Suggested time allotment: 8 to 10 hours

Unit 3
MODULE
1

DESCRIBING MOTION

Many of the things around us move. Some move slowly like the turtles and clouds, others move much more quickly like the satellites. Because motion is so common, it seems to be very simple. But in science, describing motion actually entails careful use of some definitions.

This module provides you with scientific knowledge and skills necessary to describe motion along a straight path. You will learn to describe the motion of objects in terms of position, distance travelled, and speed. You will also learn to analyze or represent motion of objects using charts, diagrams, and graphs. While these all provide the same information about the motion of objects, you will find out that one may be more helpful than the other depending on your particular objective.

At the end of this module, you are expected to answer the following questions:

When can we say that an object is in motion?

How do we describe the motion of an object?

Where?

Before you will be able to describe the motion of an object, you must first be able to tell exactly where it is positioned. Describing exact position entails two ideas: describing how far the object is from the *point of reference* and describing its direction relative to that point of reference. You will learn about the importance of point of reference and direction when you perform Activity 1.

Activity 1
Where is it?

Objective

In this activity, you should be able to describe in words the position of an object within the room or the school ground.

Procedure

1. Obtain from your teacher the piece of paper that describes where you will find the object.

   Q1. Were you able to find the object? Was it easy or difficult?
   Q2. Is the instruction clear and easy to follow? What made it so?

2. Put back the object to its place, if you found it. Otherwise, ask your teacher first where it is located before you move on to the next step.

3. Revise the instruction to make it more helpful. Write it on a separate sheet of paper and let another group use it to find the object.

   Q3. Were they successful in finding the object? Was it easy for them or difficult?
   Q4. What other details or information included in your instruction that made it clearer and easier to follow?
   Q5. In your own words, what is point of reference and how important it is?

Describing through visuals

The position of an object can be described in many ways. You can use words, like what you did in Activity 1. You can also use visuals, like diagrams or graphs. Use the examples to explore how these help in providing accurate descriptions of positions of objects.

Using diagrams

Consider the diagram in Figure 1. The positions of the objects are described in the diagram by their coordinates along the number line.

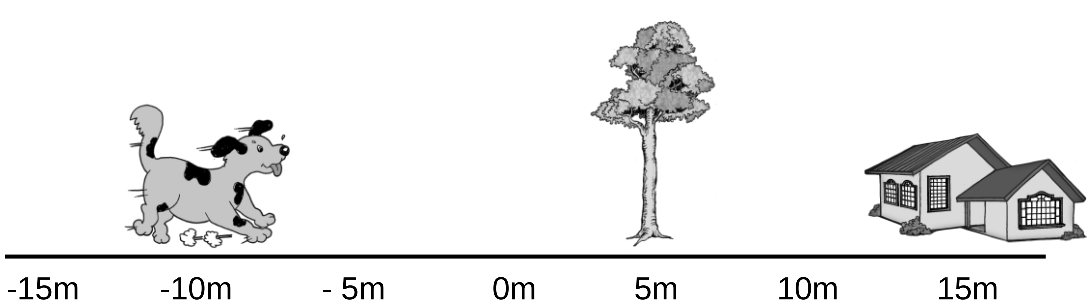


Figure 1

Q6. What is the position of the dog?
Q7. What is the position of the tree?
Q8. What is the position of the dog with respect to the house?
Q9. What is the position of the tree with respect to the dog?

Here is another example. In this diagram, the positions of the ball rolling are shown at equal intervals of time. You can use the diagram to describe the position of the ball at any given time.

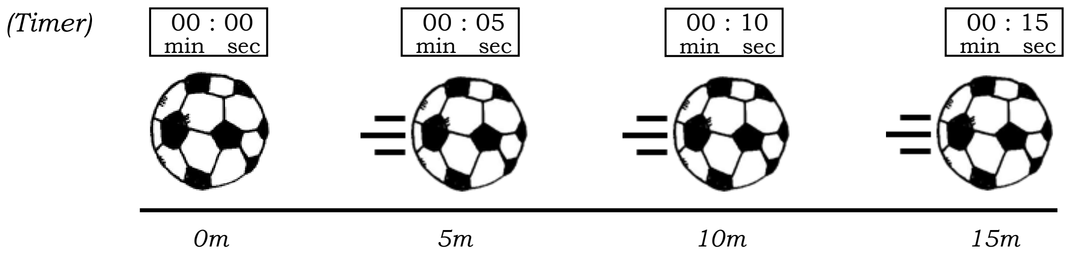


Figure 2

Q10. What is the initial position of the ball? What is its final position?
Q11. What is the position of the ball at 10 seconds?
Q12. At what time is the position of the ball equal to 5 meters?

Using graphs

Another way to describe the motion of the ball is by the use of motion graphs. Convert the diagram in Figure 2 to graph by following the guide below.

I. Fill up Table 1 using the data in Figure 2. Note that the positions of the ball are shown every 5 seconds.

Table 1: Position of the ball vs time

Time (s)	Position of the ball (m)
0	0

II. Plot the values in Table 1 as points on the graph in Figure 3. Note that *time* is plotted on the X-axis while *position* is plotted on the Y-axis. An example is given below.

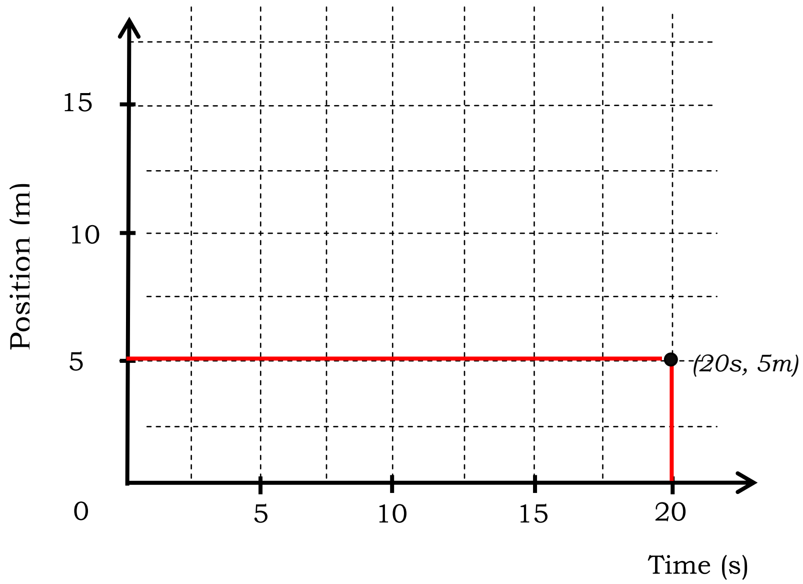


Figure 3

III. Lastly, draw a straight diagonal line through the points in the graph.

The graph that you have just drawn in Figure 3 is called *position-time graph.* You can also use this graph to describe the position of the ball at any given time. For example, if you are asked to find the position of the ball at 10 seconds, all you need to do is to find the point along the diagonal line where the vertical line at the 10 second-mark intersects (Figure 4). Then find where the horizontal line from that point of intersection will cross the Y axis, which is the position axis. This will give you the position of the ball at 10 seconds.

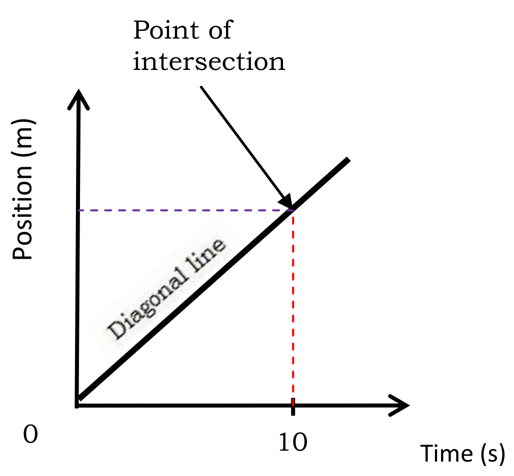


Figure 4

Now try answering the following questions using your own position-time graph.

Q13. What is the position of the ball at 7.5 seconds?

Q14. At what time is the position of the ball equal to 12.5 meters?

How Far?

In science, motion is defined as the change in position for a particular time interval. You can then start describing motion with the question, "How far did the object travel?" There are actually two ways to answer this question. First is by getting the total length of the path travelled by the object. In Figure 5 for example, the dog ran 10m to the east, then 5m to the south, and another 10m to the west. So it has travelled a total of *25 meters*. The other way is by measuring the distance between the initial position and final position of the object. Based again on Figure 5, the dog has travelled *5 meters to the south*.

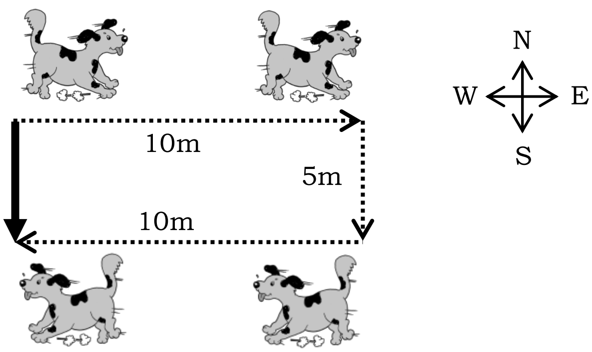


Figure 5

In science, the first measurement gives the **distance** travelled by the object (represented by broken lines) while the second measurement gives its **displacement** (represented by continuous line).

Here are more illustrations showing the difference between distance travelled (*represented by broken lines*) by an object and its displacement (*represented by continuous lines*).

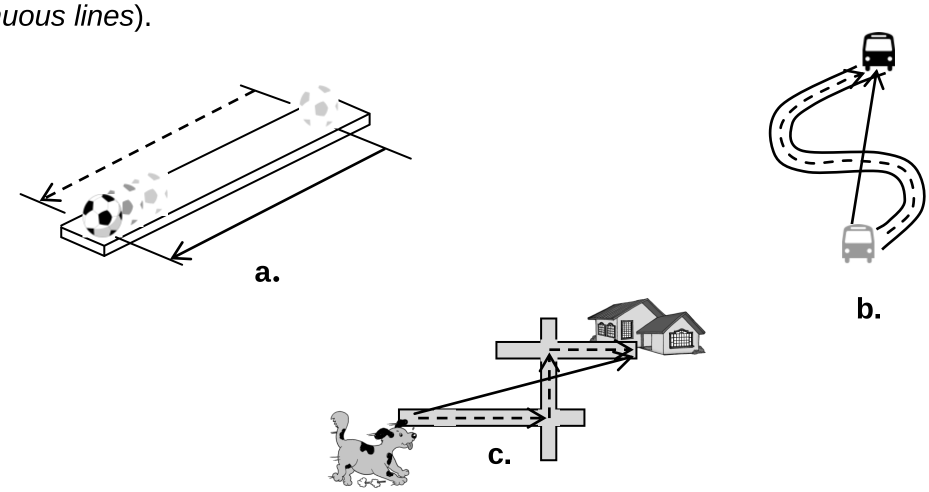


Figure 6

Can you give one difference between distance and displacement based on the given examples? When can displacement be equal to zero? Is it possible to get zero displacement? What if the ball, the car, and the dog in the illustration go back to their starting positions, what will happen to their respective distances? How about their displacements? If you answered these questions correctly, then you have most probably understood the difference between distance and displacement.

- *Distance refers to the length of the entire path that the object travelled.*
- *Displacement refers to the shortest distance between the object's two positions, like the distance between its point of origin and its point of destination, no matter what path it took to get to that destination.*

When a graph is plotted in terms of the distance travelled by the object and the time it took to cover such distance, the graph can be called *distance-time graph*. If the graph is plotted in terms of displacement and time, it is called *displacement-time graph*. Refer to the graph in Figure 7. What is the displacement of the object after 2 seconds? What is its displacement after 6 seconds? How will you describe the motion of the object between 0s and 2s, between 2s and 4s, and between 4s and 6s?

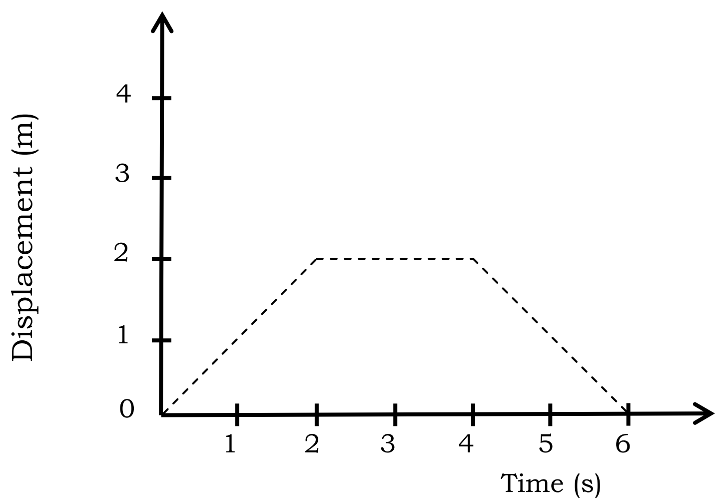


Figure 7

Activity 2
My home to school roadmap

Objective

In this activity you should be able to make a roadmap that shows how you get to school from your house.

Procedure

1. Devise a way to easily measure distance. Let your teacher check your non-standard measurement for precision.
2. Using your measuring device, gather the data that you will need for your roadmap. Make sure that you take down notes of all names of the roads, landmarks, corners, posts, and establishments you pass by. Record your data properly.
3. Using your gathered data, draw your house-school roadmap on a short bond paper. Decide on the most convenient scale to use when you draw your roadmap. An example is shown below.

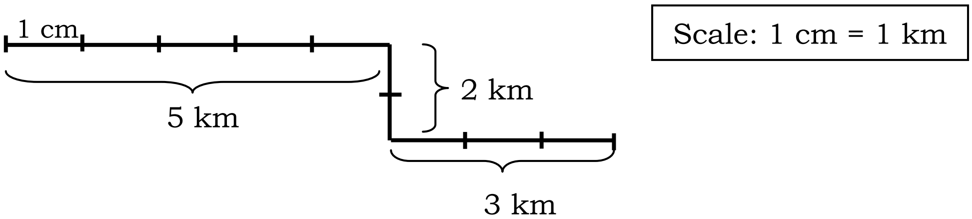


Figure 8

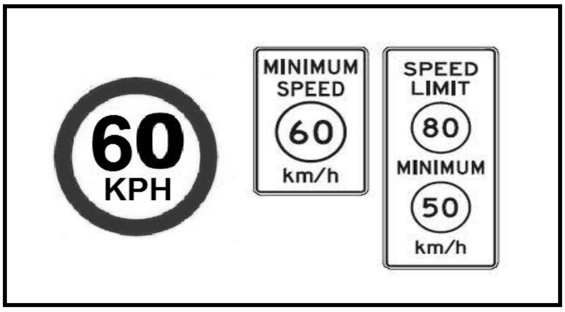
4. Label your roadmap properly, including names of the roads, establishments, etc. Specify also the length of road.
5. Finally, let your teacher check again your work.
   Q1. What is the total length of your travel from your house to your school?
   Q2. What is the total displacement of your travel?

How fast?

After determining how far the object moves, the next question will be "How fast did the object move?" This information can be provided by the object's speed or velocity.

Are you familiar with the traffic signs below? These signs tell us the maximum or minimum speed limits allowed by law for road vehicles. In general, the minimum speed limit in the Philippines is 60 km/h and the maximum speed limit is 100 km/h.

What are the units used in the above examples of speed limits? What quantities do these units represent that are related to speed?



Activity 3
Fun walk

Objective

In this activity you should be able to gather data to determine who walks fastest.

Procedure

1. Start by choosing a spacious place to walk straight.
2. Half of the group will walk while the other half will observe and record data.
3. Mark on the ground the starting line. All participants must start from the starting line at the same time.
4. Upon receiving the go signal, all participants must start to walk as fast as they could. The other members should observe closely as the participants walk and determine who walks fastest.
5. Repeat #4 but this time, collect data to support your conclusion. Discuss within your group how you are going to do this.
   - Q1. What quantities did you measure for your data?
   - Q2. How did you combine these quantities to determine how fast each participant was walking?
   - Q3. How did you use the result to determine who walked fastest?

Speed

The questions in the above activity are actually referring to *speed*. If you know the speed of each participant, you can tell who is the fastest. Speed is defined as distance travelled divided by the time of travel.

$$speed = \frac{distance\ travelled}{time\ of\ travel}$$

The units of speed can be miles per hour (mi/h), kilometres per hour (km/h), or meters per second (m/s).

- Q4. At constant distance, how is speed related to the time of travel?
- Q5. At constant time to travel, how is speed related to the distance travelled?
- Q6. Who was travelling faster than the other, a person who covered 10 meters in 5 seconds or the one who took 10 seconds to cover 20 meters?

Speed and direction

In describing the motion of an object, we do not just describe how fast the object moves. We also consider the direction to where it is going. Speed with direction is referred to as *velocity*. The sample weather bulletin below will show you the importance of knowing not just the speed of the storm but also its direction.

Table 2: Sample weather bulletin

Weather Bulletin: Tropical Storm "Juaning" *Wednesday, 27 July 2011 at 09:27:14 AM*	
Location of Center	90 km East of Infanta, Quezon
Coordinates	14.8°N, 122.5°E
Strength of the winds	Max. wind speed of 85 km/hr near the center & gustiness of up to 100 km/hr
Movement	11km/hr going West-Northwest
Forecast	On Wednesday AM: Expected to make landfall over Polillo Island between 8am to 10am and over Southern Aurora by 1pm to 3pm and will traverse Central Luzon

Whenever there is a storm coming, we are notified of its impending danger in terms of its speed and direction. Aside from this, we are also informed about its strength. Do you know that as the storm moves, its winds move in circles? The circular speed of the winds of the storm determines its strength. Different storm signals are given in places depending on the circular speed of the winds of the storm and the distance from the center.

Study again the weather bulletin above. Which is the speed for the circular motion of the typhoon winds? Which is the speed for the motion of the storm as a whole along the path? How important are speed and direction in determining the weather forecast for the next hours?

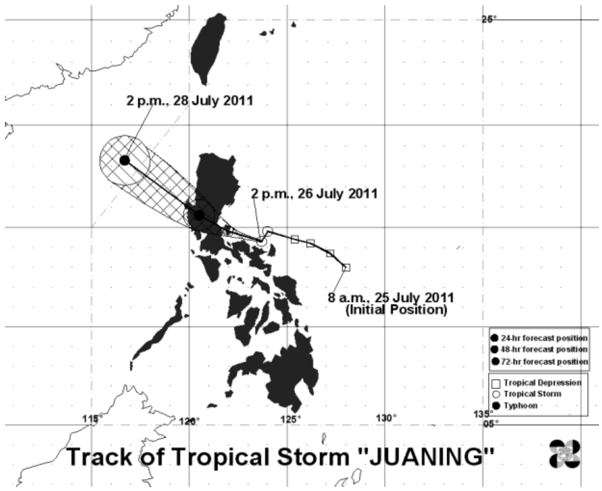
Constant speed vs instantaneous speed

If you solved for the distance travelled by each participant over the time he took to cover such distance, then you have computed for his *average speed*. But why average speed and not just speed? It is considered average speed because it represents the speed of the participant throughout his travel. During his travel, there were instants that his speed would vary. His speed at an instant is called *instantaneous speed*. Similarly, the velocity of a moving body at an instant is called *instantaneous velocity*. The instantaneous speed may be equal, greater than, or less than the average speed.

When an object's instantaneous speed values are always the same, then it means that the object is moving with *constant speed*. We refer to this as *constant motion*. Where you will be and what time you will reach your destination is easily predicted when you move at constant speed or velocity.

Are you familiar with the speedometer? Speedometer is a device used to measure the instantaneous speed of a vehicle. Speedometers are important to the drivers because they need to know how fast they are going so they know if they are already driving beyond the speed limit or not.

How fast is the velocity changing?



Source: http://drrm.region4a.dost.gov.ph/

Figure 9. Track of tropical storm "Juaning"

In reality, objects do not always move at constant velocity. Storms like "Juaning" also do change their speeds, directions, or both. The next activity will help you analyze examples of motion with changing velocities (or with changing speed, since we are only trying to analyze examples of motion in only one direction) using tape charts and motion graphs.

Activity 4
Doing detective work

Consider this situation below:

> Supposed you were having your on-the-job training in a private investigating company. You were asked to join a team assigned to investigate a 'hit and run' case. The alleged suspect was captured by the CCTV camera driving down a road leading to the place of incident. The suspect denied the allegation, saying that he was then driving very slowly with a constant speed. Because of the short time difference when he was caught by the camera and when the accident happened, he insisted that it was impossible that he would already be at the place when the crime happened. But when you were viewing the scene again on the camera, you noticed that his car was leaving oil spots on the road. When you checked these spots on site, you found out that they are still evident. So you began to wonder if the spots can be used to investigate the motion of the car of the suspect and check whether he was telling the truth or not.

Here is an activity that you can do to help you with your investigation. You will analyze the motion using strips of papers with dots. For this activity, assume that the dots represent the 'oil drops' left by the car down the road.

Materials

- ruler
- paper strips with dots
- cutter or pair of scissors

Procedure

A. Using tape chart

1. Obtain from your teacher paper strips with dots.
2. Label each dot. Start from 0, then 1, 2, 3, and so on. In this example, each dot occurred every 1 second.

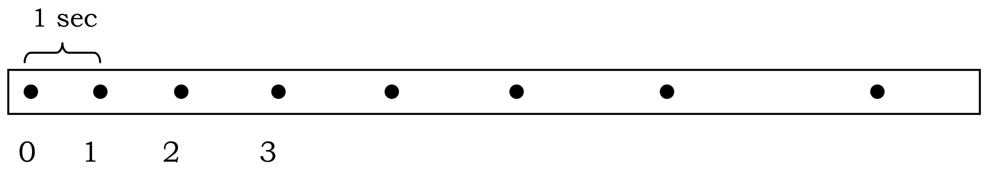


Figure 10

3. Examine the distances between successive dots.
   Q1. How will you compare the distances between successive dots?

4. Cut the strip at each drop, starting from the first to the last drop, and paste them side by side on a graph paper to form a tape chart as shown in Figure 11.

   Q2. How do the lengths of the tapes compare?

   Q3. If each tape represents the distance travelled by the object for 1 second, then what 'quantity' does each piece of tape provide?

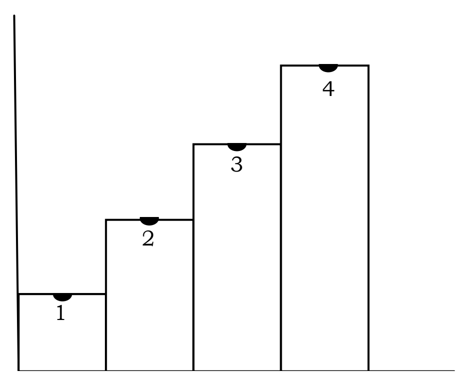


Figure 11. Sample tape chart

   Q4. What does the chart tell you about the speed of the car?

The difference in length between two successive tapes provides the object's **acceleration** or its *change in speed or velocity for a time interval of 1 second.*

   Q5. How will you compare the changes in the lengths of two successive tapes?
   Q6. What then can you say about the acceleration of the moving car?

B. Using motion graphs

5. Measure the distance travelled by the car after 1 second, 2 seconds, and so on by measuring the distance between drops *0 and 1*, *0 and 2*, and so on. Enter your measurements in Table 3 on the right.

Table 3

Time of travel (s)	Distance travelled (m)
1	
2	
3	
4	
5	

6. Plot the values in Table 3 as points on the graph in Figure 12 on the right.

Q7. How does your distance-time graph look like?

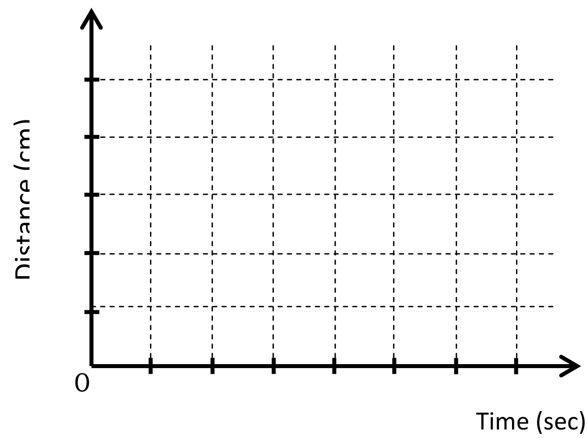


Figure 12

7. Join the mid-points of the tops of the tapes with a line. You have now converted your tape chart to a speed-time graph.

8.

Q8. How does you graph look like? How is this different from your graph in Figure 12?

Q9. How will you interpret this graph in terms of the speed and acceleration of the moving car?

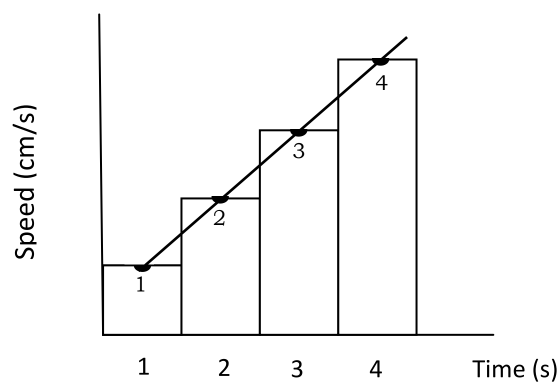


Figure 13

Q10. If you found out in your investigation that the arrangement of oil drops left by the car is similar to what you used in this activity, was the suspect telling the truth when he said that he was driving with constant speed?

In this module, you have learned how to describe the motion of objects in terms of position, distance and displacement, speed and velocity, and acceleration. You have also learned how to represent motion of objects using diagrams, charts, and graphs.

Let us summarize what you have learned by relating distance, displacement, speed, velocity, and acceleration.

- If an object does not change its position at a given time interval, then it is at rest or its speed is zero or not accelerating.
- If an object covers equal distance at equal intervals of time, then it is moving at constant speed and still not accelerating.
- If an object covers varying distances at equal intervals of time, then it is moving with changing speed or velocity. It means that the object is accelerating.

Links and References

Chapter 2: Representing Motion. Retrieved March 14, 2012 from http://igcse-physics--41-p2-yrh.brentsvillehs.schools.pwcs.edu/modules

Chapter 3: Accelerated Motion. Retrieved March 14, 2012 from http://igcse-physics--41-p2-yrh.brentsvillehs.schools.pwcs.edu/modules

HS Science IV: Physics in your environment. *Teacher's Edition*. 1981. Science Education Center. Quezon City

Suggested time allotment: 4 to 5 hours

Unit 3
MODULE

2

WAVES AROUND YOU

Waves occur all around you in the physical world. When you throw a stone into a lake, water waves spread out from the splash. When you strum the strings of a guitar, sound waves carry the noise all around you. When you switch on a lamp, light waves flood the room. Water, sound, and light waves differ in important ways but they all share the basic properties of wave motion. For instance, you can see water waves and surfers would say that they enjoy riding the waves. On the other hand, you don't see sound waves and light waves but you experience them in other ways. Your ears can detect sound waves and your skin can get burned by ultraviolet waves if you stay under the sun for too long.

A **wave** is a periodic disturbance that moves away from a source and carries energy with it. For example, earthquake waves show us that the amount of energy carried by a wave can do work on objects by exerting forces that move objects from their original positions. Have you personally experience an earthquake? How did it feel? Did you know that you can understand earthquakes by studying waves?

In this module, you would be doing three activities that would demonstrate the properties of wave motion. After performing these activities, you should be able to:

1. explain how waves carry energy from one place to another;
2. distinguish between transverse and longitudinal waves;
3. distinguish between mechanical and electromagnetic waves; and
4. create a model to demonstrate the relationship among frequency, amplitude, wavelength, and wave velocity.

Warm up. What are Waves?

Activity 1 will introduce you to different types of waves distinguished according to the direction of vibrations of particles with respect to the direction in which the waves travel. Activity 2 will give you a background of the terms and quantities used in describing periodic waves. Finally, Activity 3 will strengthen your understanding of the properties of waves and how they propagate.

Try to wave at your seatmate and observe the motion of your hand. Do you make a side-to-side motion with the palm of your hand? Do you do an up-and-down motion with your hand?

1. Describe your personal hand wave.

The repetitive motion that you do with your hand while waving is called a **vibration**. A vibration causes wave motion. When you observe a wave, the source is always a vibration.

2. Think of a still lake. How would you generate water waves on the lake?

Waving is a common gesture that people do to catch someone's attention or to convey a farewell.

Activity 1. Let's Make Waves!

What happens when waves pass by?

Objective

In this activity, you will observe and draw different types of waves and describe how they are produced. You will also describe the different types of waves.

Time Allotment: 30 minutes

Materials

- A rope (at least five meters long)
- A colored ribbon
- A coil spring (Slinky™)
- A basin filled with water
- A paper boat

Procedure

A. What are transverse waves?

1. Straighten the rope and place it above a long table. Hold one end of the rope and vibrate it up and down. You would be able to observe a **pulse**. Draw three sketches of the rope showing the motion of the pulse at three subsequent instances (snapshots at three different times). Draw an arrow to represent the direction of the pulse's motion.

Time 1

Time 2

Time 3

a. What is the source of the wave pulse?

b. Describe the motion of your hand as you create the pulse.

c. Describe the motion of the pulse with respect to the source.

You will now tag a specific part of the rope while making a series of pulses. A **periodic wave** can be regarded as a series of pulses. One pulse follows another in regular succession.

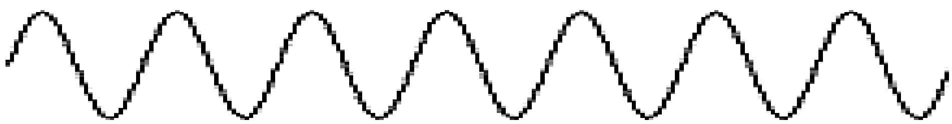


Figure 1. Periodic wave

Tie one end of the rope on a rigid and fixed object (e.g heavy table, door knob, etc).

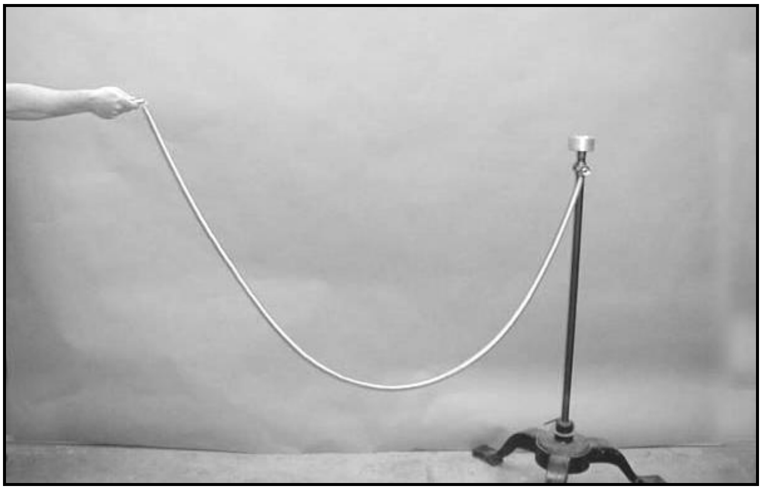


Figure 2. Rope tied to a rigid object

Attach a colored ribbon on one part of the rope. You may use adhesive tape to fix the ribbon. Make a wave by continuously vibrating the end of the rope with quick up-and-down movements of your hand. Draw the **waveform** or the shape of the wave that you have created.

Ask a friend to vibrate the rope while you observe the motion of the colored ribbon. Remember that the colored ribbon serves as a marker of a chosen segment of the rope.

a. Does the wave transport the colored ribbon from its original position to the end of the rope?

b. Describe the vibration of the colored ribbon. How does it move as waves pass by? Does it move in the same direction as the wave?

B. What are longitudinal waves?

1. Connect one end of a long table to a wall. Place coil spring on top of table. Attach one end of the coil spring to the wall while you hold the other end.

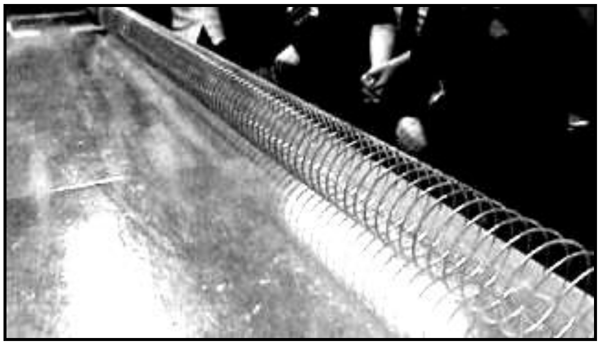


Figure 3. Coil spring on a flat table with one end attached to a wall

Do not lift the coil spring. Ask a friend to vibrate the end of the coil spring by doing a back-and-forth motion parallel to the length of the spring. Observe the waves along the coil spring. Draw how the coil spring looks like as you move it back-and-forth.

2. Attach a colored ribbon on one part of the coil spring. You may use an adhesive tape to fix the ribbon. Ask a friend to vibrate the coil spring back-and-forth while you observe the motion of the colored ribbon. Remember that the colored ribbon serves as a marker of a chosen segment of the coil spring.

   a. Does the wave transport the colored ribbon from its original position to the end of the rope?

   b. Describe the vibration of the colored ribbon. How does it move as waves pass by?

C. What are surface waves?

1. Place a basin filled with water on top of a level table. Wait until the water becomes still or motionless. Create a wave pulse by tapping the surface of the water with your index finger and observe the direction of travel of the wave pulse. Tap the surface of the water at regular intervals to create periodic waves. View the waves from above and draw the pattern that you see. In your drawing, mark the source of the disturbance.

2. Wait for the water to become still before you place your paper boat on the surface. Create periodic waves and observe what happens to your paper boat.

   a. Do the waves set the paper boat into motion? What is required to set an object into motion?

   b. If you exert more energy in creating periodic waves by tapping the surface with greater strength, how does this affect the movement of the paper boat?

3. If you were somehow able to mark individual water molecules (you used a colored ribbon to do this earlier) and follow them as waves pass by, you would find that their paths are like those shown in the figure below.

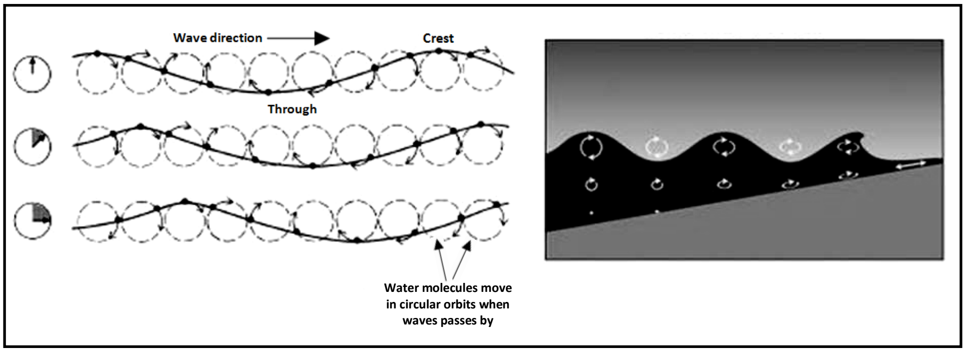


Figure 4. Surface waves

   a. As shown in the figure, the passage of a wave across a surface of a body of water involves the motion of particles following a ___________ pattern about their original positions.

   b. Does the wave transport water molecules from the source of the vibration? Support your answer using the shown figure.

D. Summary

1. Waves can be typified according to the direction of motion of the vibrating particles with respect to the direction in which the waves travel.

   a. Waves in a rope are called ____________ waves because the individual segments of the rope vibrate ____________ to the direction in which the waves travel.

   b. When each portion of a coil spring is alternatively compressed and extended, ____________ waves are produced.

   c. Waves on the surface of a body of water are a combination of transverse and longitudinal waves. Each water molecule moves in a _______________ pattern as the waves pass by.

2. How do we know that waves carry energy?

3. What happens when waves pass by?

Activity 2. Anatomy of a Wave
How do you describe waves?

Background

You had the experience of creating periodic waves in Activity 1. In a periodic wave, one pulse follows another in regular succession; a certain waveform – the shape of individual waves – is repeated at regular intervals.

Most periodic waves have **sinusoidal** waveforms as shown below. The highest point and lowest point of a wave are called the **crest** and the **trough** respectively. The **amplitude** is the maximum displacement of a vibrating particle on either side of its normal position when the wave passes.

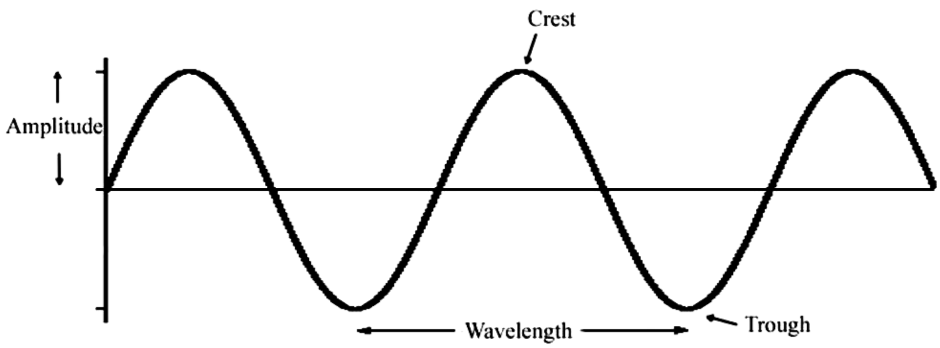


Figure 5. Sinusoidal wave

Objective

In this activity, you will identify the quantities used in describing periodic waves.

Time Allotment: 40 minutes

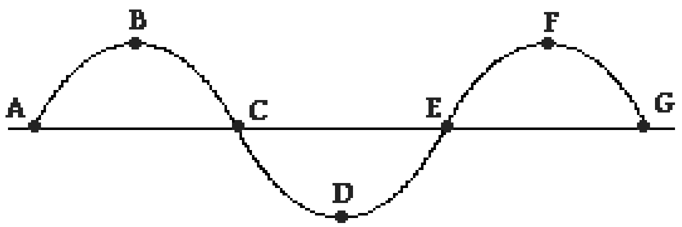
Materials

- A ruler
- A basin filled with water
- A rope (at least five meters long)
- A colored ribbon
- A watch or digital timer

Procedure

A. How can you measure the wavelength of a wave?

1. The **wavelength** of a wave refers to the distance between any successive identical parts of the wave. For instance, the distance from one crest to the next is equal to one full wavelength. In the following illustration, this is given by the interval B to F. Identify the other intervals that represent one full wavelength.



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2. Place a basin filled with water on top of a level table. Wait for the water to become still. Create a vibration by regularly tapping the surface of the water with your index finger. You would be able to see the subsequent crest of the water waves.

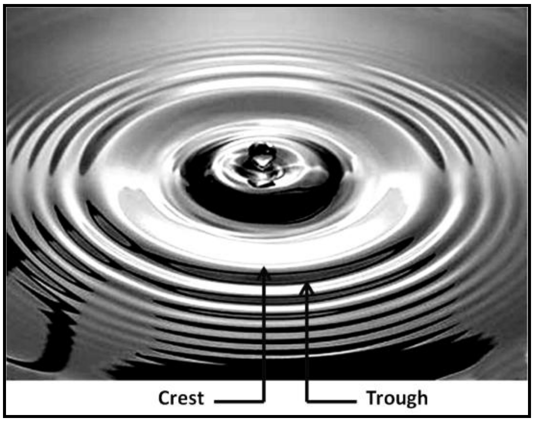


Figure 6. Crest and trough on a water wave

Draw the water waves as you see them from the top of the basin. Label one wavelength in your drawing.

3. Increase the rate of the vibrations you create by tapping the surface of the water rapidly. What happens to the wavelength of the waves?

   Draw the water waves as you see them from the top of the basin. Compare it with your drawing in number 2.

B. How do you measure the frequency of a wave?

1. The **frequency** of a series of periodic waves is the number of waves that pass a particular point every one second. Just like what you have done in Activity 1, attach a colored ribbon on a rope to serve as a tag. Tie one end of the rope on a fixed object and ask a friend to create periodic waves by regularly vibrating the other end of the rope.

2. You will count how many times the colored ribbon reached the crest in 10 seconds. You will start counting once the ribbon reaches the crest a second time. It means that one wave has passed by the ribbon's position. Ask another friend with a watch or a digital timer to alert you to start counting and to stop counting after 10 seconds. Record the results in Table 1.

3. It is also useful to consider the **period** of a wave, which is the time required for one complete wave to pass a given point. The period of each wave is

$$period = \frac{1}{frequency}$$

   From the identified frequency of the observed periodic waves, the period can be calculated. For example, if two waves per second are passing by, each wave has a period of ½ seconds.

Table 1. Frequency and period of the wave

Number of waves (N cycles) that passed by the ribbon in 10 seconds	**Frequency** of the waves (N cycles/10 seconds)	**Period** of the waves (seconds)

The unit of frequency is the **hertz** (Hz); 1 Hz = 1 cycle/second.

4. If you increase the frequency of vibration by jerking the end of the rope at a faster rate, what happens to the wavelength?

C. How do you measure the speed of a wave?

1. Using the rope with ribbon. Create periodic waves and estimate their wavelength. Count the number of waves that pass by the ribbon in ten seconds. Compute the frequency of the waves. Record the results in Table 2.

2. The wave speed is the distance traveled by the wave per second.

wave speed = distance traveled per second = frequency x wavelength

From the basic formula that applies to all periodic waves, you can see that wave speed, frequency and wavelength are independent of the wave's amplitude.

a. Using the data from number 1, calculate the wave speed of the observed periodic waves. Record the result in Table 2.

Table 2. The speed of a wave

Estimated wavelength (meters)	**Number of waves** (N cycles) that passed by the ribbon in 10 seconds	**Frequency** of the waves (N cycles/10 seconds)	**Wave speed** (meter/second)

Summary

1. What is the relationship between wave speed, wavelength and frequency?

2. Suppose you observed an anchored boat to rise and fall once every 4.0 seconds as waves whose crests are 25 meters apart pass by it.

   a. What is the frequency of the observed waves?

   b. What is the speed of the waves?

Activity 3. Mechanical vs. Electromagnetic Waves
How do waves propagate?

Objective

In this activity, you will differentiate between mechanical waves and electromagnetic waves.

Time Allotment: 30 minutes

Materials

- Findings from Activity 1
- Chart of the electromagnetic spectrum

A. What are mechanical waves?

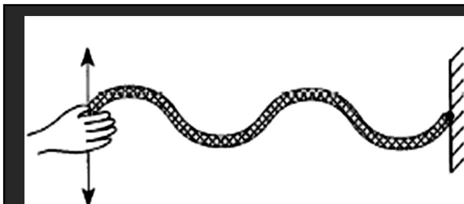
1. When you created waves using a rope in Activity 1 Part A, you were able to observe a moving pattern. In this case, the **medium** of wave propagation is the ***rope***.

   a. In Activity 1 Part B, what is the medium of wave propagation?

   b. In Activity 1 Part C, what is the medium of wave propagation?

2. The waves that you have created in Activity 1 all require a medium for wave propagation. They are called **mechanical waves**.

   a. How can you generate mechanical waves?



*The medium of propagation for the wave shown above is the **rope**.*

3. All three kinds of waves – transverse, longitudinal, and surface – are sent out by an earthquake and can be detected many thousands of kilometers away if the quake is a major one.

   a. What do you think is the source of earthquake waves?

   b. What is the medium of propagation of earthquake waves?

B. What are electromagnetic waves?

1. Energy from the sun reaches the earth through **electromagnetic waves**. As opposed to mechanical waves, electromagnetic waves require no

material medium for their passage. Thus, they can pass through empty space. Locate the electromagnetic spectrum chart in your classroom. A smaller image of the chart is shown below. Identify the common name of each wave shown in the chart.

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________

2. The **electromagnetic spectrum** shows the various types of electromagnetic waves, the range of their frequencies and wavelength. The wave speed of all electromagnetic waves is the same and equal to the speed of light which is approximately equal to 300 000 000 m/s.

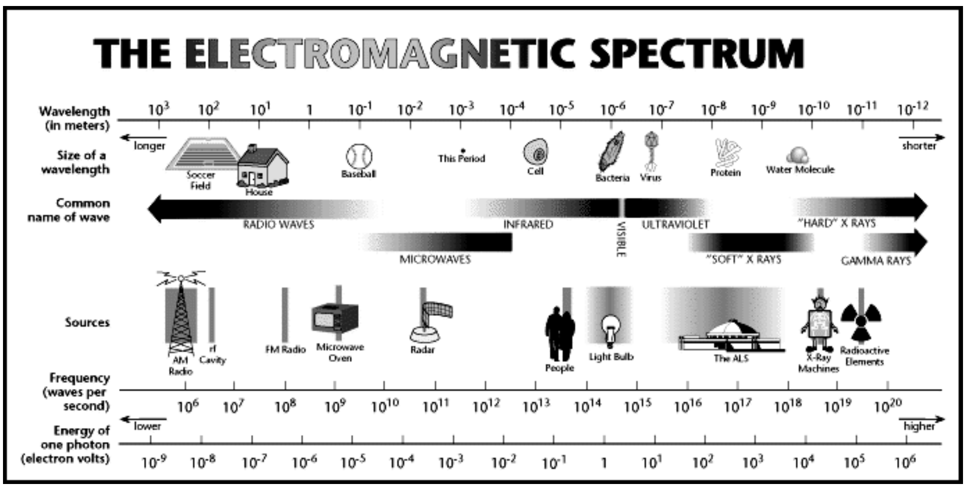


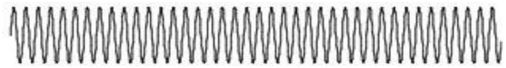
Figure 7. The electromagnetic spectrum

a. Examine the electromagnetic spectrum.

1. Describe the relationship between frequency and wavelength of each electromagnetic wave.

2. Draw waves to represent each electromagnetic wave. Your illustrations must represent the wavelength of a wave relative to the others. For instance, gamma rays have a very small wavelength compared to the other waves in the spectrum.

1. **Gamma Rays**
2. ___________
3. ___________
4. ___________
5. ___________
6. ___________
7. ___________



b. The Sun is an important source of ultraviolet (UV) waves, which is the main cause of sunburn. Sunscreen lotions are transparent to visible light but absorb most UV light. The higher a sunscreen's solar protection factor (SPF), the greater the percentage of UV light absorbed. Why are UV rays harmful to the skin compared to visible light?

Compare the frequency and energy carried by UV waves to that of visible light.

C. Summary

1. Mechanical waves like sound, water waves, earthquake waves, and waves in a stretched string propagate through a _______________ while __________________ waves such as radio waves, visible light, and gamma rays, do not require a material medium for their passage.

Review. Waves Around You

The activities that you have performed are all about wave motion or the propagation of a pattern caused by a vibration. Waves transport energy from one place to another thus they can set objects into motion.

What happens when waves pass by?

Activity 1 introduced you to transverse waves, longitudinal waves, and surface waves. You observed the motion of a segment of the material through which the wave travels.

1. Transverse waves occur when the individual particles or segments of a medium vibrate from side to side perpendicular to the direction in which the waves travel.

2. Longitudinal waves occur when the individual particles of a medium vibrate back and forth in the direction in which the waves travel.

3. The motion of water molecules on the surface of deep water in which a wave is propagating is a combination of transverse and longitudinal displacements, with the result that molecules at the surface move in nearly circular paths. Each molecule is displaced both horizontally and vertically from its normal position.

4. While energy is transported by virtue of the moving pattern, it is important to remember that there is not net transport of matter in wave motion. The particles vibrate about a normal position and do not undergo a net motion.

How can you describe waves?

In Activity 2, you have encountered the important terms and quantities used to describe periodic waves.

1. The crest and trough refer to the highest point and lowest point of a wave pattern, respectively.

2. The amplitude of a wave is the maximum displacement of a particle of the medium on either side of its normal position when the wave passes.

3. The frequency of periodic waves is the number of waves that pass a particular point for every one second while the wavelength is the distance between adjacent crests or troughs.

4. The period is the time required for one complete wave to pass a particular point.

5. The speed of the wave refers to the distance the wave travels per unit time. It is related to the frequency of the wave and wavelength through the following equation:

wave speed = frequency x wavelength

How do waves propagate?

Finally, Activity 3 prompted you to distinguish between mechanical and electromagnetic waves.

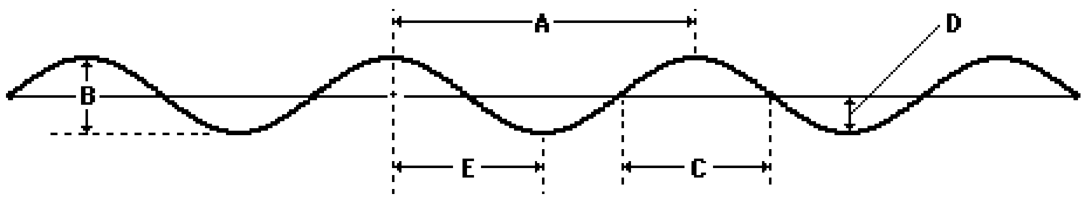
1. In mechanical waves, some physical medium is being disturbed for the wave to propagate. A wave traveling on a string would not exist without the string. Sound waves could not travel through air if there were no air molecules. With mechanical waves, what we interpret as a wave corresponds to the propagation of a disturbance through a medium.
2. On the other hand, electromagnetic waves do not require a medium to propagate; some examples of electromagnetic waves are visible light, radio waves, television signals, and x-rays.

Up Next. Light

In the next module, you would learn about visible light, the most familiar form of electromagnetic waves, since it is the part of the electromagnetic spectrum that the human eye can detect. Through some interesting activities, you would come across the characteristics of light, how it is produced and how it propagates. You would need the concepts that you learned from this module to fully understand and appreciate the occurrence of light.

Pre/Post Test

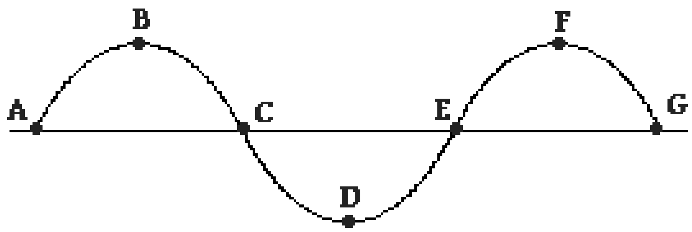
Consider the diagram below to answer questions 1 and 2.



1. The wavelength of the wave in the diagram above is given by letter ______.

2. The amplitude of the wave in the diagram above is given by letter _____.

3. Indicate the interval that represents a half wavelength.



   a. A to E
   b. B to F
   c. A to B
   d. C to E

4. A pulse sent down a long string eventually dies away and disappears. What happens to its energy?
   a. The energy disappears with the wave.
   b. The energy is remains along the length of the string.
   c. The energy is transferred from the wave to the environment.
   d. The pulse does not carry energy.

5. Mechanical waves transport energy from one place to another through
   a. Alternately vibrating particles of the medium
   b. Particles traveling with the wave
   c. Vibrating particles and traveling particles
   d. None of the above

6. In a transverse wave, the individual particles of the medium
   a. move in circles
   b. move in ellipses
   c. move parallel to the direction of travel
   d. move perpendicular to the direction of travel

7. The higher the frequency of a wave,
    a. the lowerits speed
    b. the shorter its wavelength
    c. the greater its amplitude
    d. the longer its period

8. Of the following properties of a wave, the one that is independent of the others is its
    a. amplitude
    b. wave speed
    c. wavelength
    d. frequency

9. Waves in a lake are 5.00 m in length and pass an anchored boat 1.25 s apart. The speed of the waves is
    a. 0.25 m/s
    b. 4.00 m/s
    c. 6.25 m/s
    d. impossible to find from the information given

10. Energy from the sun reaches the earth through
    a. ultraviolet waves
    b. infrared waves
    c. mechanical waves
    d. electromagnetic waves

References and Web Links

Anatomy of an electromagnetic wave. Available at:
http://missionscience.nasa.gov/ems/02_anatomy.html

Electromagnetic waves. Available at:
http://www.colorado.edu/physics/2000/waves_particles/
[3] Hewitt, P. (2006). Conceptual Physics 10th Ed. USA: Pearson Addison-Wesley.

The anatomy of a wave. Available at:
http://www.physicsclassroom.com/class/waves/u10l2a.cfm

The nature of a wave. Available at:
http://www.physicsclassroom.com/class/waves/u10l1c.cfm

Suggested time allotment: 8 to 10 hours

Unit 3
MODULE
3

SOUND

Would you like to try placing your palm on your throat while saying – “What you doin?” What did your palm feel? Were there vibrations in the throat? Try it again and this time, say – “Mom! Phineas and Ferb are making a title sequence!”

In the previous module you learned about wave properties and common characteristics like pitch and loudness. You will also learn the 2 kinds of waves according to propagation. These are the longitudinal and transverse waves. Sound is an example of a longitudinal wave. It is also classified as a mechanical wave. Thus there has to be matter for which sound should travel and propagate. This matter is better known as medium.

Terms to Remember

Longitudinal Wave
- Wave whose motion is parallel to the motion of the particles of the medium

Mechanical wave
- Wave that need a medium in order to propagate

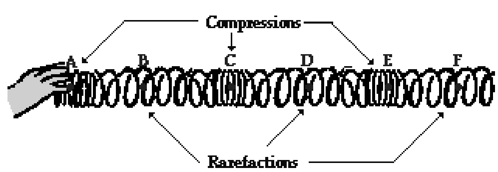


Figure 2. Longitudinal wave

How does sound propagate?

In Activity 1, you will try to explore how sound is produced. You are going to use local materials available in your community to do this activity. You can do “*Art Attack*” and be very creative with your project.

Activity 1
My own sounding box

Objectives

In this activity, you should be able to construct a sounding box to

1. demonstrate how sound is produced; and

2. identify factors that affect the pitch and loudness of the sound produced.

Materials Needed

- shoe box
- variety of elastic or rubber bands (thin and thick)
- extra cardboard – optional
- pair of scissors or cutter
- ruler

TAKE CARE! **Handle all sharp tools with care.**

Procedure

1. Cut and design your shoe box as shown in Figure 2.

2. Put the rubber bands around the box. Make sure that the rubber bands are almost equally spaced and that the rubber bands are arranged according to increasing thickness from the lower end to the other end of the box.

3. Use your finger to pluck each rubber band. Listen to the sound produced.

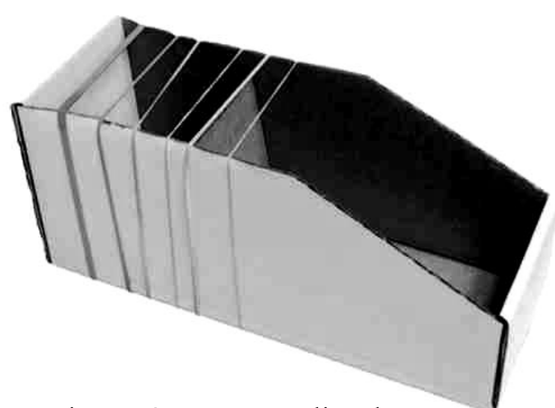


Figure 2. My sounding box

Q1. What physical signs did you observe when you plucked each band. Did you hear any sound? What produced the sound?

Q2. How different are the sounds produced by each band with different thickness?

4. This time use the fingers of one hand to stretch one of the elastics. Pluck the elastic with the fingers of the other hand and observe.

   Q3. Are there changes in the note when you plucked the stretched band?

5. Repeat step 4 with the other elastic bands.

   Q4. Arrange the elastics in sequence from the highest note to the lowest note produced.

When we talk or make any sound, our vocal cords vibrate. When there are no vibrations felt, no sound is produced. This means that sounds are caused by vibrations. Vibrations of molecules are to the to-and-fro or back-and-forth movement of molecules. Vibrations are considered as a disturbance that travels through a medium. This vibratory motion causes energy to transfer to our ears and is interpreted by our brain. Sound waves are examples of **longitudinal waves**. They are also known as mechanical waves since sound waves need medium in order to propagate.

In Activity 1, vibrations produced by the elastic band produced sound. The sounding box amplified (increase in amplitude) this sound.

Sound waves can travel in air. When they come in contact with our eardrums, the vibrations of the air force our eardrums to vibrate which is sensed and interpreted by our brain.

Can sound waves also travel in other media like solids and liquids?

You can try this one. Place your ear against one end of a tabletop. Ask a friend to gently tap the other end of the table with a pencil or a ruler. What happens? Then ask your friend to again gently tap the other end of the table but this time, make sure that your ear is not touching the table. What happens? In which situation did you encounter louder and more pronounced sound? In which situation did you encounter the sound clearly?

Sound is produced by the slight tapping of the table with a pencil or a ruler. This can be heard clearly at the other end of the table. This shows that sound waves can also travel through wood or solid. Sound is more distinct in solids than in air. This also means that sound is heard much louder when it travels in solids than in air.

What about in liquids? Can sound travel in liquids too? Liquids are better transmitters of sound than gases. If two bodies are struck together underwater, the sound heard by a person who is underwater is louder than when heard in air, but softer than in solids.

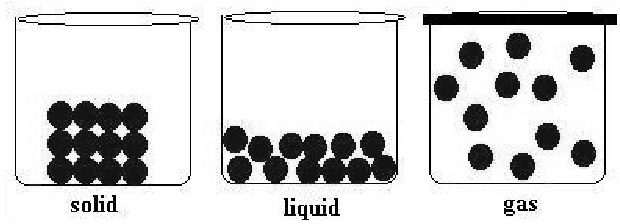


Figure 3: Molecules of different media

As you can see in Figure 3, particles of solids are more closely packed than particles of liquid and gas. This is why sound produced in solids is much more distinct and loud than when it is propagated or produced in liquids and gas. Between liquids and gases, on the other hand, liquid particles appear more closely spaced than gases. This means that louder sound will be produced in liquids than in gases.

Spacing of particles of the medium like solid, liquid and gas is an important factor on how would is transmitted. Take a look at Figure 3, liquid particles are closer to each other than the particles in the gas. Sound waves are transmitted easier in liquids. Between liquids and solids, the particles of solids are even closer together than the liquid molecules; therefore, sound travels even faster in solids than in liquids. Since different media transmit sound differently, sound travels at different speeds in different materials. Since solid is the best transmitter of sound, ***sound travels fastest in solids and slowest in gases*.**

The table below shows the speed of sound in different materials.

Table 1: Speed of sound in different materials

Materials	Speed of Sound V (m/s)
Air (0^oC)	331
He (0^oC)	1005
H (20^oC)	1300
Water	1440
Seawater	1560
Iron and Steel	5000
Aluminum	5100
Hard wood	4000

Sound speed is dependent on several factors such as (1) atmospheric pressure, (2) relative humidity, and (3) atmospheric temperature. Remember these weather elements you studied in your earlier grades? High values of these elements lead to faster moving sound. When you are in the low lands and the surrounding is hot, sound travels fast. Do you want to know why sound travels faster in hot air? There are more molecular interactions that happen in hot air. This is because the hot particles of air gain more kinetic energy and so there is also an increase in the mean velocity of the molecules. Since sound is a consequence of energy transfer through collisions, more collisions and faster collisions means faster sound.

Going a little deeper on this, speed of sound basically depends on the *elastic property* and the *inertial property* of the medium on which it propagates. The elastic property is concerned with the ability of the material to retain or maintain its shape and not to deform when a force is applied on it. Solids as compared to liquids and gases have the highest elastic property. Consequently, solid is the medium on which sound travels fastest. This means that the greater the elastic property, the faster the sound waves travel. The iniertial property, on the other hand, is the tendency of the material to maintain its state of motion. More inertial property means the more inert (more massive or greater mass density) the individual particles of the medium, the less responsive they will be to the interactions between neighbouring particles and the slower that the wave will be. Within a single phase medium, like air for example, humid air is more inert than humid air. This is because water that has changed to vapor is mixed with the air. This phenomenon increases the mass density of air and so increases the inertial property of the medium. This will eventually decrease the speed of sound on that medium.

Sound cannot travel in a vacuum. Remember that sound is a mechanical wave which needs medium in order to propagate. If no matter exists, there will be no sound. In the outer space, sound would not be transmitted.

Sound waves possess characteristics common to all types of waves. These are frequency, wavelength, amplitude, speed or velocity, period and phase. Just like other waves, sound also exhibits wave properties just like reflection, refraction, diffraction, and interference. More than these properties are pitch and loudness of sound. *Pitch* refers to the highness or lowness of sound. *Loudness* is how soft or how intense the sound is as perceived by the ear and interpreted by the brain. Do you want to find out more characteristics and properties of sound? Activity No. 2 will let your discover some of these properties using your sounding box.

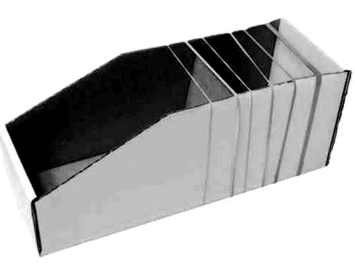
Activity 2
Properties and characteristics of sound

Objective

In this activity, you will use your sounding box to describe the characteristics of sound and compare them with those of sound produced by a guitar.

Materials Needed

- Sounding Box
- Wooden rod
- Ruler
- Guitar



Procedure

Part 1: Sounding the Box...

1. Label the rubber bands of your sounding box as S1, S2 and so on. Labeling should start with the thinnest rubber band.

2. Pluck each rubber band. Listen to the sounds produced.

   Q1. What did you observed when you plucked each of the rubber bands and sound is produced? How then is sound produced?

   Q2. Is there a difference in the sound produced by each of the rubber bands? How do they differ?

   Q3. Which band produced a higher sound? Which band produced a lower sound?

   Q4. How can you make a softer sound? How can you make a louder sound?

   Q5. What factors affect the pitch and loudness of the sound produced by the rubber bands?

3. Stretch one of the rubber bands and while doing so, pluck it again.

   Q6. Is there a change in the sound produced when you pluck the rubber band while stretching it? How does stretching the rubber band affect the pitch of the sound produced?

4. Place a ruler (on its edge) across the sounding box as shown in Figure 3. Pluck each rubber band and observe.

   Q7. Is there a difference in the sound produced when the ruler is placed across the box?

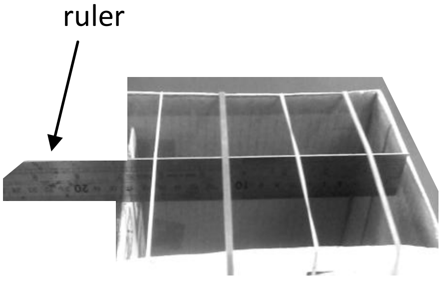


Figure 3: With stretch rubber bands

5. Move the ruler off center to the left or to a diagonal position so that one side of each rubber band is shorter than the other side (Figure 4). Pluck again each rubber band on each side of the ruler and observe.

Figure 4: Diagonal Stretching of the bands

Q8. Which part of the rubber band (shorter side or longer side) provides higher pitch? Which part provides lower pitch?

Q9. Again, what factors affect the pitch of the sound produced by the rubber bands?

Part 2: The Guitar...

6. Strum each guitar string without holding the frets. (String #0 is the lower most string while string #6 is the uppermost string.)

7. Record all you observations in the table provided.

String #	Pitch (High or Low)
0	
1	
2	
3	
4	
5	
6	

Q10. Which string vibrates fastest when strummed?

Q11. Which string vibrates slowest when strummed?

Q12. Which string has the highest frequency?

Q13. Which string has the highest pitch?

Q14. Which has the lowest frequency?

Q15. Which string has the lowest pitch?

Q16. How would you relate pitch and frequency?

The highness or lowness of sound is known as the **pitch** of a sound or a musical note. In Activity No. 2 you were able to relate vibrations, frequency and pitch using your improvised sounding box and a guitar. The pitch of a high frequency sound is also high and a low frequency sound is also; lower in pitch.

When you were in your earlier grades you studied about the human ear. Our ear and that of animals are the very sensitive sound detectors. The ear is a part of the peripheral auditory system. It is divided into three major parts: *the outer ear, the middle ear and the inner ear.*

The outer ear called the *pinna* collects the sound waves and focuses them into the ear canal. This canal transmits the sound waves to the eardrum.

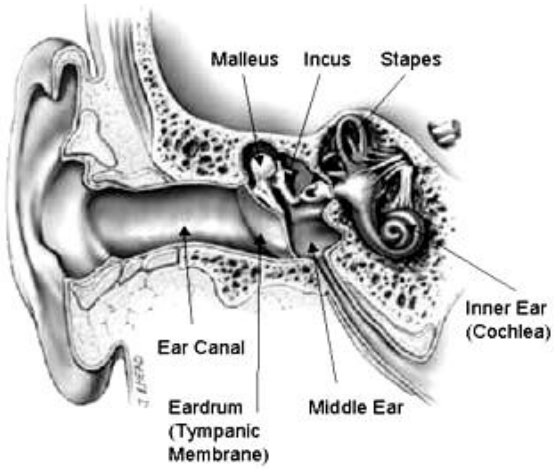


Figure 4: The human ear

The ear canal is the eardrum membrane or the *tympanum*. It separates the outer and the middle ears physically. Air vibrations set the eardrum membrane in motion that causes the three smallest bones (*hammer, anvil and stirrup*) to move. These three bones convert the small-amplitude vibration of the eardrum into large-amplitude oscillations. These oscillations are transferred to the inner ear through the oval window.

Behind the oval window is a snail-shell shaped liquid –filled organ called the *cochlea.* The large-amplitude oscillations create waves that travel in liquid. These sounds are converted into electrical impulses, which are sent to the brain by the auditory nerve. The brain, interprets these signals as words, music or noise.

Did you know that we can only sense within the frequency range of about 20 Hz to about 20000 Hz? Vibrational frequencies beyond 20 000 Hz is called ***ultrasonic frequencies*** while extremely low frequencies are known as ***infrasonic frequencies***. Our ear cannot detect ultrasonic or infrasonic waves. But some animals like dogs can hear sounds as high as 50 000 Hz while bats can detect sounds as high as 100 000 Hz.

We can see images of your baby brother or sister when the OB-Gyne asks your mommy or nanay to undergo ultrasound. ***Ultrasonic waves*** are used to help physicians see our internal organs. Nowadays, ultrasonic technology is of three kinds: 2-dimensional, 3-dimensional, and 4-dimensional categories. In the 3- and 4-dimensional ultrasonic technologies, the features of the fetus are very clearly captured.

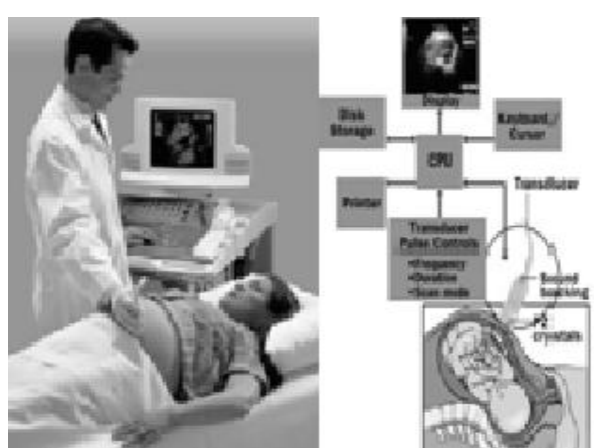


Figure 5: Ultrasound

It has also been found that ultrasonic waves can be used as rodent and insect exterminators. The very loud ultrasonic sources in a building will usually drive the rodents away or disorient cockroaches causing them to die from the induced erratic behavior. What other applications of sound do you have in mind? Do you want to share them too?

Loudness and Intensity

Do you still remember intensity of light in the previous module? In sound, intensity refers to the amount of energy a sound wave. Figure 6 shows varying intensity of sound. High amplitude sounds usually carry large energy and have higher intensity while low amplitude sound carry lesser amount of energy and have lower intensity.

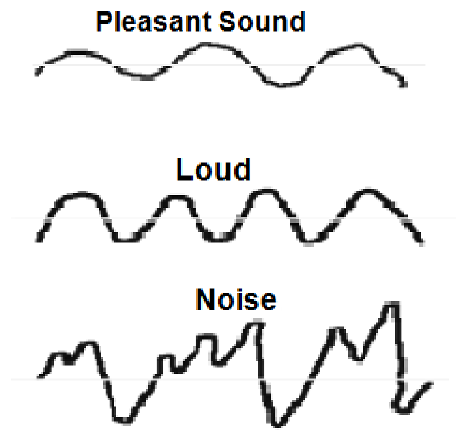


Figure 6: Varying sounds

Sound intensity is measured by various instruments like the oscilloscope. ***Loudness*** is a psychological sensation that differs for different people. Loudness is subjective but is still related to the intensity of sound. In fact, despite the subjective variations, loudness varies nearly logarithmically with intensity. A logarithmic scale is used to describe sound intensity, which roughly corresponds to loudness. The unit of intensity level for sound is the decibel (dB), which was named after *Alexander Graham Bell* who invented the telephone. On the decibel scale, an increase of 1 dB means that sound intensity is increased by a factor of 10.

Father and son duo interprets the loudness of a sound differently. The son considers the rock music a soft music while the father considers it a loud sound. The father may even interpret the sound as a distorted sound, which is known as noise. Noise is wave that is not pleasing to the senses.


Figure 7: Father and Son Duo

Table 2. Sound Levels of different sound sources

Source of sound	Level (dB)
Jet engine, 30 m away	140
Threshold of pain	120
Amplified rock music	115
Old subway train	100
Average factory	90
Busy street traffic	70
Normal conversation	60
Library	40
Close whisper	20
Normal breathing	10
Threshold of hearing	0

Let's see how you interpret sound yourselves. Look for 3 more classmates and try Activity 3. This will test your ability to design and at the same time show your talents!

Activity 3
Big time gig!

Objectives

In this activity, you should be able to:

1. create musical instruments using indigenous products and
2. use these instruments to compose tunes and present in a Gig. Students may also utilize other indigenous musical instruments.

Materials Needed

- Indigenous materials such as sticks, bottles or glassware available in your locality to be used as musical instrument
- Localized or improvised stringed instruments
- Localized or improvised drum set

Procedure

1. Form a group of four (4). One can play a stringed instrument, while the other can play the drum and the 3rd member can use the other instrument that your group will design or create. The last member will be your group's solo performer.
2. Look for local materials which you can use to create different musical instruments.

3. Try to come up with your own composition using the instruments you have created.
4. In the class GIG you are to play and sing at least 2 songs (any song of your choice and your original composition).
5. Check the Rubric included to become familiar with the criteria for which you will be rated.

Big Time Gig!

Rubric Scoring

Task/ Criteria	4	3	2	1	Score
Improvised/ Localized musical instruments	• Makes use of local or indigenous materials • The improvised instruments produce good quality sound comparable to standard musical instruments.	• Makes use of local materials only. • The improvised instruments produce good quality sound.	• Makes use of local materials only. • The improvised instruments produce fair quality sound.	• Makes use of local materials only. • The sound produced by the improvised instruments is not clear and distinct.	
Composition	The group's original composition has good melody. The lyrics provided are thematic and meaningful	The group's original composition has fair melody and the lyrics provided are thematic and meaningful	The group's original composition has fair melody and the lyrics provided are ***NOT*** thematic but meaningful	The group's original composition has fair melody and the lyrics provided are ***NEITHER*** thematic nor meaningful	
Performance	• The group was able to successfully use the improvised musical instruments in their GIG. • The group was able to provide good quality rendition or performance	• The group was able to successfully use the improvised musical instruments in their GIG. • The group was able to provide fair rendition.	• The group was able to use the improvised musical instruments but some were out of tune • The group was able to provide fair rendition.	• The group was able to use the improvised musical instruments but MOST were out of tune • The group was able to provide fair rendition	

Task/ Criteria	4	3	2	1	Score
Cooperation and Team Work	Each one of them completed their task so as to come up with the expected output - GIG	3 out of 4 members completed their task so as to come up with the expected output - GIG	2 out of 4 completed their task so as to come up with the expected output - GIG	Only 1 out of the 4 members did his/her job	
				TOTAL:	

How was your GIG? Did you enjoy this activity? Aside from the concepts and principles in sound you learned and applied for a perfect performance what other insights can you identify? Can you extend your designs to come up with quality instruments using indigenous materials? You can be famous with your artworks...

Sound waves are mechanical waves than need for a medium for sound to propagate. Vibrations of the medium create a series of compression and rarefaction which results to longitudinal waves. Sound can travel in all media but not in vacuum. Sound is fastest in matter that is closely packed like solid and slowest in gas. Speed of sound is dependent on factors like temperature, humidity and air pressure. High temperature brings much faster sound. Increased humidity, on the other hand makes sound travel slower. As pressure is increased, speed is also increased. Inertial and elastic properties of the medium also play an important part in the speed of sound. Solids tend to be highly elastic than gases and thus sound travel fastest in solids. In a single phase matter however, the inertial property which is the tendency of the material to maintain its motion also affect speed of sound. Humid air is more massive and is more inert than dry air. This condition brings lesser molecular interactions and eventually slower sound. Sound, just like other waves do have characteristics such as speed, frequency, wavelength, amplitude, phase and period. Like any other wave, sound exhibit properties like reflection, refraction, interference and diffraction. Other properties are loudness and pitch. Pitch is dependent on the frequency of sound wave. The higher frequency the higher the pitch of the sound produced.

Organisms like us are capable of sensing sound through our ears. Just like other organism, our ears do have parts that perform special tasks until the auditory signals reach and are interpreted by our brain. Frequencies beyond the audible to human are known as ultrasonic (beyond the upper limit) and infrasonic (below the lower limit). Intensity and loudness are quantitative and qualitative descriptions of the energy carried by the wave. High amplitude waves are intense and are sensed as loud sound. Low amplitude sound waves are soft sound. Music is a special sound that forms patterns and are appealing to our sense of hearing.

Reading Materials/Links/Websites

http://www.physicsclassroom.com/Class/sound/u11l2c.cfm
http://en.wikipedia.org/wiki/Sound#Sound_wave_properties_and_characteristics
http://personal.cityu.edu.hk/~bsapplec/characte.htm
http://www.slideshare.net/agatonlydelle/physics-sounds

Suggested time allotment: 5 to 6 hours

Unit 3
MODULE
4

LIGHT

Do you still remember Sir Isaac Newton? What about Christian Huygens? Did you meet them in your earlier grades? These people were the first to study about light.

In this module, you will learn about light. You will also find out that there are different sources of light and that light exhibits different characteristics and properties. Finally, you will design a simple activity to test whether light travels in a straight light or not.

What are the common sources of light?
How do these common sources produce light?
What are the common properties and characteristics of light?

Sir Isaac Newton believed that light behaves like a particle while Christian Huygens believed that light behaves like a wave. A 3rd scientist, Max Planck came up with what is now known as the *Dual-Nature of Light*. He explained that light can be a particle and can also be a wave. To complete our knowledge about the nature of light, James Clark Maxwell proposed the *Electromagnetic Theory of Light*.

While these scientists dig deep into the nature of light and how light are propagated, let us be more familiar with ordinary materials we use as common sources of light. The **Sun** for example is known as a *natural source* of light. Sun is also considered as a *luminous body* (*an object capable of producing its own light*). Other sources are the lamps, bulbs, and candles. These are the *artificial sources*.

In your earlier grades you learned about energy transformation. Energy transformation is needed to convert or transform forms of energy to light or other forms. In bulbs, electric potential is converted to light. In lamps, chemical energy is transformed to light.

In Activity 1, you will try to observe transformation of chemical energy from chemical substances such as oil to light. Further, you will also gather data which chemical substance is best by relating it to the brightness of the light produced. In this activity, you will use the *langis kandila* or *lampara* as we call it in the Philippines or the *Diwali* lights as it is known in other countries like India.

Activity 1
Light sources: Langis kandila or lampara

Objectives

In this activity, you should be able to:
1. construct a simple photometer;
2. determine which chemical substance produce the brightest light; and
3. infer that brightness of light is dependent on the distance of the source.

Materials Needed

- an electric glow lamp (Small lamp is needed)
- candle - weighing 75 grams
- wedge with sloping surfaces (sharp angle about 60° to 70° that serve as the photometer (made of white wood or paper)
- *langis kandila* or *lampara*
- variety of vegetable oil (about 5)
- aluminum pie containers or small clay pots
- cotton string for wick
- set of books or tripod that will serve as platform for *Diwali* lights

Procedure

Part 1: Improvised Photometer

Arrange the electric glow lamp, the candle and the wedge as shown on the right. Make sure that you do this activity in a **dark room** for good results.

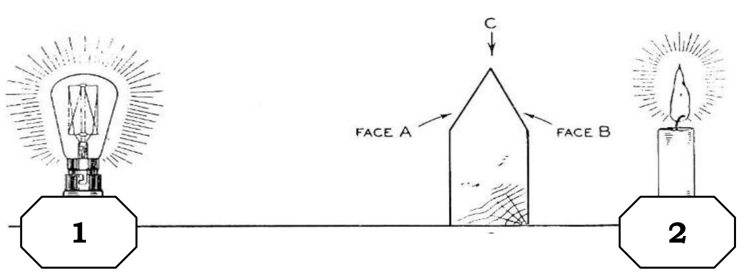


Figure 1. Improvised photometer set up

Illuminate the side “A” of the wedge by the lamp and side “B” by the candle. In general the lamp side will look brighter than the other.

Move the wedge nearer to the candle to a spot at which you as an observer, looking down on the two surfaces of the wedge (from "C") cannot see any difference between them in respect of brightness. (*They are then equally illuminated; that is to say the candle light falling on "B" is equal in intensity to the electric light falling on "A."*)

Calculate the power of the lamp relative to the candle. (*E.g. If both side of the wedge showed equal illumination when it is about 200 cm from 1, and 50 cm from 2, the distances are as 4 to 1. But as light falls off according to the square of the distance:* $(200)^2 = 40\ 000$ *and* $(50)^2 = 2\ 500$ *or 16 to 1.).* **Thus the candle-power of the lamp is 16.**

Q1. What is the candle power of your set up? *(Include your computations.)*

Part 2: Langis Kandila or Lampara

Figure 3: Langis kandila or lampara

1. Make 5 *langis kandila* or *lampara* using aluminium pie containers or small clay pots as shown. Label your *langis kandila* as DL-KL1, DL-KL2 and so on.

2. Pour different variety of vegetable oil in each of the pot.

3. Use the improvised photometer to determine the brightness of each of the candle.

4. Replace the candle you used in the 1st part with the *langis kandila*.

5. Compute the candle power of the lamp with respect to the *langis kandila*. You may refer to step 4 for the step by step process of determining the candle power using the improvised photometer. Record your data on the provided table:

Table 1. Brightness of Vegetable Oil Variety

Diwali* Lights/*Langis Kandila	**Vegetable Oil Variety**	**Brightness/Luminous Intensity (Candela)**
DL-LK 1	Canola Oil	
DL-LK 2	Butter	
DL-LK 3	Margarine	
DL-LK 4	Corn Oil	
DL-LK 5	Olive Oil	

Q2. Which among the *langis kandila* or *lampara* is the brightest?

Part 3: Intensity vs Distance from light source

1. Position your brightest *Diwali* light or *langis kandila* 20 inches or about 50 cm from the wedge. Compute the brightness of the *Diwali* light.
2. Move the *langis kandila* or *Diwali* light 10 cm closer then compute the brightness.
3. Repeat step 2 and each time move the *langis kandila* or *Diwali* light 10 cm closer to the wedge. Compute the corresponding brightness and record your data on the table below.

Distance from the Wedge (cm)	Observation	Brightness (Candela)
50		
40		
30		
20		
10		

Q3. How would you relate the brightness or intensity of light with the distance from the source?

Brightness of light depends on the source and the distance from the source. Brightness however, is qualitative and is dependent of the person's perception. Quantitatively, brightness can be expressed as luminous intensity with a unit known as *candela*. The unit expression came from the fact that one candle can approximately represent the amount of visible radiation emitted by a candle flame. However, this decades-ago assumption is inaccurate. But we still used this concept in Activity 1 as we are limited to an improvised photometer. If you are using a real photometer on the other hand, *luminous intensity refers to the amount of light power emanating from a point source within a solid angle of one steradian*.

Further, in Activity 1, varied chemical sources produced different light intensity. Likewise, different distances from the light source provided varied intensity.

As mentioned earlier, James Clark Maxwell discovered the Electromagnetic Theory of Light. He combined the concepts of light, electricity and magnetism to come up with his theory forming electromagnetic waves. Since these are waves they also exhibit different characteristics of waves such as wavelength, frequency and wave speed which you have studied in the previous module. There are different forms of electromagnetic waves arranged according to frequency. This arrangement of the electromagnetic waves is known as Electromagnetic spectrum. The visible part of which is known as white light or visible light. The next activity will lead you to explore the characteristics of the electromagnetic spectrum.

Activity 2
My spectrum wheel

Objectives

In this activity, you should be able to

1. construct a spectrum wheel and
2. explore the characteristics of light such as energy, frequency and wavelength.

Materials Needed

- Spectrum Wheel Pattern
- Cardboard or illustration board
- Button fastener
- Glue or paste

TAKE CARE! **Handle all sharp Objects with care.**

Procedure

Part 1: Spectrum Wheel

1. Cut the two art files that make up the wheel on the next pages.

2. Cut along the lines drawn on the top wheel. The small window near the center of the wheel should be completely cut out and removed.

3. Punch a whole into the center of the two wheels together. You may use a button fastener to hold the two wheels securely in place, one on top of the other, but they should be free to rotate relative to each other.

4. When you see a region of the EM spectrum show up in the open window and the "W,F,E" that correspond to that region showing up under the flaps then you know that you have done it right.

Source: Sonoma State University (http://www.swift.sonoma.eu


VISIBLE
INFRARED
MICROWAVE
RADIO
EM SPECTRUM
GAMMA-RAY
X-RAY
ULTRAVIOLET
1-10eV, 10⁻⁷ m, 10¹⁵ Hz
1-10⁻³eV, 10⁻³-10⁻⁶m, 10¹¹-10¹⁴ Hz
10⁻³-10⁻⁶ eV, 1-10⁻³m, 10⁸-10¹¹ Hz
<10⁻⁶ eV, >1m, <10⁸ Hz
ENERGY, WAVELENGTH, FREQUENCY
>10⁶ eV, <10⁻¹² m, >10²⁰ Hz
10³-10⁶ eV, 10⁻⁹-10⁻¹²m, 10¹⁷-10²⁰ Hz
10-10³eV, 10⁻⁷-10⁻⁹m, 10¹⁵-10¹⁷ Hz

Part 2: Characteristics of Light

Try out your Spectrum Wheel by positioning the inner most of the flaps on EM SPECTRUM. This will simultaneously position the other flaps to ENERGY, WAVELENGTH & FREQUENCY.

Turn the upper wheel and observe the combinations.

Fill in the table below with the corresponding combinations you have observed using your Spectrum Wheel.

Table 1. Characteristics of Light

EM Spectrum	***Energy***	***Frequency***	***Wavelength***	***Frequency x wavelength***
Radio				
Microwave				
Infrared				
Visible Light				
Ultraviolet				
X-Ray				
Gamma Ray				

Q1. How are frequency and wavelength related for a specific region of the spectrum?

Q2. What can you observe with the values of the product of frequency and wavelength in the different spectra?

Q3. How is ENERGY related to FREQUENCY?

Now that we are familiar with the electromagnetic spectrum and the corresponding energies, frequencies and wavelength probably we can see some applications of these in everyday living. UV rays are highly energetic than other spectral regions on its left. This could be a possible reason why we are not advised to stay under the sun after 9:00 in the morning. Prolong use of mobile phones may cause ear infection. This may be due to a higher energy emitted by microwaves used in cellular phones than radio waves commonly used in other communication devices. What about the visible spectrum? Do you want to know more about this spectral region?

What are the frequencies and energies of the visible spectrum? This is the visible light. Sir Isaac Newton used a prism to show that light which we ordinarily see as white consists of different colors. **Dispersion** is a phenomenon in which a prism separates white light into its component colors. Activity 3 will provide you more information about visible light. In this activity, you will be able to detect relationships between colors, energy, frequency, wavelength and intensity.

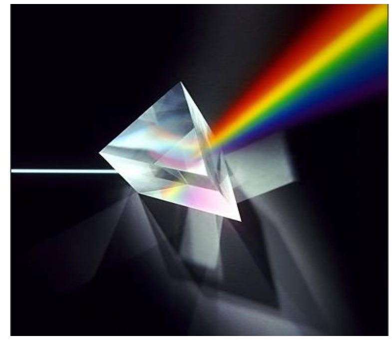


Figure 4. Color spectrum

Activity 3
Colors of light – color of life!

Objectives

In this activity, you should be able to

1. make a color spectrum wheel;
2. explore the characteristics of color lights; and
3. observe how primary colors combine to form other colors.

Materials Needed

- Color Spectrum Wheel Pattern Cardboard or illustration board
- white screen
- plastic filters (green, blue and red)
- 3 pieces of high intensity flashlights
- button fastener
- glue or paste

TAKE CARE! **Handle all sharp Objects with care.**

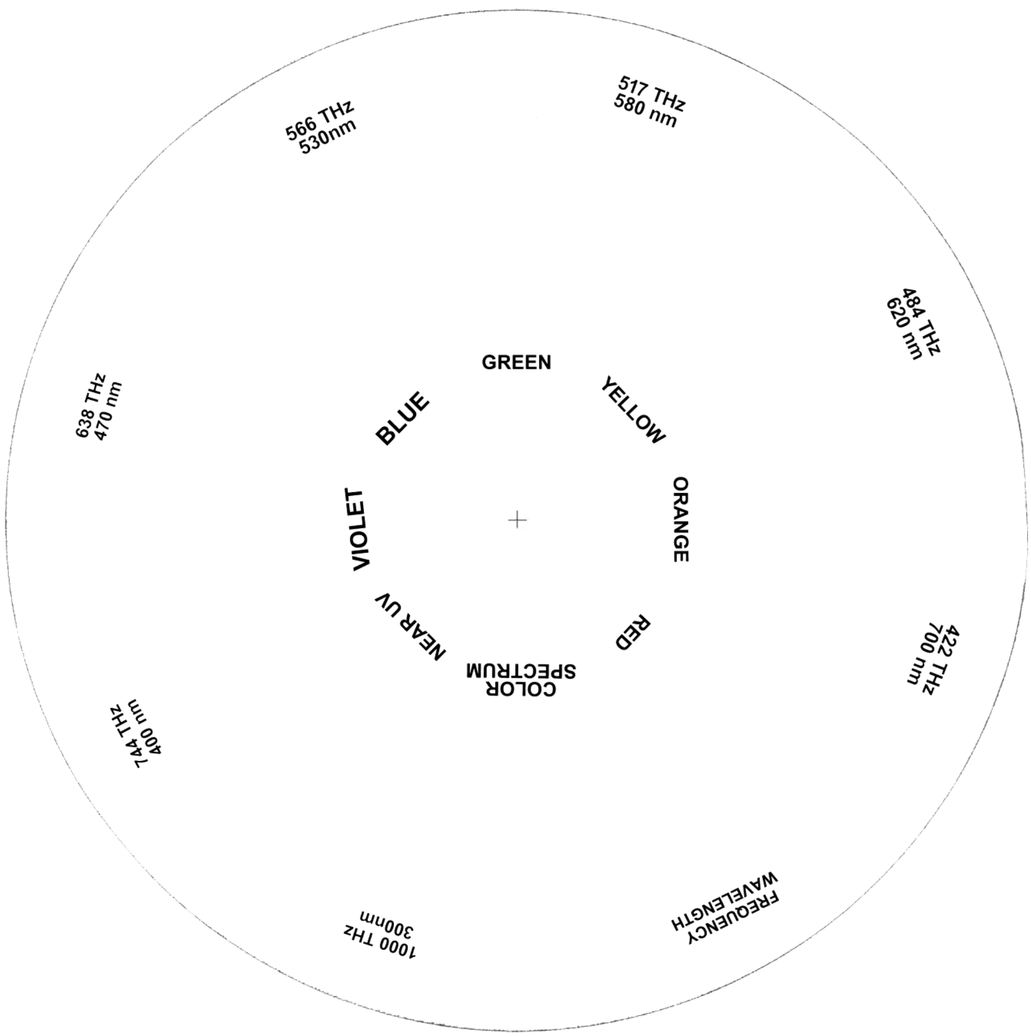
Procedure

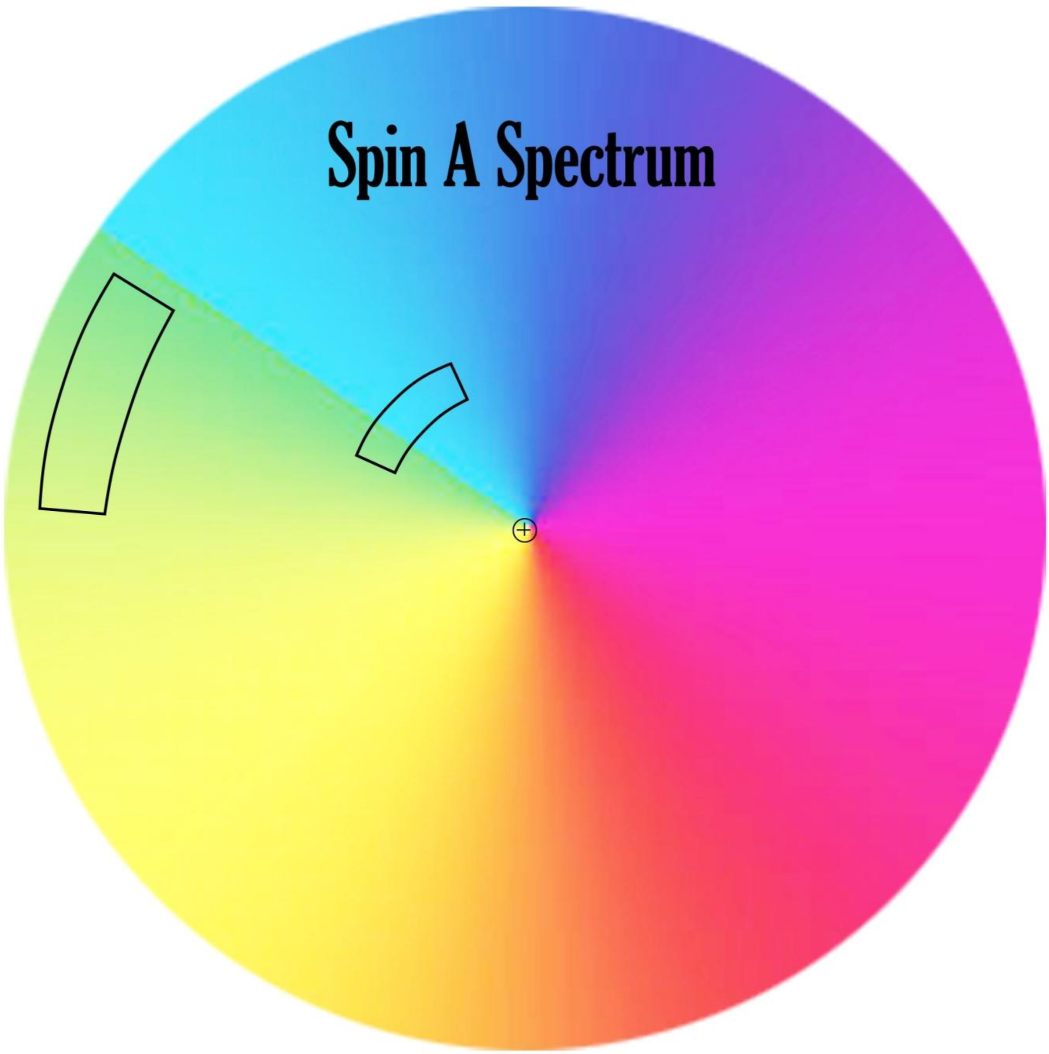
Part 1: Color Wheel

1. Cut the two art files that make up the wheel on the next pages.

2. Cut along the lines drawn on the top wheel. Cut the 2 sides as shown. The small window near the center of the wheel should be completely cut out and removed.

3. Punch a hole at the center of the two wheels. You may use a button fastener to secure the two wheels together one on top of the other, but they should be free to rotate relative to each other.
4. When you see a region of the *Color spectrum* show up in the open window and the "*W,F,E*" that correspond to that region showing up under the flaps then you know that you have done it right.




Spin A Spectrum

Part 2: Characteristics of Light

1. Try out your Color Spectrum Wheel by positioning the inner most of the flaps on COLOR SPECTRUM. This will simultaneously position the other flaps to ENERGY, WAVELENGTH & FREQUENCY.

2. Turn the upper wheel and observe the combinations.

3. Fill in the table below with the corresponding combinations you have observed using your Spectrum Wheel.

Table 1. Characteristics of Color Lights

Color Spectrum	Energy (eV)	Frequency (THz)	Wavelength (nm)	Frequency x wavelength (m/s)
Red				
Orange				
Yellow				
Green				
Blue				
Violet				

4. You will need to convert the equivalents of frequencies to Hz and the equivalent wavelengths to meters. Note that *terra (T)* is a prefix for 10^{14} while *nano (n)* is a prefix equivalent to $10^{-9.}$

Q1. Which color registers the highest frequency? shortest wavelength?
Q2. Which color registers the lowest frequency? longest wavelength?
Q3. What do you observe with the wavelength and frequency of the different colors?
Q4. What did you observe with the product of wavelength and frequency for each color? What is the significance of this value?
Q5. What can you say about the speed of the different colors of light in air?
Q6. Give a plausible explanation as to why white light separate into different colors.

Part 3: Combining Colors

1. Cover the lens of the flashlight with blue plastic filter. Do the same with the 2 other flashlights. The 2^{nd} flashlight with green plastic filter and the 3^{rd} with red plastic filter.

2. Ask 2 other groupmates to hold the 2 other flashlight while you hold on to the 3^{rd} one. Shine these flashlights on the white screen and note the colors projected on the screen.

3. Let 2 color lights from the flashlights overlap. Observe what color is produced and fill in the table below.

Table 2. Color that you see

Color of Plastic Filter	Color that you see projected on the screen
Green	
Blue	
Red	

Table 3. Color Mixing

Color Combination	Resulting Color
Green + Blue	
Blue + Red	
Red + Green	
Red + Green + Blue	

Dispersion, a special kind of refraction, provided us color lights. This phenomenon is observed when white light passes through a triangular prism. When white light enters a prism and travels slower in speed than in vacuum, color separation is observed due to variation in the frequencies (and wavelength) of color lights. Remember the concept of refractive indices in the previous module? The variations in frequencies (and wavelengths) are caused by the different refractive indices of the varying color light. Thus, blue light with greater refractive index refracts more and appears to bend more than red light. But do you really think that light will bend when travelling in space? The last activity in this module will test your ability to design an experiment to test if light travels in a straight line or not.

Activity 4
Light up straight!

Objective

In this activity, you should be able to design an experiment given several materials to show that light travels in a straight line.

Materials Needed

- 2 pieces of cardboard
- cutting tool
- bright room
- ruler or meter stick
- permanent marker
- pencil
- any object (e.g. medium size Johnson's face powder box)

TAKE CARE!

Handle all sharp objects with care.

Handle all lighting tools with care to avoid being burnt.

General Instructions

1. Given the materials design a 5-6 step procedure to test that light follows a straight line or not.

2. Remember that you are only allowed to use the materials specified in this particular activity.

3. Check the rubric scoring for your guide.

Lighting Up Straight!
Rubric Scoring

Task/ Criteria	4	3	2	1	Score
Experiment Procedure	• Steps are logically presented. • The procedure included about 5-6 steps. • All materials given to the group are utilized in the procedure	• Steps are logically presented. • The procedure included about 3-4 steps. • 75% of the materials given to the group are utilized in the procedure	• Steps are logically presented. • The procedure included about 3-4 steps. • 50% of the materials given to the group are utilized in the procedure	• Steps are logically presented. • The procedure included about 2-3 steps. • 25% of the materials given to the group are utilized in the procedure	
Result of Experiment Try-out/ Feasibility	The group has successfully attained the object to prove that light travels in a straight line using their designed procedure.	The group has attained the object to prove that light travels in a straight line using their designed procedure but there are some steps that are not very clear.	The group has partially attained the object to prove that light travels in a straight line using their designed procedure.	The group had some effort but was not able to attained the object to prove that light travels in a straight line using their designed.	
Cooperation and Team Work	Each one of them completed their task so as to come up with the expected output.	About 75% of the members completed their task so as to come up with the expected output.	About 50% of the members completed their task so as to come up with the expected output.	About 25% of the members did his/her job	
				TOTAL:	

Light, accordingly has wavelike nature and particle-like nature. As a wave, it is part of the electromagnetic waves as the visible spectrum. This visible spectrum is also known as white light. White light undergoes dispersion when it passes through a prism. The variations of refractive indices result to variations in the refraction of color lights dependent on the frequencies (and wavelength) of the color lights. This brings about blue light being refracted more than the other color lights and thus appears to be bent. However, light travels in a straight line path in a particular medium.

Brightness or intensity and colors are special properties of light. These can be observed in different phenomena such as rainbows, red sunset, and blue sky. You can identify many other applications of light and colors as you become keen observers of natural phenomena.

Reading Materials/Links/Websites

http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/glossary/term-full.php?t=dispersion
http://www.physicsclassroom.com/class/refrn/u14l4a.cfm

Suggested time allotment: 5 to 6 hours

Unit 3
MODULE
5
HEAT

For sure, you have used the word 'heat' many times in your life. You have experienced it; you have observed its effects. But have you ever wondered what heat really is?

In your earlier grades, you learned that heat moves from the source to other objects or places. Example is the kettle with water placed on top of burning stove. The water gets hot because heat from the burning stove is transferred to it.

This module aims to reinforce your understanding of heat as an energy that transfers from one object or place to another. You will determine the conditions necessary for heat to transfer and the direction by which heat transfers by examining the changes in the temperature of the objects involved. You will observe the different methods of heat transfer and investigate some factors that affect these methods. The results will help you explain why objects get hot or cold and why some objects are seemingly colder or warmer than the others even if they are exposed to the same temperature.

How is heat transferred between objects or places?
Do all objects equally conduct, absorb, or emit heat?

What is Heat?

Have you ever heard of the term "thermal energy" before? Any object is said to possess thermal energy due to the movement of its particles. How is heat related to thermal energy? Like any other forms of energy, thermal energy can be transformed into other forms or transferred to other objects or places. Heat is a form of energy that refers to the thermal energy that is 'in transit' or in the process of being transferred. It stops to become heat when the transfer stops. After the energy is transferred, say to another object, it may again become thermal energy or may be transformed to other forms.

Thermometer

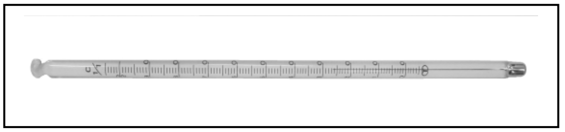


Figure 1. Thermometer

Heat transfer is related to change in temperature or change in the relative hotness or coldness of an object. Most of the activities found in this module will ask you to collect and analyze temperature readings to arrive at the desired concepts. To achieve this, you have to use the laboratory thermometer, which is different from the clinical thermometer we use to determine our body temperature. The kind that you most probably have in your school is the glass tube with fluid inside, usually mercury or alcohol. Always handle the thermometer with care to avoid breaking the glass. Also, be sure that you know how to read and use the device properly to get good and accurate results. Inform your teacher if you are not sure of this so that you will be guided accordingly.

Activity 1
Warm me up, cool me down

Objective

In this activity, you should be able to describe the condition necessary for heat transfer to take place and trace the direction in which heat is transferred.

Materials Needed

- 2 small containers (drinking cups or glasses)
- 2 big containers (enough to accommodate the small containers)
- tap water
- hot water
- food coloring
- laboratory thermometers (with reading up to 100^{o}C)

Procedure

1. Label the small and big containers as shown in Figure 2.

2. Half fill containers 1, 2, and A with tap water. Half fill also container B with hot water. *Be careful when you pour hot water into the container.*

3. Add few drops of food coloring on the larger containers.

Figure 2

4. Measure the *initial temperature* of water in each of the 4 containers, in degree Celsius (°C). Record your measurements in Table 1.

5. Carefully place container 1 inside container A (Figure 3). This will be your *Setup 1*.

6. Place also container 2 inside container B. This will be your *Setup 2*.

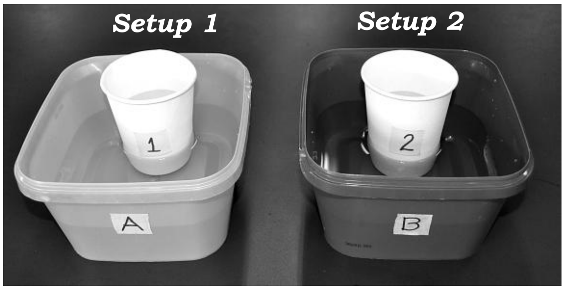


Figure 3

7. Measure the temperature of water in all containers 2 minutes after arranging the setups. Record again your measurements in the table (after 2 minutes).

8. Continue to measure and record the temperature of water after 4, 6, 8, and 10 minutes. Write all your measurements in the table below.

Table 1. Temperature readings for Setup 1 and Setup 2

Container		Temperature (°C) of Water After					
		0 min (initial)	**2 mins**	**4 mins**	**6 mins**	**8 mins**	**10 mins**
Setup 1	**1**-*Tap water*						
	A-*Tap water*						
Setup 2	**2**-*Tap water*						
	B-*Hot water*						

Q1. In which setup did you find changes in the temperature of water inside the containers? In which setup did you NOT find changes in the temperature of water inside the containers?
Q2. In which setup is heat transfer taking place between the containers?
Q3. What then is the condition necessary for heat transfer to take place between objects?

9. Refer to the changes in the temperature of water in the setup where heat transfer is taking place.
Q4. Which container contains water with higher initial temperature? What happens to its temperature after 2 minutes?
Q5. Which container contains water with lower initial temperature? What happens to its temperature after 2 minutes?
Q6. If heat is related to temperature, what then is the direction of heat that transfers between the containers?

Q7. What happens to the temperature of water in each container after 4, 6, 8, and 10 minutes? What does this tell us about the heat transfer taking place between the containers?
Q8. Until when do you think will heat transfer continue to take place between the containers?

If your teacher allows it, you may continue to measure the temperature of the water in both containers for your basis in answering Q8. And if you plot the temperature vs. time graph of the water in both containers, you will obtain a graph similar to Figure 4.

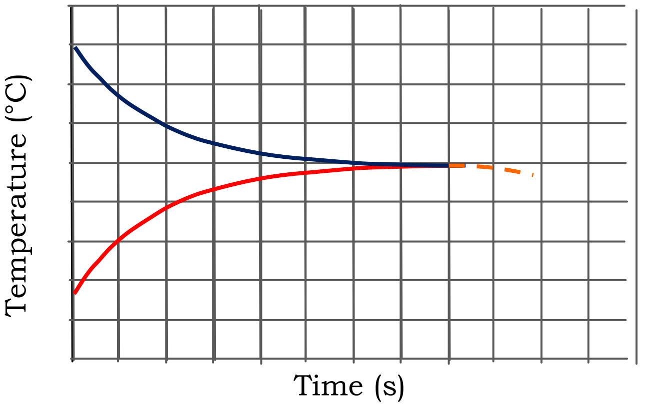


Figure 4

10. Analyze the graph and answer the following questions:

Q9. What does the blue curved line on the graph show? Which container does this represent?
Q10. What does the red curved line on the graph show? Which container does this represent?
Q11. What does the orange broken line in the graph show? Is heat transfer still taking place during this time? If yes, where is heat transfer now taking place?

If you do not have laboratory thermometers in your school, you may still perform the activity above using your sense of touch. You can use your fingers or hands to feel the objects being observed. But be very careful with this especially if you are dealing with hot water. You have to take note also that touching is not always reliable. Try out this simple activity below.

> Prepare three containers. Half fill one container with hot water, but not hot enough to burn your hand. Pour very cold water into the second container and lukewarm water in the third container. First, simultaneously place your left hand in the hot water and your right hand in the cold water. Keep them in for a few minutes. Then take them out, and place both of them together into the container with lukewarm water. How do your hands feel? Do they feel equally cold?

If you try out this activity, you will observe that your left hand feels the water cold while your right hand feels it warm. This is due to the initial conditions of the hands before they were placed into the container with lukewarm water. So if you use sensation to determine the relative hotness or coldness of the objects, make sure to feel the objects with different hands or fingers.

How Does Heat Transfer?

In the previous activity, you explored the idea that heat transfers under certain conditions. But how exactly is heat transferred? The next activities will allow you to explore these different methods by which heat can be transferred from one object or place to another.

Activity 2
Which feels colder?

Objective

In this activity, you should be able to describe heat transfer by conduction and compare the heat conductivities of materials based on their relative coldness.

Materials Needed

- small pieces of different objects (copper/silver coin, paper, aluminum foil, iron nail, etc.)
- laboratory thermometer

Procedure

Part A: To be performed one day ahead.

1. Place a laboratory thermometer inside the freezer of the refrigerator.

2. Place also your sample objects inside the freezer at the same time. Leave them inside the freezer overnight.

Part B: To be performed the next day.

3. Take the temperature reading from the thermometer inside the freezer.

Q1. What is the temperature reading inside the freezer?

Q2. If ever there is a way to measure also the temperature of the objects placed inside the freezer, how do you think will their temperature compare with each other and with the temperature reading from the thermometer?

4. Touch one object lightly with your finger and feel it.

Q3. Did heat transfer take place between your finger and the object? If yes, how and in what direction did heat transfer between them?

Q4. Did you feel the object cold? What made it so? (Relate this to your answer in Q3.)

5. Touch the rest of the objects inside the freezer using different fingers, then observe.

Q5. Did the objects feel equally cold? What does this tell us about the amount of heat transferred when you touch each object?

Q6. Which among the objects feels ‘coldest’? Which feels ‘warmest’?

Q7. Which among the objects is the best conductor of heat? Which object is the poorest conductor of heat?

Activity 2 demonstrates heat transfer by **conduction**, one of the methods by which heat is transferred. Conduction takes place between objects that are in contact with each other. The energy from the object of higher temperature is transferred to the other object through their particles that are close or in contact with each other. Then the particles receiving the energy will also transfer the energy to other places within the object through their neighboring particles. During this process, only the energy moves, not the matter itself. This can be observed in Activity 1. You have observed that the hot colored water stayed inside container B and did not mix with the water inside container 2. So this shows that only the energy transferred between the containers.

Here is another example of heat transfer by conduction. Think of a metal spoon put in a bowl of a hot *champorado* that you were about to eat when you suddenly remembered that you had to do first a very important task. When you came back, you noticed that the handle of the spoon became really hot! How do you think this happened? The heat from the *champorado* is transferred to the part of the spoon that is in direct contact with the food by conduction. Then it is transferred to the cooler regions of the spoon through its particles. Why did you feel the spoon hot? When you touched the spoon, heat is also transferred to your hand by conduction. So your hand gained heat or thermal energy, and this makes you feel the object hot.

Can you now explain why your hand that was previously dipped into hot water felt the lukewarm water cold while the other hand that was previously dipped into very cold water felt it hot?

Heat Conductivities

In the previous activity, you found out that some objects conduct heat faster than the others. This explains why we feel some objects colder or warmer than the others even if they are of the same temperature. Which usually feels warmer to our feet – the tiled floor or the rug?

More accurate and thorough experiments had been carried out long before to determine the heat or thermal conductivity of every material. The approximate values of thermal conductivity for some common materials are shown below:

Table 2: List of thermal conductivities of common materials

Material	Conductivity W/(m·K)	Material	Conductivity W/(m·K)
Silver	429	Concrete	1.1
Copper	401	Water at 20°C	0.6
Gold	318	Rubber	0.16
Aluminum	237	Polypropylene plastic	0.25
Ice	2	Wood	0.04 - 0.4
Glass, ordinary	1.7	Air at 0°C	0.025

Solids that conduct heat better are considered good conductors of heat while those which conduct heat poorly are generally called *insulators*. Metals are mostly good conductors of heat. When we use a pot or pan to cook our food over a stove, we usually use a pot holder made of fabrics to grasp the metal handle. In the process, we are using an insulator to prevent our hand from being burned by the conductor, which is the metal pan or pot. Why are woven fabrics that are full of trapped air considered good insulators?

Activity 3
Move me up

You have previously learned that water is a poor conductor of heat, as shown in Table 2. But why is it that when you heat the bottom of the pan containing water, the entire water evenly gets hot quickly? Think of the answer to this question while performing this next activity.

Objective

In this activity, you should be able to observe and describe convection of heat through liquids.

Materials Needed

- 2 transparent containers (drinking glass, beaker, bottle)
- dropper
- hot water
- cold water
- piece of cardboard

Be careful not to bump the table or shake the container at any time during the experiment.

Procedure

1. Fill one of the glass containers with tap water.

2. While waiting for the water to become still, mix in a separate container a few drops of food coloring with a small amount of very cold water. *(You may also make the food coloring cold by placing the bottle inside the refrigerator for at least an hour before you perform the activity.)*

3. Suck a few drops of cold food coloring using the dropper and slowly dip the end of the medicine dropper into the container with tap water, down to the bottom. See to it that the colored water does not come out of the dropper yet until its end reaches the bottom of the container.

4. Slowly press the dropper to release a small amount of the liquid at the bottom of the container. Then slowly remove the dropper from the container, making sure not to disturb the water. Observe for few minutes.

Q1. Does the food coloring stay at the bottom of the container or does it mix with the liquid above it?

5. Fill the other container with hot water.

6. Place the cardboard over the top of the container with hot water. Then carefully place the container with tap water on top of it. The cardboard must support the container on top as shown in Figure 5.

Figure 5

Q2. What happens to the food coloring after placing the container above the other container? Why does this happen?

Q3. How is heat transfer taking place in the setup? Where is heat coming from and where is it going?

Q4. Is there a transfer of matter, the food coloring, involved during the transfer of heat?

Q5. You have just observed another method of heat transfer, called **convection**. In your own words, how does convection take place? How is this process different from conduction?

Q6. Do you think convection only occurs when the source of heat is at the bottom of the container? What if the source of heat is near the top of the container? You may try it by interchanging the containers in your previous experiment.

What you found out in this experiment is generally true with *fluids*, which include liquids and gases. In the next quarter, you will learn about convection of heat in air when you study about winds.

So what happens in your experiment? When you placed the glass on top of another glass with hot water, heat transfer takes place from the hot water to the tap water including the colored water. This makes these liquids expand and become lighter and float atop the cooler water at the top of the container. This will then be replaced by the cooler water descending from above.

Activity 4
Keep it cold

So far you have learned that heat can be transferred by conduction and convection. In each method, a material, either a solid or a liquid or gas, is required. But can heat also transfer even without the material? If we stay under the sun for a while, do we not feel warm? But how does the heat from this very distant object reach the surface of the earth? The transfer of energy from the sun across nearly empty space is made possible by **radiation**. Radiation takes place even in the absence of material.

Do you know that all objects, even ordinary ones, give off heat into the surrounding by radiation? Yes, and that includes us! But why don't we feel it? We do not feel this radiation because we are normally surrounded by other objects of the same temperature. We can only feel it if we happen to stand between objects that have different temperature, for example, if we stand near a lighted bulb, a burning object, or stay under the Sun.

All objects emit and absorb radiation although some objects are better at emitting or absorbing radiation than others. Try out this next activity for you to find out. In this activity, you will determine how different surfaces of the object affect its ability to absorb heat.

Introduction

One hot sunny day, Cobi and Mumble walked into a tea shop and each asked for an order of iced milk tea for takeout. The crew told them as part of their promo, their customers can choose the color of the tumbler they want to use, pointing to the array of containers made of the same material but are of different colors and textures. Cobi favored the container with a dull black surface, saying that the milk tea will stay cooler if it is placed in a black container. Mumble remarked that the tea would stay even cooler if it is in a container with bright shiny surface.

Prediction

1. If you were in their situation, which container do you think will keep the iced milk tea cooler longer? Explain your choice.

2. Assuming an initial temperature of 5°C, predict the possible temperatures of the milk tea in each container after 5, 10, 15, and 20 minutes. Assume that the containers are covered.

Cup	Temperature (°C)				
	0 min	5 min	10 min	15 min	20 min
Dull black container	5°C				
Bright shiny container	5°C				

Task:

Design a laboratory activity that will enable you to test your prediction. See to it that you will conduct a fair investigation. Start by answering the questions below:

- What problem are you going to solve? (*Testable Question*)

  ____

- What are you going to vary? (Independent variable)

  ____

- What are you not going to vary? (Controlled Variables)

  ____

- What are you going to measure? (Dependent variables)

  ____

1. Write down your step by step procedure. Note that you may use the light from the sun or from the lighted bulb as your source of energy.

2. Collect your data according to your procedure. Present your data in tabulated form.

3. Analyze your data and answer the following questions:

Q1. Which container warmed up faster?
Q2. Which container absorbs heat faster?
Q3. Which container will keep the milk tea cooler longer? Is your prediction correct?
Q4. Will the same container also keep a hot coffee warmer longer that the other?

Activity 5
All at once

So far, you have learned that heat can be transferred in various ways. You have also learned that different objects absorb, reflect, and transmit heat differently. In the next activities, you will not perform laboratory experiments anymore. All you have to do is to use your understanding so far of the basic concepts of heat transfer to accomplish the given tasks or answer the questions being asked.

Task 1

Heat transfer is evident everywhere around us. Look at the illustration below. This illustration depicts several situations that involve heat transfer. Your task is to identify examples of situations found in the illustration that involve the different methods of heat transfer.

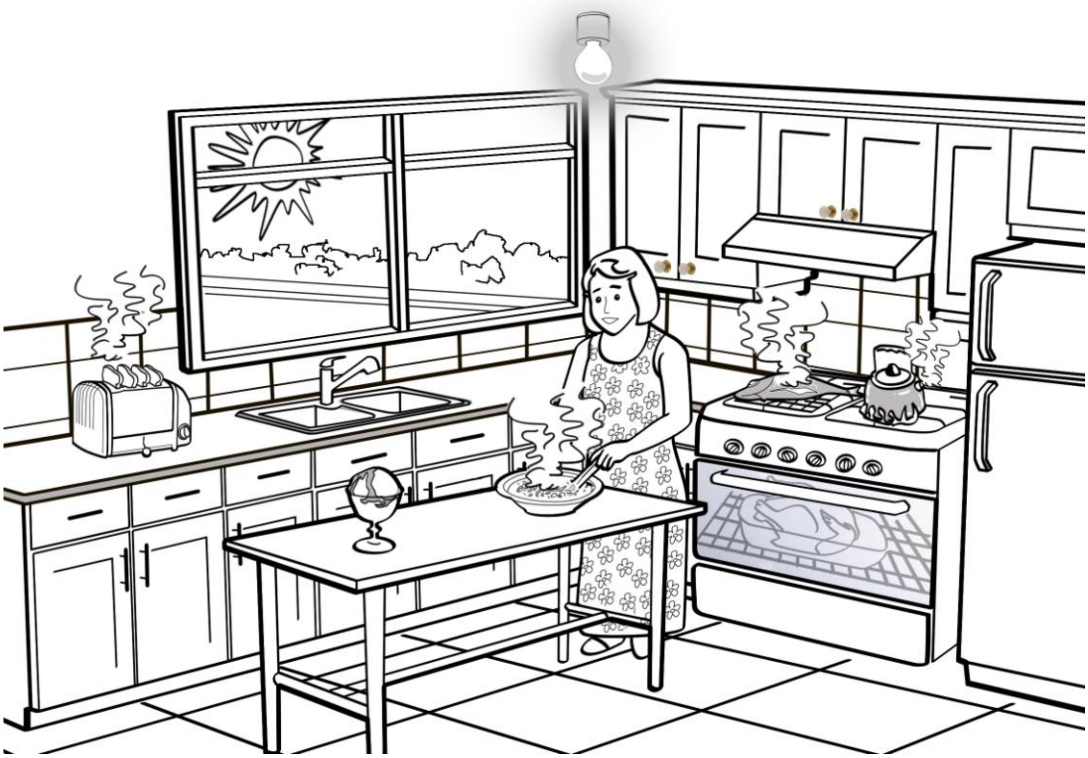


Figure 6

1. Encircle <u>three</u> situations in the drawing that involve any method of heat transfer. Label them 1, 2, and 3.

2. Note that in your chosen situations, there could be <u>more than one</u> heat transfer taking place at the same time. Make your choices more specific by filling up Table 3.

Table 3: Examples of heat transfer

	Description	Which object gives off heat?	Which object receives heat?	What is the method of heat transfer?
1				
2				
3				

Task 2

Below is a diagram showing the basic parts of the thermos bottle. Examine the parts and the different materials used. Explain how these help to keep the liquid inside either hot or cold for a longer period of time. Explain also how the methods of heat transfer are affected by each material.

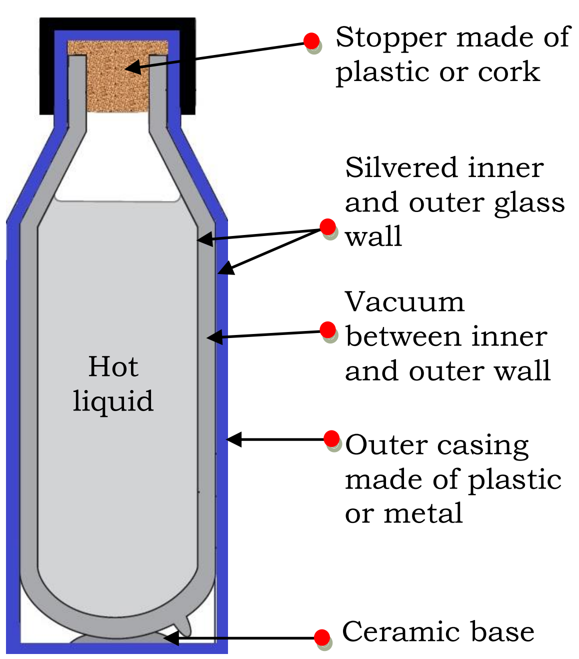


Figure 7: Basic parts of a thermos bottle

In the next module, you will learn about another form of energy which you also encounter in everyday life, **electricity**. Specifically, you will learn about the different types of charges and perform activities that will demonstrate how objects can be charged in different ways. You will also build simple electric circuits and discuss how energy is transferred and transformed in the circuit.

Links and References

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Suggested time allotment: 5 to 6 hours

Unit 3
MODULE
6

ELECTRICITY

In Module 5, you learned about heat as a form of energy that can be transferred through conduction, convection and radiation. You identified the conditions that are necessary for these processes to occur and performed activities that allowed you to investigate the different modes of heat transfer. Finally, you learned to distinguish between insulators and conductors of heat and were able to identify the uses of each.

Now you will learn about another form of energy which you encounter in everyday life, **electricity**. You must be familiar with this energy since it is the energy required to operate appliances, gadgets, and machines, to name a few. Aside from these manmade devices, the ever-present nature of electricity is demonstrated by lightning and the motion of living organisms which is made possible by electrical signals sent between cells. However, in spite of the familiar existence of electricity, many people do not know that it actually originates from the motion of charges.

In this module, you will learn about the different types of charges and perform activities that will demonstrate how objects can be charged in different ways. You will also learn the importance of grounding and the use of lightning rods. At the end of the module you will do an activity that will introduce you to simple electric circuits. The key questions that will be answered in this module are the following:

What are the different types of charges?

How can objects be charged?

What is the purpose of grounding?

How do lighting rods work?

What constitutes a complete electrical circuit?

Activity 1
Charged interactions

Objectives

After performing this activity, you should be able to:

1. charge a material by friction;
2. observe the behavior of charged objects;
3. distinguish between the two types of charges; and
4. demonstrate how objects can be discharged.

Materials Needed:

- Strong adhesive tape (transparent)
- Smooth wooden table
- Meter stick
- Piece of wood (~1 meter long) to hold tape strips
- Moistened sponge

Procedure:

1. Using a meter stick, pull off a 40- to 60- cm piece of adhesive tape and fold a short section of it (~1 cm) to make a nonsticky "handle" at that end of the tape.

2. Lay the tape adhesive side down and slide your finger along the tape to firmly attach it to a smooth, dry surface of a table.

3. Peel the tape from the surface vigorously pulling up on the handle you have made on one end. See figure below. Make sure that the tape does not curl up around itself or your fingers.

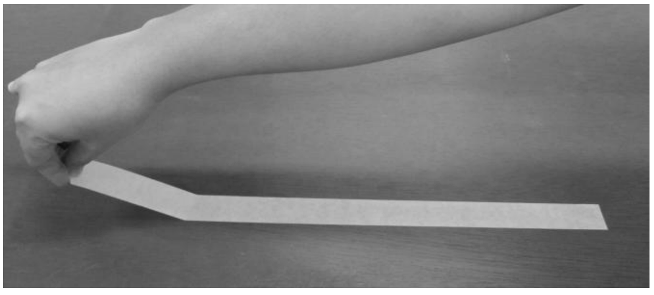

Figure 5. How to peel the tape off the surface

4. While holding the tape up by the handle and away from other objects, attach the tape to the horizontal wooden piece or the edge of your table. Make sure that the sticky side does not come in contact with other objects.

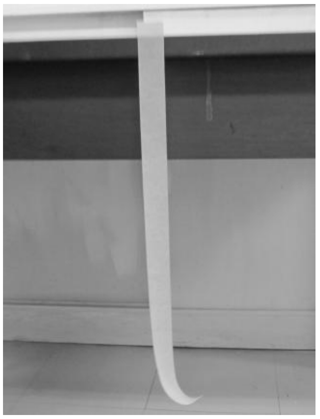

Figure 6. Attaching the tape to a holder

5. Bring your finger near, but not touching, the nonsticky side of the tape. Is there any sign of interaction between the tape and the finger?

6. Try this with another object. Is there any sign of interaction between the tape and this object?

7. Prepare another tape as described in steps 1 to 3.

8. Bring the nonsticky side of the two charged tapes you prepared near each other. Do you observe any interaction?

9. Drag a moistened sponge across the nonsticky side of the tapes and repeat steps 5, 6 and 8. Do you still observe any interaction?

10. Record your observations.

Types of Charges

You have learned in previous modules that all matter are made up of atoms or combinations of atoms called compounds. The varying atomic composition of different materials gives them different electrical properties. One of which is the ability of a material to lose or gain electrons when they come into contact with a different material through friction.

In activity 1, when you pulled the tape vigorously from the table, some of the electrons from the table's surface were transferred to the tape. This means that the table has lost some electrons so it has become **positively charged** while the tape has gained electrons which made it **negatively charged**. The process involved is usually referred to as charging up the material, and in this particular activity the process used is **charging by friction**.

It is important to remember that during the charging process, ideally, the amount of charge lost by the table is equal to the amount of charge gained by the tape. This is generally true in any charging process. The idea is known as:

The Law of Conservation of Charge
Charges cannot be created nor destroyed, but can be transferred from one material to another.
The total charge in a system must remain constant.

Electric Force

When you brought your finger (and the other object) near the charged tape, you must have observed that the tape was drawn towards your finger as if being pulled by an invisible force. This force is called **electric force** which acts on charges. An uncharged or **neutral** object that has balanced positive and negative charges cannot experience this force.

We learned from the previous section that the tape is negatively charged. The excess negative charge in the tape allowed it to interact with your finger and the other object. Recall also that when you placed the two charged tapes near each other they seem to push each other away. These observations tell us that there are two kinds of electric force which arises from the fact that there also two kinds of electrical charges. The interactions between the charges are summarized in the following law:

Electrostatic Law
Like charges repel and unlike charges attract.

But your finger and the other object are neutral, so how did they interact with the charged tape? Generally, a charged object and an uncharged object tend to attract each other due to the phenomenon of electrostatic **polarization** which can be explained by the electrostatic law. When a neutral object is placed near a charged object, the charges within the neutral object are rearranged such that the charged object attracts the opposite charges within the neutral object. This phenomenon is illustrated in Figure 3.

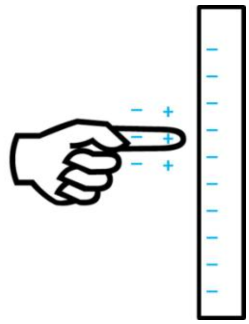

Figure 3. Polarization of a neutral object

Discharging

In Activity 1, after dragging a moistened sponge on the surface of the tape, you must have noticed that the previous interactions you observed has ceased to occur. What happened? The lack of interaction indicates that the electrical force is gone which can only happen when there are no more excess charges in the tape, that is, it has become neutral.

The process of removing excess charges on an object is called discharging. When discharging is done by means of providing a path between the charged object and a **ground**, the process may be referred to as **grounding**. A ground can be any object that can serve as an “unlimited” source of electrons so that it will be capable of removing or transferring electrons from or to a charged object in order to neutralize that object.

Grounding is necessary in electrical devices and equipment since it can prevent the build-up of excess charges where it is not needed. In the next activity, you will use the idea of grounding to discover another way of charging a material.

Activity 2
To charge or not to charge

Objective

After performing this activity, you should be able to apply the phenomenon of polarization and grounding to charge a material by induction.

Materials Needed:

- Styrofoam cup
- soft drink can
- balloon

Procedure:

1. Mount the soft drink can on the Styrofoam cup as seen in Figure 4.

Figure 4. Mounting of soft drink can

2. Charge the balloon by rubbing it off your hair or your classmate's hair. *Note: This will work only if the hair is completely dry.*

3. Place the charged balloon as near as possible to the soft drink can without the two objects touching.

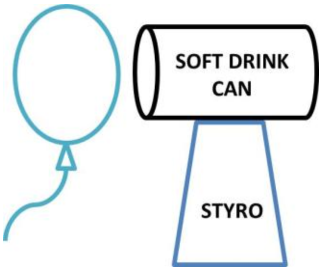

Figure 5. Balloon placed

4. Touch the can with your finger at the end opposite the balloon.

5. Remove your hand and observe how the balloon and the can will interact.

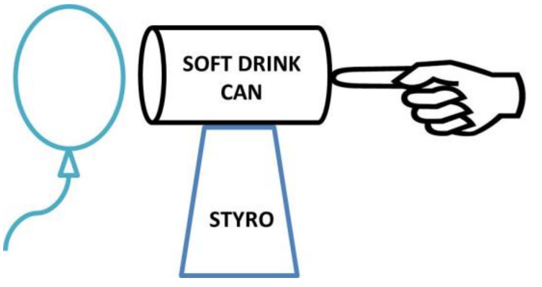

Figure 6. Touching the can

Q1. What do you think is the charge acquired by the balloon after rubbing it against your hair?
Q2. In which part of the activity did polarization occur? Explain.
Q3. What is the purpose of touching the can in step #4?
Q4. Were you able to charge the soft drink can? Explain how this happened.
Q5. Based on your answer in Q1, what do you think is the charge of the soft drink can?

Conductors vs. Insulators

The behavior of a charged material depends on its ability to allow charges to flow through it. A material that permits charges to flow freely within it, is a good electrical **conductor**. A good conducting material will allow charges to be distributed evenly on its surface. Metals are usually good conductors of electricity.

In contrast to conductors, **insulators** are materials that hinder the free flow charges within it. If charge is transferred to an insulator, the excess charge will remain at the original location of charging. This means that charge is seldom distributed evenly across the surface of an insulator. Some examples of insulators are glass, porcelain, plastic and rubber.

The observations you made had in Activity 2 depended on the fact that the balloon and the Styrofoam are good insulators while the soft drink can and you are good conductors. You have observed that the soft drink can has become charged after you touched one of its ends. The charging process used in this activity is called **induction charging**, where an object can be charged without actual contact to any other charged object.

In the next activity you will investigate another method of charging which depends on the conductivity of the materials

Activity 3
Pass the charge

Objective

After performing this activity, you should be able to charge a material by conduction.

Materials Needed:

- 2 styrofoam cups
- 2 softdrink cans
- balloon

Procedure:

1. Repeat all steps of Activity 2.

2. Let the charged can-cup set-up from Activity 2 touch a neutral can-cup set-up as shown in Figure 7.

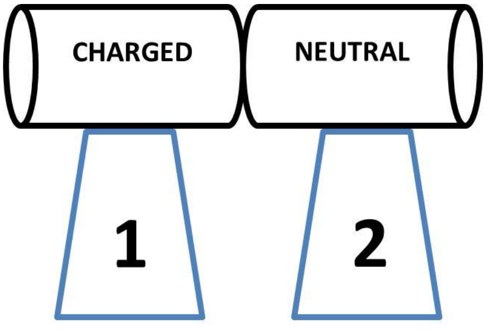

Figure 7. Putting the two set-ups into contact.

3. Separate the two set-ups then observe how the charged balloon interacts with the first and second set-up.

Q1. Were you able to charge the can in the second set-up? Explain how this happened.
Q2. Is it necessary for the two cans to come into contact for charging to happen? Why or why not?
Q3. From your observation in step 3, infer the charge acquired by the can in the second set-up.

The charging process you performed in Activity 3 is called **charging by conduction** which involves the contact of a charged object to a neutral object. Now that you have learned the three types of charging processes, we can discuss a natural phenomenon which is essentially a result of electrical charging. You will investigate this phenomenon in the following activity.

Activity 4
When lightning strikes

Objectives:

After performing this activity, you should be able to:

1. explain how lightning occurs;
2. discuss ways of avoiding the dangers associated with lightning; and
3. explain how a lightning rod functions.

Materials Needed: access to reference books or to the Internet

Procedure:

1. Learn amazing facts about lightning by researching the answers to the following questions:
   - What is a lightning?
   - Where does a lightning originate?
   - How ‘powerful’ is a lightning bolt?
   - Can lightning’s energy be caught stored, and used?
   - How many people are killed by lightning per year?
   - What can you do to prevent yourself from being struck by lightning?
   - Some people have been hit by lightning many times. Why have they survived?
   - How many bushfires are started by lightning strikes?
   - ‘Lightning never strikes twice in the same place.’ Is this a myth or a fact?
   - What are lightning rods? How do they function?

As introduced at the beginning of this module, electrical energy has numerous applications. However many of this applications will not be possible unless we know how to control electrical energy or electricity. How do we control electricity? It starts by providing a path through which charges can flow. This path is provided by an **electric circuit**. You will investigate the necessary conditions for an electric circuit to function in the following activity.

Activity 5
Let there be light!

Objectives:

After performing this activity, you should be able to:

1. identify the appropriate arrangements of wire, bulb and battery which successfully light a bulb; and
2. describe the two requirements for an electric circuit to function.

Materials Needed:

- 3- or 1.5-volt battery
- 2-meter copper wires/ wires with alligator clips
- pliers/ wire cutter
- 1.5- watt bulb/ LED

Procedure:

1. Work with a partner and discover the appropriate arrangements of wires, a battery and a bulb that will make the bulb light.

2. Once you are successful in the arrangement, draw a diagram representing your circuit.

3. Compare your output with other pairs that are successful in their arrangement.

Q1. What difficulties did you encounter in performing this activity?
Q2. How does your work compare with other pair's work?
Q3. What was necessary to make the bulb light?

Energy Transfer in the Circuit

In Activity 5, you have seen that with appropriate materials and connections, it is possible for the bulb to light. We know that light is one form of energy. Where did this energy come from? The law of conservation of energy tells us that energy can neither be created nor destroyed but can be transformed from one form to another. This tells us that the light energy observed in the bulb must have come from the electrical energy or electricity in the circuit. In fact, all electrical equipment and devices are based on this process of transformation of electrical energy into other forms of energy. Some examples are:

1. Flat iron – Electrical energy to thermal energy or heat
2. Electric fan – Electrical energy to mechanical energy
3. Washing machine – electrical energy to mechanical energy.

Can you identify other examples?

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