General- Physics-2 Q4 Week-4

Fundamental Physics I Laboratory (University of the Philippines System)

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BEHAVIOR OF LIGHT IN OPTICAL DEVICES

For GENERAL PHYSICS 2/ Grade 12/ Quarter 4/ Week 4

SELF-LEARNING KIT

NegOr_Q4_GenPhysics2_SLKWeek4_v2

FOREWORD

Mirrors and Lenses are common materials we usually use every day, from the cameras of our phones, the eyeglasses we wear, the side mirror of our vehicle, and even our eyes are some of the things in our day-to-day living that are using mirrors and lenses. In this Self-Learning Kit, we will be able to understand well the concepts of Geometrical optics that will help you understand the basics of light reflection and refraction and the use of simple optical elements such as mirrors, prisms, lenses, and fibers.

In addition, you should be able to manipulate and use algebraic formulas, deal with units, understand the geometry of circles to further understand the concepts. Furthermore, this module will allow us to predict the image size, orientation, location and type of the image formed through ray diagraming technique and mathematical equations.

OBJECTIVES

At the end of this Self-Learning Kit, you should be able to:

K: explain how images formed through (a) refection, (b) refraction and (c) paraxial approximation;
: state the law of reflection and show with appropriate drawings how it applies to light rays at plane and spherical surfaces;
S: use ray-tracing techniques to locate the images formed by plane mirrors, spherical mirrors, and lenses;
: use the mirror equations to determine location, size, orientation, and nature of images formed with plain mirrors, spherical mirrors and lenses; and
A: cite importance of mirrors and lenses in the development of LCD projector screen, microscope, and telescope.

LEARNING COMPETENCIES

Explain image formation as an application of reflection, refraction, and paraxial approximation **(STEM_GP12OPT-IVd-22).**

Relate properties of mirrors and lenses (radii of curvature, focal length, index of refraction [for lenses]) to image and object distance and sizes **(STEM_GP12OPT-IVd-23)**

Determine graphically and mathematically the type (virtual/real), magnification, location, and orientation of image of a point and extended object produced by a plane or spherical mirror **(STEM_GP12OPT-IVd-24).**

Determine graphically and mathematically the type (virtual/real), magnification, location/ apparent depth, and orientation of image of a point and extended object produced by a lens or series of lenses **(STEM_GP12OPTIVd-27).**

I. WHAT HAPPENED
PRE-TEST

FILL ME UP!

Directions: Below are the definitions of the words you will be encountering as you read this Self-Learning Kit. Find the correct words inside the box as described. Write down your answer on your notebooks/Answer Sheets.

Geometric Optics	Laws of Reflection	Normal line
Diffuse Reflection	*light ray*	*index of refraction*
Snell's law of refraction	paraxial approximation	*real image*
virtual image	*converging*	*diverging*
positive	negative	Refraction

1. ____________ refers to the incident rays that are parallel are reflected at different angles. Ex: Rough water, crumbled aluminum foil.
2. ____________ refers to the bending of light rays as it travels from one medium to another.
3. Original incoming ray.
4. A ________________ is nothing more than an imaginary line directed along the path that the light follows.
5. The two transparent optical media that form an interface are distinguished from one another by a constant called the ____________________.
6. ____________________________ relates the sines of the angles of incidence and refraction at an interface between two optical media to the indexes of refraction of the two media.
7. ____________________________ (ray optics) describes light propagation in the form of geometric rays.
8. The ____________________________ means that the angle θ between such rays and some reference axis of the optical system always remains small, i.e., ≪ 1 rad.
9. A ______________________ is formed because the ray can be projected.
10. If the sheet of paper is placed on the right of the lens, no image is formed since the rays of light coming from the common parts of the lens are diverging on the right of the lens. The image produces is therefore called ___________________.
11. A major difference between lenses and mirrors is that a concave mirror is _______________
12. and a convex mirror is ___________________.
13. The focal length of a concave mirror is therefore ________________,

14. and the focal length of convex mirror is ________________.
15. A line drawn from the center of curvature C to any point on the mirror is a ____________________ and thus bisects the angle between the incident and reflected rays.

II. WHAT I NEED TO KNOW
DISCUSSION

IMAGE FORMATION WITH MIRRORS

Mirrors, of course, are everywhere—in homes, auto headlamps, astronomical telescopes, and laser cavities, and many other places. Plane and spherical mirrors are used to form three dimensional images of three-dimensional objects. If the size, orientation, and location of an object relative to a mirror are known, the *law of reflection* and ray tracing can be used to locate the image graphically. Appropriate mathematical formulas can also be used to calculate the locations and sizes of the images formed by mirrors. In this section we shall use both graphical ray tracing and formulas.

Mirrors are optical devices that permit the reflection of light. A mirror demonstrates the law of reflection as it forms the image of the object placed before it. A mirror can be planar or spherical. ***Plane mirrors*** will always form an image that has the same size as the object, are located behind the mirror, and are oriented in the same direction as the object. A ***spherical mirror*** can be either convex or concave.

Images Formed with Flat Mirrors

The flat mirror is extremely common. Ray tracing for mirrors uses the law of reflection. It is used in Figure 1 to show how image is formed behind a flat mirror. The image formed by a flat mirror has the same size as the object and is located a distance behind the mirror equal to the distance of the object from the mirror. Flat mirrors often are used to make small rooms look bigger because of the type of image they form.

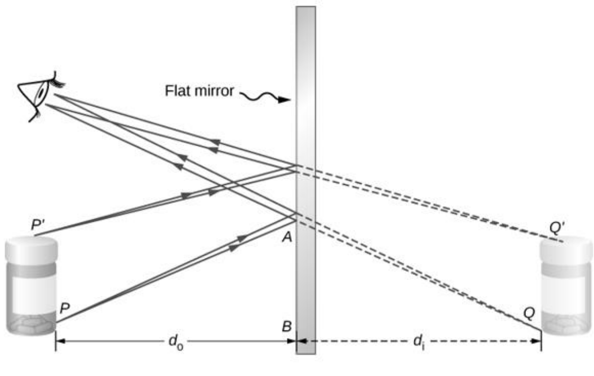

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Figure 1. Image formation in plane mirror

Reflection from a Curved Surface

With spherical mirrors, reflection of light occurs at a curved surface. The law of reflection holds, since at each point on the curved surface one can draw a surface tangent and erect a normal to a point *P* on the surface where the light is incident, as shown in Figure 2. One then applies the law of reflection at point *P* just as was illustrated in Figure 2, with the incident and reflected rays making the same angles (A and B) with the normal to the surface at *P*. Note that successive surface tangents along the curved surface in Figure 2 are ordered (not random) sections of "plane mirrors" and serve—when smoothly connected—as a spherical surface mirror, capable of forming distinct images.

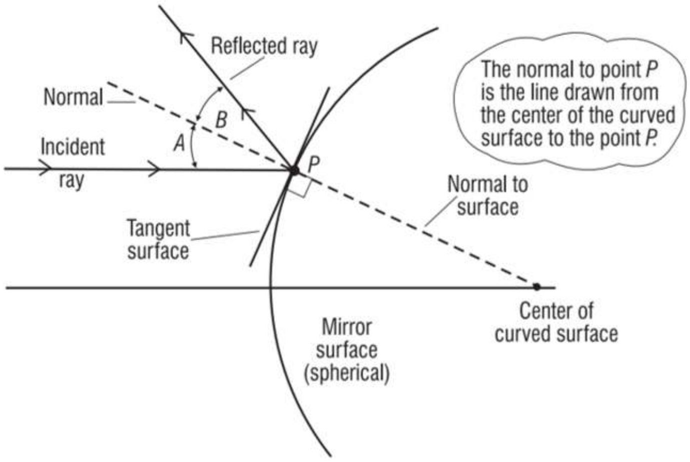

Figure 2. Reflection at a curved surface. Angle B equals angle A.

Since point *P* can be moved anywhere along the curved surface and a normal drawn there, we can always find the direction of the reflected ray by applying the law of reflection. We shall apply this technique when studying the way mirrors reflect light to form images.

Images Formed with Spherical Mirrors

As we showed earlier in Figure 2, the ***law of reflection*** can be used to determine the direction along which any ray incident on a spherical mirror surface will be reflected. Using the *law of reflection*, we can trace rays from any point on an object to the mirror, and from there on to the corresponding image point. This is the method of ***graphical ray tracing***.

Graphical Ray-Trace Method. To employ the method of ray tracing, we agree on the following:

- Light will be incident on a mirror surface *initially* from the left.
- The axis of symmetry normal to the mirror surface is its *optical axis*.

• The point where the optical axis meets the mirror surface is the *vertex*.

To locate an image, we use two points common to each mirror surface, the *center of curvature C* and the *focal point F*. They are shown in Figure 3, with the mirror vertex *V*, for both a *concave* and a *convex* spherical mirror.

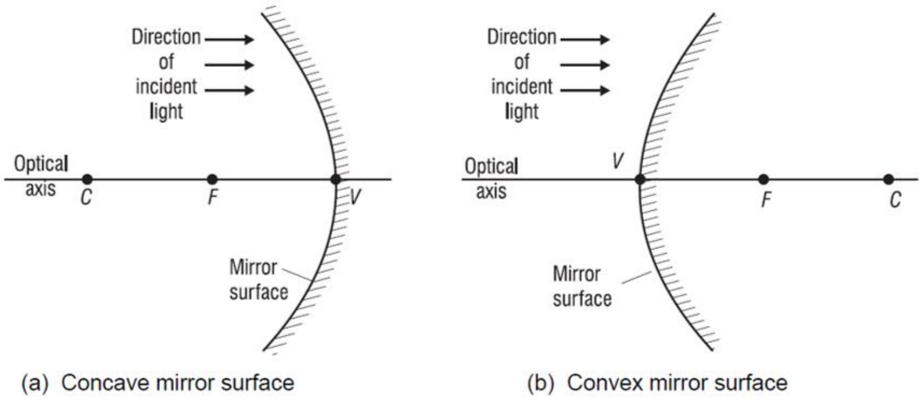

***Figure 3*.** Defining points for concave and convex mirrors

The edges of *concave* mirrors always bend toward the oncoming light. Such mirrors have their center of curvature *C* and focal point *F* located to the *left* of the vertex as seen in Figure 3.a. The edges of *convex* mirrors always bend away from the oncoming light, and their center of curvature *C* and focal point *F* are located to the *right* of the vertex. See Figure 3.b.

The important connection between parallel rays and the focal points for mirror surfaces is shown in Figure 4a and 4b. Parallel rays are light rays coming from a very distant source (such as the sun) or from a collimated laser beam. The *law of reflection*, applied at each point on the mirror surface where a ray is incident, requires that the ray be reflected so as to pass through a focal point *F* in front of the mirror (Figure 4.a) or be reflected to appear to come from a focal point *F* behind the mirror (Figure 4.b). Notice that a line drawn from the center of curvature *C* to any point on the mirror is a *normal* line and thus bisects the angle between the incident and reflected rays. As long as the transverse dimension of the mirror is not too large, simple geometry shows that the point *F*, for either mirror, *is located at the midpoint between C and* F, so that the distance *FV* is one-half the radius of curvature *CV*. The distance *FV* is called the *focal length* and is commonly labeled as *f*.

Image Location by Ray Tracing

Ray diagram or ray tracing can be used to identify the location, size, and nature of the image produced by spherical mirrors.

Figure 4 shows three key rays—for each mirror—that are used to locate an image point corresponding to a given object point. They are labeled 1, 2, and 3. Any two, drawn from object point *P*, will locate the corresponding image point *P′*. In most cases it is sufficient to locate one point, like *P′*, to be able to draw the entire image.

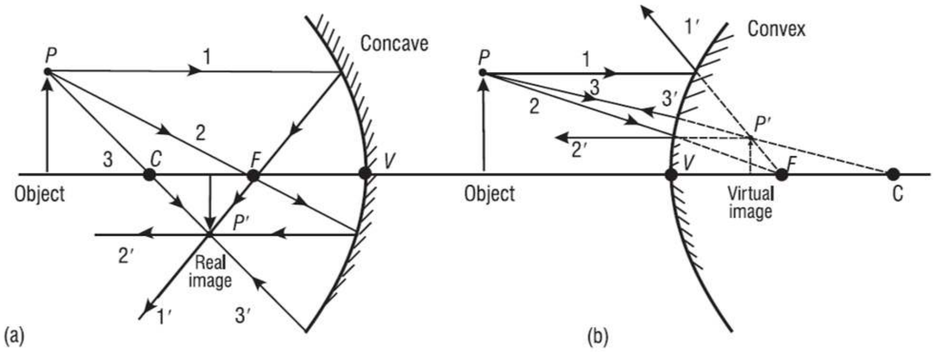

Figure 4. Key rays for graphical ray tracing with spherical mirrors

Note carefully, with reference to Figure 4 (a)and (b), the following facts:

For a concave mirror:

- The ray from object point *P* parallel to the axis, such as ray 1, reflects from the mirror and *passes through the focal point F* (labeled ray 1′).
- The ray from *P* passing through the focal point *F*, such as ray 2, reflects from the mirror *as a ray parallel to the axis* (labeled ray 2′).
- The ray from *P* passing through the center of curvature *C*, such as ray 3, *reflects back along itself* (labeled ray 3′).
- Reflected rays 1′, 2′, and 3′ converge to locate point *P′* on the image. This image is a *real* image that can be formed on a screen located there.

For a convex mirror:

- The ray from object point *P*, parallel to the axis, such as ray 1, reflects from the mirror *as if to come from the focal point F behind* the mirror (labeled ray 1′).
- The ray from *P*, such as ray 2, headed toward the focal point *F* behind the mirror, reflects from the mirror in a direction parallel to the optical axis (labeled ray 2′).
- The ray from *P*, such as ray 3, headed toward the center of curvature *C* behind the mirror, reflects back along itself (labeled ray 3′).
- Rays 1′, 2′, and 3′ diverge after reflection. A person looking toward the mirror intercepts the diverging rays and sees them appearing to come from their common intersection point *P′*, behind the mirror.

The image is *virtual* since it cannot be formed on a screen placed there.

A major difference between lenses and mirrors is that a ***concave mirror is converging,*** and a ***convex mirror is diverging***, just the opposite of lenses. The focal length of a concave mirror is therefore positive, and the focal length of convex mirror is negative. In short, the behavior mirrors are analogous to that of the lenses except that a concave mirror is analogous to a convex lens and a convex mirror is analogous to a concave lens. One example if the use of convex security mirrors in stores which produce a small upright image like the one produce by the concave lens. Another example is a concave makeup mirror, which magnifies in a manner analogous to a convex magnifying lens.

Equations for Spherical Mirrors Calculations

Ray diagrams provide useful information about the image formed yet fail to provide the information in a qualitative form. The spherical mirror equation will provide the numerical information about the image distance and size. The following derivation shows the mirror equation.

The ***spherical mirror equation*** is given by Equation below.

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

where:
p is the object distance (from object to mirror vertex *V*)
q is the image distance (from image to mirror vertex *V*)
and ***f*** is the focal length (from focal point *F to mirror* vertex *V*)

The magnification *m* produced by a spherical mirror is given in Equation below.

$$\boxed{m=\frac{h_i}{h_o}=-\frac{q}{p}}$$

where ***m*** is the magnification (ratio of image size to object size)
h_i is the transverse height of the image.
h_o is the transverse height of the object.
p and ***q*** are object and image distance respectively.

Sample Problem 1:

A 4.5 cm tall light bulb is placed at a distance of 50.0 cm from a concave mirror having a focal point length of 10.0 cm. What is the distance and the size of the image formed?

Given:

$h = 4.5\ cm$

$f = 10.0\ cm$

$p = 50.0\ cm$

Unknown:

$q =$ ______

$h' =$ ______

Formula:

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

Solution:

$$\frac{1}{10.0\ cm} = \frac{1}{50.0\ cm} + \frac{1}{q}$$

$$\frac{1}{10.0\ cm} - \frac{1}{50.0\ cm} = \frac{1}{q}$$

$$\frac{50.0\ cm - 10.0\ cm}{(10.0\ cm)(50.0\ cm)} = \frac{1}{q}$$

$$\boldsymbol{q = 12.5\ cm}$$

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

Formula:

$$\boxed{m = \frac{h_i}{h_o} = -\frac{q}{p}}$$

Solution:

$$\frac{h'}{4.5\ cm} = \frac{-\ 12.5\ cm}{50.0\ cm}$$

$$h' = \frac{(4.5\ cm)(-12.5\ cm)}{50.0\ cm}$$

h' = -1.12 cm

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

Sample Problem 2:

What is the focal length of a convex mirror that produces an image that appears 20.0 cm behind the mirror when the object is 32.2 cm from the mirror?

Given:

q= -20.0 cm

p = 32.2 cm

Formula: $\boxed{\frac{1}{p}+\frac{1}{q}=\frac{1}{f}}$

Solution:

$$\frac{1}{f}=\frac{1}{32.2\text{ cm}}+\frac{1}{-20.0\text{ cm}}.$$

$$\frac{1}{f}=\frac{-20.0\text{ cm}}{(32.2\text{ cm})}+\frac{32.2\text{ cm}}{(-20.0\text{ cm})}$$

f= -52.79 cm

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

Paraxial Approximation

Many calculations in optics can be greatly simplified by making the paraxial approximation, i.e., by assuming that the propagation direction of light (e.g., in some laser beam) deviates only slightly from some beam axis. Geometrical optics (ray optics) describes light propagation in the form of geometric rays. Here, the paraxial approximation means that the angle θ between such rays and some reference axis of the optical system always remains small, i.e., $\ll 1$ rad. Within that approximation, it can be assumed that:

$$\tan\theta \approx \sin\theta \approx \theta$$

Paraxial Approximation in Wave Optics

When describing light as a wave phenomenon, the local propagation direction of the energy can be identified with a direction normal to the wavefronts (except in situations with spatial walk-off). If the paraxial approximation holds, i.e., these propagation directions are all close to some reference axis, a second-order differential equation (as obtained from Maxwell's equations) can be replaced with a simple first-order equation. Based on this equation, the formalism of Gaussian beams can be derived, which gives a much simplified understanding of beam propagation and of fundamental limitations such as the minimum beam parameter product. Essentially, the paraxial approximation remains valid as long as divergence angles remain well below 1 rad. This also implies that the beam radius at a beam waist must be much larger than the wavelength.

The propagation modes of waveguides, particularly of optical fibers, are also often investigated based on the paraxial approximation. The validity of the analysis is then restricted to cases with a sufficiently large effective mode area and sufficiently small divergence of any beams exiting such a waveguide.

IMAGE FORMATION WITH LENSES

Lenses are at the heart of many optical devices, not the least of which are cameras, microscopes, binoculars, and telescopes. Just as the *law of reflection* determines the imaging properties of mirrors, so *Snell's law of refraction* determines the imaging properties of lenses. Lenses are essentially light-controlling elements, used primarily for image formation with visible light, but also for ultraviolet and infrared light. In this section, we shall look first at the types and properties of lenses, then use graphical ray-tracing techniques to locate images, and finally use mathematical formulas to locate the size, orientation, and position of images in simple lens systems.

Function of a lens

A ***lens*** is made up of a transparent refracting medium, generally of some type of glass, with spherically shaped surfaces on the front and back. A ray incident on the lens refracts at the front surface (according to Snell's law) propagates through the lens and refracts again at the rear surface. The ray-tracing techniques and lens formulas we shall use here are based again on *Gaussian optics,* just as they were for mirrors.

Lenses: Convex and Concave

Convex Lens is a simple type of lens that is usually used in magnifying glass that can focus sunlight to a small point. Light rays reaching the lens from a distant source, such as the sun, are nearly parallel because they must be nearly parallel at the outset to travel a large distance and reach almost the same point far away. Figure 5 shows how parallel rays of light are refracted by a convex lens. Because the speed of light is slower in glass than in air, the light rays bend toward the perpendicular when they enter the glass. Conversely, light rays bend away from the perpendicular when they leave the glass. Rays passing through the center of the lens are deflected by a negligible amount. The convex shape of the glass is designed so that all parallel rays cross at the same point after passing through the lens. Convex lenses are also called ***converging lenses*** because of their effect on the light passing through them. The simplest compound microscope is constructed from two convex lenses.

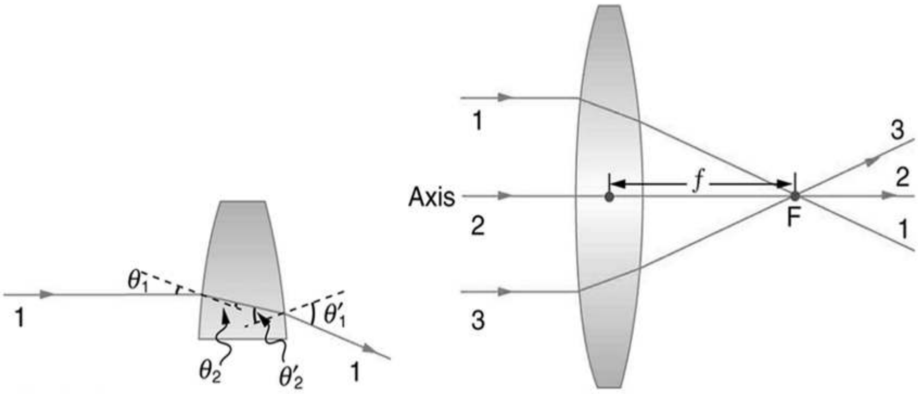

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***Figure 5*.** Converging Lens

The point at which a convex lens converges parallel light rays, as in Figure 5, is called the *focal point* **F** of the lens. The distance of the focal point from the center of the lens is called the *focal length* of the lens and is given the symbol ***f***. The stronger the lens the more effect it has on the light passing through it. Therefore, the stronger the lens the smaller *f* is.

Concave lenses diverge light rays that why it is also called *diverging lenses*. Consider the effect of concave lens in Figure 6 has on parallel light rays. Notice that the diverging rays of light all appear to come from the point F, defined as the focal point of the lens, and the distance to F from the center of the lens is defined as the focal length f of the lens. The focal length and the strength of the concave lens are negative. The negative focal length indicates that the lens has the opposite effect of a convex lens.

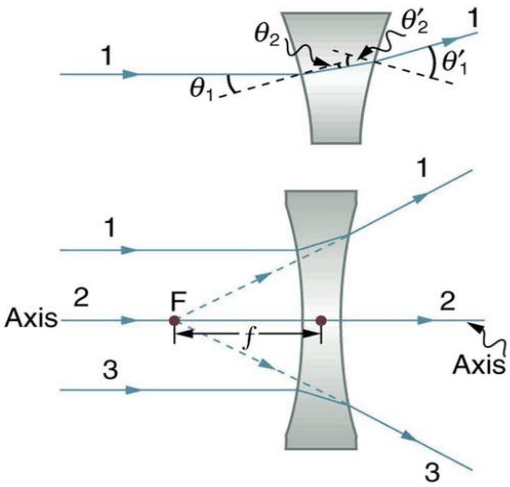

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***Figure 6*.** Diverging lens.

Image formation

The convex lens of a magnifying glass can project an image on a piece of paper as shown in Figure 7. The paper must be held at just the right distance of the lens, or the image will be blurry. A little experimenting produces reasonably good color image, which is inverted. Such image is called ***real image*** because it can be *projected*. Slide and movie projectors, cameras, and the eye also produce real images on screens, film, and the retina, respectively. Notice that the image varies in distance and size from the lens in different applications.

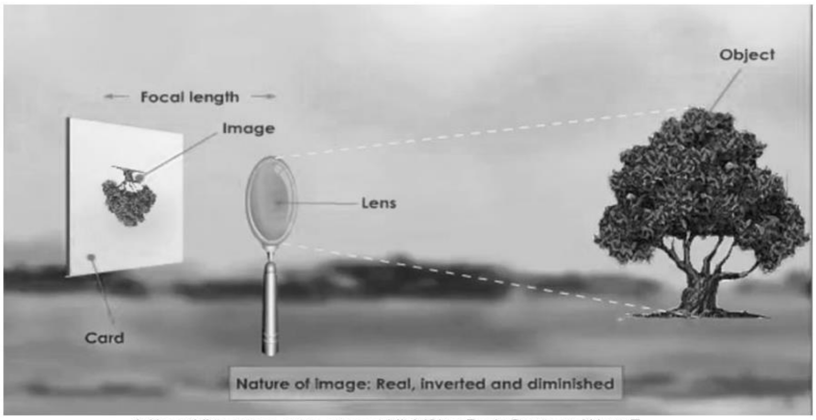

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Figure 7 . A convex lens used to project real image.

There are two methods for predicting the characteristics of images and the general behavior of lenses. Both assumes the lens is thin compared to its diameter. The first method is called ***ray tracing***, and the second method is the use of ***thin lens equations***.

Image Location by Ray Tracing

To locate the image of an object formed by a thin lens, we make use of three key points for the lens and associate each of them with a defining ray. The three points are the left focal point *F*, the right focal point *F'*, and the lens vertex (center) *V*. In Figure 8, the three rays are shown locating an image point *P'* corresponding to a given object point *P*, for both a positive and a negative lens. The object is labeled *OP* and the corresponding image *IP'*. The defining rays are labeled to show clearly their connection to the points *F*, *F'*, and *V*. In practice, of course, only two of the three rays are needed to locate the desired image point. Note also that the location of image point *P'* is generally sufficient to sketch in the rest of the image *IP'*, to correspond with the given object *OP*.

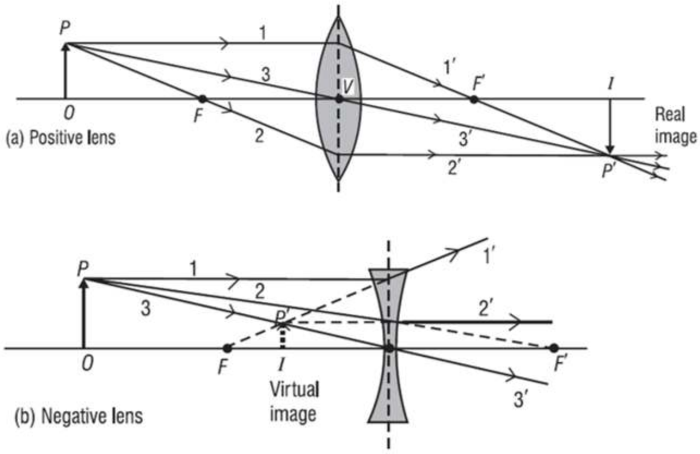


Figure 8. *Ray diagrams for image formation by positive and negative lenses*

The behavior of rays 1 and 2—connected with the left and right focal points for both the positive and negative lenses—should be apparent from another. The behavior of ray 3—going straight through the lens at its center *V*—is a consequence of assuming that the lens has zero thickness. Note, in fact, that all the bending is assumed to take place at the dashed vertical line that splits the drawn lenses in half.

In Figure 8(a), a ***real image*** is formed because the ray can be projected. If a sheet of paper is placed on the right side of the lens, a clear image will be formed on it when it is a distance from the center of the lens. If the image is held too close, the image is blurry because the rays have not yet converged. If the paper is held too far away, the image again becomes blurry because the rays have already crossed and now diverging. Note that the image is formed at the image distance (*I*). Not at the focal point.

The image produced by the concave lens in Figure 8(b) cannot be projected. If a sheet of paper is placed at the location of the image, it simply blocks the rays from reaching the lens and no image appears on the paper. If the sheet of paper is placed on the right of the lens, no image is formed since the rays of light coming from the common parts of the lens are diverging on the right of the lens. The image produced is therefore called ***virtual image***. A single concave lens always produces a virtual image. Although virtual images cannot be projected, they still can be seen with the eye. This is possible because of the convex lens system in the observer's eye converges the rays on the retina.

Equations for Thin Lens Calculations

The *thin lens equation* is given by Equation below.

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

where:
p is the object distance (from object to lens vertex *V*)
q is the image distance (from image to lens vertex *V*) and
f is the focal length (from either focal point *F* or *F'* to the lens vertex *V*)

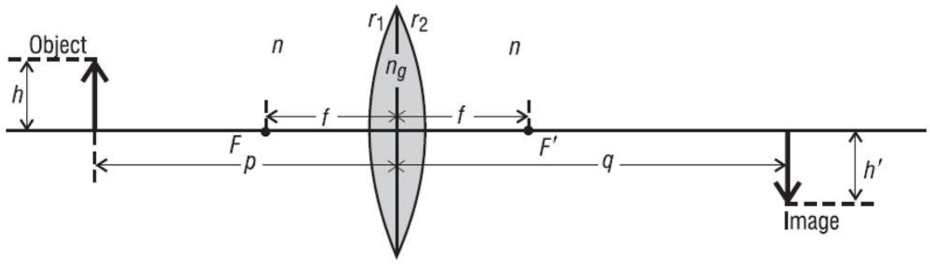


Figure 9. *Defining quantities for image formation with a thin lens*

The magnification *m* produced by a thin lens is given in Equation below.

$$\boxed{m = \frac{h_i}{h_o} = -\frac{q}{p}}$$

where:
m is the magnification (ratio of image size to object size)
h_i is the transverse height of the image.
ho is the transverse height of the object.
p and ***q*** are object and image distance respectively.

Sign Convention for Thin Lens Formulas

- Light travels initially from left to right toward the lens.
- Object distance *p* is *positive* for *real* objects located to the *left* of the lens and *negative* for *virtual* objects located to the *right* of the lens.
- Image distance *q* is *positive* for *real* images formed to the *right* of the lens and *negative* for *virtual* images formed to the *left* of the lens.
- The focal length *f* is *positive* for a *converging* lens, *negative* for a *diverging* lens.
- The radius of curvature *r* is *positive* for a *convex* surface, *negative* for a *concave* surface.
- Transverse distances (h_o and h_i) are *positive above* the optical axis, *negative below*.

Sample Problem 3:

An object 5.0 cm high is placed 24.0 cm away from a lens of focal length 8.0 cm. (a) Calculate the distance of the image. (b) Calculate the height of the image.

Given:

h = 5.0 cm

p = 24.0 cm

f = 8.0 cm

q = ________

Formula:

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

Solution:

$$\frac{1}{8.0\text{ cm}} - \frac{1}{24.0\text{ cm}} = \frac{1}{q}$$

$$\frac{24.0\text{ cm} - 8.0\text{ cm}}{(8.0\text{ cm})\ (24.0\text{ cm})} = \frac{1}{q}$$

$$12.0\text{ cm} = q$$

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

Formula:

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

Solution:

$$\frac{h'}{5.0\text{ cm}} = \frac{-12.0\text{ cm}}{24.0\text{ cm}}$$

$$h' = \frac{(5.0\text{ cm})\ (-12.0\text{cm})}{24.0\text{ cm}}$$

$$h' = -2.5\text{ cm}$$

The negative sign for *h'* means the image is inverted. In this case the image is smaller than the object.

Sample Problem 4:

What is the image distance and image size if a 3.0 cm tall light bulb is placed a distance of 30.5 cm from a diverging lens having a focal length of -10.2 cm?

Given:

h= 3.0 cm
p= 30.5 cm
f = - 10.2 cm
q= ________
h' = ________

Formula:

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

Solution:

$$\frac{1}{-10.2\text{ cm}} - \frac{1}{30.5\text{ cm}} = \frac{1}{q}$$

$$\frac{30.5\text{ cm}}{(-10.2\text{ cm})} + \frac{10.2\text{ cm}}{(30.5\text{ cm})} = \frac{1}{q}$$

$$q = -7.64\text{ cm}$$

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

Formula:

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

Solution:

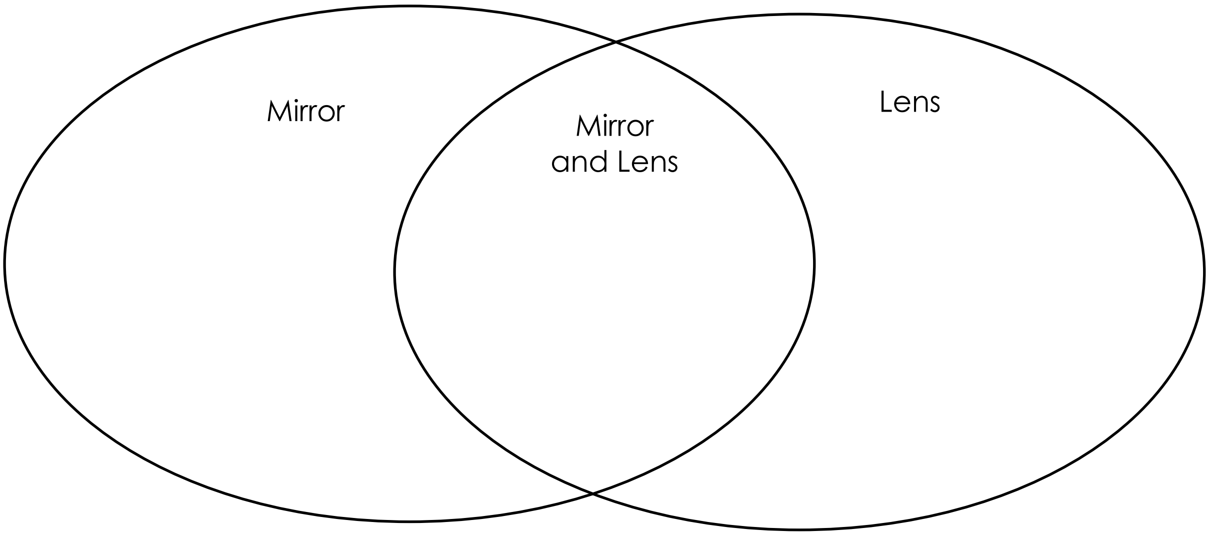
$$\frac{h'}{3.00\text{ cm}} = \frac{-7.64\text{ cm}}{30.5\text{ cm}}$$

$$h' = \frac{(3.00\text{ cm})(-7.64\text{ cm})}{30.5\text{ cm}}$$

$$h' = -0.75\text{ cm}$$

Performance Task:

Directions: Make a Venn diagram using the details here to compare and contrast a mirror and a lens. Do this in your notebook/Answer Sheet.

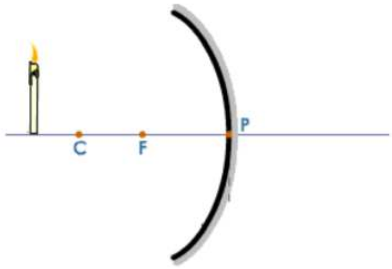


III. WHAT I HAVE LEARNED
EVALUATION/POST-TEST:

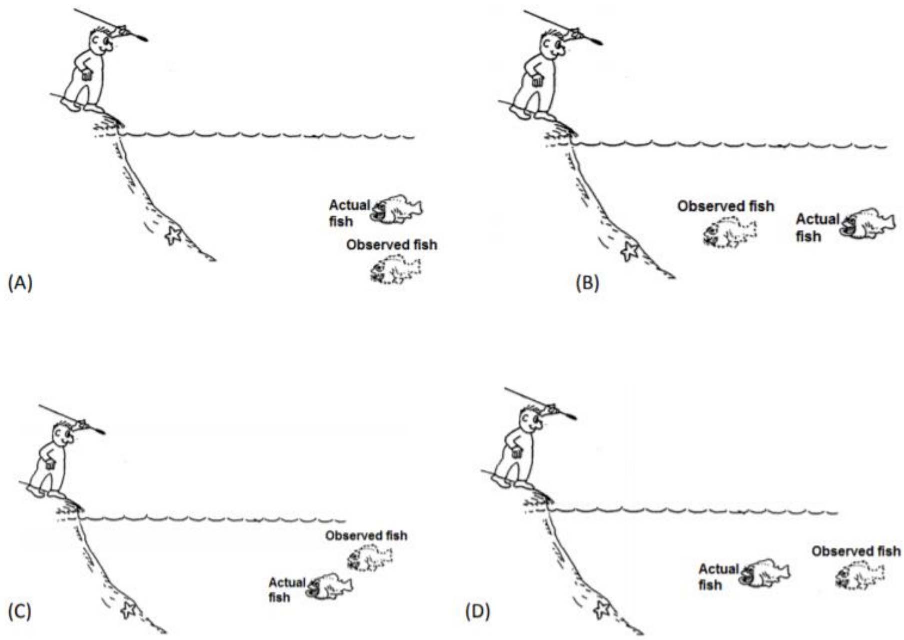
A. MULTIPLE CHOICE:

Directions: Choose the letter that corresponds to the correct answer. Write down your answer on your notebook/Activity Sheet.

1. A candle is placed in front of a concave mirror. The image produced by the mirror is:
   A. Real, inverted and magnified
   B. Real, inverted and demagnified
   C. Virtual, upright and magnified
   D. Virtual, upright and demagnified



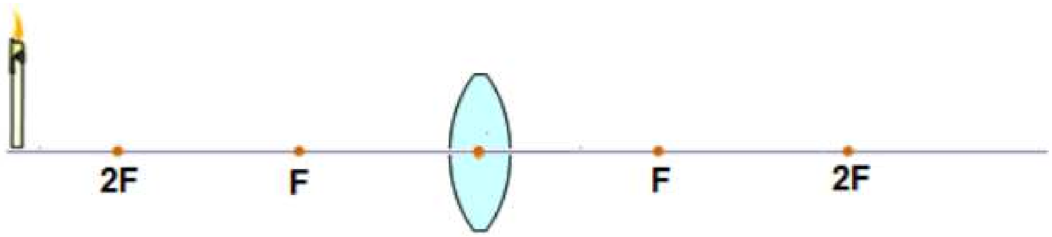
2. A boy is trying to catch a fish from a lake. Which of the following diagrams represents the image of the fish observed by the boy?



3. Which of the lens or lenses is the converging lens?
   A. I and V B. II, III and IV C. II and III D. III and IV

4. Which of the lens or lenses is the diverging lens? (Refer to the illustration in number 3)
   A. I and V B. II, III and IV C. II and III D. III and IV

5. An object is placed in front of a converging lens at a distance greater than 2F. The image produced by the lens is:
   A. Real, inverted and demagnified
   B. Real, inverted and magnified
   C. Virtual, upright and magnified
   D. Virtual, upright and demagnified



6. It relates the sines of the angles of incidence and refraction at an interference between two optical media to the indexes of refraction of the media.
   A. Law of reflection C. Law of refraction
   B. Snell's Law of refraction D. Law of lenses

7. It states that the angle of reflection equals the angle of incidence $\theta_r = \theta_i$.
   A. Law of reflection C. Law of refraction
   B. Snell's Law of refraction D. Law of lenses

8. The two transparent optical media that form an interface are distinguished from one another by a constant called the _____.
   A. index of reflection C. index of refraction
   B. Snell's Law of refraction D. index of incident rays

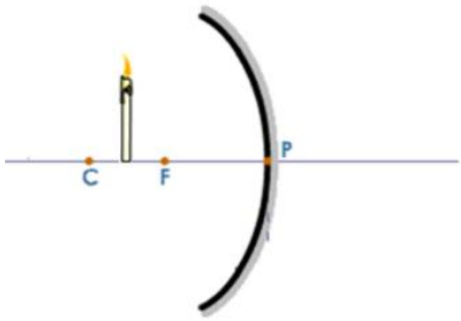
9. The ______________________________ means that the angle θ between such rays and some reference axis of the optical system always remains small, i.e., ≪ 1 rad.
   A. paraxial approximation C. index approximation
   B. spatial approximation D. reflective approximation

10. The simplest compound microscope is constructed from ____.
    A. two convex lenses C. two convex mirrors
    B. two concave lenses D. two concave mirrors

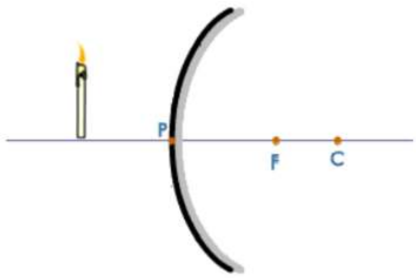
B. PROBLEM SOLVING

Directions: Graph and solve the following. Use a graphing paper in ray diagraming.

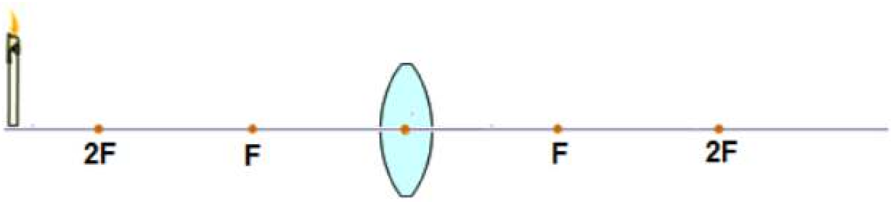
1. A candle is placed at a distance of 15 cm from of a concave mirror with a focal length of 10 cm. The candle is 4 cm tall.
   a. On the diagram below, use ray tracing to show the image produced by the mirror.



   b. Find the image distance. Is the image real or virtual?
   c. Find the size of the image. Is the image upright or inverted?



2. An object is placed at a distance of 60 cm from a converging lens with a focal length of 20 cm.
   a. On the diagram below, use ray tracing to show the image formed by the lens.



   b. Calculate the image distance. Is the image virtual or real?
   c. If the object is 10 cm tall, what is the size of the image?

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SYNOPSIS AND ABOUT THE AUTHOR

A mirror forms an image from the light rays that reflect on its surface. Planar mirrors retain the properties of the object in the image, whereas spherical mirrors (concave and convex mirrors) form varied images of the object with respect to the object's dimensions.

A lens forms an image from the light rays that if refracts. Lenses can be classified based on how they refract light rays. Converging lenses "collect" refracted rays to a single point. Diverging lenses, on the other hand, scatter these rays.

Real images for both mirrors and lenses can be projected on a screen. Virtual images, on the other hand, cannot be projected.

ANSWER KEY

1.Diffused Reflection 11.converging
2.Refraction 12.diverging
3.Incident ray 13.positive
4.Light ray 14.negative
5.Index of refraction 15.normal line
6.Snell's law
7.Geometric Optics
8.paraxial approximation
9.real image
10.virtual image

POST TEST

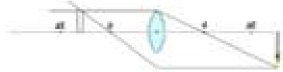
I.MULTIPLE CHOICE

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

II. PROBLEM SOLVING

1. a.(see figure below)
b. di = 30 cm; it is real
c. hi = 8 cm; it is inverted
d. (see figure below)

2. a. (see figure below)
b. di = 30 cm; it is real
c. hi = 5 cm; it is inverted



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