Module 4
Optical Instruments

What this module is about

In the previous modules, you learned about the properties of light. You also learned how images are formed by mirrors and lenses. Now it is time to apply these ideas to some common optical lenses and to show how such devices work.

In this module you will study different optical instruments in the following lessons:

- **Lesson 1 – The Human Eye and the Camera**
- **Lesson 2 – Microscopes and Telescopes**
- **Lesson 3 – Laser and Holography**

What you are expected to learn

After going through the module you are expected to:

1. identify the parts of a human eye;
2. discuss the different eye defects and how lenses correct these defects;
3. compare the similarities and differences between the principle of the camera and the human eye;
4. show using ray diagrams how images are formed in a telescope and a microscope; and
5. explain the principle of a hologram.

How to learn from this module

Here is a simple guide for you in going through the module:

1. Read and follow the instructions carefully
2. Answer the pretest before you start the lessons.
3. Check your answers against the key to answers provided at the last page of the

module.

4. After taking the pretest, read and study carefully the different lessons on optical instruments.
5. Perform all the activities to have a better understanding of the topic.
6. Take the self-tests at the end of each lesson for you to determine how much you learn and remember about the lesson.
7. Take the posttest prepared at the end of the module for you to assess how much you learned from this module.

Have fun in learning these lessons about optical instruments! Good luck!

What to do before (Pretest)

A. Multiple Choice: Write the letter of the best answer.

1. Which part of the human eye refracts rays and forms the image of an object?
   a. cornea
   b. iris
   c. lens
   d. retina

2. A camera forms an image in a sensitive film while an eye forms the image on the
   c. cornea
   d. iris
   c. pupil
   d. retina

3. Which statement about the parts of the eye and their uses is **FALSE**?
   a. The eyelid opens or shuts the eye.
   b. The iris enables the eye to see nearby objects.
   c. The pupil controls the intensity of the incoming light.
   d. The retina serves as the screen where the image is formed.

4. A farsighted person needs a convex lens as this lens can make the image fall
   a. on the eyeball
   b. before the retina of the eye
   c. on the retina of the eye
   d. beyond the retina of the eye

5. What can a camera do which a human eye cannot do?
   a. It can form images of object.
   b. It can adjust to dim and bright lights.
   c. It can change focus from short to long distances.
   d. It can give a permanent record of the scene on which it is focused.

6. Which of the following optical instruments does NOT form a real, inverted and smaller image?
   a. camera
   b. human eye
   c. pinhole camera
   d. simple microscope

7. An optical device used to see very far or distant objects clearly is the
   a. camera
   b. compound microscope
   c. simple microscope
   d. telescope

8. A compound microscope is an optical system. Which statement does **NOT** describe it?
   a. It makes small objects look bigger.
   b. It is used to magnify distant objects clearly.
   c. It consists of two converging lens - an objective lens and an eyepiece.
   d. It has an eyepiece that enlarges the image created by the objective lens.

9. A simple microscope produces
   a. an enlarged and real image
   b. an enlarged and virtual image
   c. an erect and real image
   d. an erect and smaller image

10. Which describes a hologram?
   a. It is a recording of an image.
   b. An ordinary light is needed to make a hologram.
   c. It forms a true three-dimensional image of the object.
   d. It is a photographic record of only one view of the object.

B. Identify the terms or phrases referred to in the following.

_____ 1. The part of the eye where the image of an object is formed
_____ 2. The part of the camera which corresponds to the iris of the eye
_____ 3. The kind of lenses used to correct nearsightedness
_____ 4. The ability of the eye to adjust the shape of its lens in order to focus on objects at different distances
_____ 5. An eye defect which focuses the image beyond the retina
_____ 6. A lens prescribed to correct presbyopia
_____ 7. An optical device that forms magnified virtual and erect image
_____ 8. An optical device to magnify very distant objects
_____ 9. An optical system consisting of two converging lenes that magnifies a magnified object
_____ 10. A technique to reproduce image through interference effect

Key to answers on page 19

Lesson 1 The Human Eye

The eye is the most remarkable optical instrument. What are the parts of the human eye?

The eye is spherical in shape and is about 2.5 cm in diameter. The essential parts of the human eye, considered as an optical system, are shown on Figure 1.1.

1. The white coat or **sclera** is the hard, tough outer coat of the eyeball which maintains the shape of the eyeball and protects the eyes. The transparent **cornea** in front of the sclera admits light into the eyeball. The region behind the cornea is a liquid called **aqueous humor**.

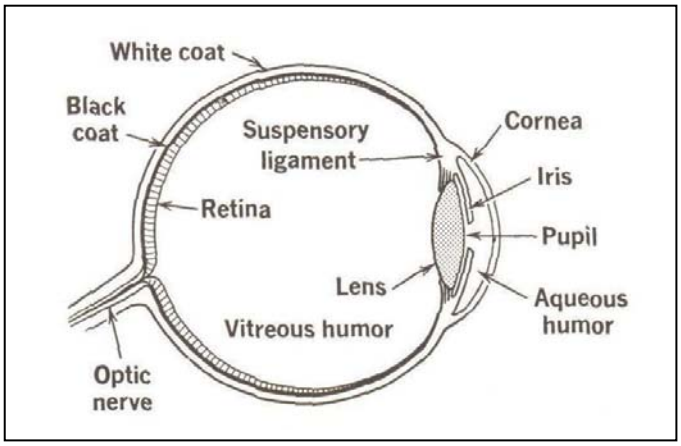

Fig. 1.1 The structure of the eye

2. The middle coat or **choroids layer** contains a black pigment, whose function is to absorb stray rays of light and prevent the blurring of images.

3. The inner coat, or **retina** covers only the rear portion of the eyeball. The nerves of the eyes spread through the retina, forming a light sensitive screen to receive images. Structures in the retina, known as rods, enables us to see in the dark.

4. The **crystalline lens** is a double convex lens that forms a real, inverted and smaller object on the retina. (Figure 1.2)

5. In front of the lens is the **iris**, which serves as a diaphragm to regulate the amount of light entering the inner eye.

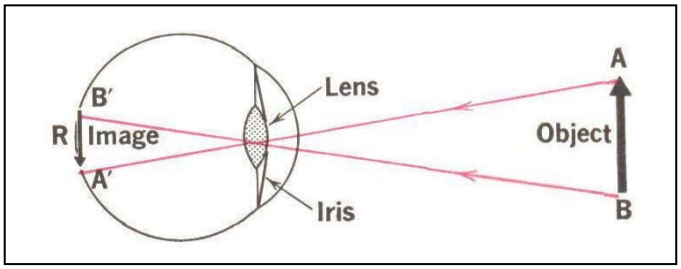

Fig. 1.2 Image formed in a human eye

6. The **pupil** is the opening in the center of the iris. In a dark room the pupil becomes larger to admit more light, in bright sunlight it becomes smaller reducing the amount of light admitted thus protecting the retina from damage by exposure to intense light.

7. Behind the lens, the eye is filled with a thin watery jelly called **vitreous humor**.

8. The **eyelids** act as shutters to screen out the light and, in general, to protect the eye.

What you will do

Activity 1.1 Identify Parts of an Eye

Look at the eye of another person. Identify the parts of the eye that you can see.

Key to answers on page 19

How does the eye focus?

For an object to be seen clearly or sharply, the image must be formed exactly on the retina. To see objects at different distances, the eye adjusts itself by changing the shape of its lens. If the object is near, the image distance increases and the lens become rounder and thicker. Its focal length is shortened so that the image distance is kept constant and the image is kept on the retina.

If the object is far, the image distance decreases such that the muscles attached to the outer edges of the eye lens cause the lens to become thinner and flatter. This increases its focal length and enables the image to be focused sharply on the retina.

This ability of the eye to focus the image of an object at different distances is called the **power of accommodation**.

When the eye muscles are perfectly relaxed as when a person is looking at a distant object, the lens has its greatest focal length and is said to be adapted to the far point. When the object is so near that the lens has its shortest possible focal length, the object is said to be at the near point.

For a normal eye, the shortest distance for distinct vision is 25 centimeters. The lens muscles are completely relaxed when we look at objects more than 6 meters away.

Common Eye Defects

When the eye loses its ability to change the shape of its lens, vision becomes poor and defective. Properly chosen eye glasses are needed to correct these eye defects.

1. Nearsightedness or myopia

A nearsighted person or myope can see near objects clearly but has difficulty focusing on far objects. This occurs when you have a long eyeball and lenses that are too convex, causing the image to be formed in front of the retina. Eyeglasses with concave lenses are prescribed to correct nearsightedness.

Study figure 1.3 which shows image formation in a nearsighted individual and how it is corrected by a concave lens.

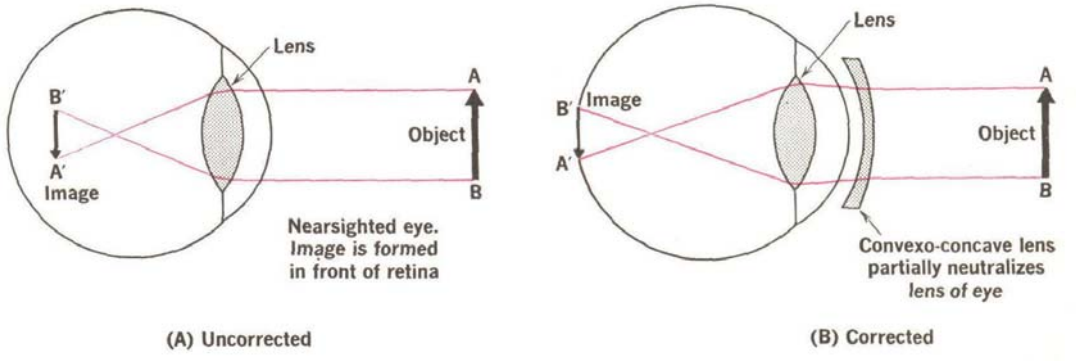

Fig 1.3 A concave lens may be used to correct nearsightedness.

2. Farsightedness or hyperopia

A farsighted person or hyperope can see very far objects clearly but has difficulty focusing on near objects. This is due to having a short eyeball and too flat lenses that cause the image to be formed beyond the retina. Eyeglasses with convex lenses are prescribed to correct farsightedness.

Study figure 1.4 which shows the image formation in a farsighted individual and how it is corrected by a convex lens.

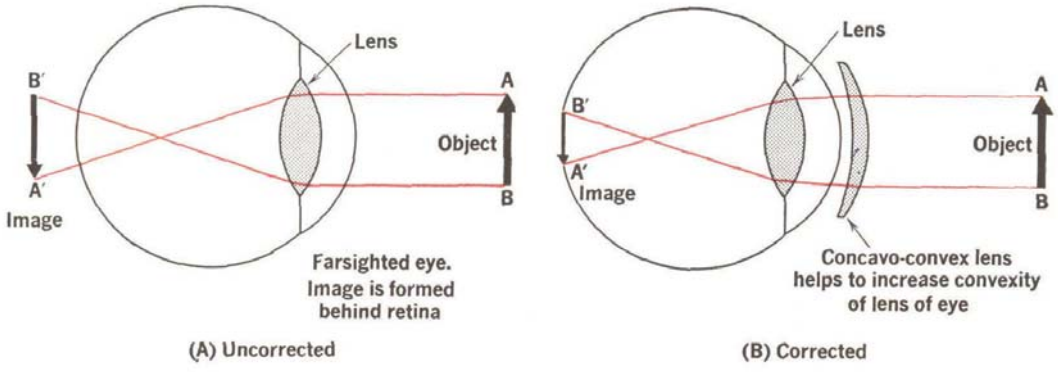

Fig. 1.4 A convex lens may be used to correct farsightedness.

3. Presbyopia

For an older person, the power of accommodation is reduced due to the decrease in the elasticity of the lens and the lessened ability of the eye muscle to increase the roundness of the lens. This inability is called **presbyopia**. To remedy this, bifocal lenses are usually prescribed.

4. Astigmatism

The unevenness in the curvature of the lens of the eyeball causes astigmatism which results in blurred vision and headaches. An astigmatic person will see horizontal and vertical lines not equally distinct and clear. This is usually corrected with cylindrical lenses.

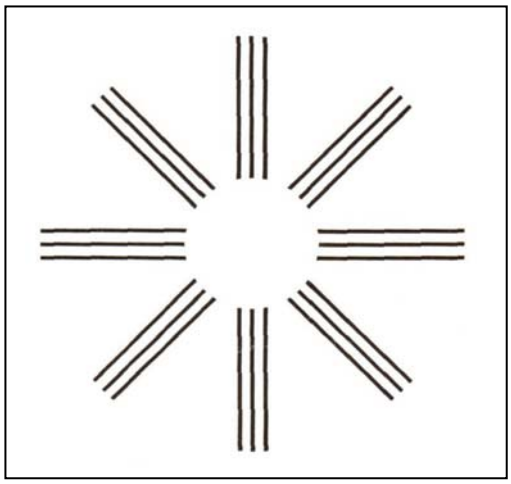

Fig 1.5
The lines are not all equally distinct if the eye is astigmatic.

The Camera and the Eye

Your eyes enable you to see the color and beauty of things around you. Sometimes you do not like to leave and forget such sights. To have an exact and permanent record of them, you use a camera.

A good way to find out how a camera works is to make a simple one.

What you will do

Activity 1.2 A Pinhole Camera

Materials: empty powdered milk can (11 cm long and 10 cm in diameter)
small nail and hammer
black cartolina (about 35 cm x 30 cm)
tape or paste
wax paper, about 14 cm^2

Procedure:

1. Get a milk can and remove its cover. Make a tiny hole in the center of its bottom using a small nail and hammer. (Figure 1.6a)

2. Make a tiny tube out of the black cartolina. The tube must fit into the can. Cover one end of the tube with wax paper. (Figure 1.6b)

3. Slide the covered end of the black tube into the can. You now have a pinhole camera. (Figure 1.7)

4. Point the pinhole to a distant object such as a building or tree. View this object through the open end of the black tube. Move the tube to get a clearer view of the object on the wax paper. The wax paper serves as the screen for the camera.

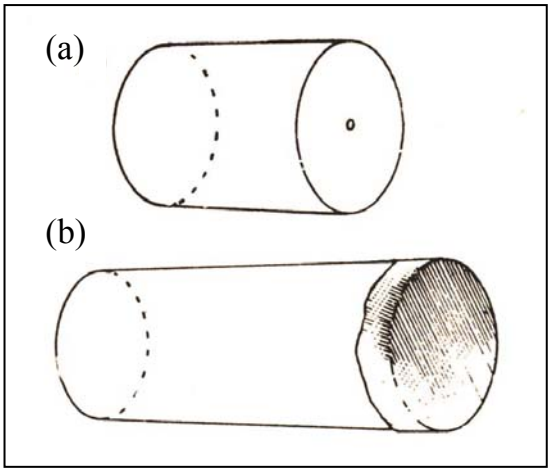

Fig. 1.6

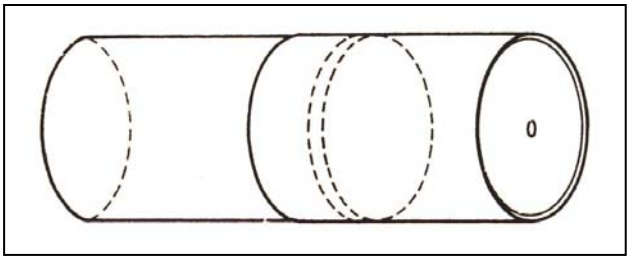

Fig. 1.7

Answer these:

1. What is formed on the wax paper? _____

2. Compare what you see on the wax paper with the object to which the camera is pointed. (Figures 1.8) _____
_____

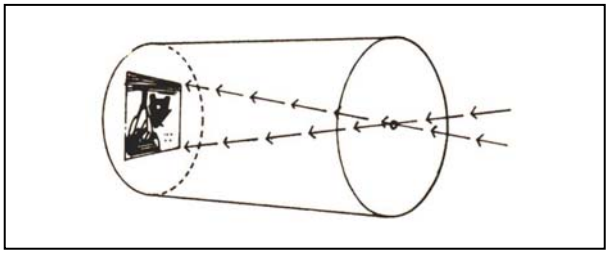

Fig. 1.8 A pinhole camera

Key to answers on page 19

The real camera has a lens instead of a pinhole and uses a film for a screen instead of a wax paper.

The basic elements of a camera are, namely: a converging lens, a light sensitive film to record an image, and a shutter to let the light from the lens strike the film. The lens forms an inverted, real and smaller image in the film.

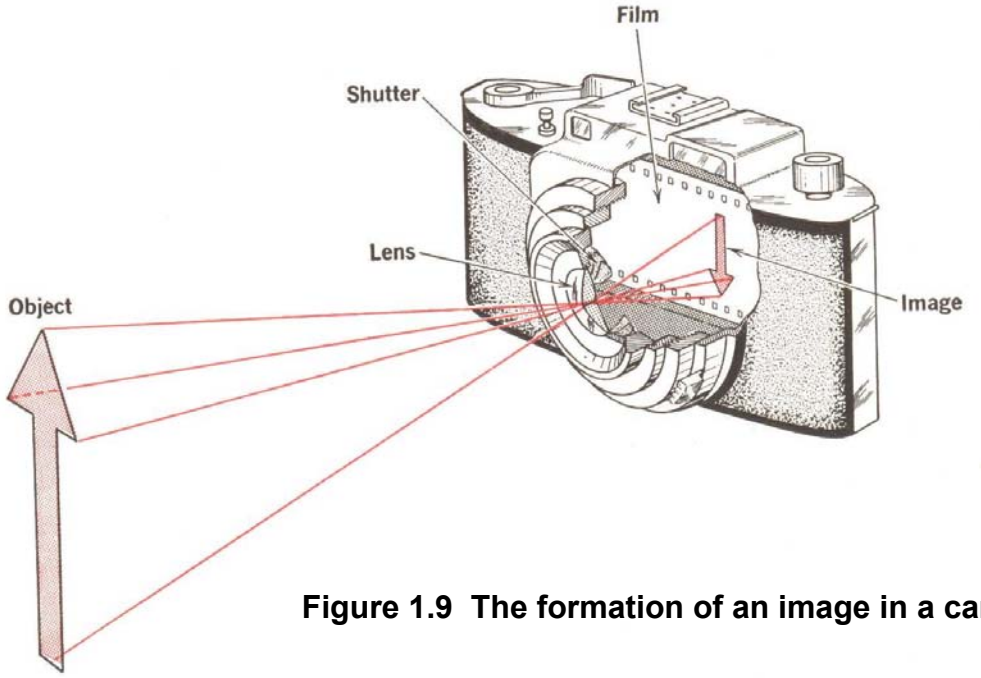

Figure 1.9 The formation of an image in a camera.

When the camera is in proper focus, the position of the film coincides with the position of the real image formed by the lens. With a converging lens, the image distance increases as the object distance decreases. Hence in focusing the camera, the lens is moved closer to the film for a distant object and farther from the film for a nearby object. Often, this is done by turning the lens in a threaded mount.

Know This:

A camera is similar to a human eye in several aspects. The shutter of a camera excludes unnecessary light just as the eyelids do. The diaphragm regulates the amount of light that enters the camera through the aperture just as the iris regulates the amount of light that enters the eye through the pupil. In the dark, the pupil dilates, while it constricts in bright light. A camera has a simple converging lens or a system of lenses which forms images by refraction just like the lens of a human eye. The light sensitive film inside a camera corresponds to the light sensitive retina in the back of the eye, and both receive an inverted, real image that is smaller than the object.

In a camera, the lens is adjusted to form a sharp image, while our eyes have the power of accommodation to see near and distant objects. The camera gives a permanent image of the object, while the image in the eye lasts for only about 1/16 of a second before another distinct image is formed.

Source: Science in Today's World Series: Physics, 2005, pp. 231-232.

What you will do

Self-Test 1.1

A. Fill up the blanks in Table 1.1 which gives the similarities between a camera and a human eye in terms of their parts and functions.

Table 1.1 Similarities between a Camera and a Human Eye

Parts		Functions
Camera	**Human Eye**	
a. shutter	(1)	Protects, opens and closes the eyeballs to exclude unnecessary light
b. diaphragm	(2)	(3)
c. (4)	pupil	Opens and closes to control the intensity of the entering light
d. (5)	lens	(6)
e. film	(7)	Serves as screen where the image is formed

B. Answer this: Give two differences between a camera and a human eye.

1. _____

2. _____

Key to answers on page 20

Lesson 2 Microscope and Telescopes

Most optical instruments are made up of a lens or an arrangement or combination of lenses. The function of the optical systems is determined by the focal lengths of the lenses and their relative positions.

What you will do

Activity 2.1

Open your book. Get a magnifying glass. Hold it close to a page on a book. Vary the distance of the lens until you see a clear magnified image of the printed words.

Magnifying Glass: A Simple Microscope

The simple use of a converging lens is a magnifying glass. When we use a magnifying glass, we hold it very close to the object we wish to examine. This is because a converging lens produces an enlarged and erect image when the object is inside its focal point. If a screen is placed at the image distance, no image appears on it because no light is directed to the image position. The rays that reach our eye, however, behave virtually as if they came from the image position, so we call this a virtual image.

A diverging lens used alone produces a reduced virtual image. It makes no difference how far or how near the object is. When a diverging lens is used alone, the image is always virtual, erect and smaller than the object. A diverging lens is often used as a "finder on a camera". When you look at the object to be photographed through such a lens, you see a virtual image that approximates the same proportion as the photograph.

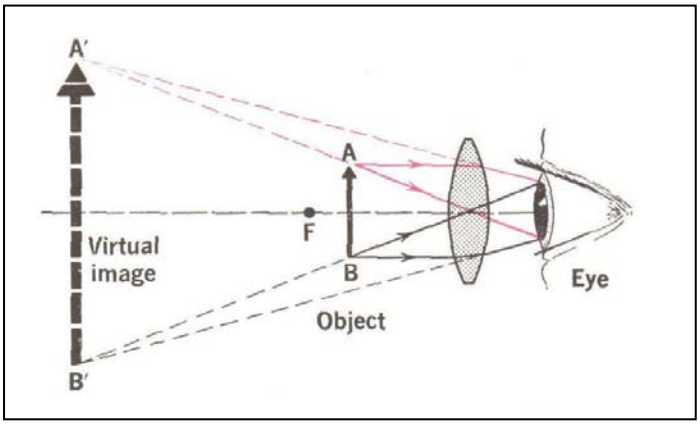

Fig. 2.1
Ray diagram of image formation in a simple magnifier

Compound Microscope

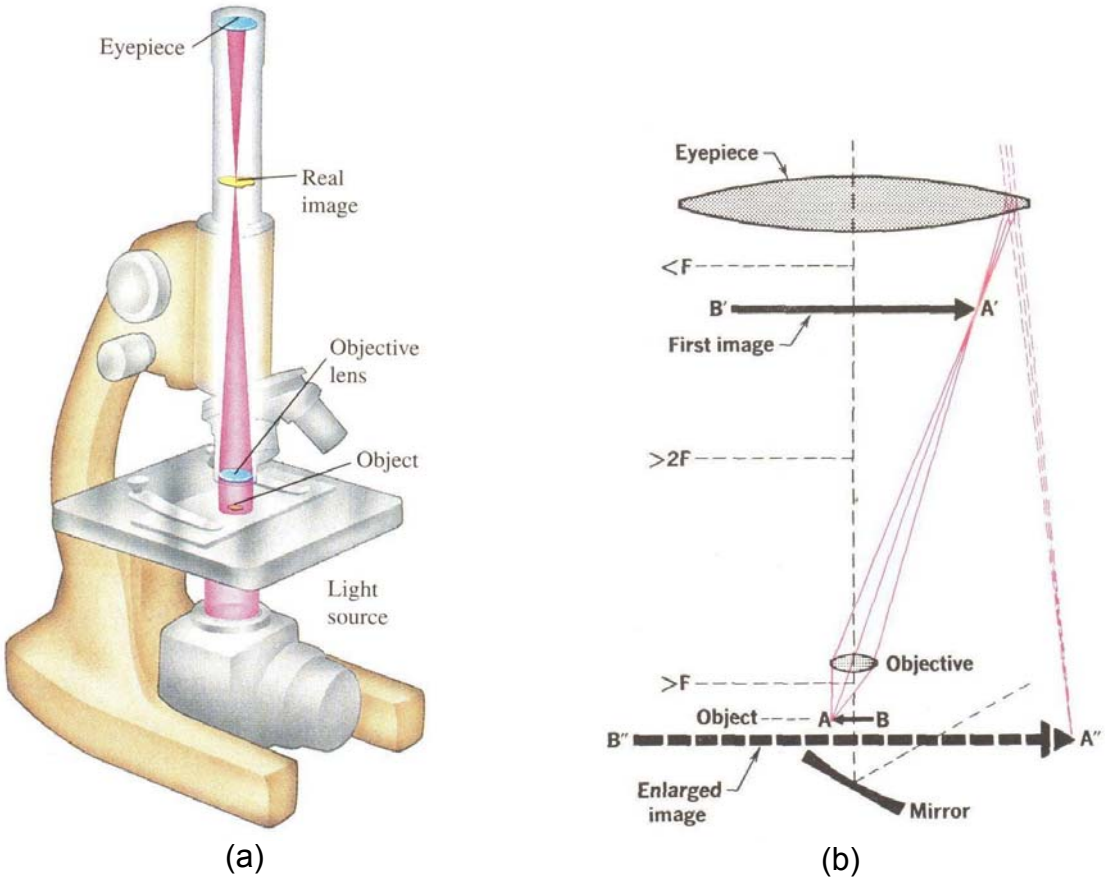

Fig. 2.2
(a) Elements of a compound microscope; (b) Ray diagram of image formation in a compound microscope

A compound microscope makes a small object look bigger so that our eye can see it. A compound microscope consists of two converging lenses of short focal lengths: the objective lens and the eyepiece lens. The object is placed close to the focal point of the objective lens to form the first image, which is an enlarged, real and inverted image. This image falls between the eyepiece lens and its focus and becomes the object for the eyepiece lens. The eyepiece forms a final virtual and enlarged image at a distance of 25 cm for distinct vision. This final image in the microscope becomes the object for the eye which forms a real image on the eye's retina.

Telescope

A telescope is used to make distant objects look closer and appear bigger. It consists of two converging lenses: the objective lens with a long focal length and the eyepiece lens with a short focal length. The objective lens is used to collect light from a distant object and to form the first image. The eyepiece lens is a magnifying lens which produces a final virtual image at a distance.

The optical system of a telescope is similar to that of a compound microscope. In both instruments, the image formed by an objective lens is viewed through an eyepiece. The key difference is that the telescope is used to view large objects at large distances and the microscope is used to view small objects at a very close distance.

An astronomical telescope is a telescope that uses lens as an objective. It is called a **refracting telescope**. In the reflecting telescope the objective lens is replaced by a concave mirror.

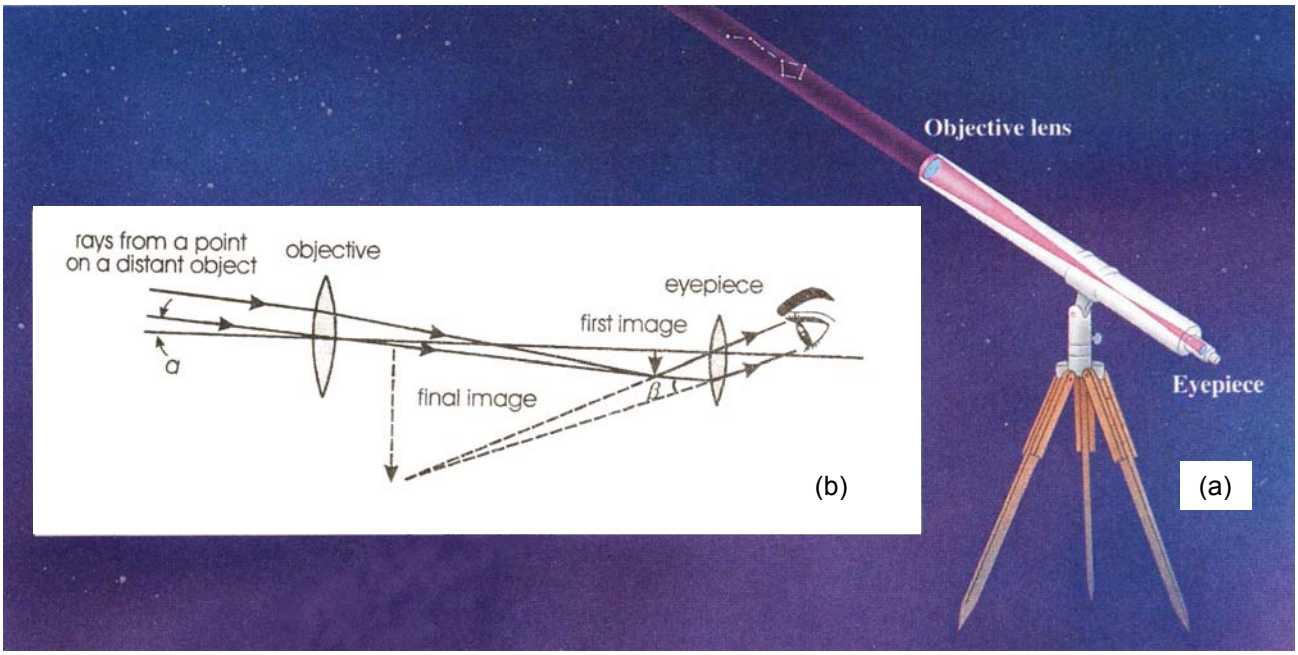

Fig. 2.3
(a) A telescope; (b) Ray diagram of image formation in an astronomical refracting telescope

What is a Hubble Space Telescope?

The Hubble Space Telescope (HST) is not only a telescope with scientific instruments. It is also a spacecraft and has power to move in orbit. A HST enables astronomers to look out at a distant star or nebula with amazing clarity. With such telescope you could peer billions of light years away and see things that happened billions of years ago.

The space telescope was named after American astronomer Edwin Hubble, whose observation of variable stars in distant galaxies confirmed that the universe was expanding and gave support to the "Big Bang Theory".

Fig. 2.4 Hubble Space Telescope
http://science.howstuffworks.com/hubble.htm

What you will do

Self-Test 2.1

Identify the terms or phrase referred to in the following:

_____ 1. It consists of a converging lens that forms virtual, magnified and erect image.
_____ 2. It is a lens system which makes distant objects appear bigger and closer.
_____ 3. It is a lens system which makes a small object look bigger.
_____ 4. It is a lens in a telescope used to collect light from a distant object to form the first image.
_____ 5. It is the lens in a telescope which serves as a magnifying lens producing a virtual image.

Key to answers on page 20

Lesson 3 Holography

What is a hologram?

Holography is a technique for recording and reproducing an image of an object through the use of interference effects. Unlike the two-dimensional images recorded by an ordinary photograph or television system, a holographic image or hologram is truly three-dimensional.

Do you know?

The hologram was invented and named by Dennis Gabor in 1947. Holo in Greek means “whole” and gram in Greek means “message” or “information”. A hologram contains the whole message or entire picture.

How does a holograph differ from a photograph?

In ordinary photography, a lens is used to form an image of an object in photographic film. Light reflected from each point on the object is directed by the lens on the film. In the case of holography, no image-forming lens is used. Instead, each point of the object being “photographed” reflects light to the entire photographic plate, so every part of the plate is exposed with light reflected from every part of the object. Most importantly, holograms are made with laser light which is a coherent light.

A conventional photograph is a recording of an image, but a hologram is a recording of the interference pattern.

How is hologram made?

The basic procedure for making a hologram is shown in Figure 3.1. The object to be holographed is illuminated by a laser light. LASER is the acronym for "light amplification by stimulated emission of radiation". Part of the light is reflected from the object to a photographic plate. The rest of the light, called the reference beam, is reflected by a mirror to the same plate. The two wavefronts interfere, and the interference pattern recorded on the plate constitutes the hologram.

An example of a hologram is the silver sticker on an original VCD used to identify if the VCD is pirated or not. Another hologram is the sticker at the back of the original battery of a cellular phone.

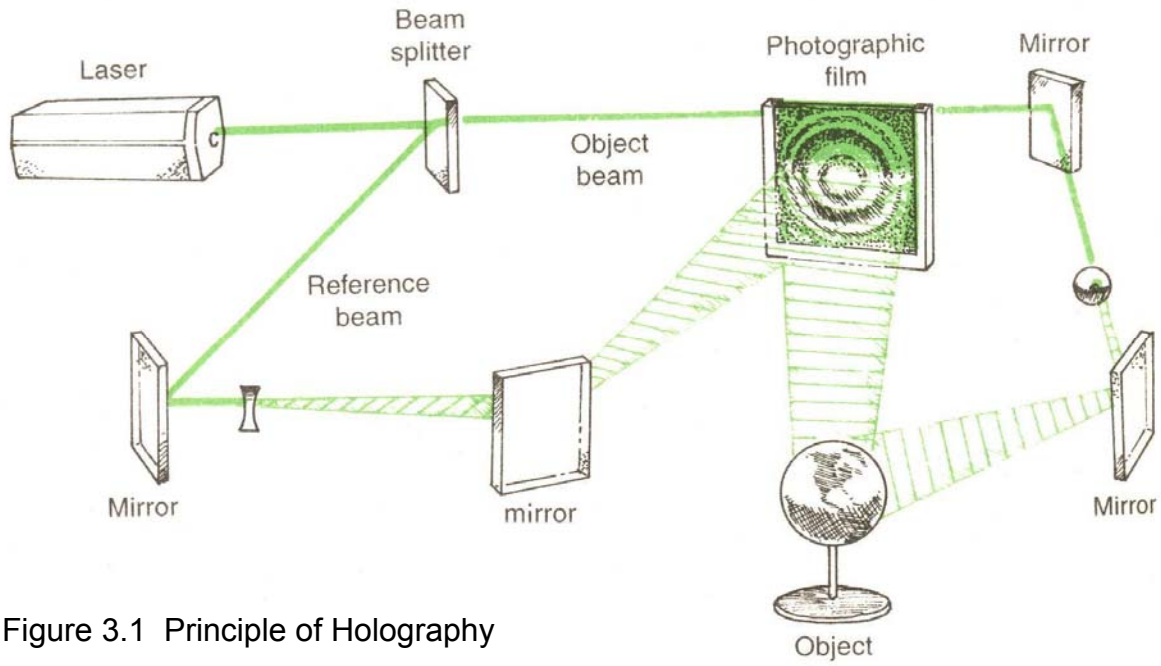

Figure 3.1 Principle of Holography

What are some uses of holograms?

Holograph systems are used with laser beams to scan the universal bar codes on grocery store items. Holograms have many other possible uses. They can store tremendous amount of data in a limited space, give details of structural flaws in a machine parts, display the interior of body organs, and bring three-dimensional television pictures into your home.

What you will do

Self-Test 3.1

A. Multiple Choice: Write the letter of the best answer.

1. It is a technology that uses laser light to produce a three-dimensional image of an object or scene.
   a. photography
   b. holography
   c. stenography
   d. x-ray

2. What kind of light is needed in hologram?
   a. ordinary light
   b. neon light
   c. coherent light
   d. incoherent light

3. Who invented the first hologram?
   a. Gottfried Leibnitz
   b. Thomas Edison
   c. Dennis Gabor
   d. Robert Brown

4. The following are applications of holography **EXCEPT** one:
   a. scanning of universal bar codes on grocery items
   b. storing tremendous amount of data in a limited space
   c. displaying the interior of body organ
   d. locating criminals

5. A hologram contains the whole message or entire picture.
   a. True
   b. False

B. Give the differences between a photograph and a hologram.

_____

_____

Key to answers on page 20

Let's Summarize

1. The most important parts of the eye are the:
   a. eyelid – opens and shuts the eye
   b. iris – regulates amount of light entering the eye
   c. pupil – opens and closes to control intensity of entering light
   d. lens – refracts light to form images

e. retina – serves as a screen where the image is formed

2. A nearsighted individual can see near objects clearly but has difficulty focusing on far objects. Nearsightedness is corrected with a concave lens.

3. A farsighted individual can see far objects clearly but has difficulty focusing near objects. Farsightedness is corrected with eyeglasses with convex lens.

4. Astigmatism is due to unevenness in the curvature of the lens of the eyeball which results to blurred vision. It is corrected with cylindrical lenses.

5. Presbyopia is the inability of the eye muscles to increase the roundness of the lens, thus reducing its power of accommodation. Bifocal lens is prescribed to remedy this defect.

6. A camera and a human eye both form real, inverted and smaller images of objects.

7. A camera can produce a permanent record of an image while eyes do not.

8. In a camera, the lens is adjusted to form a sharp image while the eyes has the power of accommodation to see near or far objects.

9. A simple microscope consists of a single lens which produces a magnified, virtual and erect image.

10. A compound microscope consists of two converging lenses. It is used to view small objects at a very close distance.

11. A telescope is used to view large objects at very far distances.
    a. A refracting telescope uses a lens as an objective.
    b. A reflecting telescope uses a concave mirror as an objective.

12. Holography is a technology that uses laser light to produce a three-dimensional image of an object or scene through interference effect.

Posttest

A. Multiple Choice: Write the letter of the best answer.

1. Which part of the human eye regulates the amount of light entering the eye?
    a. cornea
    b. iris
    c. lens
    d. retina

2. An eye forms the image on the retina while a camera forms image in the
    a. diaphragm
    b. lens
    c. sensitive film
    d. shutter

3. Which statement about the parts of the eye and their uses is true?
    a. The pupil opens or shuts the eye.
    b. The eyelid regulates the amount of light.
    c. The iris enables the eye to see near object.
    d. The retina serves as the screen where the image is formed.

4. The nearsighted person needs a concave lens. This lens can make the image fall
    a. on the eyeball
    b. on the retina of the eye
    c. before the retina of the eye
    d. beyond the retina of the eye

5. Which of the following can be done by a camera but not by the human eye?
    a. form images of objects
    b. adjust to dim and bright lights
    c. change focus from short to long distances
    d. give a permanent record of the scenes on which it is focused

6. Which of the following instruments form a magnified, virtual and erect image?
    a. camera
    b. human eye
    c. pinhole camera
    d. simple microscope

7. A compound microscope is an optical device. Which statement is TRUE about a compound microscope?
    a. It consists of a single lens.
    b. It is used to magnify distant object clearly.
    c. It has an eyepiece that produces a smaller image.
    d. It is used to view a very small object at very close distance.

8. A human eye forms an image which is
    a. smaller and erect
    b. bigger and virtual
    c. inverted and real
    d. inverted and virtual

9. A telescope is an optical device used to
    a. view distant object
    b. view near object
    c. diminish large object
    d. diminish small object

10. Which statement is NOT TRUE about hologram?
    a. It is a recording of an interference pattern.
    b. A laser light is needed to make a hologram.
    c. It forms a true three-dimensional image of the object.
    d. It is a photographic record of only one view of the object.

B. Identify the terms or phrases referred to in the following.

_____ 1. The part of the camera where the image object is formed
_____ 2. The part of the eye which corresponds to the diaphragm of the camera
_____ 3. The kind of lenses used to correct farsightedness
_____ 4. The ability of the eye to adjust the shape of its lens to focus on objects at different positions
_____ 5. An eye defect which focuses the image in front of the retina
_____ 6. A lens prescribed to correct astigmatism
_____ 7. An optical device that forms bigger, erect and virtual image
_____ 8. An optical device that views a small object at close distance
_____ 9. An optical device that views a large object at very far distance
_____ 10. Light used to create a hologram

Key to answers on page 21

Key to Answers

Pretest

A.
1. c
2. d
3. b
4. c
5. d
6. d
7. d
8. b
9. b
10. c

B.
1. retina
2. diaphragm
3. concave lens
4. power of accommodation
5. farsightedness or hyperopia
6. bifocal lens
7. magnifying glass or simple microscope
8. telescope
9. microscope
10. holography

Lesson 1

Activity 1.1

The eyelid, cornea, iris, pupil are the parts of the eye that could be seen.

Activity 1.2

1. The image of the object is formed on the wax paper
2. The image observed on the wax paper is smaller, inverted and real.

Self-Test 1.1

A.

1. eyelid
2. iris
3. regulates amount of light
4. aperture
5. lens
6. refracts light and forms the image
7. retina

B.

1. In a camera, the lens is adjusted to form a sharp image while the eyes is self-focusing. It has the power of accommodation to see near and distant objects.
2. A camera gives a permanent record of the image while the eye can retain an image only at about 1/16 of a second.

Lesson 2

Self-Test 2.1

1. magnifying glass or simple microscope
2. telescope
3. microscope
4. objective lens
5. eyepiece

Lesson 3

Self-Test 3.1

A.

1. b
2. c
3. c
4. d
5. True

B.

1. A hologram is a record of an interference pattern while a photograph is a record of an image.
2. A hologram is capable of reconstructing an exact replica of the wavefront of an object
3. More than one hologram can be recorded in the same area of a photographic plate.
4. In ordinary photography, a lens is used to form an image of an object in photographic film. In holography, no image-forming lens is used.
5. Holography makes use of laser light while in ordinary photography ordinary light is used to form images.

Posttest

A.		B.	
1. b	6. d	1. sensitive film	6. cylindrical lens
2. c	7. d	2. iris	7. simple microscope
3. d	8. c	3. convex	8. compound microscope
4. b	9. a	4. power of accommodation	9. telescope
5. d	10. c	5. nearsightedness	10. laser light

References

Dull, C. E., Metcalfe, H. E. & Williams, J. E. (1960). *Modern physics*. New York: Holt, Rinehart and Winston, Inc.

Hewitt, P. G. (1993). *Conceptual physics*. (7th ed.) New York: Harper Collins College Publishers.

Padua, A. L. & Crisostomo, R. M. (1999). *Science and technology IV: Physics*. Quezon City: S.D. Publications, Inc.

Santos, G. C. & Ocampo, J. P. (2003). *Science and technology IV: Physics*. Manila: Rex Bookstore, Inc.

Sotto, R. L. (2005). *Science in today's world: Physics*. Philippine Copyright: SIBS Publishing House, Inc., Makati, Philippines.

U.P. Science Education Center. (1984). *Physics in your environment: High school science IV*. Manila: Textbook Board, Ministry of Education and Culture.

Young, H. D. & Friedman, R. A. (1996). *University physics*. New York: Addison Wesley Publishing Co., Inc.