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Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Science

Quarter 2 – Module 4

Images in Mirrors and Lenses

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City of Good Character
DISCIPLINE • GOOD TASTE • EXCELLENCE

What I Need to Know

The purpose of this module is to help you understand the qualitative characteristics of the images formed by plane and curved mirrors, and lenses. The module is divided into three lessons, namely:

- Lesson 1 – Law of Reflection
- Lesson 2 – Images formed by Mirrors
- Lesson 3 – Images formed by Lenses

After this module, you are expected to **predict the qualitative characteristics (orientation, type, and magnification) of images formed by plane and curved mirrors and lenses. S10FE-IIg-50**

Specifically, you are expected to:

- investigate the reflective properties of light using plane mirrors;
- differentiate plane and curved mirror;
- apply ray diagramming techniques in describing images formed by mirrors;
- analyze how the refraction is applied on concave and convex lenses;
- distinguish between converging and diverging lenses;
- apply ray diagramming technique in describing images formed by lenses;
- cite applications of reflection by curved mirrors and refraction by spherical lenses in daily life situations.

What I Know

Read and understand each item carefully and encircle the letter of the correct answer.

1. In the Law of Reflection, the incident ray, the reflected ray, and the normal line ________________________________.
   A. are similar in position.
   B. lie on the same plane
   C. lie on a perpendicular plane
   D. may or may not lie on the same plane

2. A ray of light is incident on a surface at 33^{o} from the normal. What will be the angle of reflected ray from the normal?
   A. 57^{o}
   B. 90^{o}
   C. 33^{o}
   D. 66^{o}

3. An incident light travels on a path shown in Figure 1. Which of the following paths is most likely to be taken by the reflected light?

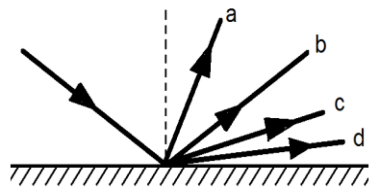


Figure 1

4. If you placed a number chart in front of a plane mirror, what numbers will you read properly in the mirror?
   A. 0, 1, 6, 8, and 9
   B. 0, 1, and 6
   C. 6 and 9
   D. 0 and 8

5. Is it **TRUE** that (I) convex mirror always forms upright, reduced, and virtual images and (II) most department stores use concave mirrors because they give a wider range of view?
   A. I only
   B. II only
   C. Both I and II
   D. Neither I nor II

6. It is a position where an object should be placed when in front of a concave mirror so that it reflects the image with the same size as the object.
   A. At the focus
   B. At the center of the curvature
   C. Between the focus and the mirror
   D. Between the center of curvature and focus

7. What type of lens produces smaller and upright images?
   A. Concave lens
   B. Convex lens
   C. Converging lens
   D. Cannot be determined

8. What property of light is observable on lenses?
   A. Diffraction
   B. Interference
   C. Reflection
   D. Refraction

9. In Figure 2, which ray(s) will pass through the *principal focus* after refraction?
   A. Ray 1 only
   B. Ray 2 only
   C. Ray 3 only
   D. Rays 1 and 2

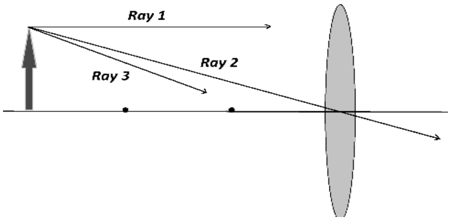


Figure 2

10. Which best describes the image for a thin convex lens that forms whenever the object is at a distance less than one focal length from the lens?
   A. Inverted, enlarged and real
   B. Inverted, diminished and real
   C. Upright, enlarged, and virtual
   D. Upright, diminished, and virtual

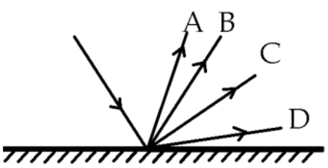
Lesson 1 Law of Reflection

What's In

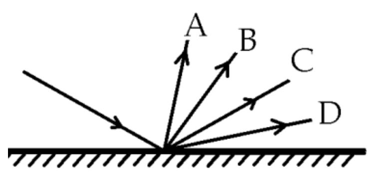
One of the most fascinating characteristics of light is its ability to bounce once it hits a surface which is known as reflection. Reflection may be specular or diffused depending on the kind of surface it hits. Specular reflection allows the formation of an image while diffused reflection allows us to see the colors of the object. This property of light allows many applications in different fields like medicine, arts, and architecture.

Choose the correct position of reflected ray.

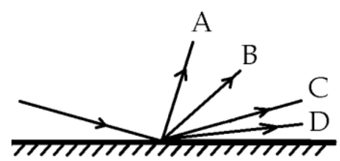
1.



2.



3.



What's New

Activity: Reflection of Light

Objectives:

1. Investigate reflective properties of light using a plane mirror.
2. Compare the angle of incidence and angle of reflection.

You Will Need:

- plane mirror (rectangular)
- laser/ flashlight
- protractor
- ruler
- bond paper
- modelling clay (optional)

Notes to the Student

1. Avoid pointing the laser in your or someone else's eyes.
2. In reading the protractor for the angle of incidence and angle of reflection, the zero marking will always start in the perpendicular line from the mirror.

Procedure:

1. Draw a straight line on a bond paper. Place the protractor along that line.
2. Let the mirror stand on the line vertically. You may use modeling clay to support the mirror.
3. Position the laser so that once turned on it is 10^0 with the perpendicular line. Measure the angle between the reflected ray and perpendicular line then record the data gathered in a table like Table 1.
4. Repeat procedure 3 for angles 20^0, 40^0, 60^0, 80^0.

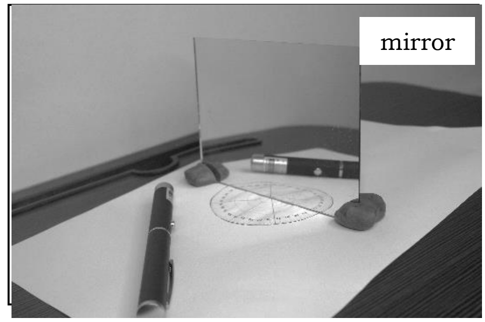


Figure 3 Setup of the activity Reflection of Light

Table 1. Angle of incidence and its angle of reflection

Angle of Incidence	Angle of Reflection
10^0	
20^0	
40^0	
60^0	
80^0	

Guide Questions:

1. What happened when the light hit the mirror?
2. How will you compare the angle of incidence with the angle of reflection?
3. State the Laws of Reflection.

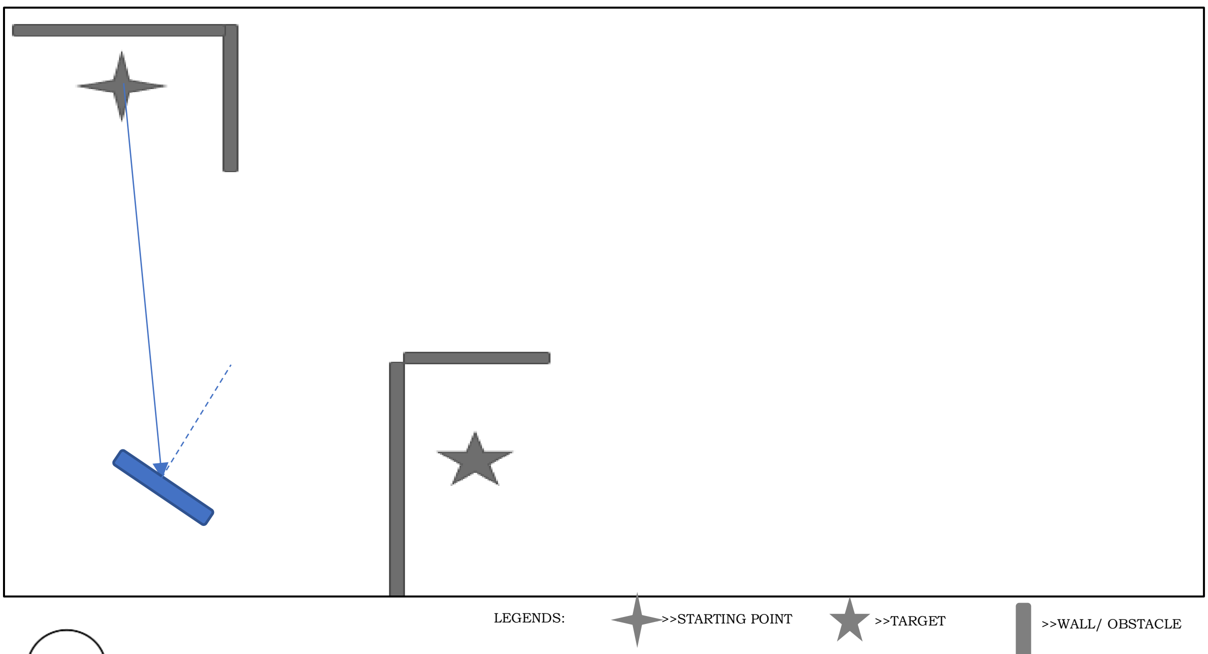
What Is It

In Activity 1, you have observed that when light hits the mirror, it is reflected at a certain angle depending on the position. The given angle is known as the **angle of incidence**. This is the angle between the **incident ray** (light coming from the source) and the **normal line** (perpendicular line with the mirror). Once the light bounces (this becomes a **reflected ray**), it forms an angle with the normal line. It is called the **angle of reflection**. You noticed that the *angle of incidence is always equal to the angle of reflection.* This is one of the premises of the **laws of reflection**. The activity also showed the other premise which is *the incident ray, reflected ray, and normal line lie on the same plane.*

Laws of Reflection states that (1) *the angle of incidence is always equal to the angle of reflection, and (2) the incident ray, reflected ray, and normal line lie on the same plane.*

What's More

Draw and place three (3) imaginary mirrors you think where it is most suited and trace a path that the light should take to hit the target from the starting point. Indicate the angle of incidence and angle of reflection on every mirror. The first mirror and the incident ray were done for you. (Note that you need to measure the angle of incident and reflection using a protractor.)



What I Have Learned

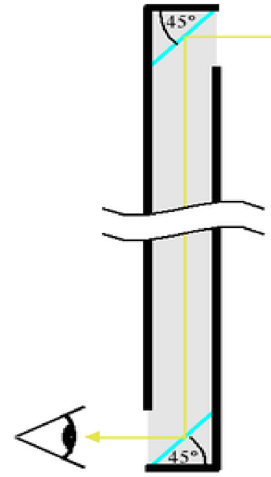
Complete the statement. Write your answers on a separate sheet of paper.

Law of reflection states that the angle of incidence is (1.)_______________ to the angle of (2.)________________, and; the incident ray, reflected ray, and (3.)________________ lie on the (4.)__________________.

What I Can Do

Make your simple periscope using only the materials available at home. A periscope is an apparatus consisting of a tube with a mirror inside by which an observer can see a thing that is otherwise out of sight i.e. submerged submarine and behind high obstacles. You may watch some video clips or search the web on how to make one.

CRITERIA	BEST 5	CLOSING TO BEST 3	FAR FROM BEST 1
CREATIVITY	Colors, layouts, and other visual elements help in expressing oneself.	Some designs and colors do not suit the overall appearance of the output.	Does not consider art in making the output
QUALITY	The output is sturdy and can be used with ease.	The output is sturdy, but it is hard to manipulate	The output is not sturdy.
TIMELINESS	Finished and submitted the output on time.	Failed to finish 75% of the output	Did not finish the task.



Periscope Principle by **GNU Free Documentation License** is licensed under CC BY-SA

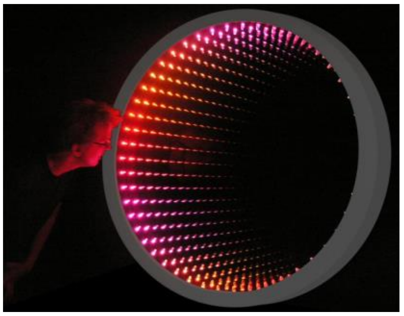
Assessment

Analyze each statement carefully. Write TRUE if the statement is correct and FALSE if the statement is incorrect.

1. If the angle of incidence is 45°, the angle of reflection is 45°
2. Incident rays and reflected rays are on a different plane.
3. The normal line is an imaginary perpendicular line that extends from the mirror.

Additional Activities

Research on how the magic trick, "*Infinity Well*", works. Explain how the law of reflection is applied in the trick. You may use a diagram to elaborate your written explanation. It may be done in a written or digital format.



Infinity Well by Light Energy Studio is licensed under CC BY-SA

Lesson 2	Images Formed by Mirrors

What's In

The difference between the reflection of a smooth object like mirrors and rough objects like walls is their ability to form images. **Images** are projected when the light from the object is reflected properly once it hits a surface.

Decode the hidden message on the picture using a mirror.

____

____

____

____

____

____

"Darkness cannot drive out darkness;
only light can do that.
Hate cannot drive out hate;
only love can do that."

Martin Luther King Jr.

What's New

Activity: Image Formed in Plane and Curved Mirror

Objectives:

1. Describe the physical characteristic of a plane and curved mirror
2. Compare the image formed by plane and curved mirror

You Will Need:

- plane mirror
- stainless spoon (check if you can clearly see your reflection)

Procedure:

1. Hold the surface of a plane mirror and the spoon. Describe the shape of the surface.

	Plane mirror	Stainless spoon
Description		

2. Hold the plane mirror and place a finger in front of it. Describe the size of the **image** of your finger. (**Image** is the figure projected on the screen or object.)
3. Do the same with the back and front of the stainless spoon.

	Plane mirror	Front of the spoon	Back of the Spoon
Description			

4. Hold the mirror arm's length away from your eyes. Observe your image. Describe your image's size and orientation.
5. Do the same with the front and back of the stainless spoon.

	Plane mirror	Front of the spoon	Back of the Spoon
Description			

Guide Questions:
1. How will you describe the physical property of the plane mirror and the spoon?
2. How does the shape of the surface affect the image formed?
3. How does the distance affect the image formed?

What Is It

Types of Mirrors

Mirrors are one of those common objects that can reflect light properly because of its smooth surface. There are two types of mirrors: plane and curved mirrors. Mirrors are described to be curved because of their shape and the types of curved mirror (concave and convex) depends on the location of the reflecting surface

Table 1. Three types of mirrors

PLANE MIRROR	CONCAVE MIRROR	CONVEX MIRROR
• has flat surface • can redirect the light	• also called converging mirror • has its reflective surface curved inwards (somewhat forming a cave) which converges the light to a point called focus.	• also called diverging mirror has its reflective surface curved outwards (forming a bulge) which scatters or diverges the light

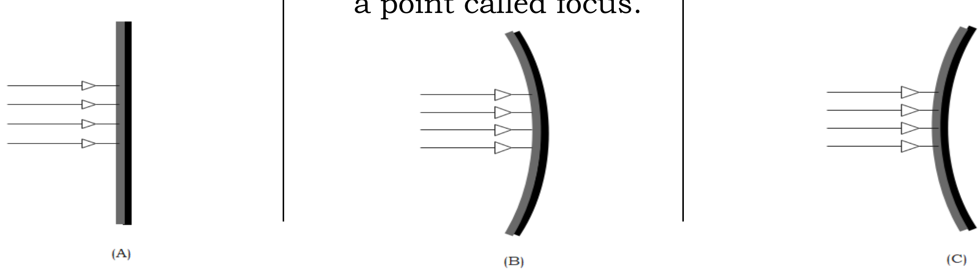
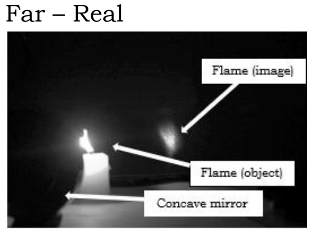
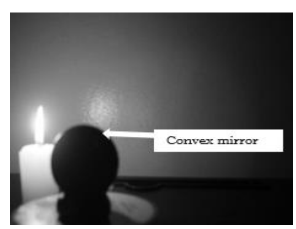
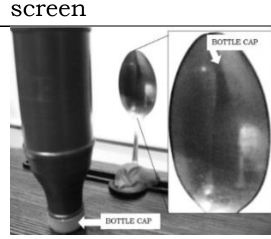


Figure 4. Three types of mirrors: (A) plane mirror; (B) concave mirror; (C) convex mirror

Image Formed by Mirrors

Images are formed when light from the object hits the mirror and reaches the eyes. Based on the activity, the images formed differ from one mirror to another.

Table 2. Description of the Image in mirrors

Description of the Image	PLANE MIRROR	CONCAVE MIRROR	CONVEX MIRROR
Size	Same size	Depends on the distance of the object from the mirror. Near – larger Very far – smaller	Smaller
Orientation	Same orientation	Depends on the distance of the object from the mirror. Near – same orientation Far – inverted	Same orientation
Distance from the mirror	Same distance from the mirror	Depends on the distance of the object from the mirror. Near – image appears farther to the mirror Far – image appears farther to the mirror Very far – image appears nearer to the mirror.	Image appears nearer to the mirror
Type	virtual	Depends on the distance of the object from the mirror. Near – Virtual Far – Real  Figure 5 concave mirror forming real image on screen	Virtual  Figure 6 Convex mirror did not form image on the screen
	 Figure 7 plane mirror with reversed writing	 Figure 8 Inverted image formed at the spoon	 Figure 9 Small image formed at the back of the spoon

Ray Diagramming Techniques in Curved Mirrors

Images formed by plane, converging, and diverging mirrors strictly follow the law of reflection, and one convenient way of analyzing it is the use of ray diagramming techniques. This uses rays that obey the law of reflection but simplified for easier examination and keep in mind that the light coming from the object travels in all directions (see figure 10).

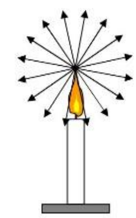


Figure 10: Ray of light from the candle travels in all direction

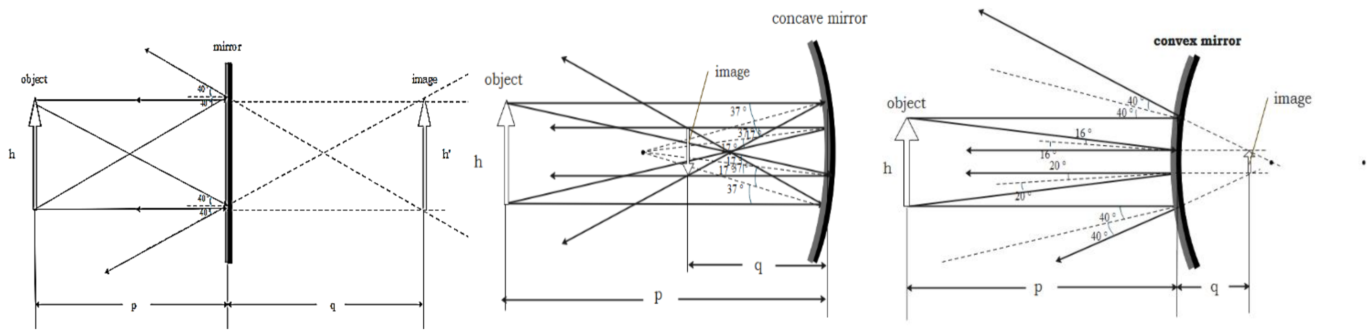


Figure 11. Ray diagram of image formed by the three types of mirror.

Here are the things that will be followed and considered (note that other references and textbooks may have more parts and rays):

1. Parts of the diagram

   A. **Mirror** – It can be a concave or convex mirror.
   B. **Principal Axis** – An imaginary line that bisects the curved mirror.
   C. **Focus (F)** – It is located along the principal axis. It depends on the type of curved mirror. The distance from the mirror to focus is called the focal length.
   D. **Center (C)** – It is located along the principal axis. Its length is twice the focal length.

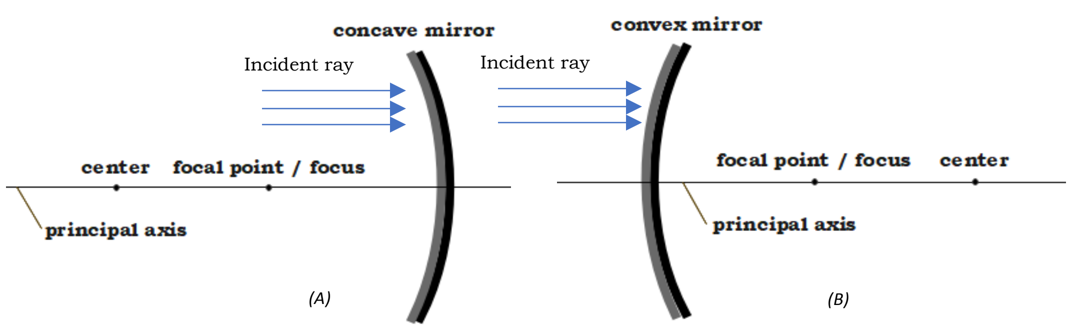


Figure 12 Parts of the diagram used in (A) concave mirror and (B) convex mirror

2. Rays to be used

A. An incident ray **PARALLEL TO THE PRINCIPAL AXIS** and when it reflects, it will (A) *pass* **TOWARDS THE FOCUS**; (B) *follow* the path **AWAY FROM THE FOCUS.**

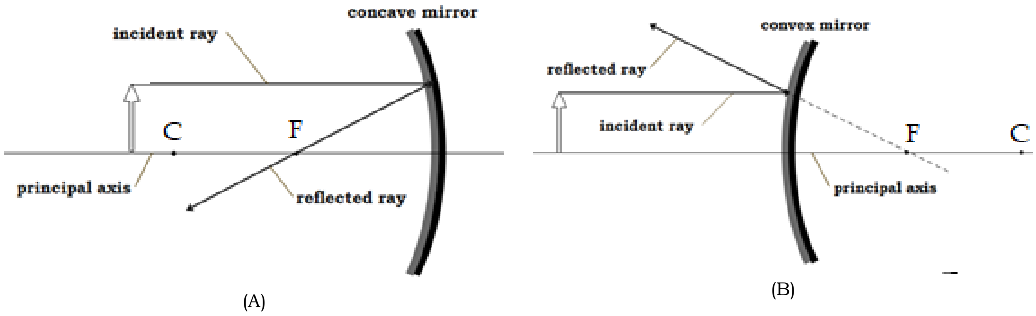


Figure 13. Ray A used in (A) concave mirror and (B) convex mirror

B. An incident ray (A)**PASSING THROUGH THE FOCUS** or (B)**MOVING TOWARDS THE FOCUS** and when it hits the mirror, it will reflect **PARALLEL TO THE PRINCIPAL AXIS**.

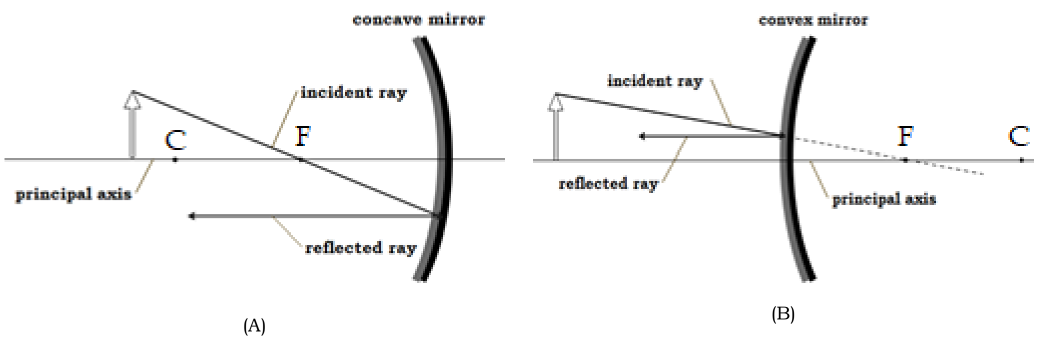


Figure 14. Ray B used in (A) concave mirror and (B) convex mirror

C. An incident ray (A)**PASSING THROUGH THE CENTER** or (B)**MOVING TOWARDS THE CENTER** and when it hits the mirror, it will reflect **TOWARDS/ALONG THE CENTER**.

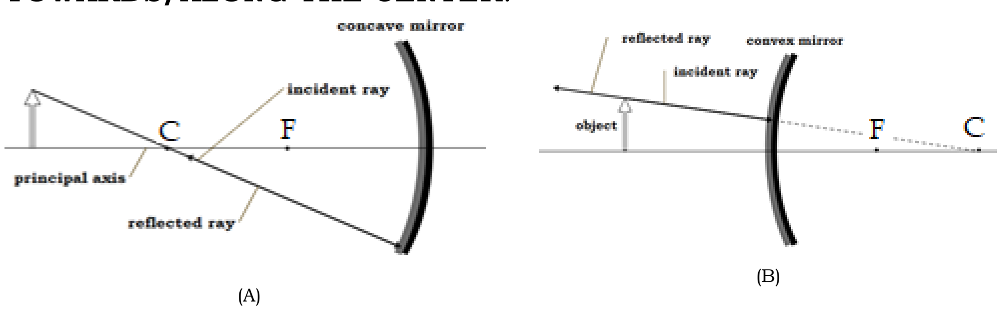


Figure 15. Ray C used in (A) concave mirror and (B) convex mirror

4. Description of the Image

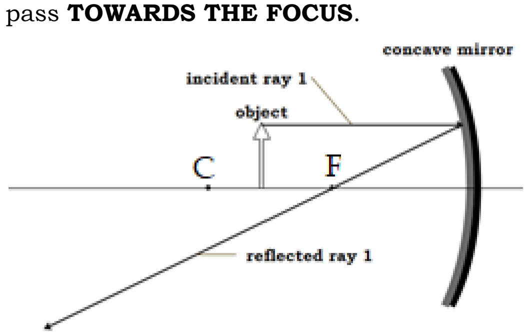
The image is formed at the intersection of the reflected rays and it can be described based on its Size, Orientation, Location, and Type (S.O.L.T). *(Note: If in case there is no intersection because the reflected rays are parallel to each other, no image is formed.)*

A. **Size (S)** – It describes the height of the image as compared to the object's height. It can be described as **SMALLER/REDUCED/ DIMINISHED/DECREASED**, **SAME SIZE,** or **LARGER/ MAGNIFIED.**
B. **Orientation (O)** – It describes the orientation of the image when compared to the object. It can be **UPRIGHT** if it has the same orientation as the object and **INVERTED** if otherwise. (Note that if the object is initially inverted, and the image is also inverted, it should be described as upright.)
C. **Location (L)** – It describes where the image is formed. It can be **IN FRONT OF THE MIRROR** or **BEHIND THE MIRROR**.
D. **Type (T)** – It describes the type of image formed. It can be described as **REAL** if the image is formed by the actual reflected ray and located at the front of the mirror. **VIRTUAL** if the image is formed by the extended reflected ray and located behind the mirror.

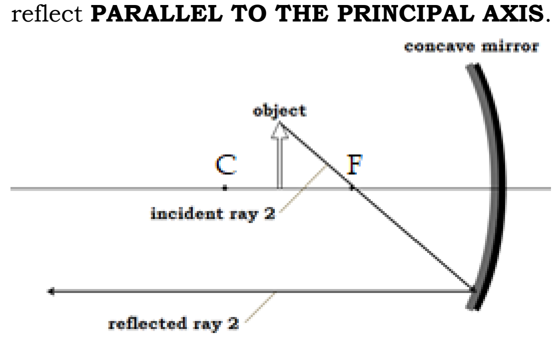
Here is an example of how ray diagramming techniques are used to locate and describe the image formed by an object.

1. Concave Mirror
   We will consider an object placed at any point between the center and the focus. We may use two pairs of incidents and reflected rays depending on the location of the object.

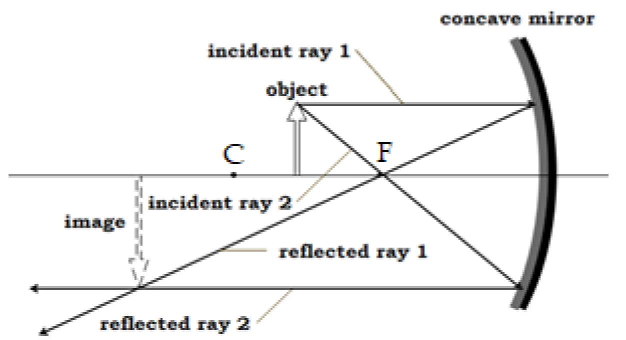
An incident ray **PARALLEL TO THE PRINCIPAL AXIS** and when it reflects, it will pass **TOWARDS THE FOCUS**.



An incident ray **PASSING THROUGH THE FOCUS** and when it hits the mirror, it will reflect **PARALLEL TO THE PRINCIPAL AXIS**.



The image is formed in the intersection of the reflected rays.



Description of the image:

S – enlarged/magnified

O – inverted

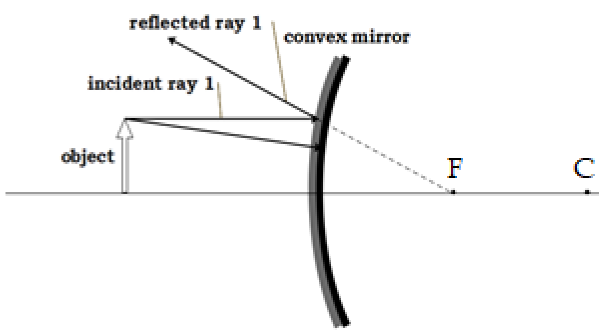
L – in front of the mirror

T - real

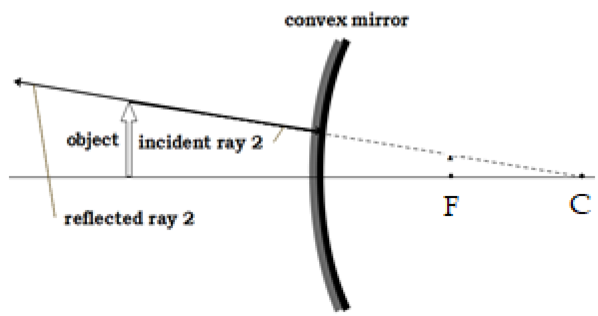
2. Convex Mirror

   We will consider an object placed a little farther than the focal length. We may use two pairs of incidents and reflected rays depending on the location of the object.

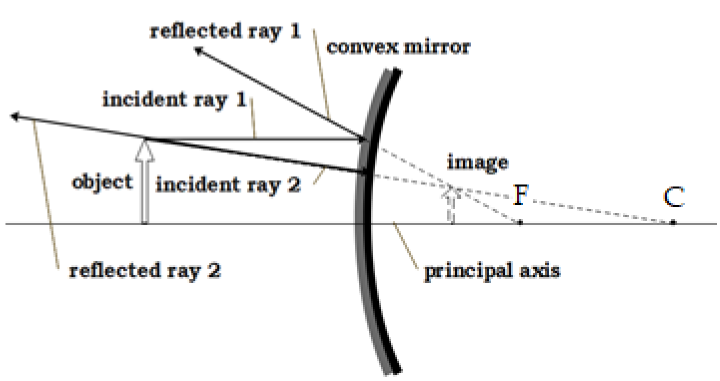
An incident ray **PARALLEL TO THE PRINCIPAL AXIS** and when it reflects, it will follow the path **AWAY FROM THE FOCUS.**



An incident ray **MOVING TOWARDS THE CENTER** and when it hits the mirror, it will reflect **ALONG THE CENTER.**



Since the reflected rays do not seem to intersect in front of the mirror, **extending the line of the reflected rays behind the mirror** forms an intersection, thus, an image is formed.



Description of the image

S – reduced/ smaller

O – upright

L – behind of the mirror

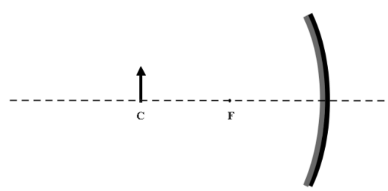
T - virtual

What's More

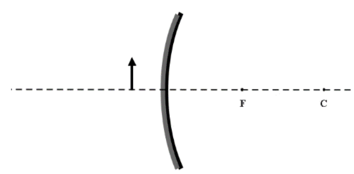
Use the ray diagramming technique to describe the image formed by the concave and convex mirror at different positions using **S-O-L-T (Size, Orientation, Location, and Type).** Use the following measurement: focal length = 1.5 cm, and height of object = 2.0 cm. (Sample diagram for nos. 1 & 6 is shown)

LOCATION OF THE OBJECT	SIZE	ORIENTATION	LOCATION	TYPE
Concave mirror				
A. At C	1.	2.	3.	4.
B. Beyond C	5.	6.	7.	8.
C. Between F and C	9.	10.	11.	12.
D. At F	13.	14.	15.	16.
E. Between F and mirror	17.	18.	19.	20.
Convex mirror				
F. Near the mirror	21.	22.	23.	24.
G. Far from the mirror	25.	26.	27.	28.

A.



F.



What I Have Learned

Answer the following questions.

1. What are the three types of mirrors?

2. How will you differentiate the three types of mirrors?

3. How will you describe the image produced by a plane mirror?

4. How will you describe the image produced by an object at varying distance from the concave mirror?

5. How will you describe the image produced by an object at varying distance from the convex mirror?

What I Can Do

The plane, concave, and convex mirrors are widely used in our society today. They can be found in households, streets, malls, stores, and other establishments. Look for 2 kinds of mirrors you can find in your home, street, or nearby places and take pictures of them. Then, briefly explain their use and how they work.

Assessment

Analyze each statement carefully. Write TRUE if the statement is correct and FALSE if the statement is incorrect.

___________1. Plane mirrors always form virtual images.
___________2. A concave mirror can form both real and virtual images depending on the object's location.
___________3. Convex mirror enlarges the size of the image.
___________4. When a parallel light reaches the concave mirror, it is reflected in the focus.
___________5. In a convex mirror ray diagram, when the incident ray travels towards the focus, the reflected ray will travel parallel to the principal axis.

Additional Activities

Mirror Equation and Magnification Formula

Describing the image formed by a mirror (using S.O.L.T) may be done mathematically through mirror equation for the distances and magnification formula.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \qquad \frac{h'}{h} = -\frac{q}{p}$$

Where:

f = focal length of the mirror
p = object's distance from the mirror
q = image's distance from the mirror
h = object's height
h' = image's height

In using the formula, the following sign convention should be considered.

Quantity	Description - sign
Focal length (f)	Concave mirror – positive (+) Convex mirror – negative (-)
Image distance from the mirror	In front of the mirror – positive (+) At the back of the mirror – negative (-)
Image height	Upright – positive (+) Inverted – negative (-)

Object's distance and height are always positive.

Let us try one example.

A 3.0-cm object is placed 5.0 cm in front of the concave mirror whose focal length is 2.0 cm. What is the image's distance and height? Then describe the image using S.O.L.T.

We will follow the **GFSA** method.

<table>
<tr>
<td>First, let us write down all the Given.
f = + 2.0 cm
p = 5.0 cm
q =?
h = 3.0 cm
h' =?</td>
<td>Next, determine the Formula to be used.
Rearranging the variables from
$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ $\frac{h'}{h} = -\frac{q}{p}$
to, since we are looking for q and h'
$\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{f} - \frac{1}{p}$ $\boldsymbol{h'} = -\frac{hq}{p}$</td>
</tr>
<tr>
<td>Then, Substitute the given values to the formula
$\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{f} - \frac{1}{p}$
$\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{2.0\ cm} - \frac{1}{5.0\ cm}$
$\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{5.0\ cm - 2.0\ cm}{10cm^2}$
$q = \frac{10\ cm^2}{3.0\ cm}$
$\boldsymbol{q = 3.3\ cm}$
Since we have the value for q
$\boldsymbol{h'} = -\frac{hq}{p}$
$\boldsymbol{h'} = -\frac{(3.0\ cm)(3.3\ cm)}{5.0\ cm}$
$\boldsymbol{h'} = -\frac{9.9\ cm^2}{5.0\ cm}$
$\boldsymbol{h' = -1.98\ cm\ or -2.0\ cm}$</td>
<td>Make sense of the computed Answer
What is the image's distance and height? Then describe the image using S.O.L.T.
The image distance is 3.3 cm.
The image height is 2.0 cm
S = The image is reduced or smaller than the object since its object's height is 3.0 cm.
O = the image is inverted since the computed value for the h' is negative.
L = The image is located in front of the mirror since the computed value for q is positive.
T = The image is real since the image is located in front of the mirror.</td>
</tr>
</table>

Now it is your time to try using the mirror equation and magnification formula.

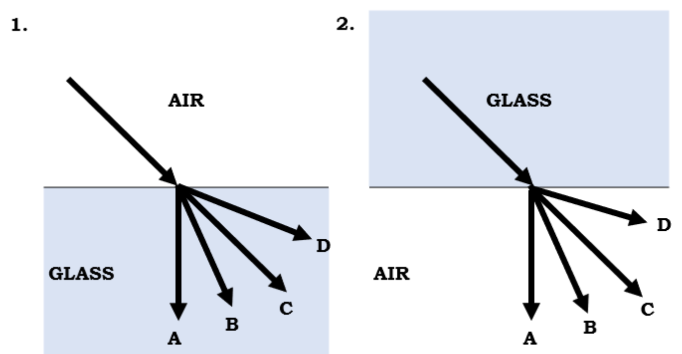
1. A 5.0 cm-tall candle is placed 30 cm in front of a concave mirror whose focal length is 20 cm. What is the image's distance and height? Describe the image using S.O.L.T.
2. You placed your face 6.0 cm from the back of the spoon, and you saw the image of your face somehow got closer to the spoon, approximately 2.0 cm. What is the spoon's focal length? Describe the image using S.O.L.T.

Lesson 3 Images Formed by Lenses

What's In

Another property of light that has many useful applications is refraction. As you had discussed in Grade 8, refraction is the bending of the light caused by the difference in density where light will travel.

Identify the direction of light after it passed from one medium to another.



What's New

Activity: Reversing Laser & Arrow

Objectives:

1. Investigate the refractive property of light using improvised materials.
2. Describe the image formed by an object in various distances from the refracting substance.

You Will Need:

- 1.5 soft drink bottle (clear and cleaned)
- Water
- Laser
- Arrow drawn on paper

Procedure: (suggested location: dark area)

1. Fill up a 1.5 bottle with water until it is full.
2. Place a clean bond paper one foot behind the bottle.
3. Point the laser in the middle of the bottle. Slowly move your hand to the right with the laser. Observe the laser light projected on the screen.
4. On a separate sheet of paper, draw the path the laser light traveled from the laser to the screen. Use the illustration below as a guide for your drawing.

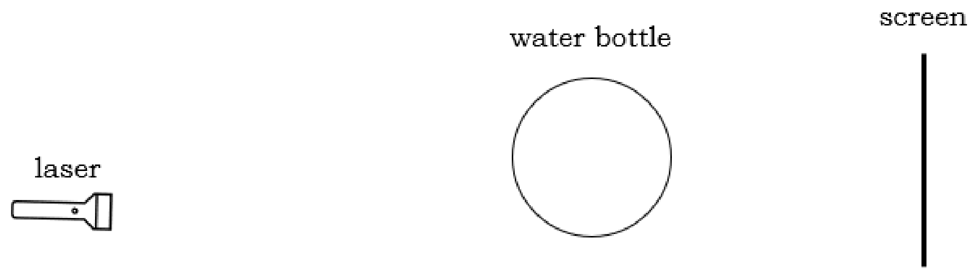


Figure 14 Setup of the activity Reversing Laser & Arrow

5. Then, slowly move your hand with the laser to the left. Observe.
6. On the same paper, draw the path where laser light traveled from the laser to the screen.
7. Get the paper with an arrow drawn on it. Place it directly behind the bottle. The arrow should be pointing to the right.
8. Then move the paper sideways (from left to right) and observe the image formed in the bottle.
9. Draw the image projected in the bottle when the arrow is directly behind the bottle
10. Repeat steps 7-9, but the paper with an arrow should be placed one foot away behind the bottle.

Guide Questions:

1. What happened when the laser light is pointed at the middle of the bottle? What does it indicate?
2. When you moved the laser to the right, what happened to the light projected on the screen? What happened when the laser was moved to the left?
3. What causes this phenomenon?
4. What happened to the orientation of the arrow when it is placed near the bottle? When it is one foot away from the bottle?

What Is It

Types of Lenses

Lenses are objects, usually made of glass, that refract light. They may form into different shapes depending on the purpose. In this module, we will focus on

spherical lenses. There are also plenty of types of spherical lenses, but we will only discuss two, convex and concave lenses.

Table 3. Types of Lenses

CONVEX LENS	CONCAVE LENS
• also known as *converging lens*	• also known as *diverging lens*
• a type of lens that is bulging or thicker at the center	• thinner in the center and thicker at the edges
• when light passes through it, the light converges at a single point	• when light passes through it, light diverges or scatters

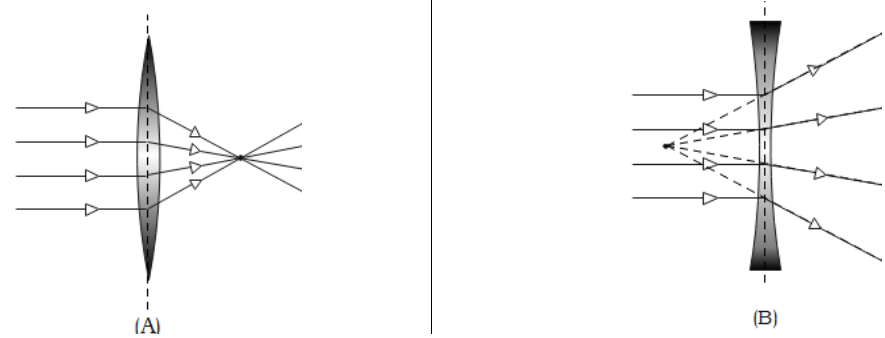


Figure 15: (A) When light passes a convex lens it converges; (B) When light passes a concave lens, it diverges.

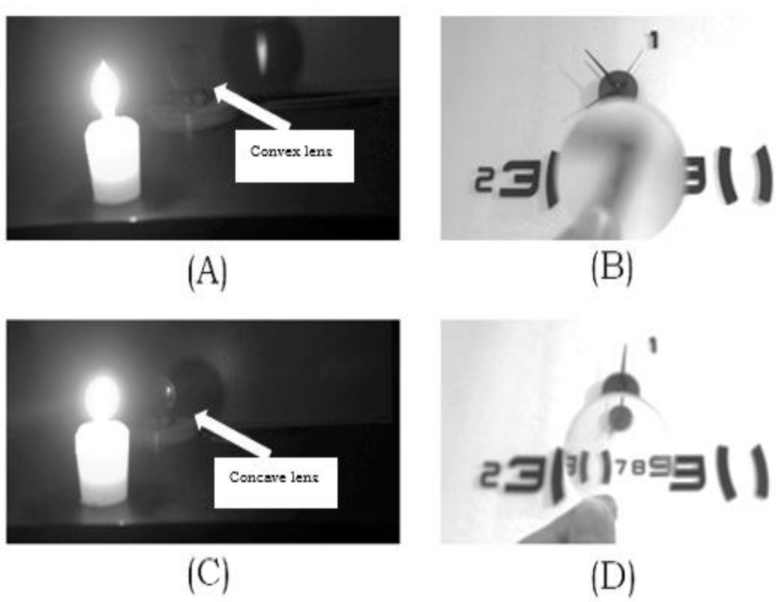


Figure 16. (A) Convex lens forming image on the screen; (B) view of the clock in a convex lens; (C) Concave lens does not form image on the screen; (D) View of the clock in a concave lens.

In the previous activity, the bottle with water serves as a lens (convex lens) and refracts the laser light. As you have noticed, the light changes its direction. This is due to the change in material that light travels – from air to water and water to air. And when an object is placed behind the bottle, the image formed is different at a varying location.

Image formation by Spherical Lenses through Ray Diagramming Techniques

Images formed by spherical lenses follow the law of refraction. Keep in mind that the light comes from the object in all directions but to analyze it easily, convenient rays will be picked to locate the image. We will not focus on the refraction that happens when light enters the lens and when light leaves the lens, but we will show the refraction that takes place in the middle of the lens. Here are the things that will be followed and considered (note that other references and textbooks may have more parts and rays):

1. Parts of the diagram

   A. **Lens –** It can be a concave or convex lens.
   B. **Principal Axis –** An imaginary line that bisects the spherical lenses horizontally.
   C. **Primary Focus (F) -** Located along the principal axis. Depends on the type of lens – for a convex lens, it is on the same side with the object and for a concave lens, it is on the opposite side of the object.
   D. **Secondary Focus (F') -** Located along the principal axis. Depends on the type of lens – for a convex lens, it is on the opposite side of the object and for a concave lens, it is on the same side with the object.
   E. **Optical Center (O)** – Located at the intersection of the principal axis and the lens.

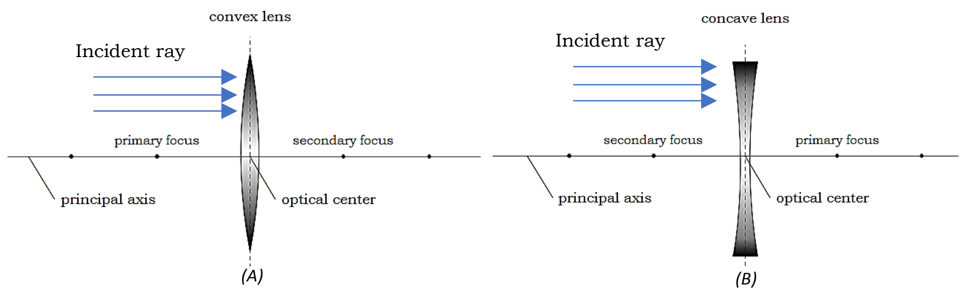


Figure 17. Parts of the diagram of (A) convex len (B) concave lens

2. Rays to be used

   A. Incident ray **PARALLEL TO THE PRINCIPAL AXIS** and when it refracts, it will **(A) MOVE TOWARDS THE SECONDARY FOCUS** or **(B)FOLLOW THE PATH ALONG THE SECONDARY FOCUS (F').**

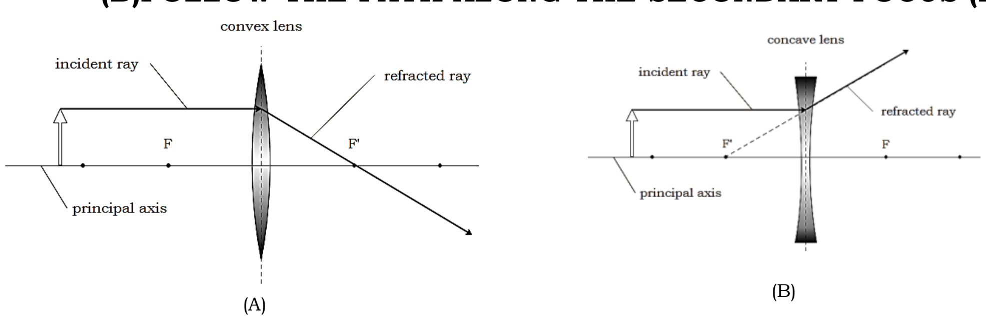


Figure 18. Ray A used in (A) convex lens and (B) concave lens

B. Incident ray (A)**PASSING THE PRIMARY FOCUS** or (B) **MOVING TOWARDS THE PRIMARY** FOCUS and when it hits the mirror, it will refract **PARALLEL TO THE PRINCIPAL AXIS**.

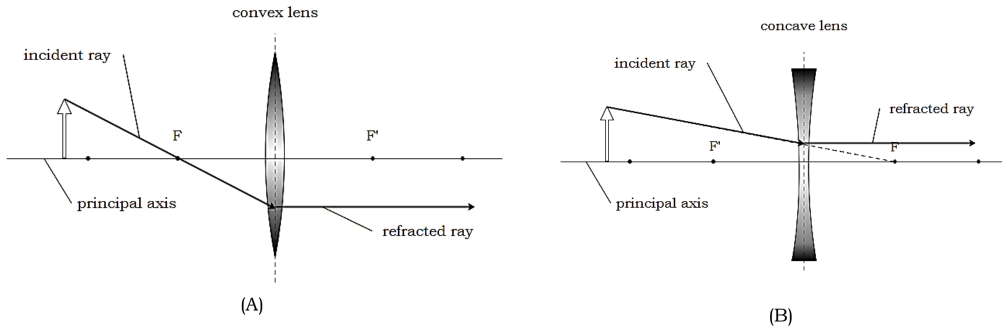


Figure 19. Ray B used in (A) convex lens and (B) concave lens

C. Incident ray **PASSING THE OPTICAL CENTER** and it will continue its path because there will be no refraction.

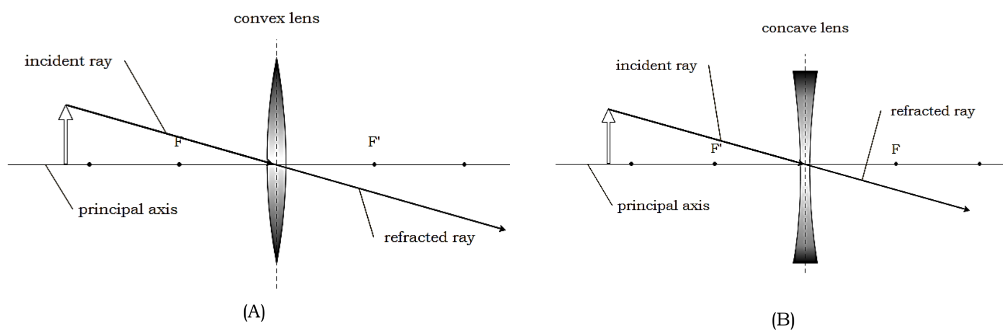


Figure 20. Ray C used in (A) convex lens and (B) concave lens

3. Description of the Image

The image is formed at the intersection of the refracted rays and it can be described based on its Size, Orientation, Location, and Type (S.O.L.T). *(Note: if in case there is no intersection because the refracted rays are parallel to each other, no image is formed.)*

A. **Size (S)** – It describes the height of the image as compared to the object's height. It can be described as **SMALLER/REDUCED**, **SAME SIZE,** or **LARGER/MAGNIFIED.**

B. **Orientation (O)** – It describes the positioning of the image when compared to the object. It can be **UPRIGHT** if it has the same position as the object and **INVERTED** if otherwise. (Note that if the object is initially inverted, and the image is also inverted, it should be described as upright.)

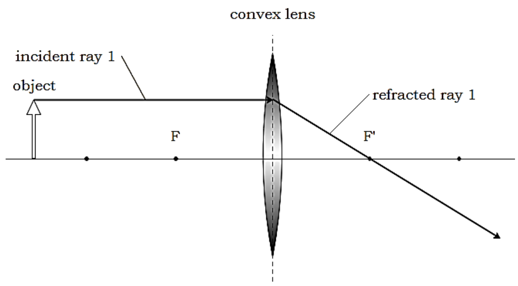
C. **Location (L)** – It describes where the image is formed. It can be on the **SAME SIDE WITH THE OBJECT** or on the **OPPOSITE SIDE OF THE OBJECT**.

D. **Type (T)** – It describes the type of image formed. It can be described as **REAL** if the image is formed by the actual refracted ray and located at the opposite side of the object. **VIRTUAL** if the image is formed by an extended refracted ray and located at the same side with the object.

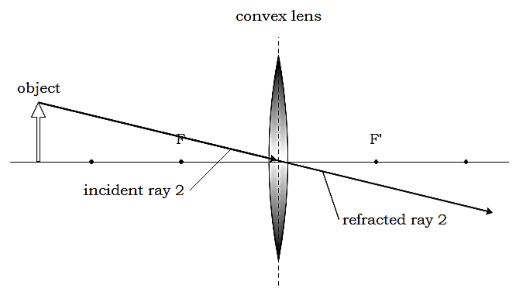
Here is an example of how ray diagramming techniques are used to locate and describe the image formed by an object.

1. Convex Lens
   We will consider an object placed far from the lens. We may use two pairs of incidents and refracted rays depending on the location of the object.

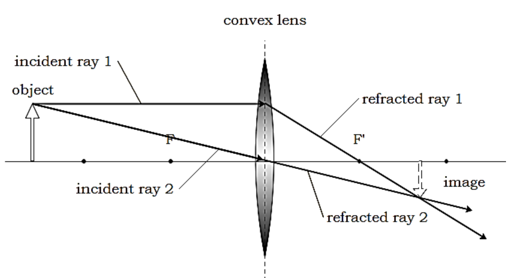
Incident ray **PARALLEL TO THE PRINCIPAL AXIS** and when it refracts, it will **MOVE TOWARDS THE SECONDARY FOCUS.**



Incident ray **PASSING THE OPTICAL CENTER** and it will continue its path because there will be no refraction



The image is formed at the intersection of the refracted rays.



Description of the image

S – reduced

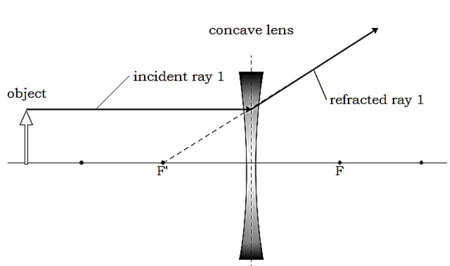
O – inverted

L – at the opposite side of the object

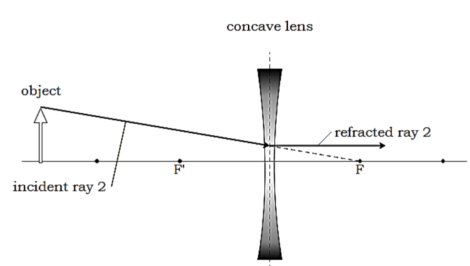
T - real

2. Concave Lens

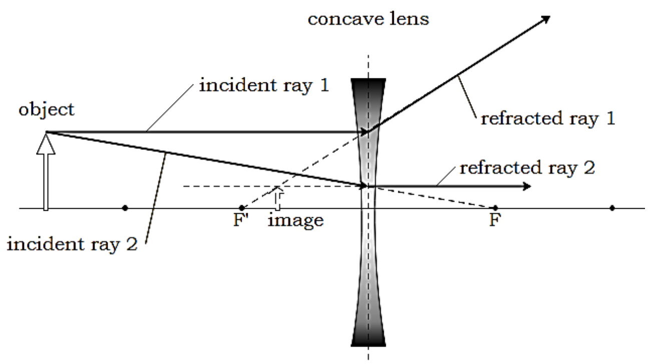
Incident ray PARALLEL TO THE PRINCIPAL AXIS and when it refracts, it will **FOLLOW THE PATH ALONG THE SECONDARY FOCUS (F').**



Incident ray **MOVING TOWARDS THE PRIMARY FOCUS** and when it hits the mirror, it will refract **PARALLEL TO THE PRINCIPAL AXIS.**



Since the refracted rays do not seem to intersect at the other side of the lens, **extending the line of the refracted rays backwards** form an intersection, thus, an image is formed.



Description of the image

S – reduced

O – upright

L – same side with the object

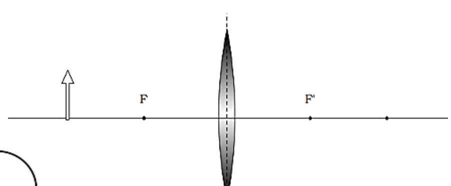
T - virtual

What's More

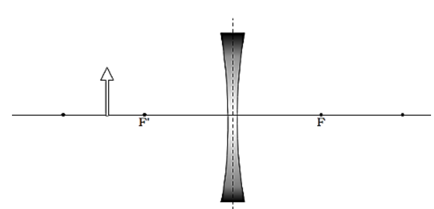
Use the ray diagramming technique to describe the image formed by concave and convex lenses at different positions using **S-O-L-T (Size, Orientation, Location, and Type).** Use the following measurement: focal length = 1.5 cm, and height of object = 2.0 cm.

LOCATION OF THE OBJECT	SIZE	ORIENTATION	LOCATION	TYPE
Convex Lens				
A. At 2F	1.	2.	3.	4.
B. Beyond 3F	5.	6.	7.	8.
C. Between F and 2F	9.	10.	11.	12.
D. At F	13.	14.	15.	16.
E. Between F and lens	17.	18.	19.	20.
Concave Lens				
F. At 2F	21.	22.	23.	24.
G. Beyond 2F	25.	26.	27.	28.
H. Between F' and 2F	29.	30.	31.	32.
I. At F'	33.	34.	35.	36.
J. Between F' and lens	37.	38.	39.	40.

A.



H.



What I Have Learned

Answer the following questions.

1. What happens when light passes a convex lens?
2. What happens when light passes a concave lens?
3. How will you describe the image produced by an object at varying distance from the convex lens?
4. How will you describe the image produced by an object at varying distances from the concave lens?

What I Can Do

Study how human eyes work including the conditions/ eye defects: Nearsightedness and Farsightedness. Make an infographic on how the normal, nearsighted, and farsighted eyes form images. Also, include the kind of lens used to correct these eye defects. (Infographic is a visual image used to represent information.)

Rubrics for scoring

Content – 10 pts. Accurate and detailed information are provided.

Organization – 5 pts. Information are organized systematically and easy for the reader to understand

Visual Appeal - 5 pts. Letters, colors, images, layouts, and other visual elements help in expressing the overall idea of the infographics

Citation – 5 pts. All sources of information are cited using APA style (7th ed.)

Assessment

Analyze each statement carefully. Write **TRUE** if the statement is correct and **FALSE** if the statement is incorrect.

___________1. Convex lens is also called a converging lens.

___________2. Virtual and real images are produced by a concave lens.

___________3. When light passes through the optical center, refraction occurs.

___________4. When a parallel light passes through a convex lens, it refracts towards the secondary focus.

___________5. When a parallel light passes through a concave lens, it refracts along with the secondary focus.

Additional Activities

Lens Maker Equation and Magnification Formula

Describing the image formed by spherical mirrors (using S.O.L.T) may be done mathematically through the lens maker equation for the distances and magnification formula for the height.

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q} \qquad\qquad \frac{h'}{h}=-\frac{q}{p}$$

Where:

f = focal length of the lens
p = object's distance from the lens
q = image's distance from the lens
h = object's height
h' = image's height

In using the formula, the following sign convention should be considered.

Quantity	Description - sign
Focal length (f)	Convex lens – positive (+) Concave lens – negative (-)
Image distance from the lens	Opposite side of the object – positive (+) Same side with the object – negative (-)
Image height	Upright – positive (+) Inverted – negative (-)

Object's distance and height are always positive.

Let us try one example.

A magnifying glass (convex lens) is used to increase the size of a small object. What is the image distance and height if a 5.0-cm focal length magnifying glass is placed 2.0 cm away from a 1.5 cm rice grain? Then describe the image using S.O.L.T.

We will follow the **GFSA** method.

First, let us write down all the **G**iven. f = + 5.0 cm p = 2.0 cm q =? h = 1.5 cm h' =?	Next, determine the **F**ormula to be used. Rearranging the variables from $\frac{1}{f}=\frac{1}{p}+\frac{1}{q}$ $\qquad$ $\frac{h'}{h}=-\frac{q}{p}$ to, since we are looking for q and h'

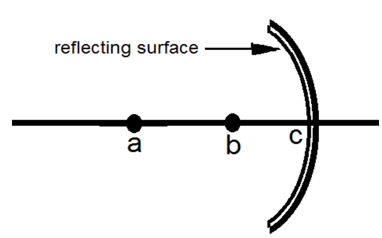
	$\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{f} - \frac{1}{p}$ $\qquad$ $\boldsymbol{h'} = -\frac{hq}{p}$
Then, **S**ubstitute the given values to the formula $\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{f} - \frac{1}{p}$ $\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{1}{5.0\ cm} - \frac{1}{2.0\ cm}$ $\frac{\mathbf{1}}{\boldsymbol{q}} = \frac{2.0\ cm - 5.0\ cm}{10cm^2}$ $q = \frac{10\ cm^2}{-3.0\ cm}$ $\boldsymbol{q = -3.3\ cm}$ Since we have the value for q $\boldsymbol{h'} = -\frac{hq}{p}$ $\boldsymbol{h'} = -\frac{(1.5\ cm)(-3.3\ cm)}{2.0\ cm}$ $\boldsymbol{h'} = -\frac{-4.95\ cm^2}{5.0\ cm}$ $\boldsymbol{h' = 2.475\ cm\ or\ 2.5\ cm}$	Make sense of the computed **A**nswer What is the image distance and height? Then describe the image using S.O.L.T. The image distance is -3.3 cm. The image height is 2.5 cm S = The image is **enlarged or bigger than the object** since its object's height is 1.5 cm. O = the image is **upright** since the computed value for the h' is positive. L = The image is located **at the same side with the object** since the computed value for q is negative. T = The image is **virtual** since the image is located at the same side with the object.

Now it is your time to try using the lens maker equation and magnification formula.

1. A 15-cm object is placed 30 cm away from a convex lens having a 45 cm focal length. What is the distance and height of the image? Then describe the image using S.O.L.T.
2. A diverging lens that has a 20-cm focal length is positioned 5.0 cm from a 2.0-cm object. Will the image be larger or smaller? Prove your answer.

Posttest

Read and understand each item carefully and encircle the letter of the correct answer.



1. Which term refers to the length between *b* and *c* in the given figure?
   A. Radius
   B. Center of curvature
   C. Focal length
   D. Vertex

2. Which of the following supports the laws of reflection?
   I. The angle of incidence is equal to the angle of reflection.
   II. The angle of incidence is greater than or less than the angle of reflection depending on the medium.
   III. The incident ray, the normal line, and the reflected ray lie on the same plane.
   IV. The incident ray, the normal line and the reflected ray lie on different planes.

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

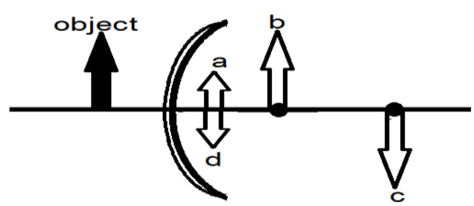
3. Which is true about the image formed in the plane mirror?

I.	Real	V.	Same size
II.	Virtual	VI.	Magnified
III.	Upright	VII.	Diminished
IV.	Inverted		

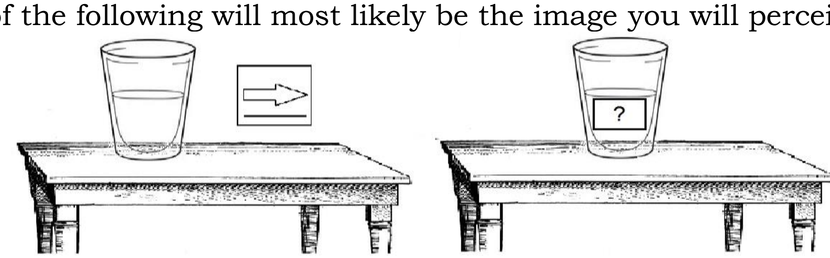
   A. I, IV, VII
   B. I, IV, V
   C. II, III, VII
   D. II, III, V

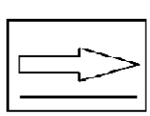
4. What image will be produced by a *convex mirror*?
   A. Virtual, upright, smaller than the object.
   B. Virtual, upright, larger than the object.
   C. Real, inverted, smaller than the object.
   D. Real, inverted, larger than the object.

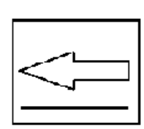
5. In what position will the image be if an object is placed in front of a *convex mirror* as shown in the figure on the right?

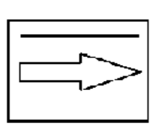


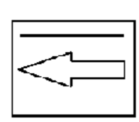
6. As shown in the figure below, a glass of water is placed in front of an arrow. Which of the following will most likely be the image you will perceive?



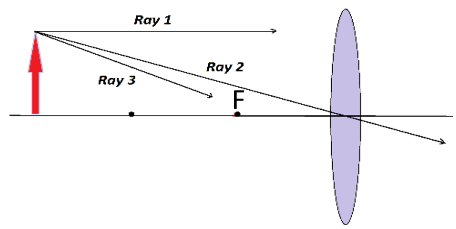
A. 

C. 

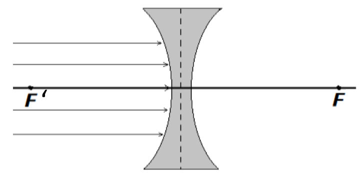
B. 

D. 

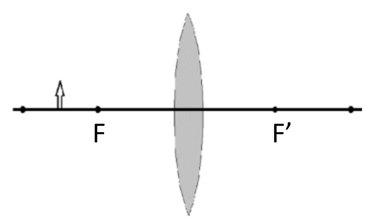
7. In the figure at the right, which ray(s) will pass through the *primary focus* after refraction?
   A. Ray 1 only
   B. Ray 2 only
   C. Ray 3 only
   D. Rays 1 and 2



8. If the light rays strike the *diverging* lens (as shown in the figure at the right), what will happen with the light rays?
   A. It will bounce back on the same side.
   B. It will converge at F'.
   C. It will diverge at F'.
   D. Nothing will happen.



9. Where will the image form if the object is placed between F and 2F as shown in the figure on the right?
   A. At F'
   B. At 2F'
   C. At infinity
   D. Beyond 2F'



10. What kind of image will be formed in the previous figure?
   A. Multiple images
   B. No image will be formed
   C. Real
   D. Virtual

Answer Key

What's In

Lesson 1	Lesson 2	Lesson 3
1. B	Darkness cannot drive out darkness;	1. B
2. C	only light can do. Hate cannot drive	2. D
3. C	out hate; only love can do.	

What's New

Lesson 1.

1. The laser bounce off to other direction.
2. The angle of incidence is equal to the angle of reflection.

Lesson 2

1. A regular mirror is flat, the spoon is curved.
2. when the shape is curved inwards, the image formed is inverted. It changed when you move it away. When the shape is curved outwards, the image is small and you can see more images.

Lesson 3

1. the light just pass through. No refraction occurs at the center of the bottle.
2. When the light is moved to the right, the light is projected on the left. Opposite happens when the light is moved to the left.
3. refraction and the shape of the container.
4. The orientation of the arrow is the same but it is enlarged. When it is moved one foot away, the arrow is inverted.

What's More

Lesson 1 – Answers may vary

Lesson 2

LOCATION OF THE OBJECT	SIZE	ORIENTATION	LOCATION	TYPE
Concave mirror				
A. At C	Same size	inverted	Front of the mirror	Real
B. Beyond C	smaller	inverted	Front of the mirror	Real
C. Between F and C	enlarged	inverted	Front of the mirror	Real
D. At F	No image	No image	No image	No image
E. Between F and mirror	enlarged	upright	Behind the mirror	virtual
Convex mirror				
F. Near the mirror	smaller	upright	Behind the mirror	virtual
G. Far from the mirror	smaller	upright	Behind the mirror	virtual

Lesson 3

LOCATION OF THE OBJECT	SIZE	ORIENTATION	LOCATION	TYPE
Convex Lens				
A. At 2F	Same size	inverted	Opposite side of object	Real
B. Beyond 2F	smaller	inverted	Opposite side of object	Real
C. Between F and 2F	enlarged	inverted	Opposite side of object	Real
D. At F	No image	No image	No image	No image
E. Between F and lens	enlarged	upright	Same side with object	virtual
Concave Lens				
F. At 2F	smaller	upright	Behind the mirror	virtual
G. Beyond 2F	smaller	upright	Behind the mirror	virtual
H. Between F' and 2F	smaller	upright	Behind the mirror	virtual
I. At F'	smaller	upright	Behind the mirror	virtual
J. Between F' and lens	smaller	upright	Behind the mirror	virtual

What I have Learned

Lesson 1.

1. Equal
2. Reflection
3. Normal line
4. Same plane

Lesson 2

1. Plane, Concave and convex mirror
2. Plane mirror has flat surface, concave mirror has inward curved surface, and convex mirror has outward curved surface.
3. The image produces by plane mirror is virtual, same size and upright.
4. The image produced by concave mirror depends on the distance of the object. If it is near, the image it produce is virtual enlarged and upright. If it is very far, the image is smaller, inverted, and real.
5. At any distance from the convex mirror, the image formed is virtual smaller and upright.

Lesson 3

1. It converges towards the focus.
2. It diverges along the focus
3. The image produced by convex lens depends on the distance of the object. If it is near, the image it produce is virtual enlarged and upright. If it is very far, the image is smaller, inverted, and real.
4. At any distance from the concave lens, the image formed is virtual smaller and upright.

Assessment

Lesson 1	Lesson 2	Lesson 3
1. T	1. T	1. T
2. F	2. T	2. F
3. T	3. F	3. F
	4. T	4 T
	5. T	5. T

Additional Activities

Lesson 2	Lesson 3.
1. q = 60 cm	1. q = 90 cm
h' = 10 cm	2. H' – 45 cm

References

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