

Science

Learner's Material

Unit 2

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Science – Grade 10
Learner’s Material
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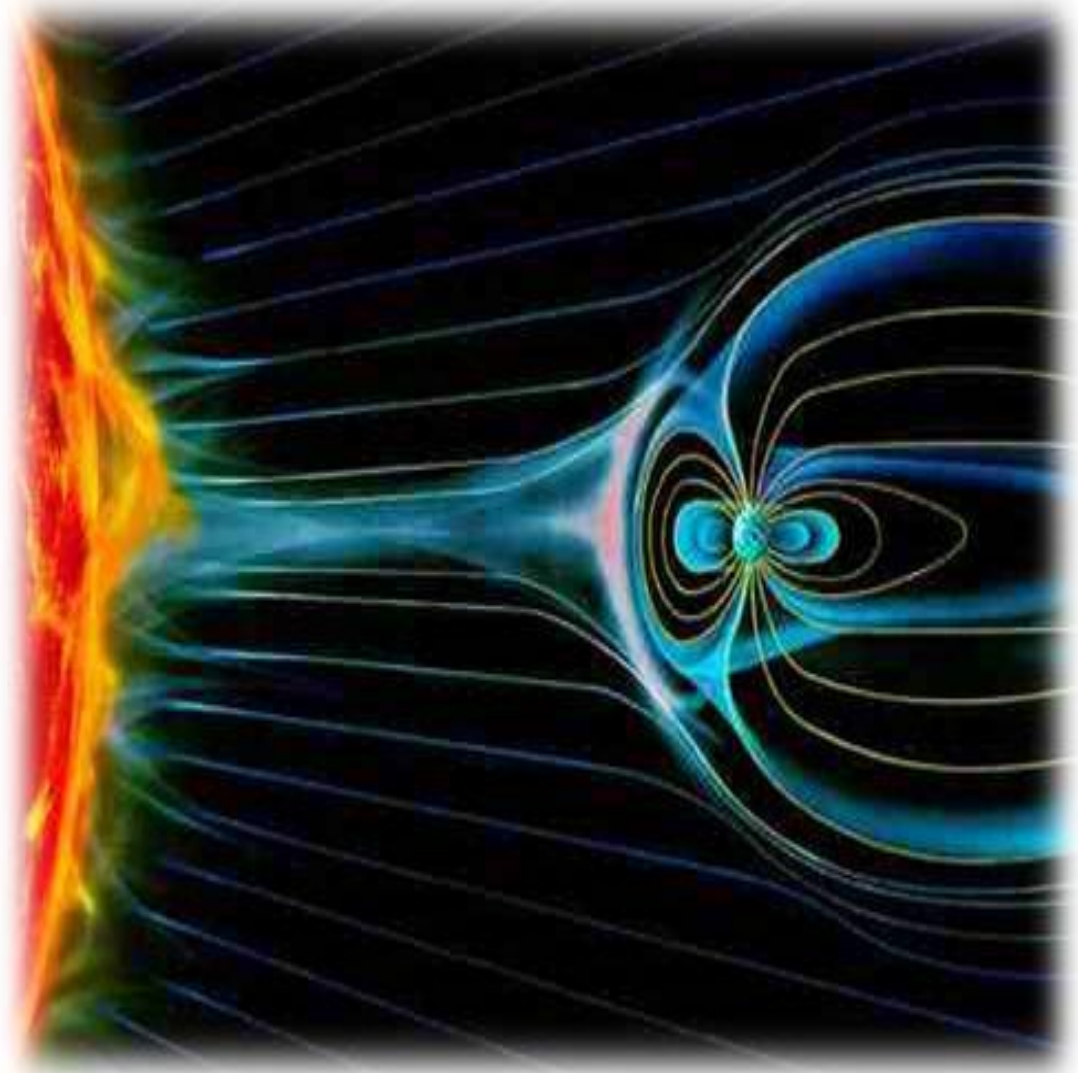
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UNIT 2

Force, Motion, and Energy *(The electric and magnetic phenomena around us)*



UNIT 2: FORCE, MOTION, AND ENERGY

(The electric and magnetic phenomena around us)

Overview

The moving iron core within the Earth acts like a giant bar magnet. It produces a weak geomagnetic field that surrounds and partially protects us from solar radiations. In like manner, the moving charges within the Sun generate an eruption of radiations. This produces a solar magnetic field that spreads throughout the solar system and beyond. Moreover, a solar wind of charged particles constantly interacts with the Earth's changing geomagnetic field.

In Grade 8 Science, you learned some characteristics of heat, visible light, and electricity whereas in Grade 9 Science, you were introduced to the forms and sources of energy. You also learned how electrical energy is generated, transmitted, and distributed. Using the principles of forces, motion and energy, Unit 2 of Grade 10 Science which is intended for the second quarter, supports investigations on the electric, magnetic and electromagnetic phenomena all around us. Eventually, this unit will help you to understand the different electromagnetic waves commonly known as the EM spectrum with a final emphasis on the visible light.

In Module 1, you will be reacquainted with basic magnetism and its relationship with electricity by exploring electric and magnetic fields surrounding devices made up of magnets and current-carrying conductors.

Moreover, a detailed study of the characteristics of the EM spectrum in Module 2 will help you appreciate the relevant applications and effects of some of the EM waves to us and our environment.

Lastly in Module 3, you will study the nature of light as it interacts with matter through reflection and refraction. There will be interesting activities on image formations using different mirrors and lenses.

The chief goal of the activities in these modules is to acquaint you with the particular phenomenon in study, enable you to observe relationships between variables, help you to develop and communicate your tentative explanations of the phenomena or models, and lead you to further inquiry and deeper understanding.

**Unit 2
MODULE**

1

**ELECTRICITY AND
MAGNETISM**

I. Introduction

In this module, you will map two invisible force fields - the electric and the magnetic fields. Within each field, forces may be exerted on matter causing it to interact with another matter because of electricity and magnetism working as two aspects of a single electromagnetic force.

You will further explore, demonstrate and explain the idea that a changing electric field produces magnetism, and a changing magnetic field produces electric current in the light of technological applications that are helpful to man.

At the end of this module, you are expected to answer the following key questions below and use the learning competencies as study guide:

How is electricity related to magnetism?
How does electricity produce magnetism? How does magnetism produce electricity?
How does an electric motor work? How does an electric generator work?
What is electromagnetic induction?

II. Learning Competencies/Objectives

1. Make a simple device that shows how a magnetic field exerts a force on a wire.
2. Demonstrate the generation of electricity by movement of a magnet through a coil.
3. Explain the operation of a simple electric motor and generator.

III. Pre-Assessment

Direction: Choose the letter of the correct answer.

1. In which case or cases is electric field present?
 - I. A spark jumping between two nearby rods.
 - II. A charge that is momentarily at rest.
 - III. A rotating bar magnet.
 - a. I only
 - b. I and II only
 - c. II and III only
 - d. I, II and III

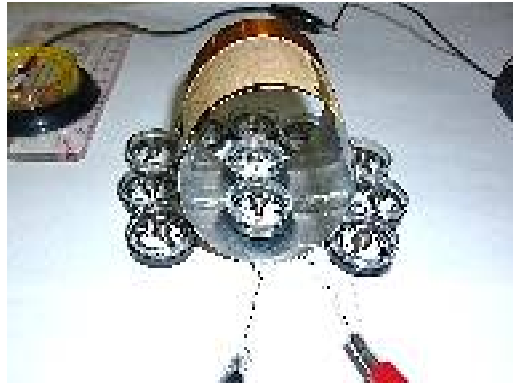
2. In which case can a magnetic field be produced?
 - a. A charged comb.
 - b. A falling glass rod.
 - c. A welder's arc flash.
 - d. A rolling plastic cylinder.

3. Which device can be used to determine the polarity of an unmarked magnet?
 - a. a charged glass stirring rod
 - b. a gold-leaf electroscope
 - c. a sprinkle of iron filings
 - d. an improvised compass

4. How will you describe the magnetic field around a straight current-carrying wire?
 - a. The magnetic field is strongest near and around the wire.
 - b. The magnetic field consists of straight lines parallel to the wire.
 - c. The magnetic field does not vary with the distance from the wire.
 - d. The magnetic field gets stronger with increasing distance from the wire.

5. Which statement about an electromagnet is TRUE?
 - a. The electric field surrounding a battery-powered electromagnet alternates constantly.
 - b. The current in the electromagnet coil temporarily magnetizes the iron core.
 - c. The electric field strength is inversely proportional to the current.
 - d. The magnetic field lines produced are all straight.

6. What can be inferred from the alignment of compass needles in the set-up below?



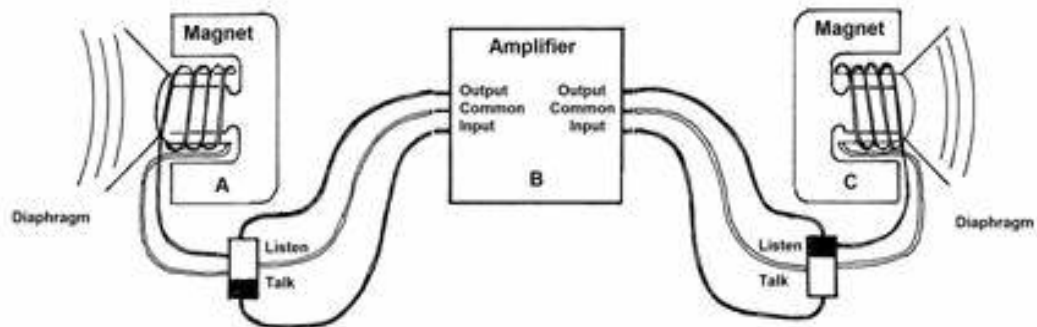
- A permanent magnet is nearby.
 - The power switch was turned off for long.
 - The current-carrying coil becomes magnetic.
 - There is a constant and uniform magnetic field around the coil.
7. As part of a traffic light system, large loops of wire are buried beneath road intersections. Which of the statements is NOT TRUE about the operation of this traffic light system?
- Vehicles driven over the buried coils activate a traffic light sensor.
 - The conducting loops activate a color-dependent field.
 - The alternating current sent through the buried coils produce an electromagnetic field in each coil.
 - A minimum number of vehicles over the coils can trigger the traffic light to change green.
8. Complete the following statement: Moving a metallic detector past a 5 peso coin creates a secondary magnetic field that is most similar to that of ____.
- a horse shoe magnet
 - a flat refrigerator magnet
 - a current-carrying, circular loop
 - a V-shaped straight wire that carries a current
9. During the Student Technologists and Entrepreneurs of the Philippines (STEP) Competition in Landscaping, a water pond transformer changes 216 V across the primary to 12 V across the secondary. If the secondary coil has 10 turns, how many turns does the primary coil have?
- 10 turns
 - 18 turns
 - 180 turns
 - 228 turns

10. What basic principle enables ALL electric motors to operate?
- Iron is the only element that is magnetic.
 - Opposite electric charges attract and like charges repel.
 - A moving conductor within a magnetic field will experience an electromotive force.
 - A current-carrying conductor placed within a magnetic field will experience a magnetic force.
11. A magnet moves inside a coil. Consider the following factors:
- strength of the magnet
 - number of turns in the coil
 - speed at which the magnet moves

Which can affect the electromotive force (*emf*) induced in the coil?

- I only
 - II only
 - III only
 - All three factors
12. Which statement about transformers is FALSE?
- A step-down voltage transformer steps up the current.
 - Transformers use mutual induction.
 - Transformers are an application of Faraday's and Lenz's Laws.
 - A transformer can function with either an alternating current (AC) or a steady direct current (DC).

13. What is TRUE about the intercom system that is shown below?



- The part A of the intercom system serves as a microphone only, while part C serves as a loudspeaker only.
- Either parts A and C of the intercom when switched as such can be used as a microphone or as a loudspeaker.
- The microphone part only basically consists of wires, a cone diaphragm, a magnet, and a coil.
- The loudspeaker part only basically consists of wires, a cone diaphragm, a magnet, and a coil.

14. What transformation can take place in an improvised generator?
- mechanical energy into electrical energy
 - electrical energy into mechanical energy
 - alternating current into direct current
 - direct current into alternating current
15. A loop of conductor lies flat on a horizontal table. A toy magnet is hanging still over it with the magnet's north-seeking pole pointing down. What happens next?
- The magnet produces a clockwise current in the coil.
 - The magnet does not produce any current in the coil.
 - The magnet produces an upward electromagnetic current.
 - The magnet produces a counterclockwise current in the coil.

IV. Reading Resources and Instructional Activities

GETTING HOOKED ON ELECTRICITY AND MAGNETISM APPLICATIONS

AVPs: *Veni, vidi, vici.*

(Audio-Visual Productions: *I came, I saw, I conquered.*)

People readily adopt emerging technologies. The use of audiovisual (AV) works be it in film productions, in business displays, or perhaps in education innovations became a trend and it is here to stay. Examples abound like our growing love for the high quality audiovisual components we listen to and watch or the endeavor of school stakeholders to provide projection technology in every classroom.

The rise of it all AV production, recording, and storing technology and industries were made possible because of the discovery of the link between electricity and magnetism. How does one begin to understand this partnership? For a start, consider doing the activity regarding audio recording devices.

Activity 1

For the Record...

(Adapted from the EMI Teaching Sequence by Jenaro Guisasola and Kristina Zuza)

Objectives:

- Identify the basic recording equipment of a digital radio studio.
- Classify whether devices use electricity and/or magnetism when used in recording audio.
- Start a literature search on electromagnetic induction's role in recording technology.

Materials:

- pictures of the radio studio control and audio room OR
- video clip on a radio station tour, video player, screen, and accessories
- pen and activity sheet/science notebook

Procedure:

PART A. Virtual Tour of a Radio Broadcasting Studio

1. Read the scenario and study the video clip or pictures selected by your teacher, similar to what is shown in Figures 1 to 3.

Activity Scenario: During non-class hours, you frequently meet your friends playing and making music together. One afternoon you decided to go to your local radio station to ask what equipment and software is needed to start recording at home.

At the broadcast studio, with the radio technician out, the staff allowed you to take pictures inside the control room and live audio room, similar to what is shown in Figures 1 to 3.



Figure 1. A control room of a local radio broadcast studio commonly known as the announcer's booth. (Used with permission from the RPN-DXKO Radio and Television Broadcast Station in Cagayan de Oro City.)

2. On your science activity notebook, make a table, similar to Table 1. List all the equipment that you can identify in the photo shown in Figure 1. Indicate with a check mark whether the equipment/device needs electricity and/or magnetism to operate.

Table 1. Radio Broadcast Studio Equipment (Control Room/Announcer's Booth)

Equipment/Device	Needs Electricity	Needs Magnetism

Guide Questions:

- Q1. How many of the devices you identified inside the control room need electricity to operate?

- Q2. How many of the devices you identified inside the control room need magnetism to operate?

- 3. On your science activity notebook, make another table similar to Table 2. List also all the equipment that you can identify in the pictures shown in Figures 2 and 3. Indicate with a check mark whether the equipment/device needs electricity and/or magnetism to operate.



Figure 2. A live audio room, commonly known as the newsroom, which is usually separated from the control room via glass partitions.



Figure 3. Back portion of a local newsroom

Table 2. Radio Broadcast Studio Equipment (Live Audio Room/Newsroom)

Equipment/Device	Needs Electricity	Needs Magnetism

Guide Questions:

Q3. How many of the devices you identified inside the live audio room need electricity to operate?

Q4. How many of the devices you identified inside the live audio room need magnetism to operate?

Q5. What other devices not shown in the photo may be used inside the live audio room?

KEY CONCEPTS

- A typical broadcast studio consists of an audio console, microphones, computers, studio monitors, and disc players.
- The audio console converts analog audio (voice via microphone) and phone calls to a digital output. It also allows for the mixing of all sound sources from CDs, computers, and other digital sources before being sent to the transmitter. A slider controls the volume of each sound source.
- The live audio and control rooms are connected by cables for the exchange of audio and digital data signal during recording, mixing, and even editing of all audio-video elements digitally stored on hard drives.




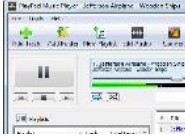



More Reading Support on Recording Technology:

What devices did recording technicians use in the past to record sound?

PART B. My Own Home Recording Studio! For Life...

1. You could be an aspiring singer, a music artist, a student who needs to record audio presentations or simply one planning to have a start-up home recording studio. Use Table 3 and extend your understanding of the recording industry by matching the devices in Column B and their respective functions in Column C with the items in Column A. Write the letter and number for coding your answer.

Table 3. A Home Recording Studio Start-Up Equipment

A Picture	Coded Answer	B Device Name	C Function
1. 	1 ___ ___	A. headphone	I. Used for playing some digital instruments, recording, adding effects, and mixing different sources of sound signals
2. 	2 ___ ___	B. studio monitor	II. Microphones and musical instruments are plugged into this, which in turn is connected to the computer
3. 	3 ___ ___	C. audio interface	III. Processor should be reasonably fast enough to record, edit, mix, store, and master a copy of the record.
4. 	4 ___ ___	D. digital audio software (DAW)	IV. Converts sound into electrical signal
5. 	5 ___ ___	E. computer unit	V. Used for “referencing” or for checking what the mix would sound like on the equipment
6. 	6 ___ ___	F. condenser or dynamic microphone	VI. Used for connecting audio interface, microphones, studio monitors, and different instruments
7. 	7 ___ ___	G. cables	VII. Commonly known as speakers but these give a sound close enough to the real sound input

Extension Activity: Learn more about the basic audio-video recording devices and make a graphic organizer on your science notebook. What parts inside these devices use electricity and magnetism to function as such?

Guide Question:

Q6. Which devices on Table 3 are powered, entirely or partially, by electromagnetic induction (the phenomenon of a changing magnetic or electric field's effect on electricity or magnetism)?

More Reading Support on Recording Technology:

In the development of the recording and data storage technology, what questions might engineers ask?

Think of some questions by now about recording technology. Can handy mobile phones or digital cameras serve as audio-visual recorder and producer? How do these devices apply electromagnetic induction?

KEY CONCEPTS

- Many of the recording technology are founded entirely or partially on the relationship between electricity and magnetism known as electromagnetic induction.
- Devices that detect and convert audio inputs to electric outputs or vice versa are called transducers. Most transducers like microphones and speakers use the “generator effect” characterized by the production of forces due to a changing electric signal within a magnetic field or a changing field near a current-carrying conductor.

To understand electromagnetic induction and its applications especially on electric motors and generators, the next set of activities will help you revisit concepts about magnets and forces associated with it, checking polarities, and analyzing magnetic fields.

SOME BASIC PRINCIPLES OF MAGNETISM

Activity 2

Test Mag...1, 2!

Testing for Evidence of Magnetism

Objectives:

- Identify the forces (attraction/repulsion) between:
 - a. two magnets, and
 - b. a magnet and magnetic/nonmagnetic materials.
- Distinguish a magnet (permanent or temporary) from a non - magnetic object.

Materials:

- pair of 3"- 6" bar magnets
- 6-10 objects made of different materials from inside the room
- science notebook and pen

Safety Precautions:

- Handle magnets with care so as not to drop those. These might break, chip off, and weaken upon impact.
- Keep magnets away from computer units/screens, memory storage drives and disks, magnetic tapes, mechanical watches, and the like.

Procedure:

1. Use a bar magnet and explore the possible effect/s it can have on the other magnet when made to interact. On your science notebook, make a table similar to Table 4 and record the observed force effect/s. Answer also the guide questions.

Table 4. Interaction between two permanent bar magnets

What I did to the pair of magnets to cause interaction...	Observed effect/s (attracted or repelled)

2. This time, use only one bar magnet and explore its possible effect/s on six to ten different objects found inside the classroom. Record the observed effect/s on a table similar to Table 5. (Exclude record on objects with no observed interaction with the magnet.)

Table 5. Interaction of a bar magnet with other objects

Objects that interacted with the magnet...	Observed effect/s (attracted or repelled)

Guide Questions:

Q7. What conditions with observable effects make magnets interact with another magnet?

Q8. In general, what conditions with observable effects make magnets interact with non-magnet materials?

Q9. What type/s of force can a magnet exert on another magnet?

Q10. What type/s of force can a magnet exert on non-magnet objects?

Q11. How will you distinguish magnets from non-magnetized magnetic materials?

KEY CONCEPTS

- Magnets exert either a force of repulsion or attraction.
- If a force of attraction only is possible between an object and a magnet, then the object interacting with the magnet contains a ferromagnetic substance and is considered naturally magnetic.
- If a force of repulsion is also possible between an object and a magnet, then the object interacting with the magnet may also be a permanent magnet or a temporarily magnetized ferromagnetic material.

Extension Question: What are the magnetic materials found in the audio and video recording tapes?

Activity 3

Induced Magnetism

Objectives:

- Induce magnetism in a magnetic material.
- Infer the polarity of the magnetized object.

Materials:

- bar magnet
- four 1-inch iron nails, screws, or paper clips
- science notebook and pen

Safety Precaution:

- Handle the magnet with care so as not to drop it. It could break, chip off and weaken upon impact.

Procedure:

1. Use the bar magnet and nails to find answers to the questions below. Record your answers on your science notebook. Use diagrams to support your answers.

Guide Questions:

- Q12. What happens if you bring two iron nails close to (or touching) each other?
- Q13. If you bring a bar magnet close to (or touching) the first iron nail, can the first iron nail attract and lift a second nail? A third one?
- Q14. What happens if vary/change the distance between the magnet and the nail/s?
- Q15. If the north pole of the bar magnet suspends the first nail by attraction, what is then the nails's polarity of induced magnetism in the indicated regions? Why?



Figure 4. Magnetic Induction on Hanging Screws

2. Choose the correct term from the enclosed choices that should go into the blank spaces on the “Sum it Up Challenge!”

Sum it Up Challenge!

The process by which the screws become magnets is called _____ 1 _____ (*electric / magnetic*) induction. This same process is the reason why magnets _____ 2 _____ (*attract / repel*) non-magnetized magnetic substances such as the screw. The screw becomes _____ 3 _____ (a *permanent / an induced*) magnet with the end nearer the magnet having _____ 4 _____ (*the same / an opposite*) polarity to that of the permanent magnet. Hence attraction happens _____ 5 _____ (*after / before*) magnetic induction occurs.

A quicker way to know the polarity of a permanent or induced magnet is by the use of a magnetic compass which you will be using in the next set of activities.

Activity 4

Detecting and Creating Magnetism

Objectives:

- Identify the polarities and strengths of a bar magnet and magnetized objects using a compass.
- Demonstrate magnetization by stroking.

Materials:

- at least 2 small magnetic compasses
- one 3-inch iron nail
- masking tape or cork stopper
- paper or any small scooping device
- cellular phone/any gadget with camera
- strong bar magnet
- narrow test tube (5/8" wide) or clear straw (5/8" wide)
- science notebook and pen
- iron filings



Figure 5. Materials for Detecting and Creating Magnetism

Safety Precautions:

- Use the magnet, compass, test tube, and the gadget with camera with care so as not to drop any of these.
- Make sure that iron filings remain sealed inside the test tube or the transparent straw (cool pearl taped on both ends). Avoid the iron filings from sticking directly to the magnet.

Procedure:**PART A. North meets south**

1. Checking Polarity. Place one magnetic compass on a horizontal surface. Then, move a bar magnet around and above it exploring the strength and polarities of the magnet. If a cellular phone or any gadget with built in camera is available, take pictures of the magnetic compass needle orientations for different locations around the bar magnet. Draw the compass needle directions and write your observations regarding the magnetic field strength on your science notebook and answer the guide questions.

Guide Questions:

- Q16. What happens when you randomly move the bar magnet roundabout and above the compass one foot or farther? Nearer than a foot?
- Q17. Compass needles are tiny magnets that are free to indicate the north and south poles of a magnet? What do you need to do to know the magnet's polarities?
- Q18. What does the compass needles indicate about the iron nail shown below in Figure 6?



Figure 6. Use of Compass Needles for Checking the Magnetism

PART B. By the touch of a magnet

1. Magnetization by stroking. Pour iron filings on a sheet of paper and check whether the filings are still non-magnetized. If magnetized, stir or move the iron filings gently on the paper.
2. Fill carefully the narrow test tube up to a quarter with these iron filings. Cover with masking tape or cork.

3. Hold the closed test tube horizontally. Shake or roll gently with your fingers to level out the iron filings inside.



Figure 7a. Leveling the Iron Filings inside the Test Tube

4. Then when levelled, touch with the north-pole end of the permanent magnet the test tube's curved end. Move the magnet along the test tube from this end to the covered end. Lift the magnet off the test tube and repeat with ten or more strokes. On your science notebook, observe and record what happens inside the tube.
5. Gently lay the test tube on a table and bring compasses near both ends of the test tube as shown in Figure 7.b below. Observe and record what happens.



Figure 7b. Testing Induced Magnetism on the Iron Filings

6. Carefully shake the test tube as shown in Figure 7.c, without moving the compasses. Test for the presence of magnetism again. Record your observations.



Figure 7c. Shaking the Iron Filings inside the Test Tube

Guide Questions:

- Q19. In step no. 4 are the iron filings in the test tube magnetized? If yes, which end is the north and which is the south? If no, what else can be done to magnetize it? Try and record your idea.
- Q20. What happened to the iron filings magnetism after several shakes?

Extension Activity: Can you magnetize also an iron nail by stroking? Do a quick activity to know the answer for yourself.

KEY CONCEPTS

- Materials which are attracted by a magnet are known as magnetic materials. Iron, cobalt, nickel and many alloys of these metals like steel and alnico are magnetic.
- Magnetic materials can be used to make permanent or temporary magnets unlike the non-magnetic materials which cannot.
- Stroking is one way of magnetization.

Extension Question: What will happen to a magnet if it is dropped too often?

ELECTRIC AND MAGNETIC FIELDS

A Look Back in History:

In 1819, Hans Christian Oersted ('Ər-stəd), a professor in the University of Copenhagen, discovered during a class demonstration that a current carrying wire caused a nearby magnetized compass needle to deflect. This observation fired up tremendous research on electromagnetism. As a result, the effect on the motion of conductors placed within a magnetic field (such as in the operation of electric motors) was also experimented much and paved the way for practical electricity.

Twelve years after this discovery, Michael Faraday ('Fer-ə-dā) conducted his famous induction ring experiment showing that current can be produced by sources of changing magnetic fields. This is the key principle to practical generation of electricity.

The next activities should help you demonstrate and explain the operation of electric motors and electric generators that basically work because of the existing relationship between magnetism and electricity.

Activity 5

Oh Magnets, Electromagnet...

May the forces be in your field!

Objectives:

- Explore the magnetic domains of a latch magnet.
- Observe and draw magnetic field patterns surrounding different magnets and magnet combinations.
- Observe and draw magnetic field patterns surrounding a simple electromagnet and a current carrying coil of wire.

Materials:

- an improvised magnetic board
- a pair of latch/refrigerator magnets
- a pair of bar magnets
- 1 neodymium magnet
- 1 U-shaped magnet
- 1 disk magnet
- 1 knife switch
- white bond paper
- small magnetic compasses
- one 3-inch iron nail
- science notebook and pen
- 2-m copper wire (AWG # 22)
- connectors with alligator clips
- battery holders with 2 AA battery

(Flat plastic bottle, water/Glycerin, iron filings/iron sand or Bargaja)



Figure 8. Commercial latch magnets (commonly known as flexible sheet refrigerator magnets), and an improvised magnetic board which is made by filling completely a leak-free, flat container (preferably plastic) with water/mineral oil, and magnetic sand.

Safety Precautions:

- Use the magnets, compasses, and magnetic boards with care so as not to drop any of these.
- The neodymium magnet is many times stronger than the ordinary disk magnet that can hold papers on refrigerator doors. Be careful not to get your fingers pinched between this kind of magnet and other magnetic material.

- Open after use the switch for the current-carrying conductors, electromagnetic nail and the current-carrying coil.

Procedure:

PART A. Watch their domains!

1. Use an improvised magnetic board and a pair of latch or refrigerator magnets similar to those shown below to observe magnetic field lines.

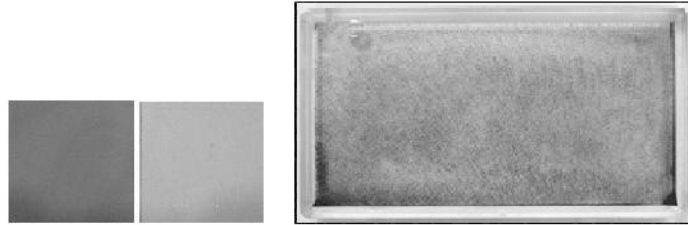

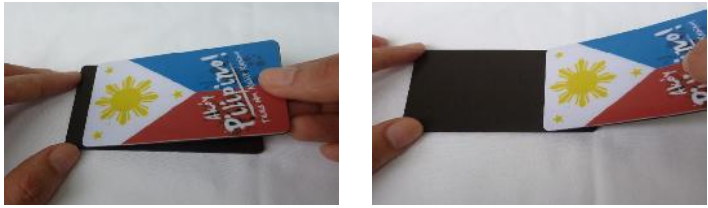
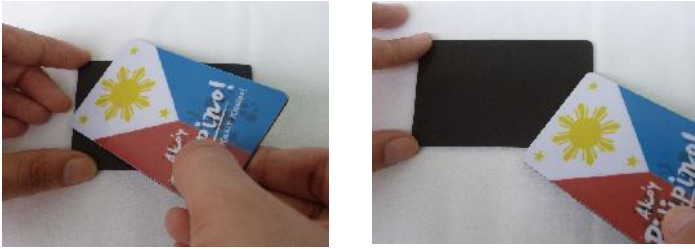


Figure 9. Sample latch magnets, commonly known as refrigerator magnets, and a magnetic board from the public science equipment package. Together, when used, will make the magnetic field surrounding the latch magnets visible. The iron filings suspended in the liquid inside the magnetic board align along the magnetic field lines.

2. Lay each latch magnet under the magnetic board. Tap gently the board until a clear pattern is formed by the iron filings. On your science notebook, draw the pattern made by the iron filings on a table, similar to Table 7. Note the orientations of the magnetic field pattern for each latch magnet. Label if needed.
3. Place one magnet on top of the other. Make sure that they are arranged perpendicularly with each other. Hold the magnet on top as shown in Table 6 below (first row). Slowly and gently pull the magnet (towards you) as shown.
4. Observe what happens. Record your observations on a table similar to Table 6.

Table 6 Interaction of a pair of latch magnets when dragged at different orientations

START OF THE TILTED PULL	END OF THE TILTED PULL	OBSERVATIONS
<p>A. Lightly drag the top latch magnet perpendicularly across the other as shown below. Use the sides with no sticker.</p> 		<p>For perpendicular orientation:</p>
<p>B. Lightly drag the top latch magnet, in parallel, over the other as shown. Use the sides with no sticker.</p> 		<p>For parallel orientation:</p>
<p>C. Lightly drag the top latch magnet obliquely over the other, and at an angle to the horizontal. The 'no sticker' sides should face each other.</p> 		<p>For oblique orientation:</p>

Guide Questions:

Q21. What have you noticed when you pulled the magnet on top perpendicularly across the other? What does this tell you about the magnetic field around the latch magnet?





Q22. How do you relate the flapping interactions of the latch magnets, at different orientations, to their magnetic domains?







Ideas for Research: The hidden structure of a refrigerator magnet can serve as a model for how a scanning probe microscope (SPM) works. This tool has a super sharp tip that is only one atom thick, allowing nanoscientists to probe across a nanoscale surface. (A nanometer is a billionth of a meter.) What new recording materials did scientists probe, study, manipulate, and control using nanotechnology?

PART B. Within the lines...

1. Place the different magnets and electromagnets under the improvised magnetic board one at a time. Each time, gently tap the magnetic board until a clear pattern is formed. On your science notebook, draw the pattern made by the iron filings on a table similar to Table 7.

Table 7. Magnets and Current-carrying Conductors

<p>Latch Magnets</p> 	<p>U-shaped Magnet</p> 
<p>Between North – North Poles of Two Bar Magnets</p> 	<p>Between South – South Poles of Two Bar Magnets</p> 

<p>Between North – South Poles of Two Bar Magnets</p> 	<p>Single Bar Magnet</p> 
<p>Disk Magnet and a Neodymium Magnet</p> 	<p>Iron nail wrapped with current-carrying wire</p> 
<p>Straight Current-carrying Wire</p> 	<p>Current-carrying Coil</p> 

Guide Questions:

- Q23. Compare the magnetic field patterns drawn in Table 7. What similarities differences have you seen among them?
- Q24. What do the magnetic field patterns, shown on the magnetic board indicate about the strength of the magnets?
- Q25. What do the magnetic field patterns indicate about the forces of interaction between magnets?
- Q26. How will you use the button compasses to describe/determine the forces of interaction between magnetic poles?

In the previous activities, you have detected and describe the invisible magnetic field line patterns around different sources of magnetism using the magnetic board.

Activity 6

Electric Field Simulation

Electric Fields, Forces, and Forms (E-3Fs)

Objectives:

- Predict the electric field directions and patterns in different locations surrounding charges and combinations of it.
- Relate electric field strength E to distance quantitatively and qualitatively

Materials:

- Table 8 Electric Fields, Forces, and Forms (E-3Fs)
- Science notebook and pen
- PC unit and accessories installed with PhET Interactive Simulation (for an actual offline or online activity)

Procedure:

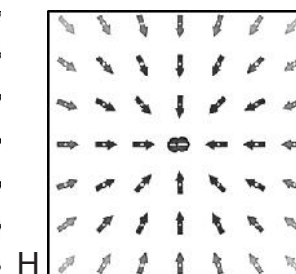
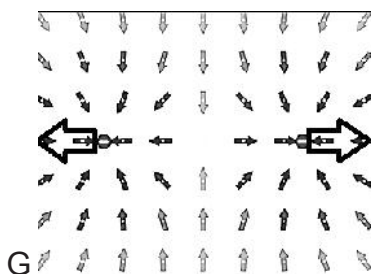
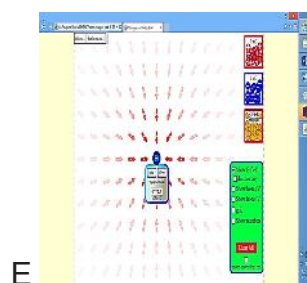
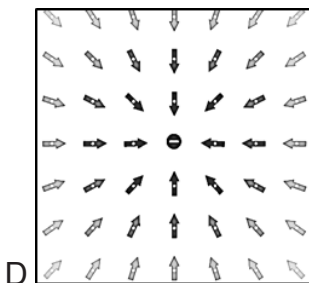
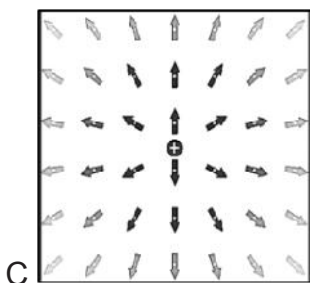
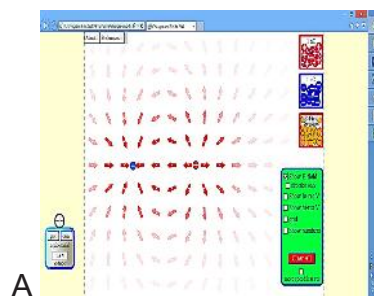
1. Study the letter-coded images of charges and electric fields in Table 8. Each image will help you explore the PhET-generated electric field patterns, electric field directions, and electric field strengths.
2. Match these images to the numbered descriptions shown on the upper left of Table 8. Using the number and letter codes, write your answers on your science notebook.

Table 8. Electric Fields, Forces, and Forms (E-3Fs)

Electric Charges and Field Descriptions

	2. Direction of electric field lines for a negative charge	3. Direction of electric field lines for a positive charge	
1. Electric field pattern for two negative charges near each other	E		4. Electric field pattern for two positive charges near each other
8. Electric field pattern for two unlike charges near each other		5. Electric field strength near the negative charge	
	7. Electric field strength far from the negative charge	6. Electric force for negative charge	

Match the electric charges and field descriptions with the images shown below from the PhET simulations on Electric Charges and Fields. Write your answers using the number and letter codes on your science notebook.



Optional Activity: PhET-based interactive simulation on electric fields

- For online simulation, navigate <http://phet.colorado.edu> through a web browser. Offline versions can also be downloaded and installed. Once installed, simply click the PhET icon to open the installed program.
- Next click “play with Sims,” then “Physics,” then “Electricity, Magnets and Circuits.” Then choose the “Charges and Fields” simulation. Click “Run now” to start the simulation.
- Once the simulation opens, play with the controls of the simulation to navigate.

The University of Colorado shares for public use an online and offline version of “The PhET Interactive Simulations Project” under the Creative Commons-Attribution 3.0 license and the Creative Commons GNU General Public License at <http://phet.colorado.edu>.

Activity 7

Magnetic Field Simulation

Magnetic Fields, Forces, and Forms (M-3Fs)

Objectives:

- Predict the magnetic field directions and patterns in different locations around the earth, a bar magnet and combinations of magnets.
- Relate magnetic field strength to distance quantitatively and qualitatively.

Materials:

- Table 9 Magnetic Fields, Forces and Forms (M-3Fs)
- Science notebook and pen
- PC unit and accessories installed with Physlet Physics and PhET Interactive Simulation (for an actual offline or online activity)

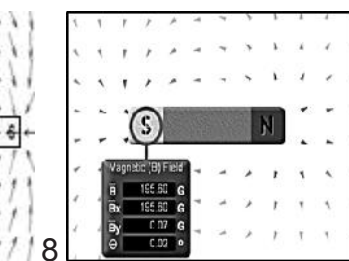
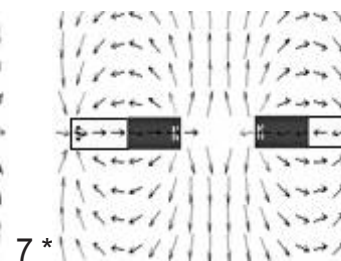
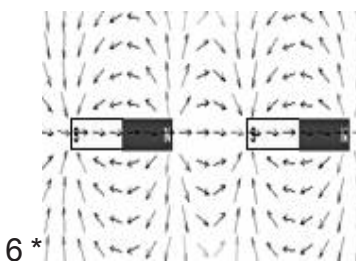
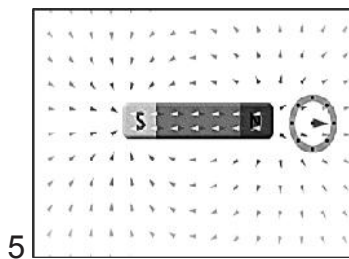
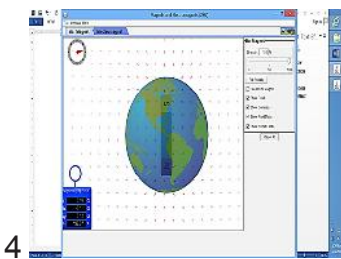
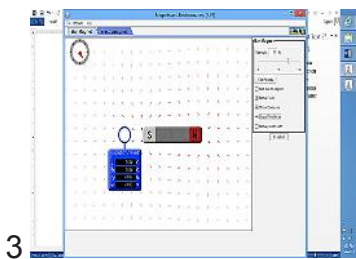
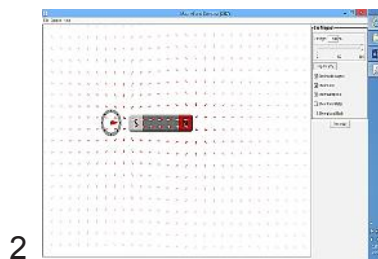
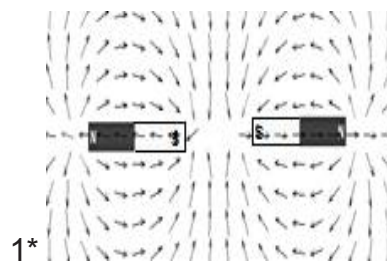
Procedure:

1. Study the number-coded images of magnets, compasses and magnetic fields in Table 9. Each image will help you explore the *Physlet Physics and PhET-generated magnetic field patterns, magnetic field lines directions, and magnetic field strengths.
2. Match these images to the letter-coded descriptions shown on the upper left of Table 9. Using the number and letter codes, write your answers on your science notebook.

Table 9. Magnetic Fields, Forces, and Forms

Magnets and Magnetic Field Descriptions		
A. Magnetic field pattern for two south poles near each other	B. Magnetic field pattern for two north poles near each other	C. Magnetic field pattern for two unlike poles near each other
D. Direction of magnetic field lines for a south pole		
M	E. Magnetic field strength near the poles	
F. Direction of magnetic field lines for a north pole		
G. Magnetic field strength far from the poles		

Match the magnets and magnetic field descriptions with the images shown below from the PhET: Magnets and Compass, and the *Physlet Physics simulations. Write your answers using the number and letter codes on your science notebook.



Optional Activity: PhET-based interactive simulation on magnetic fields

- For online simulation, navigate <http://phet.colorado.edu> through a web browser. For offline version, click the PhET icon to open the installed program.
- Next click “play with Sims,” then “Physics,” then “Electricity, Magnets and Circuits.” Then choose the “Magnets and Compass” simulation. Click “Run now” to start the simulation.
- Once the simulation opens, play with the controls to get used to the simulation. You can move the compass and the bar magnet around on the playing field and then add the earth. How does the magnetic field lines change inside and outside of the magnet as you vary the magnet’s strength? You can also use the field meter to qualitatively and quantitatively compare magnetic field changes.

Sum it Up Challenge!

On your science notebook, make any graphic organizer that will compare and contrast the concepts you learned about:

- The electric field and magnetic field patterns (directions and strengths).
- The electric and magnetic forces acting within the electric and magnetic fields.

The purpose of the next set of activities is to introduce current into a wire conductor and observe the response of the compass needle at some locations around the wire.

Activity 8

Magnetic Field Around Current-carrying Conductors

(Adapted from the DepEd-NSTIC Activity on Magnetic Fields and Electric Currents)

Objectives:

- Using a compass, explore the magnetic field around current-carrying conductors.
- Use the compass to determine the direction of the magnetic field relative to the direction of current through:
 - a) a straight current-carrying conductor; and
 - b) a current-carrying coil.

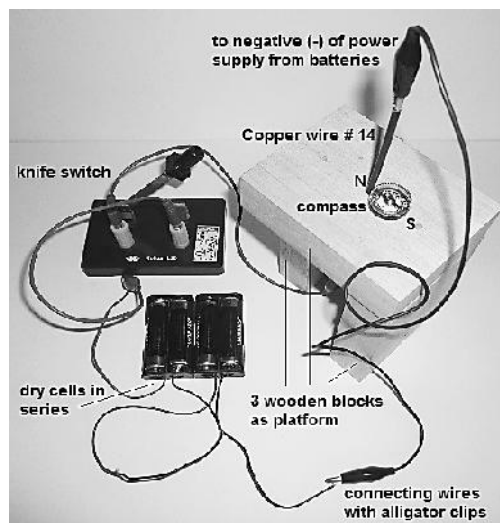
Materials:

- 3 wooden blocks with holes
- 14 gauge insulated copper wire, 20-50 cm
- 4 AA dry cell holders (in series)
- science notebook and pen
- 5 cm² used rubber mat
- 1.5 meter hook wire (#22, stranded)
- 3-cm or 4-cm diameter magnetic compass
- 1 button magnetic compass
- 3 or 4 connecting wires
- 1 fuse holder with fuse
- 1 knife switch
- cutter
- tape

Safety Precautions:

- Open the switch after observation to conserve energy. Batteries and wires may become hot if current flows for very long.

Experiment Setup A:



Procedure:

PART A. Magnetic Field around a Straight Conductor

1. Construct the circuit in Setup A as shown above. Make sure the switch is open at the start. The wire should pass vertically at least 10 cm below the wooden block.
2. On the wooden block, position the magnetic compass right next to the vertical wire in four equidistant locations relative to the north-south alignment. For all four locations, rotate the compass until its north axis aligns with the compass needle pointer. The compass shown in the setup is a sample first location.
3. Close the switch long enough for making observations.
4. Observe and draw the deflection (direction and rotation) of the compass needle's north-pole.
5. Open the switch when you are done with your observations.
6. Move the compass to the next locations to map the magnetic field. Do steps 2 to 5 for each of the remaining chosen locations.
7. Draw a short arrow to indicate the compass needle's direction and rotation in each of the four locations.
8. Reverse the polarity of your power supply and do steps 2 to 7.

Guide Questions:

- Q27. From a top-view perspective, in what direction does the north pole of the compass needle point to when the compass was positioned around the vertical current-carrying straight conductor?
- Q28. From a top-view perspective and with the current's polarity reversed, in what direction does the north pole of the compass needle point to when the compass was positioned around the vertical current carrying straight conductor?

PART B. Magnetic Field around a Coil of Conductor

1. Prepare a compass holder for the larger magnetic compass using a squared rubber mat similar to what is shown in Figure 10. Trace the perimeter of a 3-4 cm wide magnetic compass on a used rubber mat. Safely cut a hole on the mat that is big enough for the compass to fit into. Insert the compass into the hole with the north-south alignment parallel to any side.

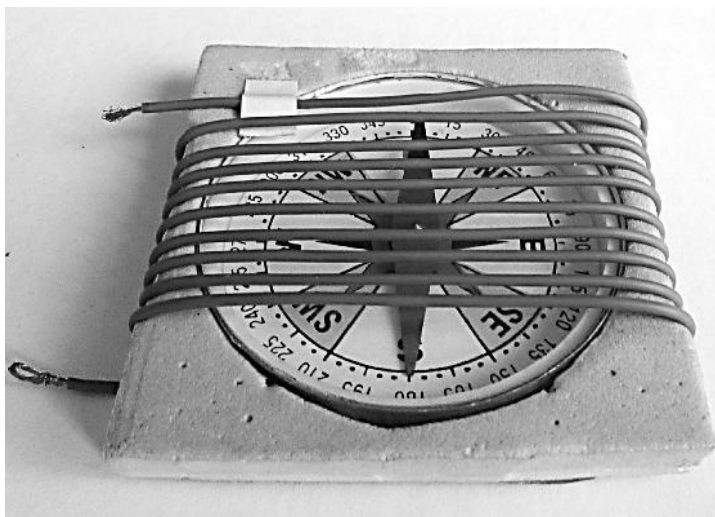
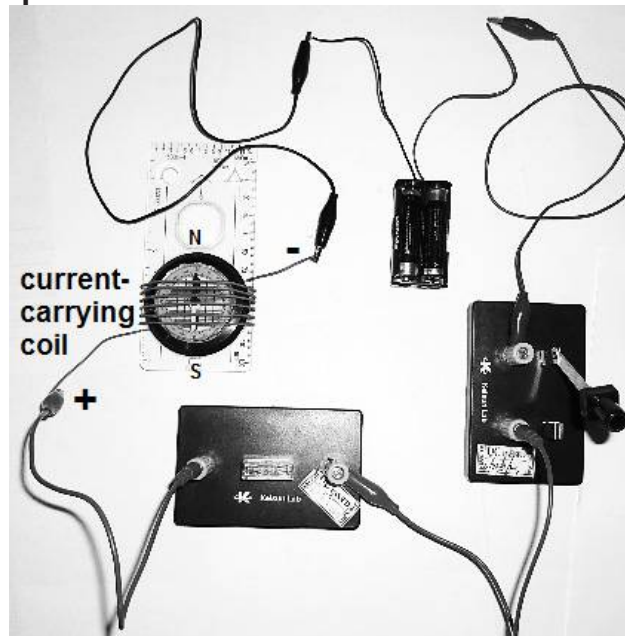


Figure 10. Coil of wire around a compass fitted into a used rubber mat

2. Strip the ends of a 1.5 meter long magnetic hook wire (#22 gauge and stranded) and wind this around the compass on its holder. For easier observations, loop the wire parallel along the north-south axis although the loops can also be oriented perpendicularly. Slowly rotate the rubber mat until the needle points north.
3. Connect the looped wire around the compass to a 3-volt power supply that is in series to the open knife switch and the fuse as shown in Experiment Setup B below.

Experiment Setup B:



4. Close the switch long enough for making observations.
5. Relative to the geographic north-south alignment, observe and draw the deflection (direction and rotation) of the compass needle's north-pole.
6. Open the switch when you are done with your observations.
7. Reverse the polarity of your power supply and do steps 4 to 6.
8. Reduce to half the number of loops around the compass and cut the excess making sure the loops are centered round the compass. Repeat step 3 to 6.

Guide Questions:

- Q29. With conventional current flowing counterclockwise, from a top-view perspective, in what direction does the north pole of the compass needle, at the center of the current-carrying coil of wire, point?
- Q30. With conventional current flowing clockwise, from a top-view perspective, in what direction does the north pole of the compass needle, at the center of the current-carrying coil of wire, point when the current's polarity was reversed?
- Q31. How will you compare the magnitude of the compass needle deflections for the different number of loops in the current-carrying coil?

Q32. If you will straighten the shortened coil of wire, how will you compare the magnitude of the compass needle deflection at the center of the previous current-carrying coil, to the compass needle deflection near the just straightened current-carrying conductor? Why?

9. Extending Inquiry – A solenoid (a coil of wire in which the length is greater than the width) was made using a 3-meter long magnetic wire wound clockwise from left to right around the iron rod. Current was then made to flow through it using a circuit similar to what is shown to Figure 11 a.

Q33. What would be the direction of the magnetic field around the current-carrying solenoid when the switch is closed?

Q34. Using arrows, draw the magnetic compass needle directions at the indicated locations in Figure 11b. Then indicate which ends of the solenoid acts similar to the north and south poles of a bar magnet.

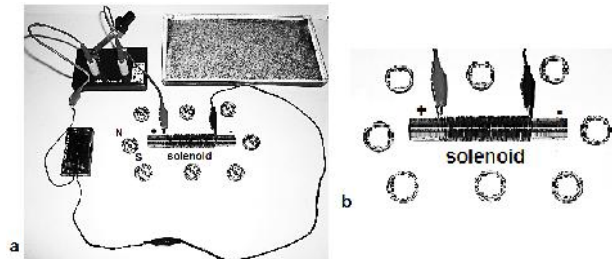


Figure 11. Checking the Magnetic Field around a Current-carrying Solenoid

FORCE ON A CURRENT-CARRYING WIRE IN A MAGNETIC FIELD

A non-magnetic current-carrying wire within a strong magnetic field, like copper for instance, will experience a magnetic force as indicated by the wire's movement relative to the magnetic field. This turning effect on a coil is used in ammeters and motors that use permanent magnets and electromagnets.

Do the next activity and try to understand the interaction between the magnetic field of the permanent magnet and the magnetic field due to the current in the conductor.

Activity 9

Making Your Own Electric Motor

Adapted from <http://www.instructables.com/id/How-to-Make-a-Homopolar>

Objectives:

- Build a simple electric motor.
- Explain the operation of a simple electric motor.

Materials:

- 1 AA battery
- 3 Neodymium magnets, 1/2" – 3/4"
- pliers or long nose
- AWG #14 – 18 solid and bare copper wire (~30 cm)
- science notebook and pen



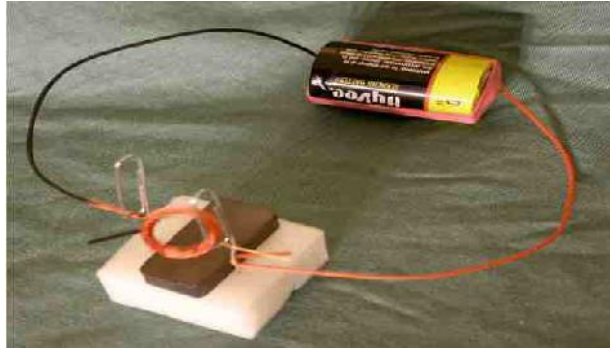
Figure 12. Materials for making an electric motor.

Safety Precautions:

- The neodymium magnet is many times stronger than the ordinary disk magnet that can hold papers on refrigerator doors. Be careful not to get your fingers pinched between these magnets and other magnetic materials.
- Wires can get hot when connected to the battery for a long time. Open the circuit once you are done with your observations.

Procedure:

1. Assembly of the Electric Motor Model – Cut the length of copper wire into three pieces. With the use of the pliers, shape the three wires into a spiral, square, heart or any figure to your liking similar to what is shown in Figure 13.



<http://ideas-inspire.com/simple-electric-motor/>

Figure 13. A sample electric motor model using neodymium magnets.

2. Make a sample pile of the three neodymium magnets, the battery and the shaped copper wire. Make adjustments to the length and width of the shaped wire. See to it that there is a bare connection between the wire ends and the neodymium magnet and also between the pivot part (balancing point) of the wire and the positive terminal of the battery. Scrape or sand off the material insulating the wire at these indicated points. Disassemble the set up when making the needed shape adjustments and sanding of the copper wire.
3. Testing of Model – Carefully pile with the three neodymium magnets and the battery on a level surface. Mount the shaped wire, with its pivot part as a rotating point, over the positive terminal of the battery. Check that the bottom ends of the wire curl loosely around the magnets forming a closed circuit. You now have a simple DC electric motor model that we will simply call a DC motor model. Give the current-carrying shaped wire a gentle spin.
4. Observe and record what happens to the shaped wire. **Warning!** Disconnect the DC motor model immediately after making observations.
5. If your DC motor does not work, stretch your tolerance, abilities, and knowledge. Have fun making your motor model demonstrate the effect of an electromagnetic force on a conductor that is within a magnetic field.

Guide Questions:

- Q35. What happens to the shaped wire once positioned over the battery's positive terminal and with both wire ends curled loosely touching the magnets?
6. Extending Inquiry of Model – Tinker with your electric motor model and try to look for other ways to demonstrate the same effect by an electromagnetic force.

- Q36. What other observations have you made regarding your electric motor model?
- Q37. What will happen if the number of neodymium magnets used in the model is reduced? Increased?
- Q38. What are the basic parts/elements of a simple electric motor?
- Q39. Based on the activity, how will you explain the operation of a simple electric motor?

ELECTROMAGNETIC INDUCTION

Now the basic parts of a DC motor can also be assembled to operate as a DC generator. What would happen if instead of causing a current-carrying conductor to move within a magnetic field, the closed circuit conductor is mechanically moved within a magnetic field?

The next activity will enable you to explore and appreciate the Earth's magnetic field and its effect on a moving giant coil. Jump in for a simple yet electrifying experience!

Activity 10

LET'S JUMP IN!

(Adapted from cse.ssl.berkeley.edu/.../lessons/...electromagnetism/mag_electromag.pdf)

Objectives:

- Observe the deflection of a galvanometer needle when an electrical cord crosses the Earth's magnetic field.
- Measure and record the magnitude of the deflection of the galvanometer needle when the electrical cord is rotated:
 - a) slowly;
 - b) quickly;
 - c) when aligned east to west; and
 - d) when aligned north to south.
- Explain the operation of a simple electric generator.

Materials:

- 10 to 20 meters flat wire (double wire, stranded) AWG #22
- two lead wires with alligator clip on at least one end
- level field or ground (at least 6 meters x 6 meters)
- micro-ammeter or galvanometer
- pliers or long nose
- one compass
- science notebook and pen

Safety Precautions:

- A galvanometer is a very low resistance instrument used to measure very small currents in microamperes. It must be connected in series in a circuit. Use the galvanometer with care and without dropping it.
- Jump in safely and observe taking turns.

Procedure:

1. Strip off at least 1" insulation on all ends of the 20 meter flat wire. Loop the stranded wires together for each end. Connect the ends of the jump wire to the terminals of the galvanometer using the connecting wires with alligator clips.



Figure 14. Generation and detection of electricity using the Earth's magnetic field and rotating loop of conductor connected in series to a galvanometer

2. Lay the loop of wire together with the galvanometer on the ground. This long loop of cord-galvanometer arrangement will serve as the closed circuit jump rope electric generator. The galvanometer will serve as detector of the electric current that may be generated due to the Earth's magnetic field and other essential components for electricity.
3. As shown in Figure 14, have members of your group stand on the jump rope, one at the far end and two near the galvanometer to secure the connections and directional marks for the chosen rotation alignment. If possible secure the connections and alignment another way, so everyone gets to observe the galvanometer freely as the cord is rotated during the jumping activity.
4. Align the jump wire electric generator in any of the geographical directions: (a) east to west, (b) north to south, and (c) northeast-southwest directions using a compass as shown in Figures 15 and 16.

5. With half of the loop on the ground, have two group members on each end pick up the free length of cord and rotate it clockwise or counter clockwise (relative to the galvanometer end) like a jump rope as shown in Figure 14 .Take turns rotating the cord and checking the galvanometer, even jumping in for fun during the activity.



Figure 15. The galvanometer and jump wire electric generator set up along the East-West (left) and along the North-South (right) alignments.

6. Try also rotating both half-lengths of the loop together and observe also the galvanometer reading.

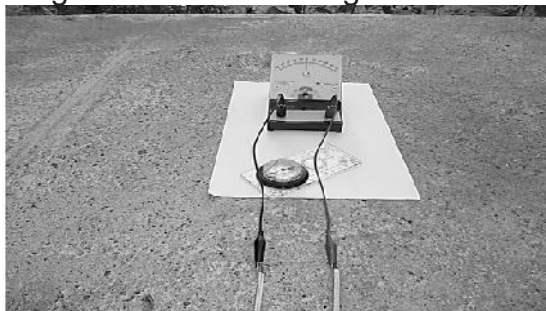


Figure 16. The galvanometer and jump wire electric generator set up along the Northeast-Southwest alignment



Figure 17. when both half-lengths of the loop are rotated together

7. This time try to generate, measure, and record the electric current readings. In doing so try to vary the following:
 - A. Speed of rotation.
 - B. Geographical alignment of rotation.
 - C. Direction of single-length loop rotation.
 - D. Length of rotated part.
 - E. Single or double half-length rotations.

8. Design and write your own graphic organizer for your observations on your science notebook.

Guide Questions:

- Q40. What effect does the rotating part of the loop have on the needle of the galvanometer?
- Q41. What effect does the speed of the rotating loop have on the generated electric current?
- Q42. Which condition or its combination would result to the greatest generated electric current? Smallest current? No current reading?
- Q43. Why does the geographical alignment of the rotating jump wire affect the galvanometer reading?
- Q44. What are the basic components of the jump wire electric generator?
- Q45. How will you explain the operation of a simple electric generator?
9. Extending Inquiry. Identify and describe the basic parts of the generator model shown in the figure below.

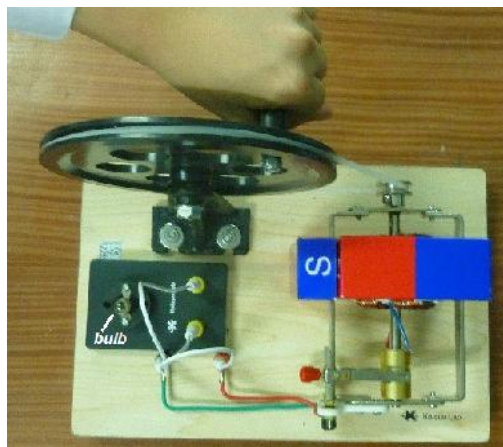


Figure 18. DC Electric Generator

- Q46. Which part/device shown in the figure above?

The activity on the jump wire generator operates using the principles of electromagnetic induction. In this activity, it is the conductor that moves within the Earth's magnetic field. Will moving a source of magnetic field instead of the conductor lead to the same findings?

Activity 11

PRINCIPLES OF ELECTROMAGNETIC INDUCTION

(Adapted from the DepEd-NSTIC Activity on Faraday's Induction)

Objectives:

- Observe the deflection of a galvanometer needle when a magnet moves inside a current-carrying coil.
- Identify and explain the factors that affect the induced current through a conductor.

Materials:

- 3.6 meters hook/connecting wires (about 20 fine strands along the length of insulated magnet wire)
- tape measure
- size D dry cell
- sticky tape and pair of scissors
- galvanometer
- two wooden blocks
- two wires with alligator clips
- pair of bar magnets
- science notebook and pen

Safety Precautions:

- A galvanometer is a very low resistance instrument used to measure very small currents in microamperes. It must be connected in series in a circuit with the pointer at the zero point mark. Use the galvanometer with care so as not to drop it.

Procedure:

1. Using a size D dry cell as guide, wind a 5-turn, a 10-turn, and a 15-turn coil out of a 60-cm, 120-cm and a 180-cm connecting wire respectively. Use small pieces of tape to hold the coil together on two or three areas. Remove the insulation from each end of the coil and strand the fine wires together for easy connection.
2. Set up the galvanometer, wooden blocks and bar magnets as shown in Figure 19.

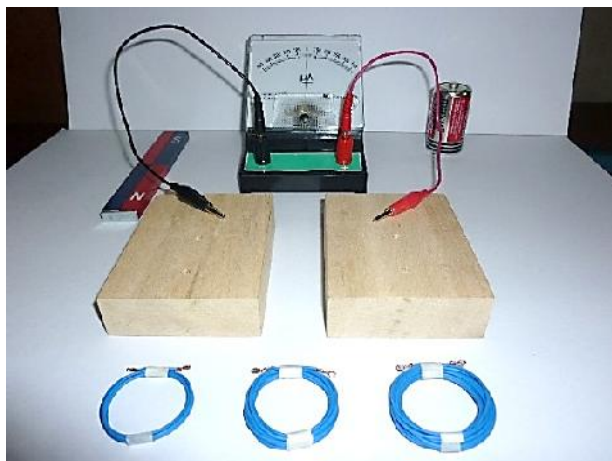


Figure 19. A simple electromagnetic induction activity set up with a galvanometer that has its zero point mark in the center of the scale. This type of galvanometer measures the presence of a very small current, its direction, and its relative magnitude.

Part A. Inducing voltage and current in a coil

3. As shown in Figure 20, lay the 5-turn coil above the two wooden blocks and connect its ends to the galvanometer via wires with alligator clips. At this point, observe what happens to the galvanometer pointer.

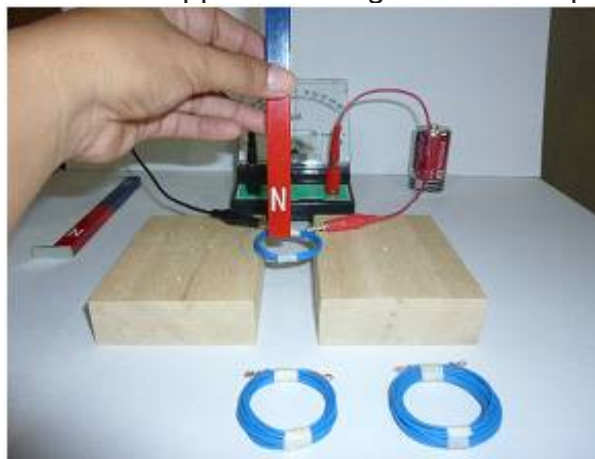


Figure 20. Move the north pole of a bar magnet into a 5-turn coil

4. Hold a bar magnet above the coil as shown in Figure 20. Move the north pole of the magnet into the coil. Observe the galvanometer pointer as you do this. On your science notebook, make a table similar to Table 10 and record your observations.

Table 10. Inducing current in a coil

Condition	Coil Without a Magnet	Magnet is Moving into the Coil	Magnet is at Rest Inside the Coil	Magnet is Moving Out of the Coil
Galvanometer pointer's deflection or non-deflection				
Galvanometer pointer's direction of deflection				

5. Hold the magnet inside the coil without moving it for a few seconds. Observe what happens.
6. Pull the magnet out of the coil. Observe the galvanometer pointer as you do this.

Q47. How will you explain the deflection or non-deflection of the galvanometer pointer as observed in the activity?

Q48. How will you compare the directions of deflection? Why do you think this is so?

Part B. Amount of induced voltage and current vs number of turns

7. Use the set up to explore the relative magnitudes of the galvanometer pointer's deflection for the 5-turn, 10-turn and 15-turn coils. Record your observations on your science notebook.

Q49. For approximately the same speed of moving the magnet into or out of each coil, what happens to the magnitude of the pointer's deflection as the number of turns in the coil increase?

Part C. Amount of induced voltage and current vs strength of magnetic field

8. Use the 15-turn coil and the set up to explore the relationship between the magnitude of the galvanometer pointer's deflection and the magnetic field strength using (a) one bar magnet, and (b) two bar magnets with like poles held together in parallel. Record your observations on your science notebook.

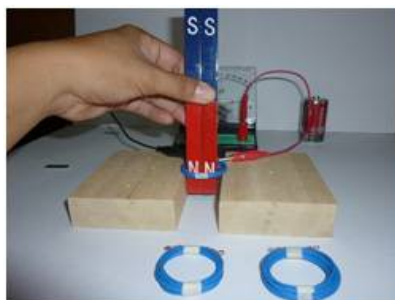


Figure 21. Move the north poles of two parallel bar magnets into a 15-turn coil.

Q50. For approximately the same speed of moving the magnet into or out of the 15-turn coil, what happens to the deflection of the galvanometer pointer as the number of bar magnets (strength of magnetic field) increase?

Part D. Amount of induced current vs rate of magnetic field change

9. Use the 15-turn coil and a bar magnet to explore the relationship between the magnitude of the galvanometer pointer's deflection and the speed of movement of the magnet into or out of the coil. Record your observations on your science notebook.

Q51. What happens to the deflection of the galvanometer pointer as the bar magnet is moved into or out of the 15-turn coil at different speeds (rate of magnetic field change)?

Part E. Coil orientation and direction of magnetic field change

10. As shown in Figure 22, move (a) a bar magnet along one of the coils (preferably the 15-turn) and observe the magnitude of the galvanometer pointer's deflection. Compare this deflection to that when (b) the bar magnet moves across (into or out) the coil at approximately the same speed. Record your observations on your science notebook.

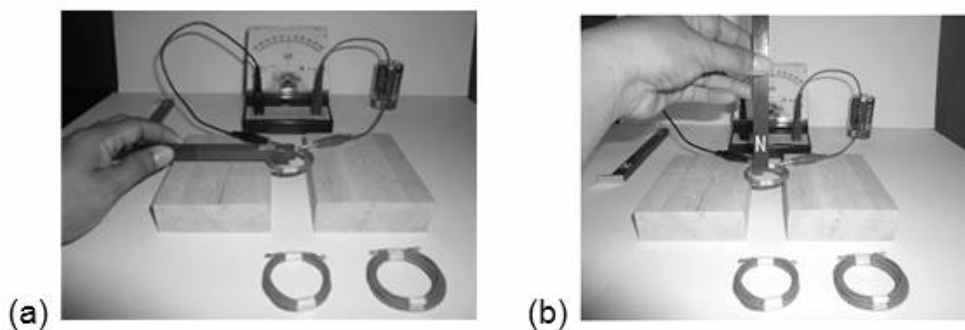


Figure 22. The bar magnet is moved (a) along or parallel to the coil orientation, and (b) across or perpendicular to the coil orientation

- Q52. How would you compare behavior of the the galvanometer pointer when the magnet moves along the coil and when the magnet moves across the coil?
- Q53. In your own words, what are the factors that affect the amount of current and hence voltage (EMF) induced in a conductor by a changing magnetic field?
- Q54. An equation for the electromagnetic force (EMF) induced in a wire by a magnetic field is $EMF = BLv$, where B is magnetic field, L is the length of the wire in the magnetic field, and v is the velocity of the wire with respect to the field. How do the results in this activity support this equation.
11. Extending Inquiry. The principle of electromagnetic induction in two nearby coils can be demonstrated by a transformer. A typical transformer has two coils of insulated wire wound around an iron core. This device changes the AC voltage of the primary coil by inducing an increased or decreased *EMF* in the secondary coil. In practical applications, why does this device operate only on alternating current and not on direct current?

Additional Reading

Speed Control Technology – To ensure road safety and minimize vehicular-related death, buses, and other public utility vehicles can be equipped with a speed control device that limits the maximum speed by using electromagnetic brakes in combination with a motor once the limit is exceeded.

Speed control motor packages include the motor, the driver (controller), and a potentiometer which allows the driver for easy speed control adjustment. When the speed of this motor is controlled, a tacho-generator connected to the motor detects the speed. It is a magnet connected directly to the motor shaft and stator coil. The stator coil detects the magnetic field and generates an alternating current (AC) voltage.

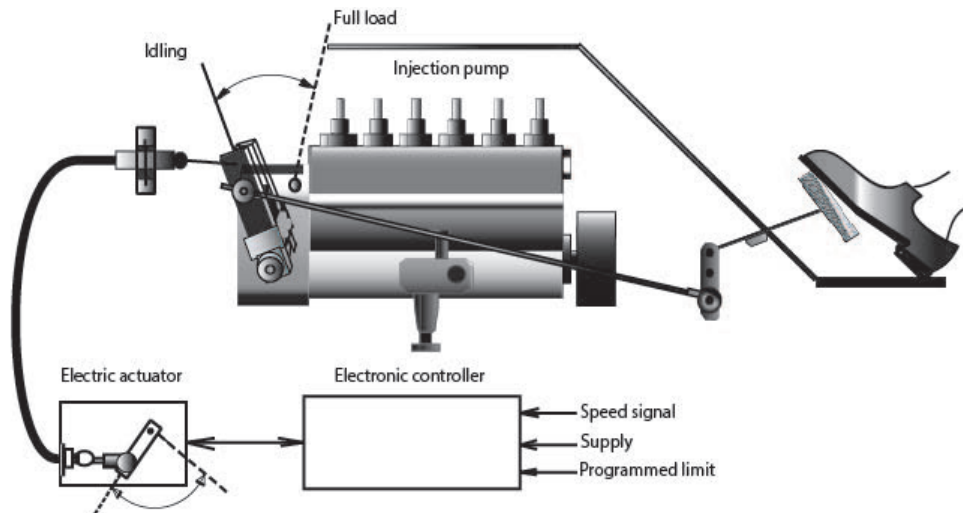


Figure 23. Motor speed control technology diagram

Since this voltage and frequency increase with a rise of the rotational speed, the rotational speed of the motor is controlled based on this signal.

Traffic Light – Vehicles waiting at intersections with coils buried underneath is within an electromagnetic field. Changes in the field activate the traffic light as programmed.

Typical red-light traffic systems have two induction-loop triggers made of rectangular or concentric wire loops buried under the road close to the stop line. This wire is connected to an electrical power source and a meter.

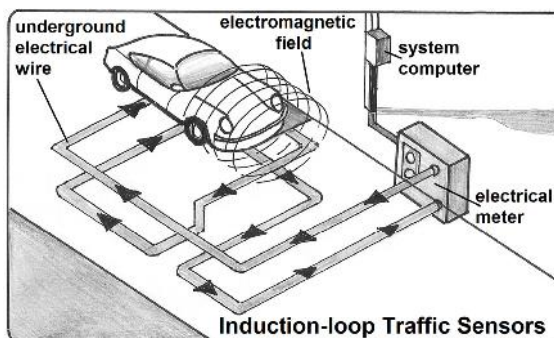


Figure 24. An induction-loop traffic system at a road intersection senses vehicles within its electromagnetic fields

The current through the wire produces a magnetic field affecting objects around the loop and the loop itself. When there is another conductive material within the magnetic field, then a changing induced voltage is detected. This results to changing magnetic flux that triggers the traffic system according to its programmed mechanism.

Metal Detector – Metal detectors trigger the “Bleep! Bleep! Bleep!” sound when objects with parts that are magnetic in nature move past it. This signal a precious find, a hidden unwanted object or a need for further security check.

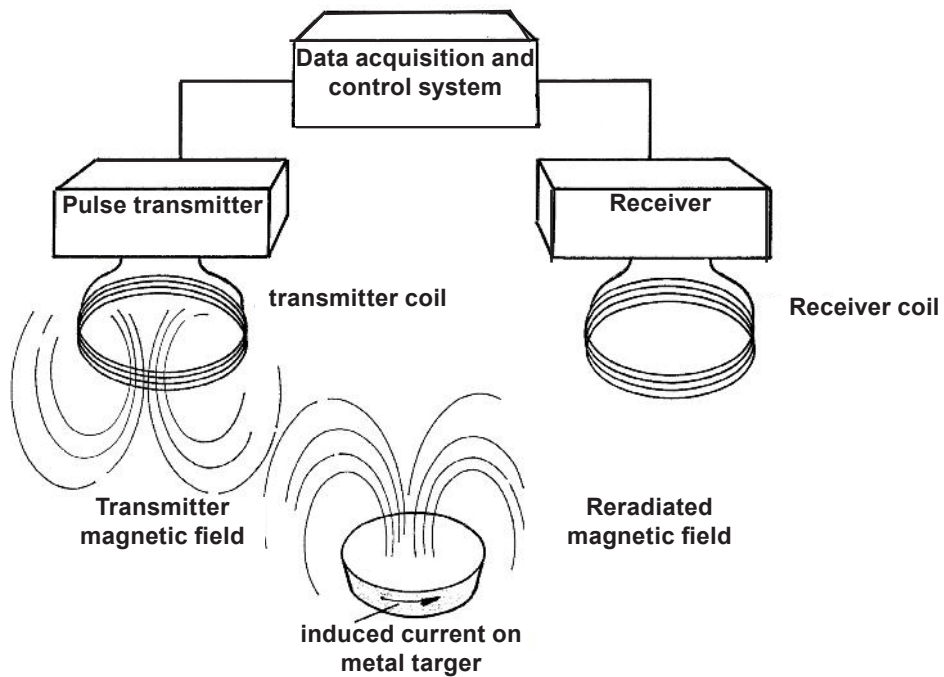


Figure 25. A basic pulse-electromagnetic induction metal detection technique

The transmitter coil is given a pulsed current long enough for the transmitter’s magnetic field to reach the metal target. The transmitter’s loop current is then turned off. The changing or collapsing magnetic field induces an electromotive force that induce charges to flow in the metal target. This induced current creates a reradiated magnetic field that can be detected by a receiver coil located at the sensor.

In some metal detectors, it is the device that is moved over the object. In other detectors, it is the object or the person that moves pass the machine. Whatever is the case, the current-carrying transmitting coil creates a changing magnetic field which in turn creates a changing electric field that creates the secondary magnetic field detected by the receiver coil.

Induction Stove – Food cooks faster when heat is conducted directly and almost entirely at the base of the cooking pot. In induction stoves, current flowing through the copper coil wound underneath the cooking surface produces an electromagnetic field small enough to surround the base of the cooking pot. The magnetic field induces an electric current within the base of the metal pot. The metal in the cookware has electrical resistance that opposes the induced current and causes friction for the pot to heat up.

How Induction Cooking Works

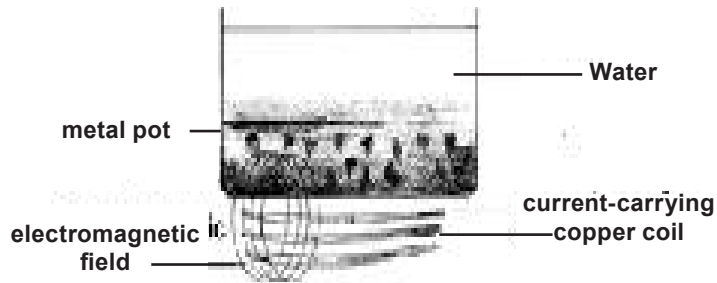


Figure 26. Induction stove working mechanism

Heat transfer in an induction stove is more efficient than that via the gas stove because almost all of its heat is conducted directly to the base of the pot unlike in gas stoves where much heat escapes around the side and heats up the room and the rest of the cooking pot.

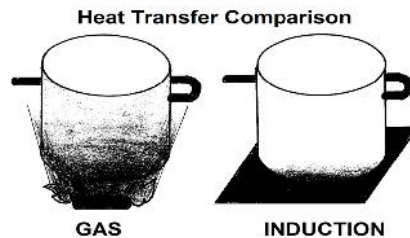


Figure 27. In induction cooking, heat loss is lesser than in gas cooking

Magnetic Recording – Computer working memories (RAM's and ROM's), mass storage memories (magnetic hard disks, floppy disks, magnetic tape drives, and optical disk drives), and practically all write-able card storage devices (magnetic cards, smart cards, and flash memory cards) make use of the magneto-optical characteristic of the recording media to store information.

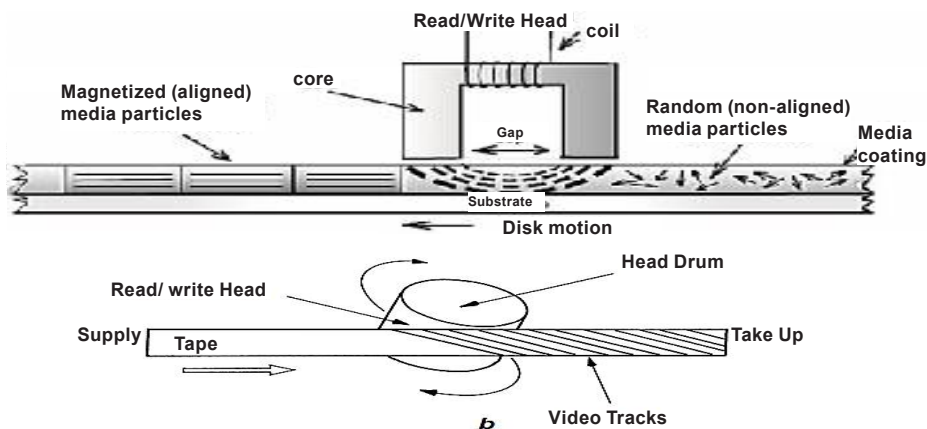


Figure 28. Read/Write Head of a Disk Player

Performance Task

An Octo Challenge Audio-Visual Presentation (AVP) Using Electromagnetic Induction (EMI)

An Enrichment Activity

Objective:

Plan, perform, and record a 5-minute audio alone or audio-visual presentation related to any Philippine National Celebration during October using devices that apply both electricity and magnetism.

Materials:

- at least one musical instrument
- audio alone or audio-video recording technology of your choice
- support materials as needed by your team
- printed transcript of spoken parts of AVP

Procedure:

1. Meet as a group and agree on the role of each member according to interests and skills in the making and recording of the AVP presentation.
2. Listed are eight October national celebrations observed by Filipinos:
 - National Children's Month
 - Philippine Consumer Welfare Month
 - Moral Guidance Week for Public Servants
 - Indigenous People's Celebration
 - Elderly Filipino Week
 - Food Safety Awareness Week
 - United Nations Celebratio
 - World Teacher's Day

Use only one event to highlight in your **AVP tribute** that will introduce briefly the audience to the making and recording of an audio-only or an audio-visual presentation using **electromagnetic induction** partially or entirely.

3. Your group has four weeks to plan, perform and record together the five-minute AVP tribute with the following guidelines:
 - a) Gather information about your selected musical instrument and recording device. Learn how these use electricity and magnetism. Give a multimedia introduction on this for a minute or two.
 - b) Dedicate the remaining three minutes in highlighting the chosen October event. Decide whether you will record an audio-only or an audio-visual

presentation taking into consideration the listening and processing efforts needed to fully appreciate the event or the reason behind it. Plan, perform and record an age-appropriate music-video tribute.

- c) Ensure that the AVP is an output of the whole circle of friends. At the end of the AVP include a brief roll of credits.
- d) The making and recording of the AVP should be done only during non-class hours inside the school premises only.
- e) You are liable for the proper and safe use of all audio-video production and recording devices whether these are personally owned or a school property. Ensure also minimal energy use.
- f) Agree on a checklist to help your group monitor your task progress. Prepare also a written transcript of your AVP's recorded audio.
- g) Prepare a digital record of your AVP on a compact disc, ready for premiere viewing in the class at the end of this module period.

Criteria for Success - The making and recording of the October-themed AVP will be rated based on the following criteria:

1. Knowledge and understanding of EMI.
2. Thinking and inquiry on the AVP plans and preparations.
3. Communication through language and style.
4. Communication through music and video presentation conventions.
5. Special Criterion on Technical Quality or Original Song Production.

Ask your teacher for this task's **GRASPS** guidelines to help your group in the successful completion of the performance task before the end of Module 1. Refer also to the corresponding performance task rubric for the **Development of an Octo Challenge Audio-Visual Presentation** as you assess your group's progress.

Your teacher will also use the same rubric in assessing your performance, content, and product-wise.

V. Summary/Synthesis/Feedback

- Many of the audio-video recording technology apply the relationship between electricity and magnetism known as electromagnetic induction.
- A typical recording studio consists of an audio-video console, microphones, computers, studio monitors or speakers, disc players and cables used for the exchange of audio and digital data signal during production, recording, mixing, and even editing of all audio-video elements digitally stored on disk drives.
- Devices that detect and convert audio inputs to electric outputs or vice versa are called transducers. Most transducers like microphones and speakers use the “generator effect” characterized by the production of electromotive forces due to either a changing electric signal within a magnetic field or a changing magnetic field near a current-carrying conductor.
- Magnetism is commonly attributed to ferromagnetism and electromagnetism depending on the material and moving charges. Every atom and all moving charges are in constant motion and therefore has a bit of magnetism due to magnetic spins and domains creating a net magnetic field.
- A magnet has two magnetic poles (north and south seeking poles).
- Stroking with a permanent magnet is one of the ways to induce or cause magnetism in an object that can be magnetized. The polarity of the induced magnetism in the object is opposite to the polarity of the nearer end of the permanent magnet. Attraction happens after magnetic induction occurs.
- A magnet attracts, but do not repel, unmagnetized ferromagnetic materials such as iron, nickel, cobalt and some of its alloys like steel and alnico.
- Both forces of attraction and repulsion is possible between magnets and between a magnet and a temporarily magnetized object.
- A magnetic field surrounds a magnet. Within this region, the magnet affects another magnet and other objects that can be magnetized.
- The magnetic field is strongest at the poles where the magnetic lines of induction (flux) are closest. The magnetic field pattern can be shown using iron filings that align along magnetic lines of induction.
- The magnetic lines of induction leave the north-pole and enter the south-pole in close loops and can be indicated by the north pole of a compass.

- The loops of magnetic field lines between like poles bend away from each other showing a force of repulsion. The lines between unlike poles join with each other to form continuous lines showing a force of attraction.
- The earth acts like a giant bar magnet and has a magnetic field similar to it.
- A charge has an electric field around it where other charges will experience an electromagnetic force. Like charges repel while unlike charges attract.
- Moving charges or current in a wire produces a magnetic field.
- An electromagnet is a coil of wire that uses current to produce a strong magnetic field.
- The magnetic field patterns of a disk magnet, an electromagnetic nail, a current carrying straight conductor, and a current carrying coil are similar to that of the single bar magnet.
- The magnetic field pattern between the poles of a U-shaped magnet resembles the field pattern between unlike poles of two bar magnets. Compasses aligned along the magnetic field show that the lines point from the north to the south poles and back forming close loops.
- If the two bar magnets with two unlike poles which are close in between is brought together, the magnetic field pattern will resemble that of the single bar magnet. Lines from one pole enter the other pole.
- Most refrigerator magnets has a pattern of alternating bands of magnetic field.
- If the direction of the current is known, the direction of the magnetic field that is perpendicular to it and the magnetic force that is perpendicular to both current and magnetic field can be determined by applying the hand rules.
- Using the right hand rule, the direction of the magnetic field follows the direction of the right hand fingers when the right thumb points in the direction of the conventional current (from positive to negative).
- Using the left-hand rule, the direction of the magnetic field follows the direction of the left hand fingers when the left thumb points in the direction of the real flow of current (from negative to positive).
- The magnetic field is strongest at the center of a current-carrying coil.

- The magnetic field increases in direct proportion to the number of turns in a coil with the compass needle, at the center of the coil of wire, deflecting about a wider angle than the compass needle along the straightened wire.
- The end of the current-carrying coil where the magnetic lines of induction come out acts as the north pole of the coil.
- A magnetic field exerts a force on a current-carrying conductor. Using the right-hand rule, the direction of this force is in the direction where the palm faces.
- The motor effect is shown when a current-carrying conductor within a magnetic field moves in the direction of the force. The force on a moving current-carrying conductor may be varied by changing the magnetic field.
- An electric motor is a device that converts electrical energy into rotational mechanical energy. A simple DC motor can be assembled using a single coil that rotates in a magnetic field. The direct current in the coil is supplied via two brushes. The forces exerted on the current-carrying wire creates a rotation-causing force on the coil.
- An electric generator is a device that converts mechanical energy into electrical energy. A simple electric generator is made when a coil or any closed loop of conductor moves through or cuts across magnetic field lines. The coil will experience an induced voltage or an electromotive force that will cause a pulsating direct current (DC) to be generated. The pulsating direct current fluctuates in value but does not change direction.
- Electromagnetic induction is a process in which electric current is generated in a conductor by a moving or changing magnetic field.
- A changing magnetic field occurs when there is relative motion between a source of a magnetic field and a conductor; it does not matter which moves.
- A changing magnetic field may also arise from a changing nearby current.
- The amount of voltage (*EMF*) induced when a conductor and a magnetic field are in relative motion depends on (a) the length L of the conductor or the number of turns in the coil, (b) the strength and orientation of the magnetic field B relative to the conductor, and (c) The relative velocity v of the changing magnetic field.

- The equation for the induced voltage or electromagnetic force (EMF) in a wire by a changing magnetic field is $EMF = BLv$. By Ohm's Law the amount of induced current is directly proportional to the induced voltage.
- A transformer uses electromagnetic induction in two nearby coils (the primary and secondary coils). Typically, the two coils of insulated wire are wound around an iron core. This device changes the AC voltage of the primary coil by inducing an increased or decreased EMF in the secondary coil.

VI. Summative Assessment

Directions. Choose the letter of the correct answer.

1. In which case or cases is an electric field present?
 - I. A spark jumping between two nearby rods.
 - II. A charge that is momentarily at rest.
 - III. A dead power line.
 - a. I only
 - b. I and II only
 - c. II and III only
 - d. I, II and III
2. Which device can be used to determine the polarity of an unmarked magnet?
 - a. a suspended magnetized needle
 - b. an improvised magnetic board
 - c. a second unmarked magnet
 - d. a charged metal rod at rest
3. In which device is magnetic field present?
 - a. A charged balloon.
 - b. A cooling soldering iron.
 - c. A very hot horse-shoe magnet.
 - d. A microphone undergoing a sound check.
4. How will you describe the magnetic field around a current-carrying coil?
 - a. The magnetic field is weakest near and around the coil.
 - b. The magnetic field vary directly with the distance from the coil.
 - c. The magnetic field is strongest inside the current-carrying coil.
 - d. The magnetic field lines are closed loops along the loops in the coil.

5. Which statement about an electromagnetic nail is NOT TRUE?
- Steady magnetic lines of induction surround a battery-powered electromagnetic nail.
 - The current in the electromagnetic nail demagnetizes the iron nail.
 - The magnetic field lines produced resemble that of a bar magnet.
 - The magnetic field strength is proportional to the nail's current.
6. What can be inferred from the alignment of compass needles around the pick-up coil below?



- Current is drawn into the coil.
 - A permanent magnet is nearby.
 - The DC power switch was turned off for long.
 - There is a uniform magnetic field around the coil.
7. What basic principle enables ALL electric generators to operate?
- Iron is the only element that is magnetic.
 - Opposite electric charges attract and like charges repel.
 - A closed-loop conductor within a changing magnetic field will have an induced electromotive force.
 - A current-carrying conductor placed within a magnetic field will experience a magnetic force.
8. Which of the following statements can be inferred from the main photo above? (For easier inspection, a paper is inserted halfway between the open disk tray and a magnetic board)



- a. The iron filings inside the magnetic board is unaffected.
 - b. The CD-DVD disk tray uses a small permanent bar magnet.
 - c. The optical system has an electric motor that drives the reader.
 - d. The optical reader has a lens system that affected the iron filings.
9. Which arrangement of three bar magnets results to an attraction between the first and the second, and a repulsion between the second and the third magnet.

	Magnet 1	Magnet 2	Magnet 3
a.	N S	N S	S N
b.	N S	S N	N S
c.	S N	N S	N S
d.	S N	S N	S N

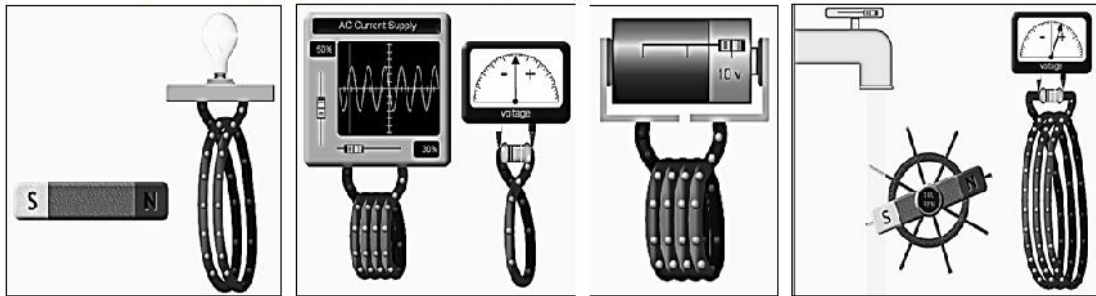
10. Complete the following statement: A metallic detector was used to check a bag for metallic objects. The transmitter coil
- a. A. draws a steady current to send a steady magnetic field towards the target to induce current in it.
 - b. draws a pulsating current to send a steady magnetic field towards the target to induce current in it.
 - c. draws a steady current to send a changing magnetic field towards the target to induce current in it.
 - d. draws a pulsating current to send a changing magnetic field towards the target to induce current in it.
11. A coil moves away from a magnet. Consider the following factors:
- I. strength of the magnet
 - II. number of turns in the coil
 - III. speed at which the magnet moves

Which can affect the electromotive force (EMF) induced in the coil?

- a. I only
- b. II only
- c. III only
- d. All three factors

12. Which set ups model the working principle of a transformer and an electric generator respectively?

Images from PhET Interactive Simulation



A.

B.

C.

D.

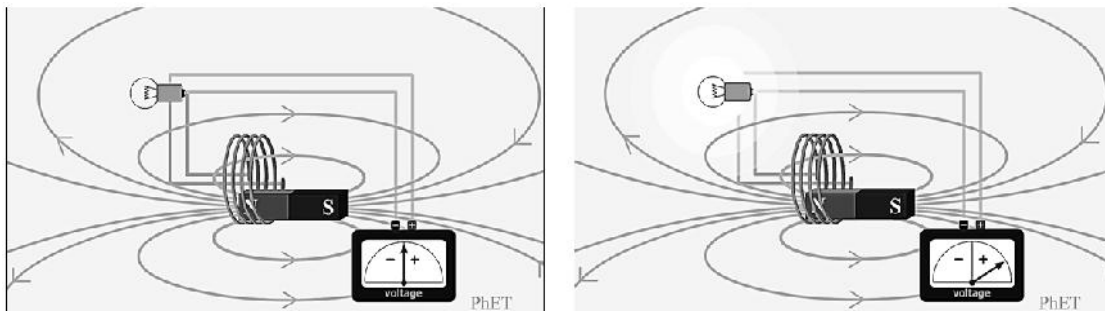
a. A and B

b. B and D

c. C and D

d. D and A

13. Which statement is TRUE about the illustration below?



SET UP A.

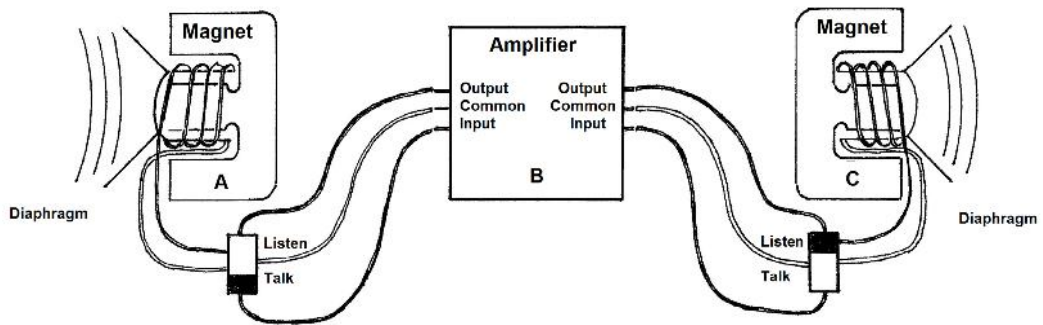
SET UP B.

- In set up A, the magnet is at rest inside the moving coil.
- In set up B, the magnet is being pulled out of the moving coil with the same speed.
- There is relative motion between the magnet and coil in set up A.
- There is relative motion between the magnet and coil in set up B.

14. What transformation can take place in a ceiling fan's electric motor?

- electrical energy into mechanical energy
- mechanical energy into electrical energy
- alternating current into direct current
- direct current into alternating current

15. What is TRUE about the intercom system that is shown below?



- The part A of the intercom system serves as a microphone only, while part C serves as a loudspeaker only.
- Either parts A and C of the intercom when switched as such can be used as a microphone or as a loudspeaker.
- The microphone part only basically consists of wires, a cone diaphragm, a magnet, and a coil.
- The loudspeaker part only basically consists of wires, a cone diaphragm, a magnet, and a coil.

Glossary of Terms

Charged particles	are sources of electric fields which result in an attraction or repulsion of other nearby charges
Electric charge	a fundamental electrical property that is either of positive or negative type to which the mutual attractions or repulsions between protons or electrons is attributed
Electric field	force field surrounding electric charges or group of charges where a force acts on charges within the field
Electric generator	device that converts mechanical energy into electrical energy usually by rotating a coil within a magnetic field
Electric motor	device that converts electrical energy into mechanical energy using the magnetic turning effect on a coil
Electricity	produced by vibrating or flowing charges

Electromagnet	magnet whose magnetic properties are produced by electric current
Electromagnetic induction	phenomenon of inducing a voltage in a conductor by changing the magnetic field near the conductor. If a magnetic field within a closed loop changes in any way, a voltage or electromotive force is induced (produced) in the loop
Electromotive force	voltage that gives rise to an electric current
Galvanometer	low resistance instrument used to measure very small currents, its direction and its relative magnitude
Magnet	object that has the magnetic ability to attract objects made of iron or other magnetic substance
Magnetic Domain	microscopic grouping of atoms with their magnetic field aligned
Magnetic field	region of magnetic influence around the magnetic poles and moving charged particles
Magnetic field lines	lines showing the shape of a magnetic field. A compass placed on such a line will turn so that the needle is aligned with it because of electromagnetic induction
Magnetic force	between magnets, it is attraction of unlike magnetic poles and the repulsion between like magnetic poles; between a magnetic field and a moving charged particle, it is a deflecting force due to the motion of the particle; the deflecting force is perpendicular to both the magnetic field lines and the direction of motion
Magnetic poles	magnetic south or north seeking regions on a magnet that produces magnetic forces
Magnetism	property of being able to attract objects made of naturally occurring magnetic substances like iron, nickel, cobalt or some of its alloys
Transformer	can step-up or step-down voltages using the principles of electromagnetic induction

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Unit 2
MODULE**2****ELECTROMAGNETIC
SPECTRUM****I. Introduction**

In Module 1, you have learned about the interrelationship between electricity and magnetism. You were able to discover how electric field could create magnetic field and vice versa.

In this module, you will learn about the different regions of the electromagnetic spectrum. This module will lead you to understand how electromagnetic waves transport energy. It also consists of activities that will enrich your understanding on the application of electromagnetic waves in our everyday living, and consequently, how these waves affect living things and the environment.

At the end of Module 2, you will be able to answer the following questions:

1. How do the regions in the electromagnetic spectrum differ in terms of wavelength, frequency and energy?
2. How do the different types of electromagnetic waves become relevant to people and environment?
3. What are the consequent effects of electromagnetic waves?

II. Learning Competencies/Objectives

1. Trace the development of the electromagnetic theory.
2. Describe how electromagnetic (EM) wave is produced and propagated.
3. Compare the relative wavelengths, frequencies and energies of the different regions of the electromagnetic spectrum.
4. Cite examples of practical applications of the different regions of EM waves.
5. Explain the effects of electromagnetic radiation on living things and the environment.

III. Pre-Assessment

A. Choose the letter of the correct answer.

1. Which two waves lie at the ends of the visible spectrum?
 - a. Infrared and Ultra-violet rays
 - b. Radio waves and Microwaves
 - c. Radio waves and X-rays
 - d. X-rays and Gamma rays

2. In the visible spectrum, which color has the longest wavelength?
 - a. Blue
 - b. Green
 - c. Red
 - d. Violet

3. Which property spells the difference between infra-red and ultra-violet radiation?
 - a. Color
 - b. Speed in vacuum
 - c. Wavelength
 - d. None of the above

4. A certain radio station broadcasts at a frequency of 675 kHz. What is the wavelength of the radio waves?
 - a. 280 m
 - b. 324 m
 - c. 400 m
 - d. 444 m

5. What type of electromagnetic waves is used in radar?
 - a. Infrared rays
 - b. Microwaves
 - c. Radio waves
 - d. Ultra-violet rays

B. Below are the applications of electromagnetic waves. State the type of electromagnetic wave used in each application.

1. Camera autofocusing
2. Radio broadcasting
3. Diagnosis of bone fractures
4. Sterilization of water in drinking fountains
5. Sterilization of medical instruments

C. Answer the following question briefly but substantially.

1. How are EM waves different from mechanical waves?
2. Give two sources of EM waves in the Earth's environment.

IV. Reading Resources and Instructional Activities

The Electromagnetic Wave Theory

Did you send text messages to somebody today? Or have you ever tried cooking in a microwave oven? Did you know that these previously mentioned human activities make use of microwaves? Microwaves carry energy, and so with the other kinds of electromagnetic waves. But what are electromagnetic waves? How can these waves become useful to us?

For a start, let us learn how the study of the electromagnetic waves came to be.

Agreement:

Do a research to find out who were the proponents on the formulation of electromagnetic theory. You may use print and non-print references to gather your information. You may limit it to 5 significant scientists. Be sure to indicate your sources/references for proper acknowledgment.

The research work enabled you to gain information about the scientists who made great contribution to the development of the electromagnetic theory.

Your gathered information will be useful in accomplishing the first activity.

Activity 1

How it came about...

The Electromagnetic Wave Theory

(Adapted from APEX Physics LP Chapter 3 Lesson 3: Student Activity 3a: The Electromagnetic Theory)

Objectives:

- Match the scientists with their contributions to the development of the electromagnetic theory.
- Make comic strips of the scientists' contributions.

Materials:

- 1 white cartolina
- 1 marker pen
- 1 pencil with eraser
- coloring materials (optional)

Procedure:

- I. Match the scientists given below with their contributions.

Scientists	Contributions
_____ 1. Ampere	a. Contributed in developing equations that showed the relationship of electricity and magnetism
_____ 2. Faraday	b. Showed experimental evidence of electromagnetic waves and their link to light
_____ 3. Hertz	c. Demonstrated the magnetic effect based on the direction of current
_____ 4. Maxwell	d. Formulated the principle behind electromagnetic induction.
_____ 5. Oersted	e. Showed how a current carrying wire behaves like a magnet

- II. Using the information you gathered previously, make a concept web/ comic strips of the contributions of the following scientists.

- A. Ampere
- B. Faraday
- C. Hertz
- D. Maxwell
- E. Oersted

Guide Questions:

- Q1. What new insights/learning did you get about our natural world?
How did it change your view about light?

You are about to explore the unknown world of EM spectrum. Read and research for more scientists who made significant contributions in the development of the study on the EM spectrum.

The Electric and Magnetic Fields Together

Accelerating electrons produce electromagnetic waves. These waves are a combination of electric and magnetic fields. A changing magnetic field produces an electric field and a changing electric field produces a magnetic field. As accelerated electrons produce an electric field of a wave, the varying electric field produces the wave's magnetic field. Both the electric field and the magnetic field oscillate perpendicular to each other and to the direction of the propagating wave.

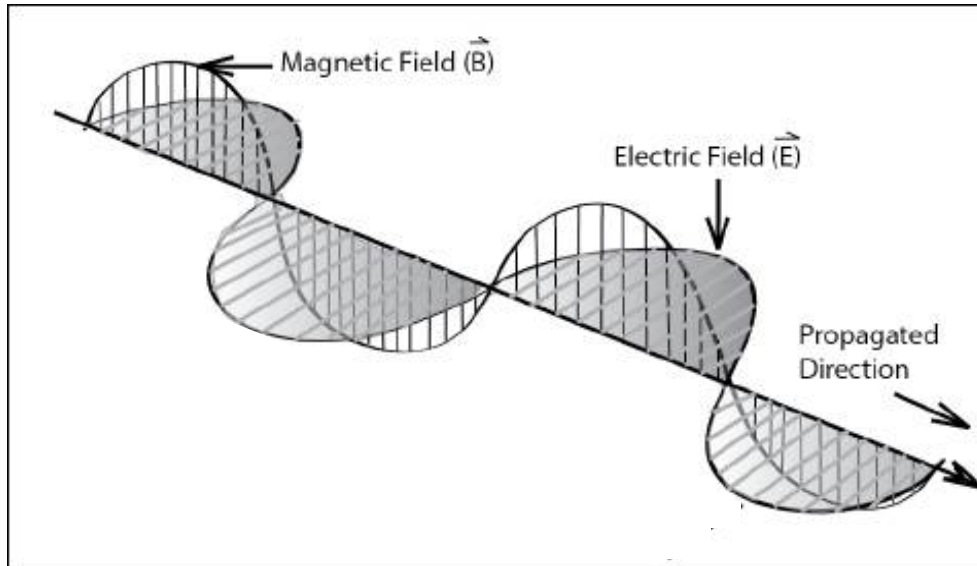


Figure 1. Electromagnetic Wave

All electromagnetic waves can travel through a medium but unlike other types of waves, they can also travel in vacuum. They travel in vacuum at a speed of 3×10^8 m/s and denoted as c , the speed of light. The wave speed, frequency, and wavelength are related by the following equation:

$$v = \lambda f$$

where v is the wave speed, or c (speed of light) expressed in meters per second, the frequency f is expressed in Hertz and the wavelength λ is expressed in meters.

Since all the EM waves have the same speed and that is equal to the speed of light, as wavelength decreases, the frequency of the wave increases.

Through the years, the advancement on the knowledge about electromagnetic waves led us to a modern technological world.

Example Problems:

(Assume that the waves propagate in a vacuum.)

1. What is the frequency of radio waves with wavelength of 20 m?

$$\begin{array}{ll} \text{Given: } v = c = 3 \times 10^8 \text{ m/s} & v = c = \lambda f \\ \lambda = 20 \text{ m} & \mathbf{f = c/\lambda} \\ f = ? & = \frac{3 \times 10^8 \text{ m/s}}{20 \text{ m}} \\ & = 1.5 \times 10^7 \text{ Hz} \end{array}$$

2. What is the frequency of light waves with wavelength of 5×10^{-7} m?

$$\begin{array}{ll} \text{Given: } v = c = 3 \times 10^8 \text{ m/s} & v = c = \lambda f \\ \lambda = 5 \times 10^{-7} \text{ m} & \mathbf{f = c/\lambda} \\ f = ? & = \frac{3 \times 10^8 \text{ m/s}}{5 \times 10^{-7} \text{ m}} \\ & = 6 \times 10^{14} \text{ Hz} \end{array}$$

Check your understanding!

Are these statements true? If not, correct them.

1. Electromagnetic waves transfer energy through vacuum.
2. A wave is a disturbance that transfers energy.
3. Most EM waves are invisible and undetectable.

The Electromagnetic Spectrum

The electromagnetic spectrum is a continuum of electromagnetic waves arranged according to frequency and wavelength. It is a gradual progression from the waves of lowest frequencies to the waves of highest frequencies. According to increasing frequency, the EM spectrum includes: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. These waves do not have exact dividing region.

The different types of electromagnetic waves are defined by the amount of energy carried by/possessed by the photons. Photons are bundles of wave energy. The energy of a photon is given by the equation:

$$\mathbf{E = hf}$$

where h is the Planck's Constant and f is the frequency of the EM wave. The value of the Planck's constant is 6.63×10^{-34} joules per second.

From among the EM waves, the gamma rays have photons of high energies while radio waves have photons with the lowest energies.

With regards to wavelength, radio waves can be likened to the size of a football field while gamma rays are as small as the nuclei of an atom.

Figure 2 will give you a clearer idea of the characteristics of the electromagnetic waves as their sizes are compared with visible materials.

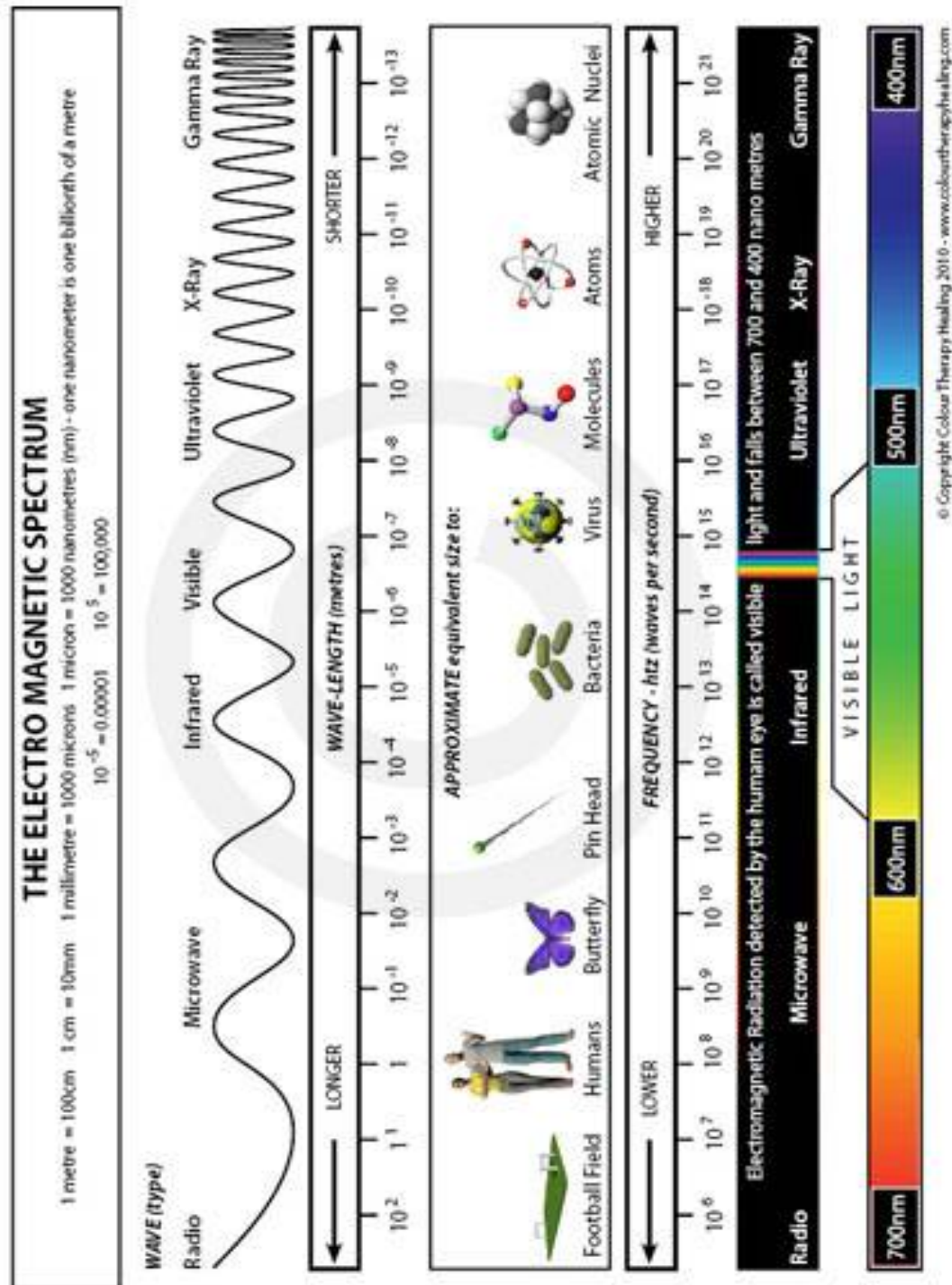


Figure 2. The Electromagnetic Spectrum

Table 1 shows the relative wavelength, frequency, and energy of each of the different types of electromagnetic waves.

Table 1. The electromagnetic waves' wavelengths, frequencies, and energies

EM Wave	Wavelength (m)	Frequency (Hz)	Energy (J)
Radio	$> 1 \times 10^{-1}$	$< 3 \times 10^9$	$< 2 \times 10^{-24}$
Microwave	$1 \times 10^{-3} - 1 \times 10^{-1}$	$3 \times 10^9 - 3 \times 10^{11}$	$2 \times 10^{-24} - 2 \times 10^{-22}$
Infrared	$7 \times 10^{-7} - 1 \times 10^{-3}$	$3 \times 10^{11} - 4 \times 10^{14}$	$2 \times 10^{-22} - 3 \times 10^{-19}$
Visible	$4 \times 10^{-7} - 7 \times 10^{-7}$	$4 \times 10^{14} - 7.5 \times 10^{14}$	$3 \times 10^{-19} - 5 \times 10^{-19}$
UV	$1 \times 10^{-8} - 4 \times 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{16}$	$5 \times 10^{-19} - 2 \times 10^{-17}$
X-ray	$1 \times 10^{-11} - 1 \times 10^{-8}$	$3 \times 10^{16} - 3 \times 10^{19}$	$2 \times 10^{-17} - 2 \times 10^{-14}$
Gamma-ray	$< 1 \times 10^{-11}$	$> 3 \times 10^{19}$	$> 2 \times 10^{-14}$

After learning about the wavelengths and frequencies of the different types of EM waves, try this next activity to learn more on other characteristics of EM waves.

Activity 2

Now you go! Now you won't!

Adapted from: <http://www.sciencebuddies.org/>

Objectives:

- Identify materials that can block or allow radio waves to pass through.
- Compare the speed of EM waves through different materials.

Materials:

Remote controlled (RC) Car and controller (both with new batteries)

Different materials to test:

- Aluminum foil
- Plastic wrapper
- Paper
- Wax paper
- Cotton
- Rubber gloves

A wide open space to test drive your RC car.

Procedure:

1. Wrap the antenna of the RC car and of the receiver with the first material you want to test, using several layers so that they are completely and securely covered.
2. Attempt to operate the RC car using the remote control. Does it work?

3. Use a stopwatch to time your test drive over a set distance.
4. Repeat steps 1 to 3 using other materials. Make sure to maintain the distance between the RC car and the remote control. Collect data in a table similar to the table below.

Set Distance: _____

Material	Does the car work? (Y/N)	Time of Travel	Observations
aluminum foil			
plastic wrapper			
paper			
wax paper			
cotton			
rubber glove			

5. Divide the materials into good and poor transmitters based on your results.

Guide Questions:

- Q2. Compare the time taken by the RC car to cover the same distance. Do some go faster or slower?
- Q3. What does this tell you about the transmission of the signal?
- Q4. What characteristic of EM waves did you discover?

Radio Waves

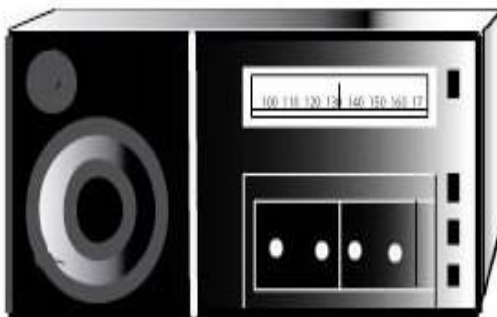


Figure 3. A radio

Radio waves have the longest wavelength in the electromagnetic spectrum. They are produced by making electrons vibrate in an antenna. They are used to transmit sound and picture information over long distances.

Radio waves have a very wide range of wavelengths. The whole region of the radio waves is divided into smaller regions or wavebands. Each waveband is allocated by law to a specific radio service. The wavelengths and frequencies of the different wavebands and their uses are shown in Table 2.

Table 2. Radio waves Frequencies

BAND	Frequency Range	Wavelength Range	Application
Extremely Low Frequency (ELF)	< 3 kHz	> 100 km	
Very Low Frequency (VLF)	3-30 Hz	10-100 km	
Low Frequency (LF)	30-300 kHz	1-10 km	Radio communication
Medium Frequency (MF)	300 kHz – 3 MHz	100m – 1 km	Radio communication (AM radio broadcasting)
High Frequency (HF)	3 – 30 MHz	10 – 100 m	Radio communication (AM radio broadcasting)
Very High Frequency (VHF)	30 – 300 MHz	1 – 10 m	Radio communication (FM radio broadcasting) TV Broadcasting
Ultra High Frequency (UHF)	300 MHz – 3 GHz	10 cm – 1 m	Radio communication (FM radio broadcasting) TV Broadcasting
Super High Frequency (SHF)	3 – 30 GHz	1 – 10 cm	Radio communication Satellite Communication
Extremely High Frequency (EHF)	30 – 300 GHz	1mm – 1 cm	

Low frequency waves are suitable for communication over great distances. But the curvature of the earth limits the range to about 80 kilometers. To extend the range, a repeater is used. The repeater receives the signal and re-transmits it to the receiving station.

High frequency waves can be reflected by the ionosphere. This enables the waves to be transmitted over great distances.

Medium and high frequency waves are used for broadcasting by local radio stations. In a radio station, sound is converted by a microphone into patterns of electric current variations called audio-frequency (AF) signals. High frequency radio waves called radio-frequency (RF) carriers can be modulated to match the electronic signal. In amplitude modulation, the amplitude of the radio waves (RF carrier) changes to match that of the audio-frequency signal. This is used in standard broadcasting because it can be sent over long distances. Very high frequency waves provide a higher quality broadcasting including stereo sound. In this process, instead of the amplitude of the RF carrier, it is the frequency of the waves that changes to match that of the signal. This is called frequency modulation.

Try the next activity to learn about the production, transmission and reception of radio waves.

Activity 3

Sound check...

Adapted from: Littell, McDougal Science. Integrated Course 1, Teacher's edition. McDougal Littell, a division of Houghton Mifflin Company C79.

Objectives:

- Produce radio waves.
- Detect radio waves.

Materials:

- Two - 25 cm copper wire
- C or D battery
- electrical tape
- metal fork
- portable radio



Procedure:

1. Tape one end of the first wire to one end of the battery. Tape one end of the second wire to the other end of the battery.
2. Wrap the loose end of one of the wires tightly around the handle of the fork.
3. Turn on the radio to the AM band and move the selector past all stations until you reach static.

4. Hold the fork close to the radio. Stroke the free end of wire across the fork's prongs.
5. At a distance of 15 cm from the radio stroke again the free end of the wire across the forks' prongs.
6. Repeat step 5 at a distance 20 cm from the radio.

Guide Questions:

- Q5. What happens when you stroke the prongs with the wire?
- Q6. How does changing the position affect the results?
- Q7. What might be the cause when you sometimes hear static sound in your radio? What can be done to resolve it?

Activity 4

Then there was sound...

Adapted from: APEX Physics LP Chapter 3 Lesson 4: Student Activity 5: The Generation, Transmission, and Reception of Radio Waves

Objectives:

- Describe how radio waves are generated, transmitted, and received.
- Name the parts of the radio transmitter and receiver and give the functions of each part.

Materials:

- 2 sheets of Manila paper
- sticky tape or paste
- 2 envelopes containing a word or phrase written in color-coded pieces of paper:
 - light blue* —————→ *parts of the transmitter/receiver*
 - pink* —————→ *waves*
 - white* —————→ *linkages*

Procedure:

1. Open the envelope labeled transmitter. Arrange the strips of paper in the order at which carrier waves are produced and then transmitted.

Blue Strips

Oscillator, microphone, modulator, amplifier, broadcast antenna, receiver antenna

Pink Strips

Sound waves, carrier, audio, amplified modulated carrier wave, modulated radio

White strips

Are fed to the (2 pieces); Generates (2 pieces); Are picked up by; Are sent to the; Increase the energy of the carrier waves and become; Transform sound waves to electrical signal then to; Put out the modulated carrier waves and pass them to the...

2. Once you are already sure of the arrangement, paste the strips on the Manila paper, leaving gaps between them.
3. Draw arrows between strips of paper to show the route of the sound and carrier waves in the transmitter. Then choose the correct linkages.
4. Open the envelope labeled receiver and arrange the strips of paper on the other Manila paper according to how the transmitted waves are received.
5. Follow the same procedure as in steps 2 and 3.

Blue strips

tuner; receiver antenna; amplifier; demodulation; loudspeaker

Pink strips

frequency of the weak modulated carrier waves; sound signals and carrier waves; sound; sound

White strips

Passes the (3 pieces); Then to; Selects the; Converts sound signal to; Removes the carrier waves leaving only the; Increases the energy of.

6. Show the continuous transmission of waves through directional arrows.
7. Post your finished work on the board and explain.

Guide Questions:

- Q8. What common problems could arise during transmission and reception of radio waves? Explain the possible cause/s of those problems.

Microwaves

Microwaves have smaller wavelengths than radio waves. They are used in satellite communications, radar, television transmission and cooking.

Applications of Microwaves Satellite Communications

Microwaves can penetrate the atmosphere of the earth. This is the reason why they are used for satellite communications. Communication satellites travel around the earth at an altitude of 35, 000 km above the equator. They move at a speed of 11 300 km/h and revolve around the earth every 24 hours, the same rate as the rotation of the earth. This makes them appear to be stationary when seen on Earth. Antennae are mounted to point in fixed directions towards these satellites. Microwaves signals are transmitted by an antenna to a satellite which amplifies and re-transmits the signal to an antenna in other parts of the world. This is how we communicate with the rest of the world.



http://www.esa.int/Our_Activities/Navigation/Galileo_satellite_set_for_new_orbit

Figure 4. An orbiting satellite

Radar



<http://phys.org/news/2013-03-nasa-kaboom-experimental-asteroid-radar.html>

Figure 5. A radar

Microwaves have short wavelengths and are reflected by small objects. This property is used in radars. Radar is the acronym of radio detection and ranging. A radar system consists of an antenna, transmitter, and a receiver. The antenna whirls around continuously to scan the surrounding area. The transmitter sends out a narrow beam of microwaves in short pulses. A distant object reflects some of the signal back to the receiver. The direction to which the signal was received gives the direction of the object. The distance of the object can be calculated from the time lag between the transmitted pulse and the reflected pulse.



Figure 6. A Television set

Terrestrial Communication

Microwaves are used to transmit television news coverage from mobile broadcast vehicles back to the station. The news crew can also set up a small antenna to send signals to a communication satellite. This is how news are broadcasted and watched live around the world.

A cell phone is a radio transmitter and receiver that uses microwaves. Cellular phones depend on overlapping network of cells or areas of land several kilometres in diameter. Each cell has its tower that receives and sends microwave signals. The figure below will give you further understanding on the process.

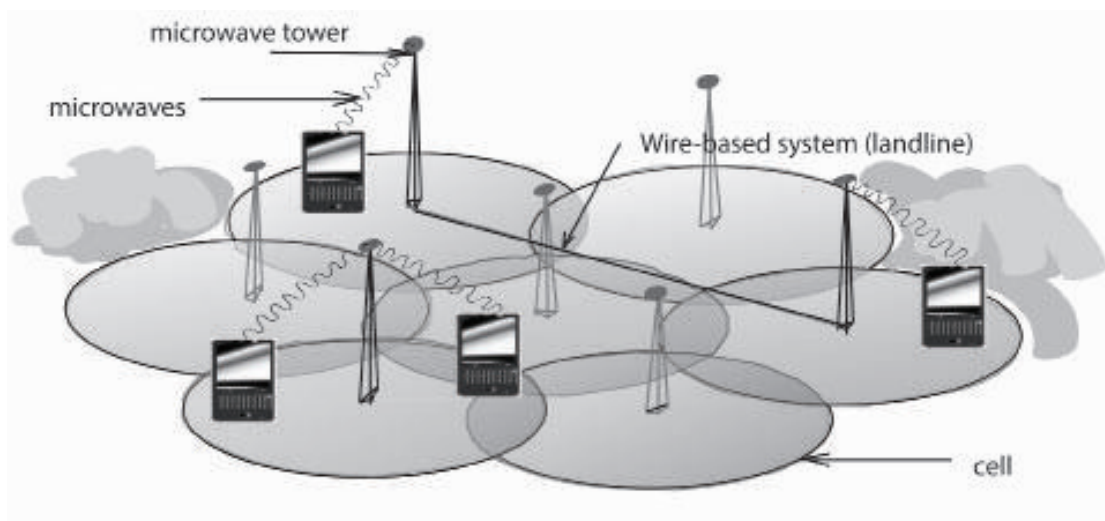


Figure 7. Transmission and reception of signals by a cellular phone

Microwave oven

In a microwave oven, foods absorb certain microwave frequencies very strongly. The microwaves penetrate the food being heated. It will agitate the water molecules within the food, thus creating molecular friction which then produces heat that will cook it.



http://linmabeltech.com/?attachment_id=885

Figure 8. A microwave oven

The next activity will give you an idea about the next type of EM wave, the infrared wave.

Activity 5

It's getting hotter

Objectives:

- Discover infrared and its effect.
- Explain the relationship between frequency and the energy carried by an EM wave.

Materials:

- prism
- 3 alcohol thermometers with blackened bulb
- sunlight

Procedure:

1. This experiment must be done in sunlight.
2. Take the initial readings of the three thermometers while in the shade. Record your readings in a data table similar to the table below.
3. Let the sunlight pass through the prism to split the sun's white light into its component colors.
4. Position one thermometer in the blue region.
5. Position another thermometer in the yellow region.
6. Position the last thermometer just below the red region.

7. Measure the temperature every after 2 minutes for 10 minutes.
8. Record the temperature readings in the three regions in the table below.

Time	Temperature Readings		
	1st Thermometer (Blue Region)	2nd Thermometer (Yellow Region)	3rd Thermometer (Red Region)
0			
2 minutes			
4 minutes			
6 minutes			
8 minutes			
10 minutes			

Guide Questions:

- Q9. Did you see any trend? Explain if there is any.
- Q10. What did you notice about the temperature readings?
- Q11. In which region have you recorded the highest temperature after 10 minutes?
- Q12. What do you think exists just beyond the red part of the spectrum?
- Q13. Discuss any other observations or problems.

Infrared

Infrared radiation lies beyond the red end of the visible light. It is emitted by all objects. The amount and wavelength of radiation depend on temperature. Below 500oC, an object emits only infrared radiation. Above 500oC, an object glows and emits both infrared and some visible light.

Our bodies radiate infrared and under infrared camera or a night vision goggle, our images appear in variety of colors. The differences in color determine the differences in temperature. For example, shades of blue and green indicate regions of colder temperature; and red and yellow indicate warmer temperature.

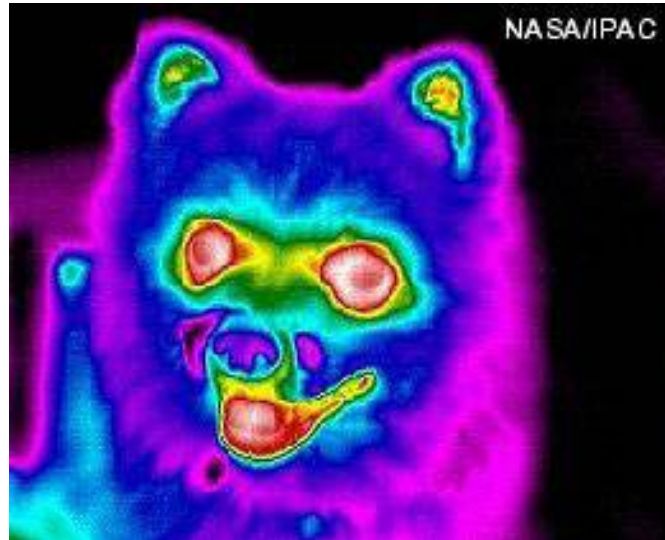


Figure 9. Infrared image of a dog

In Figure 9, the dog is covered with thick coat of fur that prevents the heat generated by the dog's body from escaping. Notice that the dog's nose is cold while the eyes and mouth areas are warm.

The following are some useful applications of IR radiation:

1. Infrared photographs taken from a satellite with special films provide useful details of the vegetation on the Earth's surface.
2. Infrared scanners are used to show the temperature variation of the body. This can be used for medical diagnosis.
3. Infrared remote controls are used in TVs, video, cassette recorders, and other electronic appliances.
4. Some night-vision goggles use IR.
5. Some autofocus cameras have transmitter that sends out infrared pulses. The pulses are reflected by the object to be photographed back to the camera. The distance of the object is calculated by the time lag between the sending and receiving of pulses. The lens is then driven by a built-in motor to adjust to get the correct focus of the object.

The Visible Spectrum

When white light passes through a prism, it is separated into its constituent colors: the red, orange, yellow, green, blue, indigo and violet. These colors do not distinctly separate but they continuously change from red to violet. Red color has the longest wavelength from among these colors and violet has the shortest.

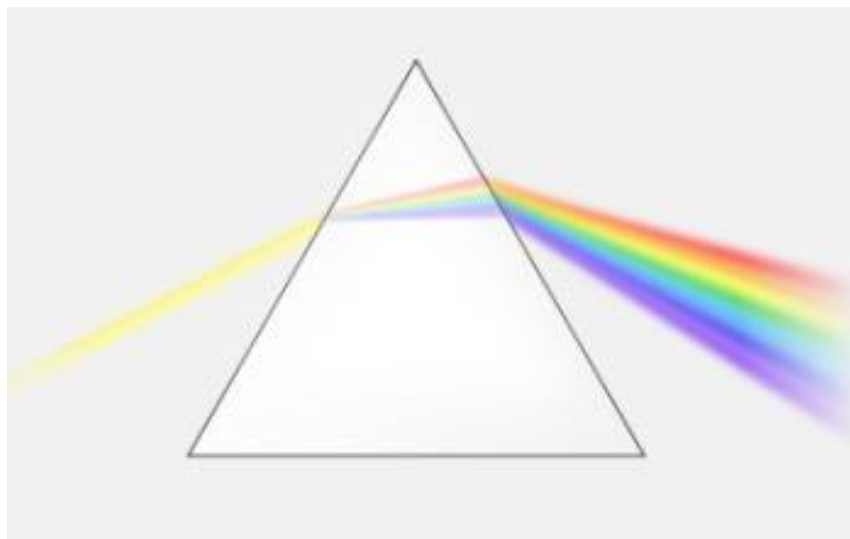


Figure 10. The Visible Spectrum

Our eyes are sensitive to electromagnetic waves of wavelengths that ranges from 4×10^{-7} m to 7×10^{-7} m. This is the range of wavelengths of white light. Thus, the spectrum of white light is therefore called the visible spectrum. Table 3 shows the wavelengths of the different colors that constitute the white light.

Table 3. The Wavelength of the Different Colors of Light

Color	Wavelength (nm)
Violet - Indigo	390 to 455
Blue	455 to 492
Green	492 to 577
Yellow	577 to 597
Orange	597 to 622
Red	622 to 700

The next activity introduces the next part of the electromagnetic spectrum. Perform this activity to have a deeper understanding about this kind of EM wave. This activity should be done early in the morning so as to expose the material throughout the day.

Activity 6

Screen the UV out

Objectives:

- Block UV rays of the sun.
- Discover the effects of UV rays.

Materials:

- Ziploc snack bag
- newspaper
- sunscreen/sunblock
- black construction paper
- permanent marker

Procedure:

1. Cut a piece of newspaper to fit snugly inside a Ziploc snack bag.
2. Outside the snack bag, draw two lines with a marker dividing the bag into three equal parts from the top of the bag to the bottom.
3. Apply a thin coat of sunscreen in the leftmost part.
4. Cover the middle part with black construction paper.
5. The right part should be left fully exposed.
6. Place the snack bags in a place fully exposed to sunlight.
7. Recover the snack bags in the afternoon.

Guide Questions:

Q14. How does the newsprint vary in the three divisions of the newspaper?

Q15. What does this indicate?

Q16. How does this realization impact to your personal life?

Extension Activity: For a more noticeable result, continue exposing the material for several days.

Perform the same activity during a cloudy day or inside the house. Observe and compare the degree of effect to that during a bright sunny day.

Ultraviolet Radiation

Ultraviolet radiation lies just beyond the violet end of the visible spectrum. Ultraviolet waves have shorter wavelengths than the visible light and carry more energy.

Some Uses of UV Radiation

The sun is our main source of ultraviolet radiation but there are also artificial sources of UV light. Ultraviolet radiation in UV lamps are used by banks to check the signature on a passbook. The signature is marked on the passbook with fluorescent ink. It becomes visible when viewed under an ultraviolet lamp. These lamps are also used to identify fake banknotes.

Ultraviolet radiation is also used in sterilizing water from drinking fountains. Some washing powder also contains fluorescent chemicals which glow in sunlight. This makes your shirt look whiter than white in daylight.

Ultraviolet radiation in sunlight produces vitamin D in the skin and gives us tanning effect. But since UV rays have high energy, it could be harmful to some extent. It could burn the skin and hurt our eyes. Overexposure to UV radiation may cause skin cancer. Suntan or sunscreen lotions serve as filters to protect the body from ultraviolet radiation.

X-rays

X-rays come just after the ultraviolet rays. They are of shorter wavelength but carries higher energy than the UV.



Figure 11. An X-ray film

X-rays are produced using an X-ray tube. They are emitted when fast moving electrons hit a metal target. X-rays were discovered by Wilhelm Conrad Roentgen in 1895.

Long wavelength X-rays can penetrate the flesh but not the bones. They are used in X-ray photography to help doctors look inside the body. They are useful in diagnosing bone fractures and tumors.

Short wavelength X-rays can penetrate even through metals. They are used in industry to inspect welded joints for faults.

All X-rays are dangerous because they can damage healthy living cells of the body. This is the reason why frequent exposure to X-rays should be avoided. Too much exposure to X-rays can damage body tissues and can cause cancer.

Gamma Rays

Gamma rays lie at the other end of the electromagnetic spectrum. They are shortest in wavelength and highest in frequency. They carry the highest amount of energy, thus, they are more dangerous. Gamma rays are emitted by stars and some radioactive substances. They can only be blocked with lead and thick concrete.

Gamma rays are very strong that they can kill living cells. Gamma rays are used to treat cancer through the process called radiotherapy. They are also used for sterilization of drinking water.

V. Summary/Synthesis/Feedback

- A wave is a disturbance that transfers energy.
- James Clerk Maxwell formulated the Electromagnetic Wave Theory which says that an oscillating electric current should be capable of radiating energy in the form of electromagnetic waves.
- Heinrich Hertz discovered the Hertzian waves which is now known as radio waves.
- Hertz is the unit used to measure the frequency of waves.
- Electromagnetic (EM) waves have unique properties.
 - ▶ EM waves can travel through a vacuum.
 - ▶ EM waves travel at the speed which is constant in a given medium and has a value of $c = 3.0 \times 10^8$ m/s in vacuum.
 - ▶ EM waves are disturbances in a field rather than in a medium.
 - ▶ EM waves have an electric field that travels perpendicular with the magnetic field.
 - ▶ EM waves form when moving charged particles transfer energy through a field.
- Most EM waves are invisible to the eye but detectable. Only the visible light is seen by humans.
- Waves in the EM spectrum include the following from the longest wavelength to the shortest wavelength.
 - ▶ Radio waves
 - ▶ Microwaves
 - ▶ Infrared waves
 - ▶ Visible light
 - ▶ Ultraviolet
 - ▶ X-rays
 - ▶ Gamma rays

The order also shows the increasing frequency and energy of the EM waves.

- The waves in the various regions in the EM spectrum share similar properties but differ in wavelength, frequency, energy, and method of production.
- The regions in the EM spectrum have various uses and applications as follows:

EM Wave	Applications / Uses
Radio waves	Radio and television communication
Microwaves	Satellite television and communication
Infrared waves	Remote control, household electrical appliances
Visible light	Artificial lighting, optical fibers in medical uses, screen of electronic devices
Ultraviolet	Sterilization, Fluorescence
X-rays	Medical use, engineering applications
Gamma rays	Medical treatment

- Each type of EM wave poses a certain degree of risk and danger to people and environment.

VI. Summative Assessment

A. Multiple Choice. Choose the letter of the correct answer.

- Which electromagnetic wave carries more energy than the others?
 - microwaves
 - radio waves
 - UV radiation
 - visible light
- What electromagnetic wave is sometimes called heat rays?
 - gamma rays
 - infrared
 - radio waves
 - visible light
- What is the frequency range of UV radiation?
 - $3.5 \times 10^9 - 3 \times 10^{11}$ Hz
 - $3.5 \times 10^{11} - 3 \times 10^{14}$ Hz
 - $7.5 \times 10^{14} - 3 \times 10^{16}$ Hz
 - $7.5 \times 10^{16} - 3 \times 10^{19}$ Hz
- What is the range of frequencies are our eyes sensitive to?
 - $3 \times 10^9 - 3 \times 10^{11}$ Hz
 - $3 \times 10^{11} - 4 \times 10^{14}$ Hz
 - $4 \times 10^{14} - 7.5 \times 10^{14}$ Hz
 - $7.5 \times 10^{14} - 3 \times 10^{16}$ Hz
- What is the wavelength of the wave with a frequency of 3×10^9 Hz?
 - 1.0×10^{-1} m
 - 1.0×10^1 m
 - 1.0×10^{-2} m
 - 1.0×10^2 m

B. Below are the applications of electromagnetic waves. State the type of electromagnetic wave used in each application.

- Satellite communications
- Texting
- TV broadcasting
- Radar
- Checking bankbook signature

C. Answer the following questions briefly.

1. Describe the mathematical relationship between frequency and wavelength.
2. What is the function of a tower in cell phone operation?
3. What does a radio transmitter do?
4. How can infrared radiation be detected if cannot be seen?
5. Why are high frequency electromagnetic waves like gamma rays harmful to living things?

Glossary of Terms

Electromagnetic wave	a disturbance in a field that carries energy and does not require a medium to travel
Frequency	number of cycles a wave completes in one second; expressed in Hertz
Radar	short for radio detecting and ranging. A way of detecting aircrafts and ships from a distance and estimating their locations
Radio Receivers	receives radio waves and convert them back to sounds
Radio Transmitter	attaches information to the radio signal by modulating it
Wavelength	the distance measured from one crest of a wave to the next crest or from one through to the second through

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Unit 2
MODULE**3****LIGHT: MIRRORS &
LENSES****I. Introduction**

In the previous module, you learned about electromagnetic spectrum. You gained an understanding of the different electromagnetic waves and their benefits. One of the most common among these electromagnetic waves is the visible light.

In this module, you will study two of the properties of visible light - reflection and refraction. A closer look into these properties will be done through different observable examples and experimentations using mirrors and lenses. As you walk through the pages of this module, you will be able to use the laws of reflection and refraction in order to describe and explain how images are formed by mirrors and lenses. You will also be able to solve problems pertaining to the position and magnification of images formed by mirrors and lenses.

One of the thrusts of this module is to make you aware of the purposes of the different types of mirrors and lenses so you can select the right type of mirrors and lenses that you can use in your daily lives.

At the end of Module 3, you will be able to answer the following questions:

1. How do the laws of reflection and refraction explain the functions of some optical instruments?
2. How does changing the location of the object from the lens/mirror affect the image formed?
3. How does changing the focal length of the lens/curved mirror affect the image formed?

II. Learning Competencies/Objectives

1. Predict the qualitative characteristics (location, orientation, type, and magnification) of images formed by plane and curved mirrors and lenses.
2. Determine the quantitative characteristics (location, orientation, type, and magnification) of images formed by plane and curved mirrors and lenses.
3. Distinguish between converging and diverging mirrors and lenses.
4. Apply ray diagramming techniques in describing the characteristics and positions of images formed by mirrors and lenses.
5. Derive the mirror and lens equations.
6. Identify ways in which the properties of mirrors and lenses determine their use in optical instruments (e.g., cameras and telescopes).

III. Pre-Assessment

Directions. Choose the letter of the correct answer.

1. You see the reflection of the clock without numbers in your plane mirror. The image formed by the hands of the clock shows the time of 3:30. What is the real time?
 - a. 3:30
 - b. 8:30
 - c. 9:30
 - d. 10:30
2. How much larger will your classroom seem to appear if the entire two adjacent walls of your classroom consist of plane mirrors?
 - a. 2x larger
 - b. 3x larger
 - c. 4x larger
 - d. can't be determined
3. Where is the image located if an object is 30 cm in front of convex mirror with a focal length of 20 cm?
 - a. Between F and V
 - b. Between C and F
 - c. In front of the mirror
 - d. Can't be determined

4. What is the distance of your image from you if you stand 1.5m in front of a plane mirror?
 - a. 1.5 m
 - b. 2.0 m
 - c. 3.0 m
 - d. 4.5 m

5. Zed stands 1.5-m tall in front of a plane mirror. What is the height of his image?
 - a. 4.5 m
 - b. 3.0 m
 - c. 2.0 m
 - d. 1.5 m

6. A light ray, traveling parallel to a concave mirror's axis, strikes the mirror's surface. The reflected ray _____.
 - a. passes through the mirror's focal point
 - b. again travels parallel to the mirror's axis
 - c. travels at right angles to the mirror's axis
 - d. passes through the mirror's center of curvature

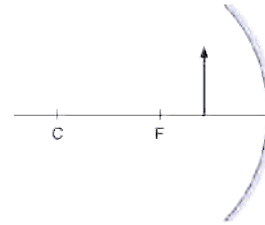
7. An object is placed between a concave mirror and its focal point. What is the type and orientation of the image formed?
 - a. virtual and inverted
 - b. real and inverted
 - c. virtual and erect
 - d. real and erect

8. What kind of mirror is used in automobiles and trucks to give the driver a wider area and smaller image of traffic behind him?
 - a. Plane mirror
 - b. Convex mirror
 - c. Concave mirror
 - d. None of the above

9. What type of mirror do dentists usually use to see clearly the images of our teeth?
 - a. Plane mirror
 - b. Convex mirror
 - c. Concave mirror
 - d. None of the above

10. When a small object is placed on the principal axis of a concave mirror between the focus and the mirror (as in the figure below), the image formed is _____.

- a. erect, magnified, and virtual
- b. inverted, magnified, and real
- c. inverted, reduced, and real
- d. erect, reduced, and real



11. A white sheet of paper cannot act as mirror because it _____ the rays of light.

- a. diffracts
- b. diffuses
- c. interferes
- d. refract

12. You see your face clearly if you look down on a pool of still water. Which one of the following statements gives the best explanation for this observation?

- a. Light entering the water is dispersed.
- b. Regular reflection of light happens on the surface of still water.
- c. Irregular reflection of light happens on the surface of still water.
- d. Light is reflected from the surface of water in different directions.

13. Where should the object be placed in front of a concave mirror to form a virtual and magnified image?

- a. At the focus
- b. At the center of curvature
- c. Between the focus and the vertex
- d. Between the center of curvature and focus

14. Which of the following is/are true of a concave mirror?

- I. It will never form a real image
- II. An inverted image will be formed if the object distance is greater than the focal length
- III. An object can be magnified if placed at f

- a. I only
- b. II only
- c. I and II
- d. I, II, and III

15. A light ray, traveling parallel to a concave lens' axis and strikes the lens, will refract and _____.
- pass through the lens' focal point
 - travel parallel to the principal axis
 - continue to travel in the same direction
 - travel at right angles to the principal axis
16. What kind of image is formed by concave lenses?
- always real
 - always virtual
 - could be real or virtual; depends on the distance of the object from the focal point
 - could be real or virtual, but always real when the object is placed at the focal point
17. Sun's rays are observed to focus at a point behind a lens. What kind of lens was used?
- Converging Lens
 - Diverging Lens
 - Focusing Lens
 - None of the above
18. This optical instrument uses 2 convex lenses to make a smaller object larger.
- Camera
 - Microscope
 - Oscilloscope
 - Telescope
19. Which of the following optical instruments will be used to produce a reduced and inverted image of a distant object?
- Camera
 - Projector
 - Microscope
 - Refracting Telescope
20. A photocopy "Xerox" machine produces an image that is of equal size as the object. Considering the location of an object in a convex lens, where is the object located or placed to produce an image that is of equal size to the object?
- At F'
 - At $2F'$
 - Between F' and V
 - Between $2F'$ and F'

IV. Reading Resources and Instructional Activities

Reflection of Light in Mirrors

Have you noticed the word “AMBULANCE” in an ambulance car? How is it written? Did you ever wonder why it is written that way? You will find the answers to these questions as you go through this module. Try the following activity to study one of the properties of light.

Activity 1

Mirror, mirror, on the wall...

Objectives:

- Determine the height, width, and the distance from the mirror of the image formed by plane mirrors.
- Compare the actual height, width and the distance from the mirror of the object with that of the image formed by plane mirror.

Materials:

- 1 (10 cm x 15 cm) plane mirror
- 1 graphing paper
- 10 one-peso coins
- modeling clay
- pen

Procedure:

1. Let the mirror stand vertically along a line on a graphing paper as shown in Figure 1. Use the modeling clay to support the plane mirror.

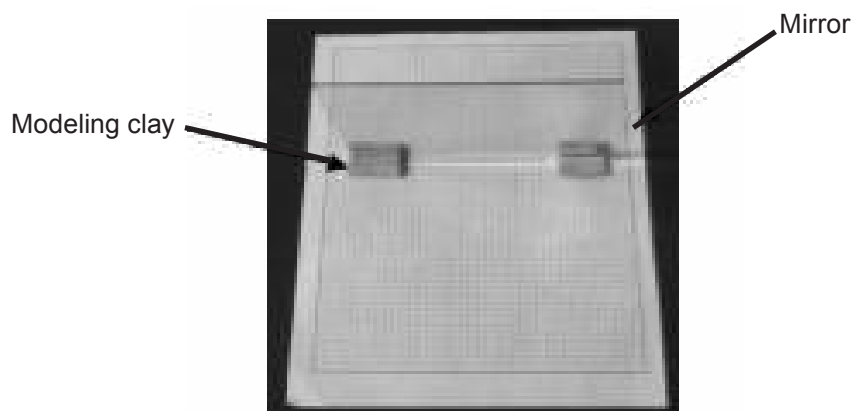


Figure 1. A Plane Mirror on a Graphing Paper.

2. Using a pen, make three (3) different marks along the intersections on the graphing paper in front of a mirror.

3. Measure the distance of each mark from the mirror by counting the number of parallel lines between the mark and the base of the plane mirror. Record your data in a table similar to Table 1 below.
4. Look at the images of the marks formed by the mirror. Measure the distance of each image from the mirror by counting the number of parallel lines between the image and the base of the mirror. Record this also in Table 1.

Table 1. Distance of the Object and Image from the Mirror

Mark	Number of Parallel Lines	
	Between the Mark and the Mirror	Between the Image and the Mirror
Mark 1		
Mark 2		
Mark 3		

Q1. Refer to Table 1, compare the distance (number of parallel lines) from the mirror of the object with that of the image.

5. Stack 10 pieces of one-peso coin in front of the plane mirror as in Figure 2. Using a ruler, measure the height and width of the stack of coins. Measure also the height and width of the image as seen on the mirror. Enter your measurements in a table similar to Table 2.

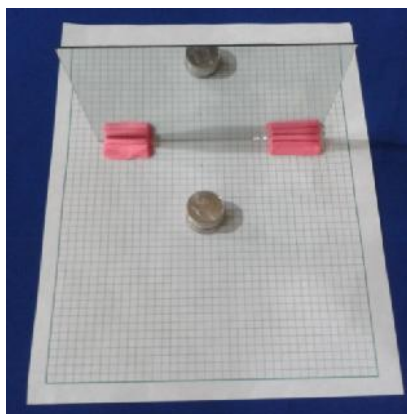


Figure 2. Stack of Coins In front of the Plane Mirror

Table 2. Height and Width of Object and Image

Description	Object	Image
Height (cm)		
Width (cm)		

Q2. How do the height and width of the object compare with the height and width of the image?

Reflection is the bouncing off of light rays when it hits a surface like a plane mirror. In the activity, you used plane mirrors and located the object distance, p and the image distance, q and found out that p is equal to q . In plane mirrors, the image appears as if it is behind the mirror but actually not, so the image is virtual. The value therefore of image distance, q is negative. The height of the image, h' in plane mirrors is always the same as the height of the object, thus its magnification, M is 1. The magnification formula is written below:

$$M = \frac{h'}{h} = \frac{-q}{p}$$

To learn more about reflection of light in plane mirrors, try the next activity. However, here are some important terms which you need to understand first.

Incident Ray. The ray of light approaching the mirror represented by an arrow approaching an optical element like mirrors.

Reflected Ray. The ray of light which leaves the mirror and is represented by an arrow pointing away from the mirror.

Normal Line. An imaginary line (labeled N in Figure 3) that can be drawn perpendicular to the surface of the mirror at the point of incidence where the ray strikes the mirror.

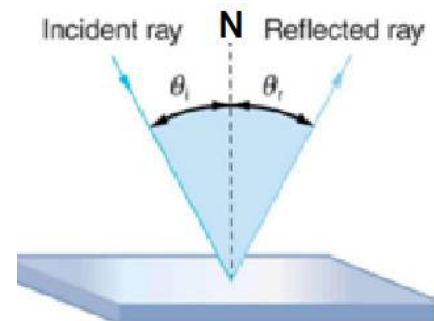


Figure 3. Reflection of a Light Ray on a Plane Mirror

The angle between the incident ray and the normal line is known as the angle of incidence, θ_i . The angle between the reflected ray and the normal is known as the angle of reflection, θ_r .

Activity 2

Angle of Incidence vs. Angle of Reflection

Objectives:

- Compare the angle of reflection and the angle of incidence.
- State one of the laws of reflection.

Materials:

- 1 plane mirror
- 1 low – frequency laser/ laser pen/laser pointer
- 1 paper protractor (see Appendix A)

Procedure:

1. Let the mirror stand vertically along the edge of the paper protractor as shown in Figure 4. Use the clay to support the plane mirror.

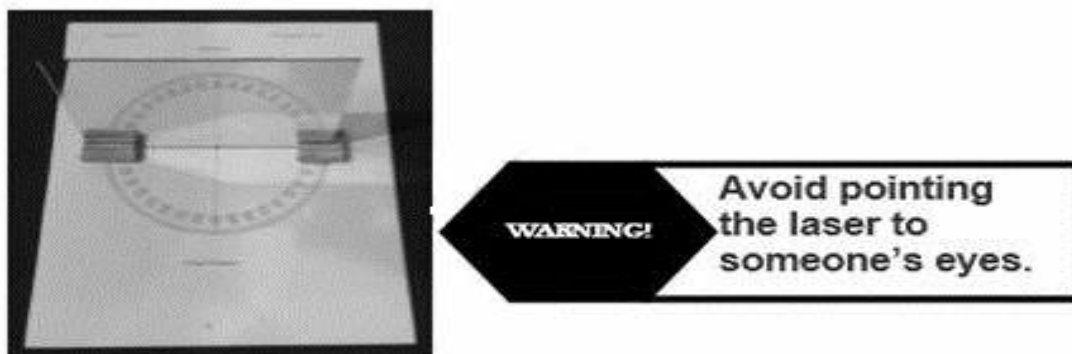


Figure 4. A Plane mirror on a paper protractor

2. Position the laser beam such that it hits the mirror at an angle of 10° with the normal line. Measure the angle between the reflected ray and the normal line. Record your measurement in a table similar to Table 3.
3. Make three trials and get the average.
4. Repeat steps 2 to 4 for angles 20° , 30° , 40° , and 50° . Enter all your measurements in Table 3.

Table 3. Angles of Incidence and Reflection

Angle of Incidence	Angle of Reflection			
	Trial 1	Trial 2	Trial 3	Ave.
10°				
20°				
30°				
40°				
50°				

Q3. How does the angle of incidence compare with the angle of reflection?

Q4. A periscope is an instrument for observation over, around or through an obstacle. Explain how light travels in a periscope. Diagram the light rays as these pass through the periscope.

In the activity, you found out that the angle of incidence (θ_i) is equal to the angle of reflection (θ_r).

In symbols:

$$\theta_i = \theta_r$$

This is one of the laws of reflection. The other law states that:

“The normal line, incident ray, and the reflected ray lie on the same plane.”

Reflection of light is employed significantly in making optical instruments like periscopes. Periscopes allow sea navigators in a submarine to see the surface of the water.

Try the next activity to further investigate the reflection of light in plane mirrors

Activity 3

Mirror Left-Right Reversal

Objectives:

- Describe the images formed by plane mirror.
- Show an understanding of reversal effect in mirrors by writing laterally inverted letters and words.

Materials:

- alphabet chart
- 1 plane mirror

Procedure:

1. Place the alphabet chart in front of the plane mirror. Identify all capital letters in the alphabet that can be read properly in front of the mirror.
2. Write at least 3 words (all in capital letters) that can be read properly both with a mirror and without a mirror in front of it.

- Q5. What are the letters of the alphabet (in capital) that can be read properly in front of a mirror?
- Q6. Think of words (in capital letters) that can be read properly both with a mirror and without a mirror. What are these words?
- Q7. Write the sentence below on a clear sheet of paper in such a way that it can be read properly in front of a mirror:

Honesty is the best policy.

Mirror Left-Right Reversal

Figure 5 shows a girl combing her hair with her left hand. However, in her image, you will notice that she is combing her hair with her right hand. This effect is known as the mirror left-right reversal. The left side of the object appears as the right side of the image and the right side appears as the left. This also explains why the word “AMBULANCE” in an ambulance car is flipped.



Figure 5. Mirror Left-Right Reversal

Do the next activity to learn more about reflection of light, this time using two plane mirrors. You will explore how the angle between two plane mirrors affects the number of images formed.

Activity 4

Who wants to be a Millionaire?

Objectives:

- Identify the relationship between the number of images formed and the angle between the two mirrors.
- Use the gathered data to derive the formula for determining the number of images formed when two mirrors are kept at a certain angle.

Materials:

- 1 one-peso coin
- 1 paper protractor
- 2 plane mirrors

Procedure:

1. Place two plane mirrors at an angle of 90° and place the one-peso coin between the mirrors as shown in Figure 6.



Figure 6. Two plane mirrors at 90 degree angle

2. Count the number of images formed. Record this in a table similar to Table 4 below.
3. Try to vary the angle between the mirrors.

Q8. What happens to the number of images formed as you vary the angle between the mirrors?

4. Set the angle between the mirrors to 60° . Count and record again the number of images formed.
5. Do again step 4 for angles 45° and 30° . Enter all the values in a table similar to Table 4

Table 4. Number of Images Formed

Angle	Number of Images
90°	
60°	
45°	
30°	

- Q9. Refer to Table 4. What relationship exists between the number of images formed and the angle between two mirrors?
- Q10. Use the data in Table 4 to derive the formula for determining the number of images formed by two mirrors?
- Q11. How should the mirrors be arranged such that an infinite number of images will be formed or seen?

Multiple Images

Have you seen a lot of money in your previous activity? Multiple images are formed by the reflection that happens when arranging at least two mirrors. Figure 7 shows three images of a toy car in front of two mirrors at 90°. The number of images, N , can be determined using the formula $N = (360/\text{angle between the mirror}) - 1$. Parallel mirrors on the other hand produce infinite number of images.

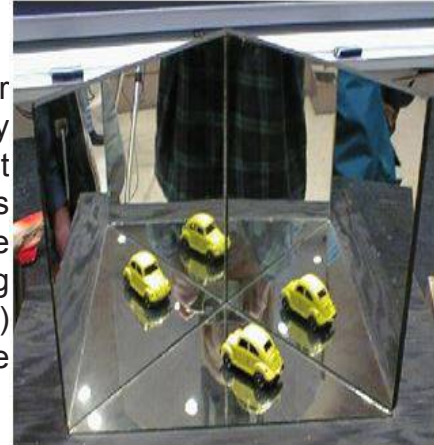
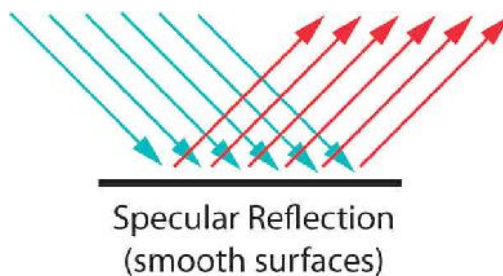


Figure 7. Multiple Images Formed by Two Plane Mirrors at 90° Angle

Reflection not only happens on a smooth surface like plane mirrors, but also happens on rough surfaces. This is why reflection is classified into two types.

Types of Reflection:

1. Specular/ Regular Reflection. This is a reflection of light on smooth surfaces such as mirrors or a calm body of water. An example of this is the image of the Mayon volcano on a calm water shown in Figure 8b.



(a)

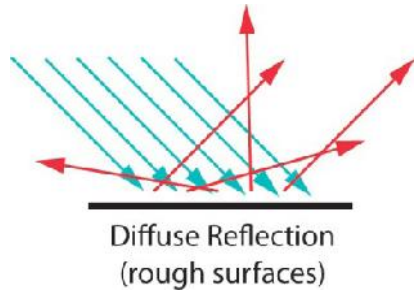


(b)

Sources: <http://www.orcagrowfilm.com/Articles.asp?ID=148> & http://www.wallpaperup.com/225284/landscape_nature_trees_mountain_Mount_Mayon_Philippines_Luzon_reflection_volcano_g.html

Figure 8. Specular Reflection. (a) Parallel light rays reflect in one direction (b) Mayon Volcano and its reflection on calm water

2. Diffused/Irregular Reflection. This is a reflection of light on rough surfaces such as clothing, paper, wavy water, and the asphalt roadway. An example of this is the image of a mountain on a wavy body of water as shown in Figure 9b.



(a)



(b)

Sources: <http://www.orcagrowfilm.com/Articles.asp?ID=148> & http://www.wallpaperup.com/29790/sunset_mountains_reflection.html

Figure 9. Diffused Reflection. (a) Parallel light rays reflect in different directions. (b) A mountain and its reflection on wavy water

The following lesson presents a specular/ regular reflection (because it happens on a smooth surface) but the reflected rays do not follow one direction. Why is that so? Let us find out.

Reflection on Spherical Mirrors

Look at your reflection on a shiny metal spoon. Is your reflection the same on the two surfaces of the spoon? How will you compare your reflection on the two surfaces of the spoon? This is a reflection on curved mirrors.

A curved mirror is a reflecting surface in which its surface is a section of sphere. There are two kinds of curved mirrors, the concave and the convex mirrors. A spoon is a kind of a curved mirror with both concave and convex surfaces.

Two Kinds of Spherical Mirrors:

1. The Concave Mirror

- It is a curved mirror in which the reflective surface bulges away from the light source.
- It is called Converging Mirror because the parallel incident rays converge or meet/intersect at a focal point after reflection.

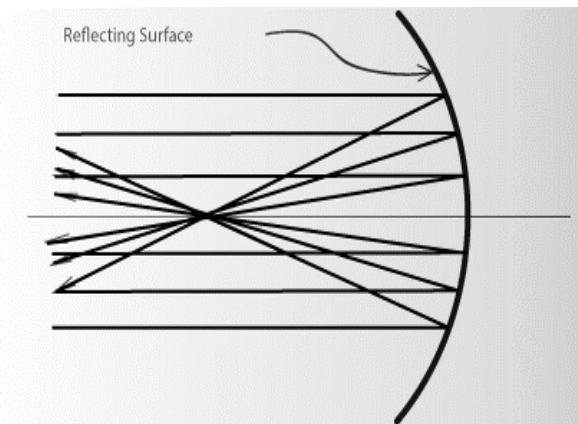


Figure 10. Parallel rays converge after reflection on a concave mirror

2. The Convex Mirror

- It is a curved mirror in which the reflective surface bulges towards the light source.
- It is called Diverging Mirror because the parallel incident rays diverge after reflection. When extending the reflected rays behind the mirror, the rays converge at the focus behind the mirror.



Figure 11. Parallel light rays diverge after reflection on a convex mirror

To know more about curved mirrors and how images are formed when objects are placed in front of them, try Activity 5 below.

Activity 5

Images Formed by Curved Mirrors

Objective:

Describe the location, size, and orientation of the images formed by curved mirrors.

Materials:

- Improvised optical bench apparatus
- Curved mirror (concave and convex)
- Mirror stand
- Screen or white cardboard
- Flashlight
- Meter stick
- Sheet of paper (colored black)

Procedure:

1. Cut a U-shaped object from a cartolina with a size that fits the glass cover of the flashlight. Attach the U-shaped object to the cover of the flashlight. Refer to Figure 12.



Figure 12. A U-shaped object attached to the flashlight

2. Position the concave mirror intact with the mirror stand at the center of two meter sticks as shown in Figure 13 below.

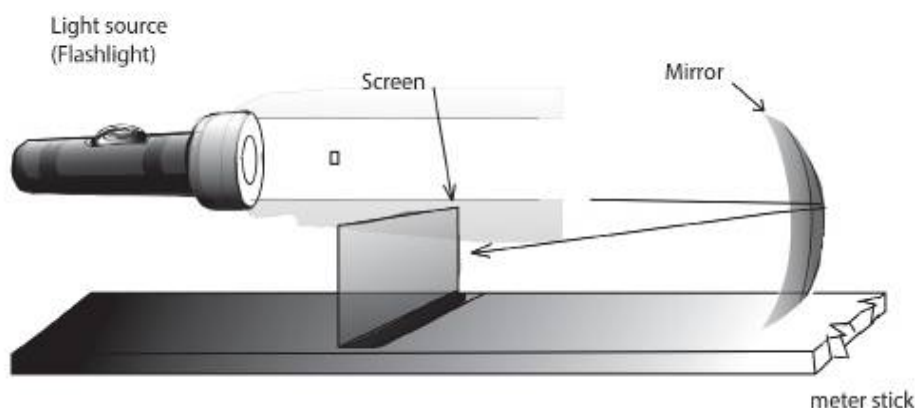


Figure 13. Set-up for Curved Mirror Experiment

3. Mark the improvised optical bench or meter sticks at the following points: the focal point F (see the specified focal length on label of the mirror), and the center of curvature, C which is equal to $2F$.
4. Place the flashlight at a distance farther than the center of curvature, C in front of the mirror.
5. Allow the light rays coming from the flashlight to strike the mirror.
6. Place a screen (a white cardboard) at a distance in front of the mirror. Move the screen in different distances in front of the mirror until a clear and sharp image of the U-shape is formed on the screen. Note the size and location of the image formed (on the screen).
7. Do the same thing in different location of the object by moving the flashlight at the center of curvature C , near the focal point, F at the focal point, and between the focal point and the mirror.

Q12. What happens to the size and location of the image when you bring the flashlight nearer to the concave mirror?

8. Repeat steps 3, 5, and 7 using a convex mirror. This time, you will not use the screen. Look through the convex mirror to see the image.

Q13. What is the generalization from the nature of images formed by convex mirror and concave mirror?

This activity is adapted from Lesson Plans in Science IV, Unit II Energy in the Environment, Activity 2.5 Images Formed by Curved Mirrors.

In Activity 5 using a concave mirror, you observed that images formed on the screen are inverted. Images formed on a screen, after reflection, are called real images because they are formed by the intersection of real reflected rays.

A virtual image, on the other hand, does not form on a screen because a virtual image is formed by the intersection of non-real rays.

Images Formed by Curved Mirrors

In locating the image formed in curved mirror graphically, three important points are considered. The following important points are enumerated below.

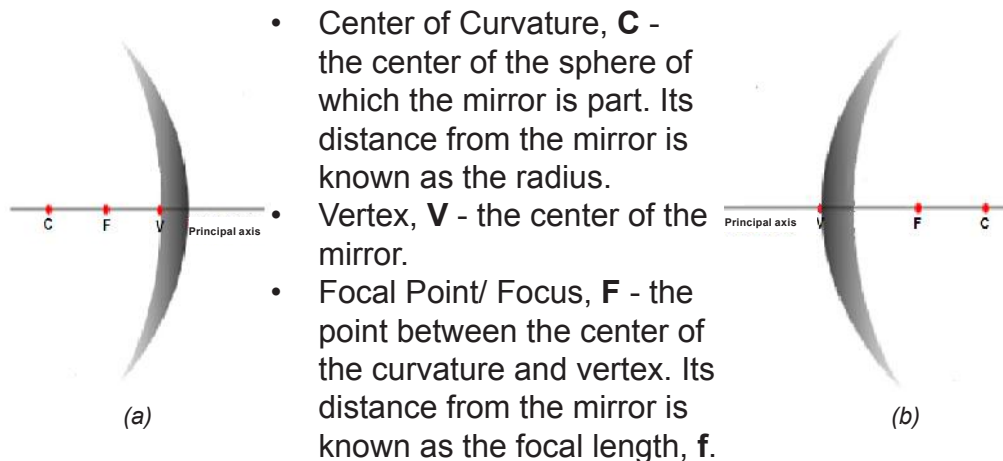
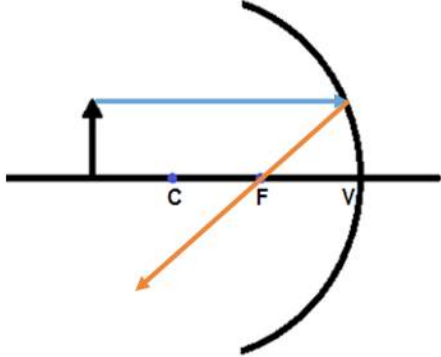
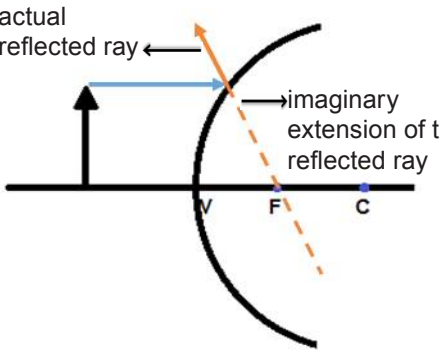
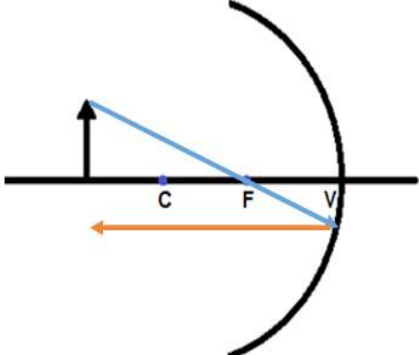
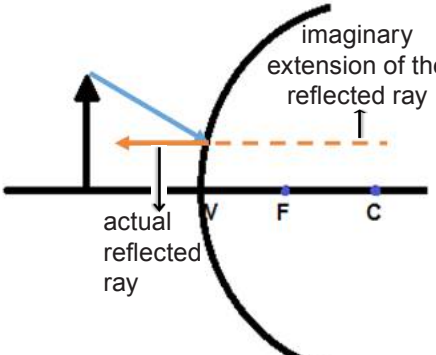


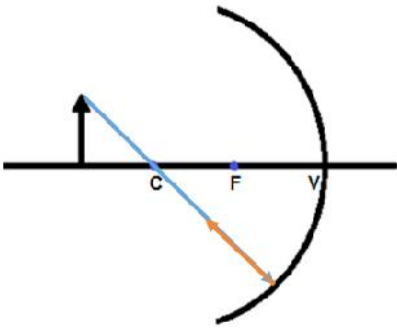
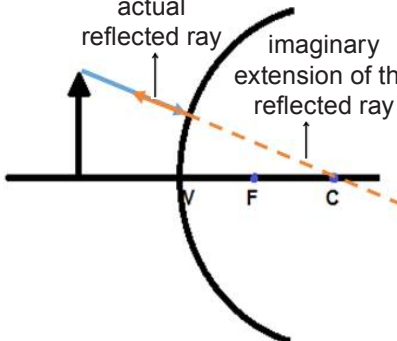
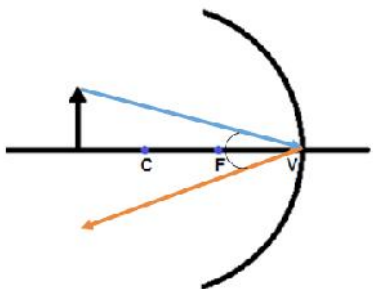
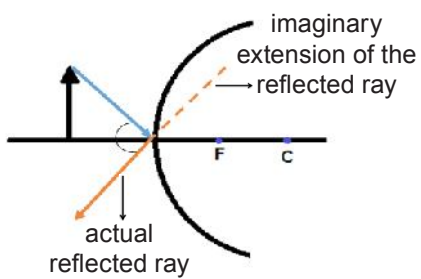
Figure 14. Curved Mirrors (a) Concave Mirror (b) Convex Mirror

The 'Four Principal Rays' in Curved Mirrors

Images formed in a curved mirror can be located and described through ray diagramming. The P – F ray, F – P ray, C – C ray, and the V ray are the 'Four Principal Rays' in curve mirrors. These rays, applied for concave and convex mirrors, are presented in Table 5.

Table 5. The 'Four Principal Rays' on Concave and Convex Mirrors

Concave Mirror (Converging Mirror)	Convex Mirror (Diverging Mirror)
 <p>1. <u>P – F Ray.</u> A ray of light parallel to the principal axis is reflected passing through the principal focus, F.</p>	 <p>1. <u>P – F Ray.</u> A ray of light parallel to the principal axis is reflected as if passing through the principal focus, F.</p>
 <p>2. <u>F – P Ray.</u> A ray of light passing through the focus, F is reflected parallel to the principal axis.</p>	 <p>2. <u>F – P Ray.</u> A ray of light directed towards the focus, F is reflected parallel to the principal axis.</p>

 <p>3. <u>C – C Ray.</u> A ray of light passing through the center of curvature, C reflects back along its own path.</p>	 <p>3. <u>C – C Ray.</u> A ray of light directed towards the center of curvature, C reflects back along its own path.</p>
 <p>4. <u>V Ray.</u> A ray of light directed to the vertex reflects at equal angle from the principal axis</p>	 <p>4. <u>V Ray.</u> A ray of light directed to the vertex reflects at equal angle from the principal axis.</p>

In determining the position and nature of the image graphically, the 'Four Principal Rays' are used. Ray diagramming is used in the graphical method of locating the image. The following are ray diagramming steps using the 'Four Principal Rays' in determining the position and the nature of the image of an object formed by concave mirror and convex mirror.

1. From the object, draw the first ray (P – F ray). From the same point on the object, draw the second (F – P ray), third (C – C ray), and fourth (V ray) rays.
2. The intersection of the four rays is the image point corresponding to the object point. For example, if you started diagramming from the tip of the arrow-shaped object, the intersection of the reflected rays is also the tip of the arrow-shaped image. Thus, you can determine completely the position and characteristics of the image.

3. For a convex mirror, light rays diverge after reflection and converge from a point that seems to be behind the mirror (virtual focus); but the procedure for locating images is the same as for concave mirror.

In the next activity, you will use the steps described above to locate and describe the images formed by concave and convex mirrors through graphical method. To do this, always start by drawing the curved mirror and its principal axis, then identify the F and C on the principal axis. Next is to draw the object then diagram the rays from the object.

Activity 6

Are you L-O-S-T after Reflection?

Objective:

Construct ray diagrams to determine the location, orientation, size, and type of images formed by curved mirror.

Materials:

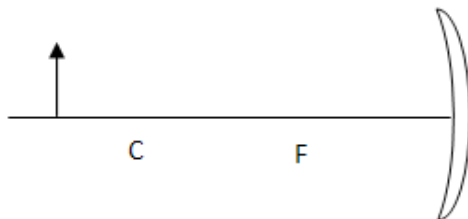
- Protractor and ruler
- Sheets of paper

Procedure:

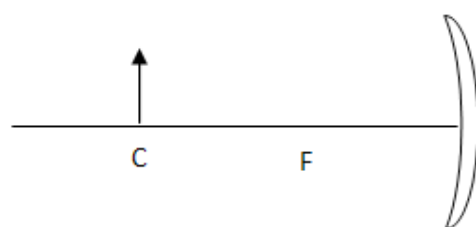
1. Using the protractor and the ruler, copy each of the diagrams (A – G) below on a separate sheet of paper. As much as possible, use the four principal rays to locate the image formed in a curved mirror.

Concave Mirror

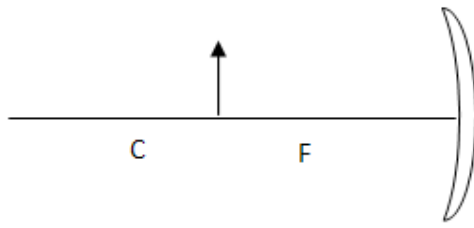
A.



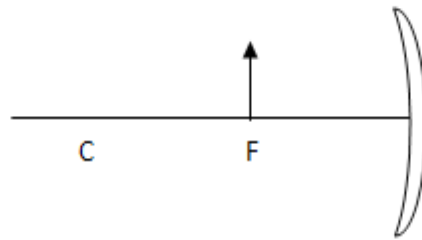
B.



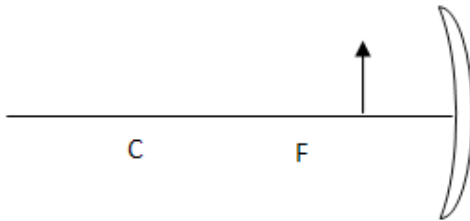
C.



D.

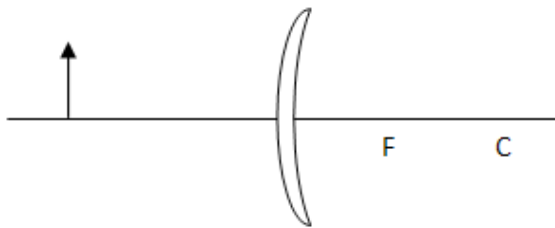


E.

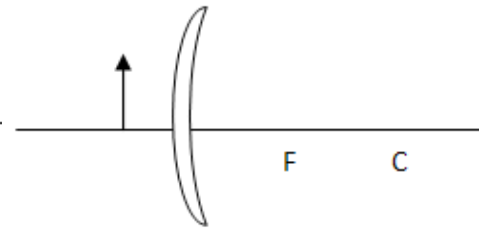


Convex Mirror

F.



G.



2. Use a table similar to Table 6 below to summarize the characteristics and location of the images formed.

Table 6. Location, Orientation, Size, and Type of Image Formed in Curved Mirrors

Location of Object	Image			
	Location	Orientation (upright or inverted)	Size (same, reduced or enlarged)	Type (real or virtual)
CONCAVE				
A. Farther than the Center of Curvature				
B. At the Center of Curvature				
C. Between the Center of Curvature and the Focal point				
D. At the Focal point				
E. Between the Focal point and the Center of the lens (Vertex)				
CONVEX				
F. Farther than C in front of the Mirror				
G. Between F and V in front of the Mirror				

Q14. Refer to Table 6. How does the location of the object affect the characteristics and location of the image formed in a concave mirror? Convex mirror?

Q15. What type of mirror do dentists usually use to clearly see the images of our teeth? Why?

Q16. What kind of curved mirror do you see in most of the department stores? Why do they use such kind of mirror?

This activity, which you have just performed is more detailed on the location, orientation, size, and type of the images formed. Did this activity in curved mirrors confirm your observations in the previous activity (Activity 5)?

The Mirror Equation

Ray diagrams provide useful information about the image formed, yet fail to provide the information in a quantitative form. Ray diagrams will help you determine the approximate location and size of the image, but it will not provide you with the numerical information about image distance and object size. To determine the exact location and size of the image formed in a curved mirror, an equation is needed. The following derivation shows the mirror equation using the Figure 15 below.

From the first and fourth rays, similar triangles are seen in the figure below.

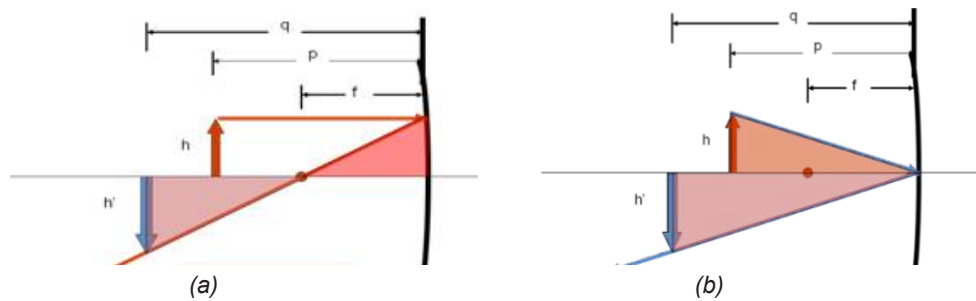


Figure 15. Similar Triangles Formed using the (a) first ray (P – F ray) and (b) fourth ray (V ray).

From the height of the object, h and the height of the image, h' shown in Fig. 15 (a), you can arrive at the first equation,

$$\frac{h'}{h} = \frac{q - f}{f} \quad \text{Equation 1}$$

Similarly, as shown in Fig. 15 (b), the second equation can be derived as

$$\frac{h'}{h} = \frac{q}{p} \quad \text{Equation 2}$$

Combining Equations 1 and 2, you will get

$$\frac{q - f}{f} = \frac{q}{p} \quad \text{Equation 3}$$

Rearranging Equation 3, you will arrive at

$$\frac{q}{f} - 1 = \frac{q}{p}$$

$$\frac{q}{f} = \frac{q}{p} + 1$$

$$\frac{1}{f} = \frac{q}{pq} + \frac{1}{q}$$

and finally,

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Mirror Equation

where: f = focal length or distance from the mirror and the focal point, F

p = distance of the object from the mirror

q = distance of the image from the mirror

The equation above, called **mirror equation**, applies to both concave and convex mirrors. However, for all location of objects in front of the convex mirror, the image always appears as if it is located behind the mirror. It is therefore considered that the value of image distance, q is negative. In the same manner, the focus, F in a convex mirror is located on the other side of the mirror (behind the mirror), thus, the focal length, f is also negative.

Sample Problem:

A 5.00-cm tall light bulb is placed at a distance of 45.0 cm from a concave mirror having a focal length of 10.5 cm. Determine the image distance and the image size.

Given:

height of the object, $h = 5.00$ cm

distance of the object, $p = 45.0$ cm

focal point, $f = 10.5$ cm

Find:

distance of the image, $q = ?$

height of the image, $h' = ?$

The mirror equation must be used to determine the distance of the image, q .

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$
$$\frac{1}{10.5 \text{ cm}} = \frac{1}{45.0 \text{ cm}} + \frac{1}{q}$$
$$\frac{1}{10.5 \text{ cm}} - \frac{1}{45.0 \text{ cm}} = \frac{1}{q}$$
$$\frac{45.0 \text{ cm} - 10.5 \text{ cm}}{(10.5 \text{ cm})(45.0 \text{ cm})} = \frac{1}{q}$$
$$q = 13.7 \text{ cm}$$

To determine the image height, the magnification equation is needed. Since three of the four quantities in the equation are known, the fourth quantity can be calculated.

$$\frac{h'}{h} = \frac{-q}{p}$$
$$\frac{h'}{5.00 \text{ cm}} = \frac{-13.7 \text{ cm}}{45.0 \text{ cm}}$$
$$h' = \frac{(5.00 \text{ cm})(-13.7 \text{ cm})}{45.0 \text{ cm}}$$
$$h' = -1.52 \text{ cm}$$

The negative value for image height indicates that the image is an inverted image.

Try solving this...

1. What is the image distance and image height if a 7.00-cm tall object is placed 30.0 cm from a concave mirror having a focal length of 10.0 cm?
2. A magnified, inverted image is located a distance of 30.0 cm from a concave mirror with a focal length of 15.0 cm. What is the object distance?

Sample Problem:

What is the focal length of a convex mirror that produces an image that appears 15.0 cm behind the mirror when the object is 27.5 cm from the mirror?

Given:

$$q = -15.0 \text{ cm}$$

$$p = 27.5 \text{ cm}$$

Find:

$$f = ?$$

To determine the focal length, f , the mirror equation will be used. Substitute and solve for f .

$$\begin{aligned}\frac{1}{f} &= \frac{1}{p} + \frac{1}{q} \\ \frac{1}{f} &= \frac{1}{27.5 \text{ cm}} + \frac{1}{-15.0 \text{ cm}} \\ \frac{1}{f} &= \frac{-15.0 \text{ cm} + 27.5 \text{ cm}}{(27.5 \text{ cm})(-15.0 \text{ cm})} \\ \mathbf{f} &= \mathbf{-33.0 \text{ cm}}\end{aligned}$$

The negative value for focal length confirms that the mirror used is a convex mirror.

Try solving this...

3. An object is placed 33.7 cm from the convex mirror with a focal length of 10.7 cm. Determine the image distance.
4. A 7.0-cm tall light bulb is placed a distance of 37.5 cm from a convex mirror having a focal length of -12.5 cm. Determine the image distance and the image size.

The Sign Conventions for Mirror

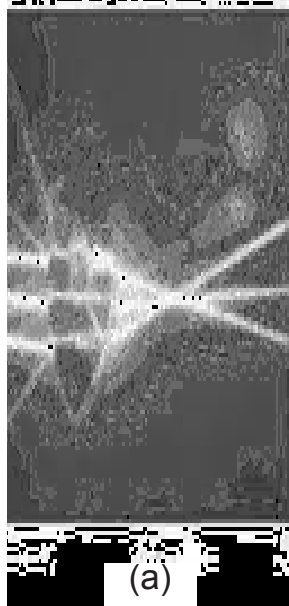
- f is positive (+) if the mirror is a concave mirror
- f is negative (-) if the mirror is a convex mirror
- q is (+) if the image is a real image and located on the object's side of the mirror.
- q is (-) if the image is a virtual image and located behind the mirror
- h' is (+) if the image is an upright image
- h' is (-) if the image is an inverted image

Refraction of Light in Lenses

You learned in Grade 8 that Refraction is the bending of light when it travels from one medium to another of different optical densities. The ancient Greeks used the concept of light refraction in their living like using a lens to focus light rays. A lens is a transparent material made of glass or plastic that refracts light rays and focuses (or appear to focus) them at a point.

Types of Lenses

1. Convex Lens



- It is thicker in the center than edges.
- It forms real images and virtual images depending on position of the object.
- It is also called Converging Lens because the light that passes through it tends to converge at a particular point called the focal point.

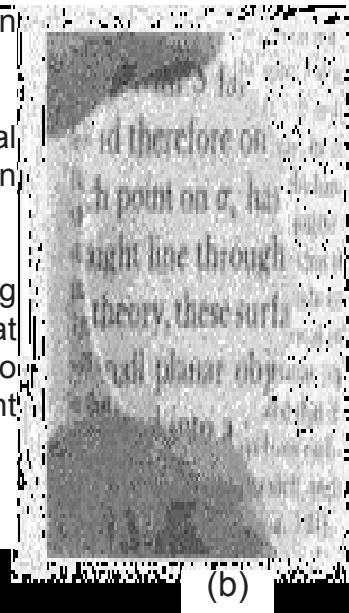
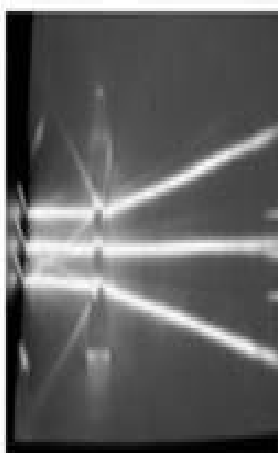


Figure 16. Convex Lens. (a) Parallel light rays converge after refraction. (b) A converging lens magnifying the words from a book

2. Concave Lens



(a)

- It is thicker at the edges and thinner in the center.
- It forms upright and reduced images.
- It is also called Diverging Lens because the light that passes through it tends to diverge at a particular point called the focal point.



(b)

Figure 17. Concave Lens. (a) Parallel light rays diverge after refraction. (b) A diverging lens demagnifying the words from a book.

Activity 7

YoU can be Magnified!

Objectives:

- Measure the focal length and linear magnification of a convex lens.
- Locate the image formed by convex lens.
- Describe the image formed by a convex lens.

Materials:

- convex lens or magnifying glass
- lens holder e.g. clay
- meterstick
- index card

Procedure:

1. Hold the convex lens under a ceiling light. A projection screen (e.g. the floor or the surface table) should be placed under the convex lens.
2. Move the convex lens up and down until a sharp image of the ceiling light is projected on the screen.
3. Measure the distance between the lens and the projection surface using a ruler.

Q17. What is the focal length of the convex lens?

Q18. How would you describe the image formed if a distant object is used?

4. Mount the convex lens on a clay. Draw a U-shaped object on an index card and mount the index card on another clay. Initially place the index card beside the zero (0) mark on the meter stick, and place the lens in front of the index card as shown in Figure 18a below:

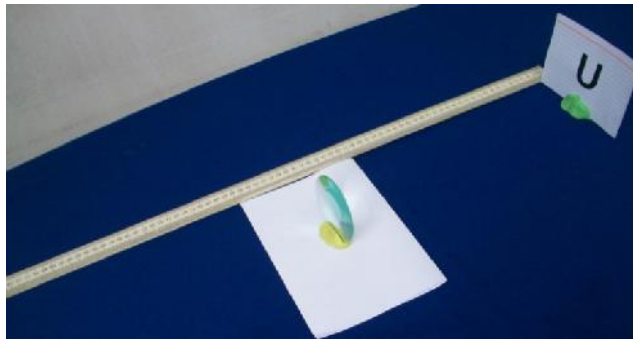


Figure 18a. Set-up for Lens Experiment

5. Look through the lens and move the lens until you can clearly see an enlarged and upright image of the U-shaped object as shown in Fig. 18b below.



Figure 18 b. Looking at the U-shaped Object through the Lens

6. Measure the distance between the convex lens and the card using a meter stick. Record your observation on the second column of a table similar to Table 7.
7. Measure the distance between the lens and your eye. Record your observation on the third column of a table similar to Table 7.
8. Move again the convex lens back and forth, until you can clearly see, this time, an enlarged and inverted image of the U-shaped object. Then, repeat steps 6 and 7.
9. Move again the convex lens so that you can clearly see a reduced and upside down image of the U-shaped object. Repeat steps 6 and 7.

Table 7. Distances from the Lens of Object and your Eye

Description of Image	Distance between the Object and the lens (cm)	Distance between the Eye and the lens(cm)
Enlarged and upright		
Enlarged and inverted		
Reduced and inverted		

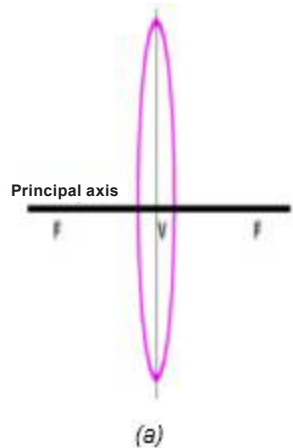
Q19. What kind of lenses are magnifying glasses? When a magnifying glass produces a sharp clear image, where is the object located in relation to the lens?

Q20. Where should a magnifying glass be placed to produce an enlarged and upright image, closer to the eye or nearer to the object? Why?

From the activity, you were able to determine the focal length of a lens. You were also able to measure the distance of the object and the image from the lens. These quantities are very significant in describing the image formed. Images formed by lenses can also be real or virtual. In Activity 7, using a convex lens, you observed that images are formed on the screen. Images formed on a screen, after refraction, are called real images because they are formed by the intersection of real refracted rays. A virtual image, on the other hand, does not form on a screen because a virtual image is formed by the intersection of non-real rays.

Images Formed by Lenses

In locating the image formed in lenses graphically, two important points are considered. The following important points are enumerated below.



- Vertex, V – The geometric center of the lens.
- Focal point/ Focus, F – A point where light rays converge (or appears to converge) when parallel light rays pass through a lens. Its distance from the vertex is called the focal length.

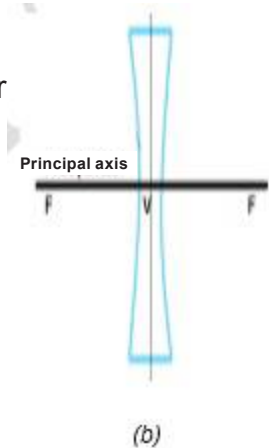
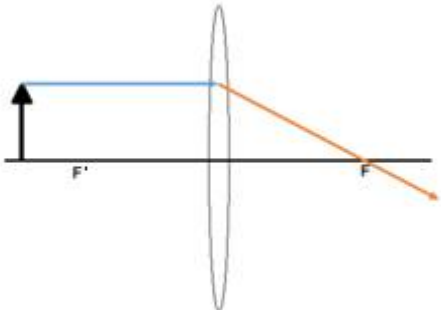
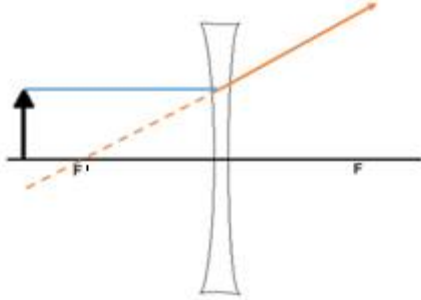


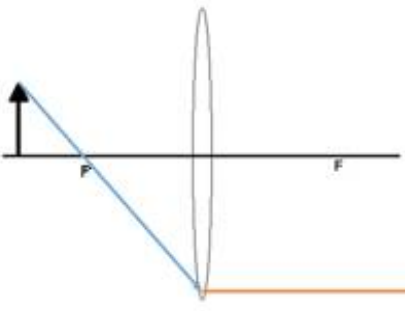
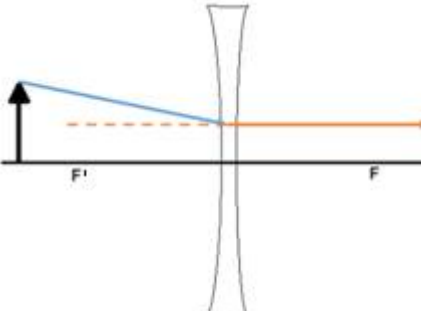
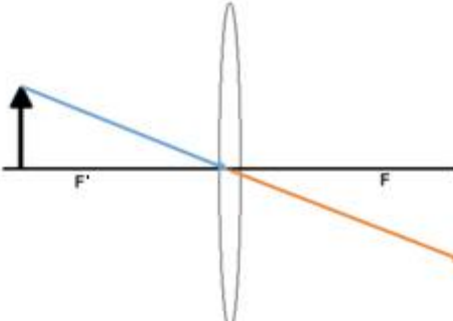
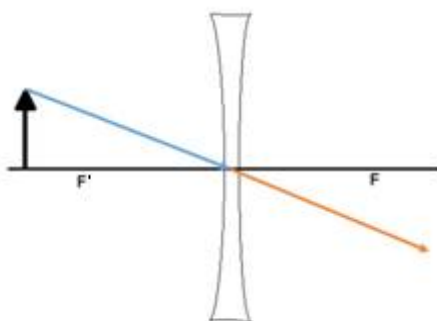
Figure 19. Lenses (a) Convex Lens (b) Concave Lens

The ‘Three Most Useful Rays’ in Lenses

Images formed in a lens can be located and described through ray diagramming. The following three most useful rays for convex and concave lenses are presented below.

Table 8. The Three ‘Most Useful Rays’ in Convex and Concave Lenses

Convex Lens (Converging Lens)	Concave Lens (Diverging Lens)
 <p>1. <u>P–F Ray</u>. A ray of light parallel to the principal axis is refracted passing through the principal focus, F behind the lens.</p>	 <p>1. <u>P–F Ray</u>. A ray of light parallel to the principal axis is refracted as if passing through the principal focus, F in front of the lens.</p>

 <p>2. <u>F–P Ray.</u> A ray of light passing through the focus, F in front of the lens is refracted parallel to the principal axis.</p>	 <p>2. <u>F–P Ray.</u> A ray of light directed towards the focus, F behind the lens is refracted parallel to the principal axis.</p>
 <p>3. <u>V Ray.</u> A ray of light passing through the exact center of the lens (Vertex) continue to travel in the same direction.</p>	 <p>3. <u>V Ray.</u> A ray of light passing through the exact center of the lens (Vertex) continue to travel in the same direction.</p>

To graphically determine the position and kind of the image formed, the ray diagram can be used. Consider the following steps using the three major rays described above:

1. From the object, draw the first ray (P–F ray). From the same point on the object, draw the second (F–P ray), and third (V ray) rays.
2. The intersection of the rays is the image point corresponding to the object point. For example, if you started diagramming from the tip of the arrow-shaped object, the intersection of the refracted rays is also the tip of the arrow-shaped image. Thus, you can determine completely the position and characteristics of the image.

3. For a concave lens, light rays diverge from a virtual focus; but the procedure for locating images is the same as for convex lenses.

In the next activity, you will use the steps described above to locate and describe the images formed by convex and concave lenses by graphical method. To do this, always start by drawing the lens and its principal axis, then identify the F and 2F on the principal axis. Next is to draw the object, then diagram the rays from the object.

Activity 8

Are you L-O-S-T after Refraction?

Objectives:

- Construct ray diagrams for lenses.
- Determine graphically the location, orientation, size, and type of image formed.
- Show graphically the changes in the image formed as an object's position is changed.

Materials:

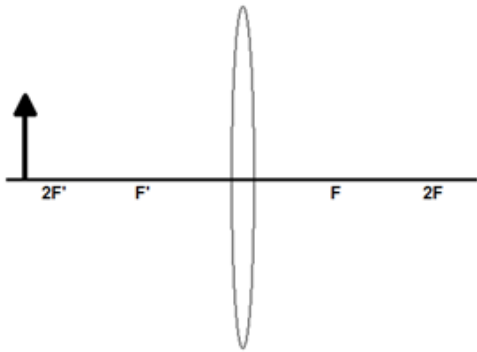
- paper
- ruler

Procedure:

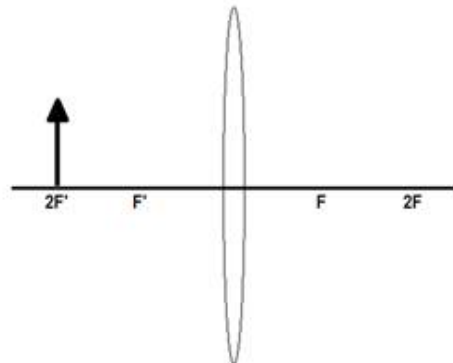
1. Copy each of the diagrams (A–H) below on a clear sheet of paper. Construct ray diagram using, as much as possible, the 'three most useful rays' for each of the following cases to determine the location, orientation, size, and type of the image.

Convex Lens

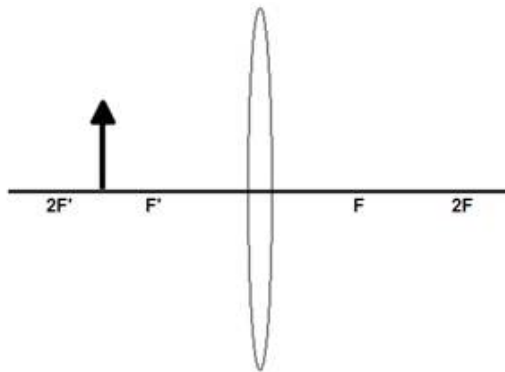
A.



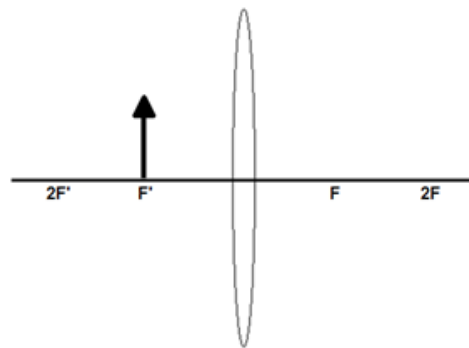
B.



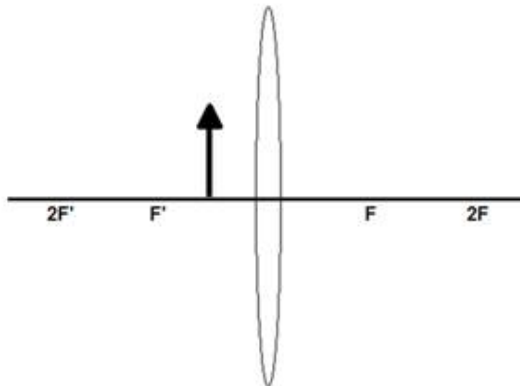
C.



D.

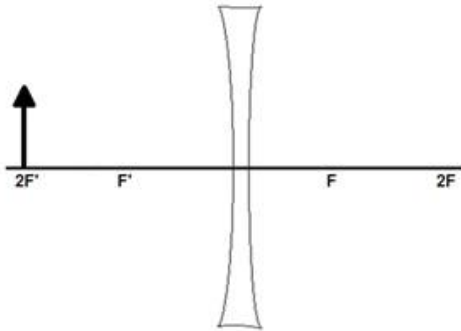


E.

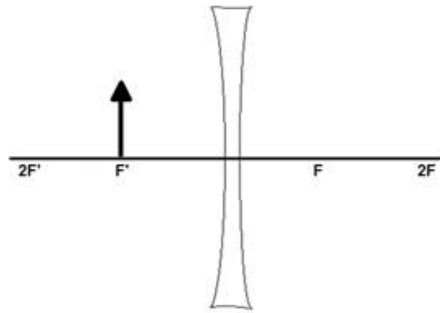


Concave Lens

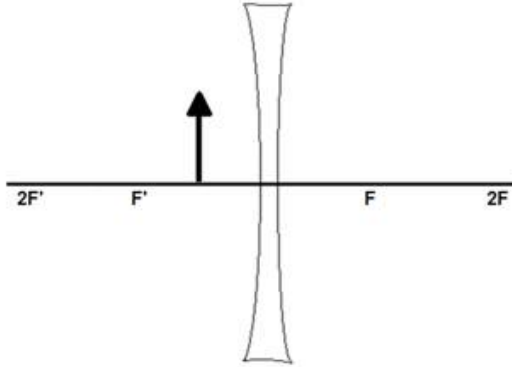
F.



G.



H.



2. Use a table similar to Table 9 below to summarize the characteristics and location of the images formed.

Table 9. Location, Orientation, Size, and Type of Image Formed by Lenses

Location of Object	Image			
	Location	Orientation (upright or inverted)	Size (same, reduced or enlarged)	Type (real or virtual)
CONVEX LENS				
A. Beyond $2F'$				
B. At $2F'$				
C. Between $2F'$ and F'				
D. At the Focal point, F'				
E. Between F' and V				
CONCAVE LENS				
F. At $2F'$				
G. At the Focal point, F'				
H. Between F' and V				

Q21. Refer to Table 9. How does the image change in its size and location, as the object comes nearer the convex lens? Concave lens?

Q22. Refer to the size of object and the size of image from the drawn ray diagrams for convex lens. Identify the location of object for which the following optical instruments are used to. Match column A with column B.

Column A	Column B
photocopy "Xerox" Machine	At Infinity
Camera	Beyond $2F'$
Telescope	At $2F'$
Projector	Between $2F'$ and F'
Magnifying Glass	Between F' and V

Q23. Why is it impossible for a concave lens to form a real image?

The Lens Equation

Ray diagram does not provide exact location and numerical information about the image formed in lenses, as in the image formed in curved mirrors through ray diagram. To determine the exact location and size of the image formed in lenses, a lens equation is needed. The following derivation shows the lens equation using the results from ray diagram.

From the first and third rays, similar triangles are seen in the diagram.

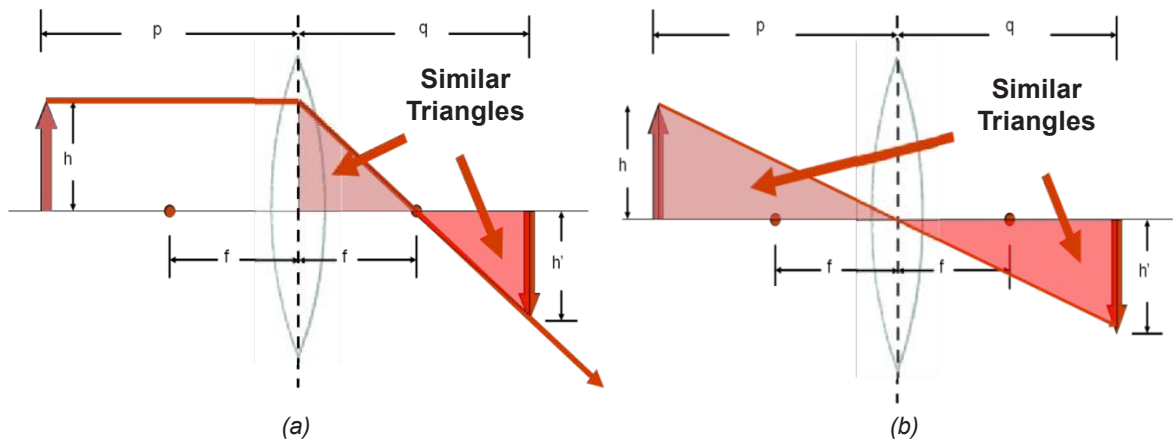


Figure 20. Similar Triangles are Formed using the (a) first ray (P – F ray) and (b) third ray (V ray).

From the height of the object, h and the height of the image, h' shown in Figure 20 (a), you can arrive at the first equation,

$$\frac{h'}{h} = \frac{q - f}{f} \quad \text{Equation 1}$$

Similarly, as shown in Figure 20(b), the second equation can be derived as

$$\frac{h'}{h} = \frac{q}{p} \quad \text{Equation 2}$$

Combining Equations 1 and 2, you will get

$$\frac{q - f}{f} = \frac{q}{p} \quad \text{Equation 3}$$

Rearranging Equation 3, you will arrive at

$$\frac{q}{f} - 1 = \frac{q}{p}$$

$$\frac{q}{f} = \frac{q}{p} + 1$$

$$\frac{1}{f} = \frac{q}{pq} + \frac{1}{q}$$

and finally,

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Lens Equation

where: f = focal length or distance from the mirror and the focal point, F

p = distance of the object from the lens

q = distance of the image from the lens

The equation above, called mirror equation, applies to both convex and concave lenses. However, in the case of the concave lens, the image will always be located on the side where the object is also located. It is therefore considered that the value of image distance, q is negative. The focal length, f in a concave lens is negative while positive in a convex lens.

Sample Problem:

What is the image distance and image size if a 5.00-cm tall light bulb is placed a distance of 45.5 cm from a convex lens having a focal length of 15.4 cm?

Given:

$$h = 5.00 \text{ cm}$$

$$p = 45.5 \text{ cm}$$

$$f = 15.4 \text{ c}$$

Find:

$$d = ?$$

$$q = ?$$

To determine the image distance, the lens equation must be used.

$$\begin{aligned}\frac{1}{f} &= \frac{1}{p} + \frac{1}{q} \\ \frac{1}{15.4 \text{ cm}} &= \frac{1}{45.5 \text{ cm}} + \frac{1}{q} \\ \frac{1}{15.4 \text{ cm}} - \frac{1}{45.5 \text{ cm}} &= \frac{1}{q} \\ \frac{45.5 \text{ cm} - 15.4 \text{ cm}}{(15.4 \text{ cm})(45.5 \text{ cm})} &= \frac{1}{q} \\ \mathbf{q} &= \mathbf{23.3 \text{ cm}}\end{aligned}$$

Since three of the four quantities in the magnification equation are known, the height of the image, h can be calculated.

$$\begin{aligned}\frac{h'}{h} &= \frac{-q}{p} \\ \frac{h'}{5.00 \text{ cm}} &= \frac{-23.3 \text{ cm}}{45.5 \text{ cm}} \\ h' &= \frac{(5.00 \text{ cm})(-23.3 \text{ cm})}{45.5 \text{ cm}} \\ \mathbf{h'} &= \mathbf{-2.54 \text{ cm}}\end{aligned}$$

The negative values for image height indicate that the image is an inverted image.

In the case of a concave lens, you found out that the image always appears in front the lens. It is therefore considered that the value of image distance, q is negative.

Sample Problem:

What is the image distance and image size if a 3.00-cm tall light bulb is placed a distance of 30.5 cm from a diverging lens having a focal length of -10.2 cm?

Given:

$$h = 3.00 \text{ cm}$$

$$p = 30.5 \text{ cm}$$

$$f = -10.2 \text{ cm}$$

Find:

$$q = ?$$

$$h' = ?$$

To determine the image distance, the lens equation will be used.

$$\begin{aligned}\frac{1}{f} &= \frac{1}{p} + \frac{1}{q} \\ \frac{1}{-10.2 \text{ cm}} &= \frac{1}{30.5 \text{ cm}} + \frac{1}{q} \\ \frac{1}{-10.2 \text{ cm}} - \frac{1}{30.5 \text{ cm}} &= \frac{1}{q} \\ \frac{30.5 \text{ cm} + 10.2 \text{ cm}}{(-10.2 \text{ cm})(30.5 \text{ cm})} &= \frac{1}{q} \\ \mathbf{q} &= \mathbf{-7.64 \text{ cm}}\end{aligned}$$

This confirms the image distance, q as negative. To determine the image height, the magnification equation is needed. Since three of the four quantities in the equation are known, the fourth quantity can be calculated. The solution is shown below.

$$\begin{aligned}\frac{h'}{h} &= \frac{-q}{p} \\ \frac{h'}{3.00 \text{ cm}} &= \frac{-7.64 \text{ cm}}{30.5 \text{ cm}} \\ h' &= \frac{(3.00 \text{ cm})(-7.64 \text{ cm})}{30.5 \text{ cm}} \\ \mathbf{h'} &= \mathbf{-0.75 \text{ cm}}\end{aligned}$$

Try solving this...

1. Determine the image distance and image height for a 8.00-cm tall object placed 46.5 cm from a convex lens having a focal length of 16.0 cm.
2. A 3.10-cm diameter coin is placed a distance of 25.0 cm from a concave lens that has a focal length of -11.0 cm. Determine the image distance and the diameter of the image.

The Sign Conventions for Lenses

- f is + if the lens is a double convex lens (converging lens)
- f is - if the lens is a double concave lens (diverging lens)
- q is + if the image is a real image and located behind the lens
- q is - if the image is a virtual image and located on the object's side of the lens
- h' is + if the image is an upright image (and therefore, also virtual)
- h' is - if the image is an inverted image (and therefore, also real)

So far, you have learned two of the properties of light which are the reflection and refraction. You have gained concepts on the rules of reflection and refraction to describe and explain how the images are formed by mirrors and lenses. You also solved problems pertaining to the exact location and magnification of images formed by mirrors and lenses. In this last activity on Module 2, you will make use of these concepts you learned to improvise an optical device. You will be asked to plan, brainstorm, design, and construct one of the following optical devices.

Activity 9

Making Improvised Optical Device

Option 1: The Camera

Task:

- Construct a pin hole camera and explain the factors that affect the image on the screen

Materials:

- illustration board/cardboard
- black cartolina, cutting mat
- pin/sewing needle, glue/sticky tape
- cutter, scissors, foot ruler, clear lamp

Procedure:

1. With your group mates and using the materials given, design and construct an improvised camera based on the information gathered from different resources.
2. A record sheet is provided to serve as your guide for accomplishing the written report on your constructed camera. Refer to your copy of Attached Assessment Tools: Problem Solving Sheet.

Option 2: The Periscope

Task:

- Construct a periscope and trace the incident and reflected rays.

Materials:

- 2 plane mirrors
- illustration board/cardboard
- cutting mat
- glue/sticky tape
- cutter, scissors, foot ruler, clear lamp

What to do:

1. With your group mates and using the materials given, design and construct an improvised periscope based on the information gathered from different resources.
2. A record sheet is provided to serve as your guide for accomplishing the written report on your constructed periscope. Refer to your copy of Attached Assessment Tools: Problem Solving Sheet.

Option 3: The Microscope**Task:**

- Set up a simple microscope and investigate the factors affecting the magnification capabilities of a microscope

Materials:

- set of lenses with different focal lengths
- specimen, light source, ruler or meter stick
- thin, clean sheet of paper to serve as the camera's screen

What to do:

1. Using the materials given, construct or set up a simple microscope. Use knowledge learned in the previous lesson and based on the information gathered from different resources.
2. Discuss with your group mates and agree on one design.
3. Use the problem-solving record sheet as your guide for writing the report on how you were able to construct your microscope.

Option 4: The Telescope**Task:**

- Construct a simple telescope and investigate the factors affecting the magnification capabilities of a telescope.

Materials:

- set of lenses with different focal lengths
specimen, light source, ruler or meter stick
thin, clean sheet of paper to serve as the camera's screen

What to do:

1. Using the materials listed above, construct a telescope based on information obtained from the previous lesson and other resources. After discussing telescope with your teammates, design a simple telescope.
2. Use the problem-solving record sheet as your guide for writing the report on how you were able to construct your telescope.

This activity is adapted from APEX Physics LP, Unit I, Chapter I, Lesson I Optical Instruments.

Problem Solving Sheet

Group No.: _____

Members: _____

Activity Title: _____

Problem: _____

Type of Problem:

construction

discovery

testing

Procedure:

What we did to solve the problem?

Sketch/Diagram of the Device/Model Constructed



What concepts our group considered in the construction of the device?

What our group found out?

What our group recommends to improve the design/model built?

V. Summary/Synthesis/Feedback

- Reflection is the bouncing of light when it hits a surface.
- Two Laws of Reflection:
 - The normal line, incident ray, and the reflected ray lie on the same plane.
 - The angle of incidence is equal to the angle of reflection.
- The reversal effect is the inversion of the image from left to right.
- Mirrors at an angle produce multiple images.
- Two Types of Reflection:
 - Specular/ Regular Reflection – reflection of light on smooth surfaces such as mirrors or a calm body of water.
 - Diffuse/ Irregular Reflection – reflection of light on rough surfaces such as clothing, paper, and the asphalt roadway.
- A curved mirror is a reflecting surface in which its surface is a section of a sphere.
- Two Kinds of Spherical Mirrors:
 - The Concave Mirror or Converging Mirror
 - The Convex Mirror or Diverging Mirror
- Important Points in Ray Diagramming:
 - Center of Curvature, C – the center of the sphere in which the mirror is part. Its distance from the mirror is known as the radius.
 - Vertex, V – the center of the mirror.
 - Focal Point/ Focus, F – the point between the center of curvature and vertex. Its distance from the mirror is known as the focal length, f.
- The 'Four Principal Rays' in Curved Mirrors
 - The P – F Ray is ray of light parallel to the principal axis, is reflected passing through the principal focus, F (concave mirror), and as if passing through the principal focus, F (convex mirror).
 - The F – P Ray is a ray of light passing through F (concave mirror) or directed towards F (convex mirror), is reflected parallel to the principal axis.
 - The C – C Ray is ray of light passing through the center of curvature, C (concave mirror) or directed towards the center of curvature, C (convex mirror) reflects back along its own path.

- V Ray is a ray of light directed to the vertex reflects at equal angle from the principal axis

- Mirror Equation:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

- A lens is a transparent material made of glass or plastic that refracts and focuses (or that appears to focus) light rays at a point.
- Two Types of Lenses:
 - Convex Lens or Converging Lens
 - Concave Lens or Diverging Lens
- The 'Three Most Useful Rays' in Lenses:
 - The P – F Ray is ray of light parallel to the principal axis is refracted passing through the principal focus, F behind the lens (convex) or as if passing through the principal focus, F in front of the lens (concave).
 - F – P Ray. A ray of light passing through F in front of the lens(convex) or directed towards F behind the lens(concave) is refracted parallel to the principal axis.
 - V Ray. A ray of light passing through the exact center of the lens (Vertex) continue to travel in the same direction.

- The Lens Equation

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

- The Magnification Equation

$$M = \frac{h'}{h} = \frac{-q}{p}$$

VI. Summative Assessment

Directions. Choose the letter of the best answer.

1. As indicated by the hands of the clock without numbers, the real time is 9:30. What is the time indicated in its image if the clock is placed in front of a plane mirror.
 - a. 2:30
 - b. 3:30
 - c. 9:30
 - d. 10:30
2. The entire two opposite walls in your room consist of plane mirrors, how much larger will your room seem to appear?
 - a. 2x larger
 - b. 3x larger
 - c. 4x larger
 - d. infinite
3. If you stand in front of two adjacent large mirrors (at 90° angle), how many images will you see?
 - a. 1
 - b. 2
 - c. 3
 - d. 4
4. If you placed a number chart in front of a plane mirror, what numbers will you read properly in the mirror?
 - a. 0, 1, 6, 8, and 9
 - b. 0, 1, and 6
 - c. 6 and 9
 - d. 0 and 8
5. An object is 6 cm in front of convex mirror with a focal length of 6 cm. What is the location of the image formed?
 - a. Between F and V
 - b. Between C and F
 - c. In front of the mirror
 - d. Can't be determined

6. A man 1.30-m tall stands 5.20 meters from a concave mirror. If the image could be formed on a screen 15.0 cm from the mirror, what is the size of the image?
- 0.07 cm
 - 3.75 cm
 - 10.5 cm
 - 14.6 cm
7. What is the focal length of the mirror in no. 6?
- 0.07 cm
 - 3.75 cm
 - 10.5 cm
 - 14.6 cm
8. An object is placed between a concave mirror and its focal point. What is the type and orientation of the image formed?
- virtual and inverted
 - virtual and erect
 - real and inverted
 - real and erect
9. A light ray, traveling parallel to a concave mirror's axis, strikes the mirror's surface. What is the direction of the reflected ray?
- It passes through the mirror's focal point.
 - It travels again parallel to the mirror's axis.
 - It travels at right angles to the mirror's axis.
 - It passes through the mirror's center of curvature.
10. An object is kept at a distance of 150 mm from a concave mirror with a radius of curvature of 600 mm. Find the image distance.
- 150 mm
 - 150 mm
 - 300 mm
 - 300 mm
11. Why is it easier to read a newspaper than a glossy magazine?
- Because incident rays of light on a newspaper reflect in different directions while incident rays of light on a glossy magazine reflect in only one direction.
 - Because incident rays of light on a newspaper reflect in only one direction while incident rays of light on a glossy magazine reflect in different directions.
 - Because incident rays of light on a glossy magazine converge at the focus.
 - Because incident rays of light on a newspaper converge at the focus.

12. What kind of mirror is used by department stores to give a wider area and smaller image of the shoppers/buyers?
- Plane mirror
 - Convex mirror
 - Concave mirror
 - None of the above
13. If you look down on a pool of wavy water, you can't see your face clearly. Which one of the following gives the best explanation for this observation?
- Light entering the water is dispersed.
 - Regular reflection of light happens on the surface of wavy water.
 - Irregular reflection of light happens on the surface of wavy water.
 - Light is reflected from the surface of water in the different direction.
14. Where should an object be placed in front of a concave mirror so that the image will have the same size as the object?
- At the focus
 - At the center of curvature
 - Between the focus and the vertex
 - Between the center of curvature and focus
15. Which of the following is/are true of a convex mirror?
- It will never form a real image
 - An inverted image will be formed if the object distance is greater than the focal length
 - An object can be magnified if it is placed at $p = 3f$
- I only
 - II only
 - I and II
 - I, II, and III
16. A light ray traveling obliquely to a convex mirror's axis, goes directly to the mirror's center of curvature before striking the mirror's surface. What is the direction of the reflected ray after hitting the mirror?
- It travels parallel to the mirror's axis
 - It passes through the mirror's focal point
 - It travels at right angles to the mirror's axis
 - It travels back through the mirror's center of curvature.

17. What type of lens produces smaller and upright images?
- Concave lens
 - Convex lens
 - Converging lens
 - Can't be determined
18. An object is kept at a distance of 80.00 cm from a convex lens of focal length 25.00 cm. Find the distance between its image and lens.
- 19.05 cm
 - 25.25 cm
 - 36.36 cm
 - no image
19. A light ray, traveling parallel to the axis of a convex lens, strikes the lens. What happens to this ray after traveling through the lens?
- It travels crossing the axis at a point equal to twice the focal length.
 - It travels to the axis passing between the lens and its focal point.
 - It travels to the axis passing through its focal point.
 - It travels parallel to the principal axis.
20. Sun's rays are observed to focus at a point behind the fishbowl near the window. The fishbowl act as what type of lens?
- Converging Lens
 - Diverging Lens
 - Focusing Lens
 - None of the above

Glossary of Terms

Concave Lens	a kind of lens that is thicker at the edges and thinner in the center. It is called a diverging lens.
Concave Mirror	a curved mirror in which the reflective surface bulges away from the light source. It is called a converging mirror.
Convex Lens	a kind of lens that is thicker in the center than the edges. It is called a converging lens.
Convex Mirror.	a curved mirror in which the reflective surface bulges towards the light source. It is called a diverging mirror.
Plane Mirror	a polished or smooth surface (as of glass) that forms images by reflection.
Reflection of Light	the bouncing of light rays when it hits a surface.
Refraction of Light	the bending of light rays when passing obliquely from one medium into another.

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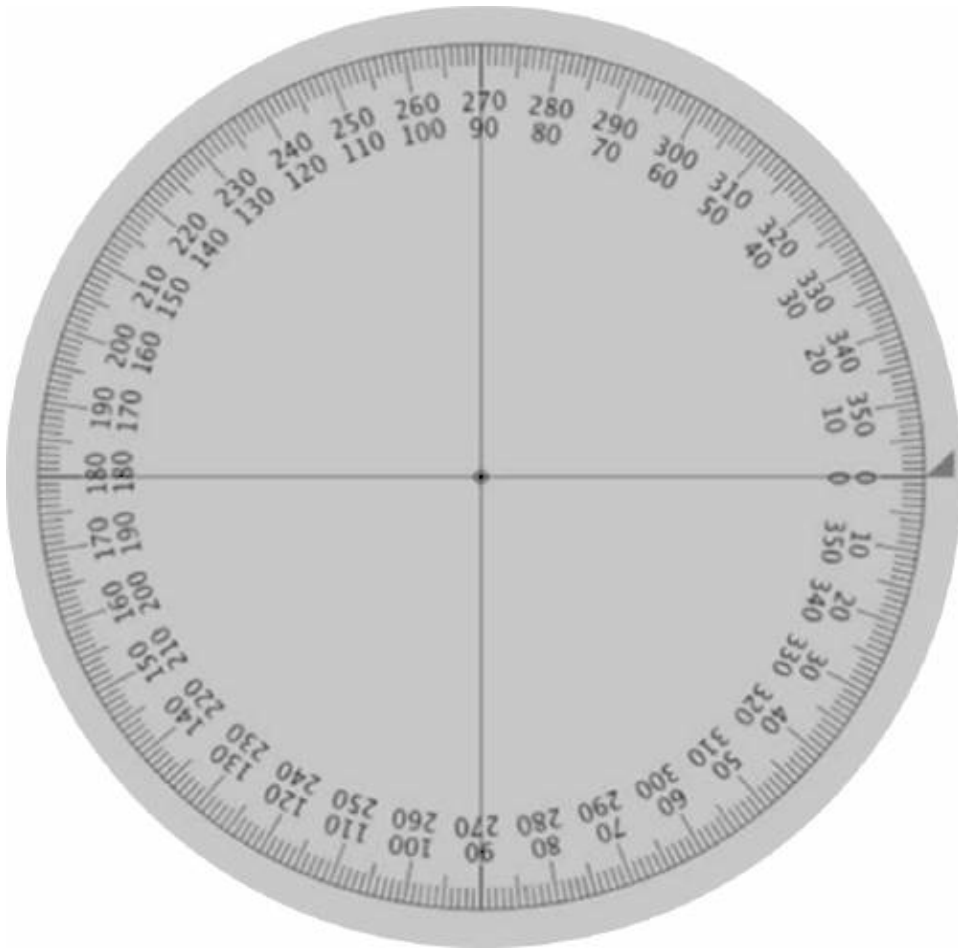
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Appendix A



A Paper Protractor