
   I. It uses magnets to create a circular motion.
   II. It uses magnets to create rotational motion.
   III. It converts electrical energy into a mechanical one.
   IV. It depends on the interaction of magnetic and electric fields.
.
   A. I and II B. II and III C. I and III D. II and IV

2. An electric generator converts energy from ____________ to ______________.
   A. chemical to electrical C. electrical to mechanical
   B. electrical to chemical D. mechanical to electrical

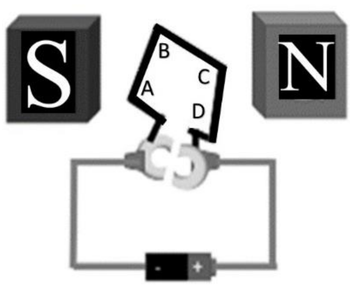
3. Which principle works with an electric motor and generator respectively?
   A. Faraday's Law and Ampere's Law
   B. Fleming's Right-Hand Rule and Electromagnetic induction
   C. electromagnetic induction and current-carrying conductor inducing a magnetic field
   D. current-carrying conductor inducing a magnetic field and electromagnetic induction

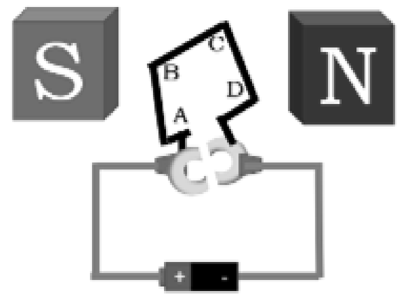
4. In which part of an electric motor is electric current supplied to create magnetic force?
   A. armature B. brushes C. commutator D. stator

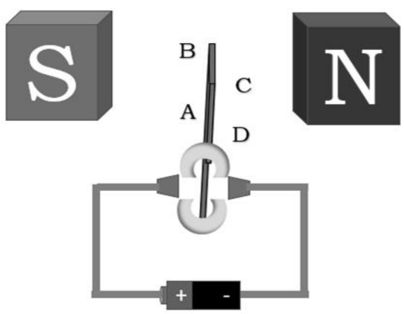
5. In which part of an electric generator is an electric current produced due to the induced electromotive force (emf)?
   A. armature B. brushes C. commutator D. stator

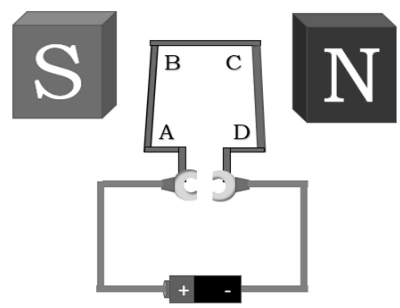
6. Which part of an electric motor provides a magnetic field allowing the inner coil wire within to rotate as the electric current passes through?
   A. armature B. brushes C. field magnet D. terminal

7. In which position an electric motor experiences a strong magnetic force?

A. 

C. 

B. 

D. 

(illustrated by Noreen Mabbagu)

8. Which part of an electric generator induces voltage difference and converts direct current (DC) into an alternating one (AC)?
   A. armature   B. brushes   C. commutator   D. stator

9. According to Fleming's Left-Hand Rule, a current-carrying wire receives no force of the magnetic field ___________
   A. at 45^0 to the magnetic field.
   B. parallel to the magnetic field.
   C. at a right angle to the magnetic field
   D. at an oblique position to the magnetic field.

10. Which statements are TRUE?
   I. Magnetic force is the push or pulls in a magnet.
   II. Electric field is the region around an electric charge.
   III. Magnetism is possible in a non-current carrying wire.
   IV. Electric field is the push or pulls experienced by an object in an electric field.

   A. I and II   B. II and III   C. III and IV   D. IV and I

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Answer Key

- **What I Know**

1. B	6. C
2. D	7. D
3. C	8. A
4. A	9. D
5. A	10. B

- **What's In**

NO.	FACT	BLUFF	Correct Answer for Bluff Choices
1			Hans Christian Oersted
2			
3			John Ambrose Fleming
4			
5			Andrei-Marie Ampere
6			Magnetic force
7			
8			Electrical current
9			magnetic field
10			

- **What's More**

Activity 3:

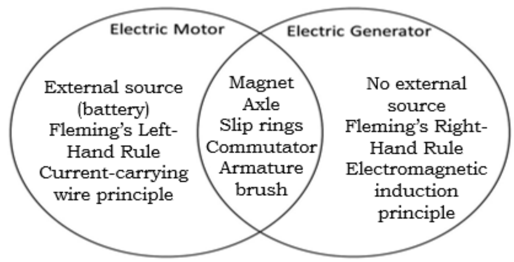

Fig. 9: Similarities and Differences of Electric Motor and Generator

Guide Question:

1. a. armature d. axle
   b. commutator e. armature
   c. brushes
2. They differ in the working principles and mnemonics used. In terms of principle, current-carrying conductor for electric motor and electromagnetic induction for generator. In terms of mnemonic, Fleming's Left Hand rule for electric motor and Flemings Right Hand Rule for generator.

Activity 4:

2,1,4,5,3

Guide Questions:

1. CD – down; AB – up
2. Armature is at horizontal position wherein electric current flows perpendicular with the magnetic field of the stationary magnets.
3. Current-carrying wire conductor

Activity 5:

1, 4, 2, 3, 5

Guide Questions:

1. AB-downward
2. Armature is at horizontal position wherein electric current flows perpendicular with the magnetic field of the stationary magnets.
3. Electromagnetic induction

- **What I Have Learned**

1. b 2. e 3. d 4. a 5. c

- **Assessment**

1. current-carrying wire principle
2. electrical to mechanical
3. electric motor
4. armature cuts magnetic field
5. brushes receive AC from the commutator

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