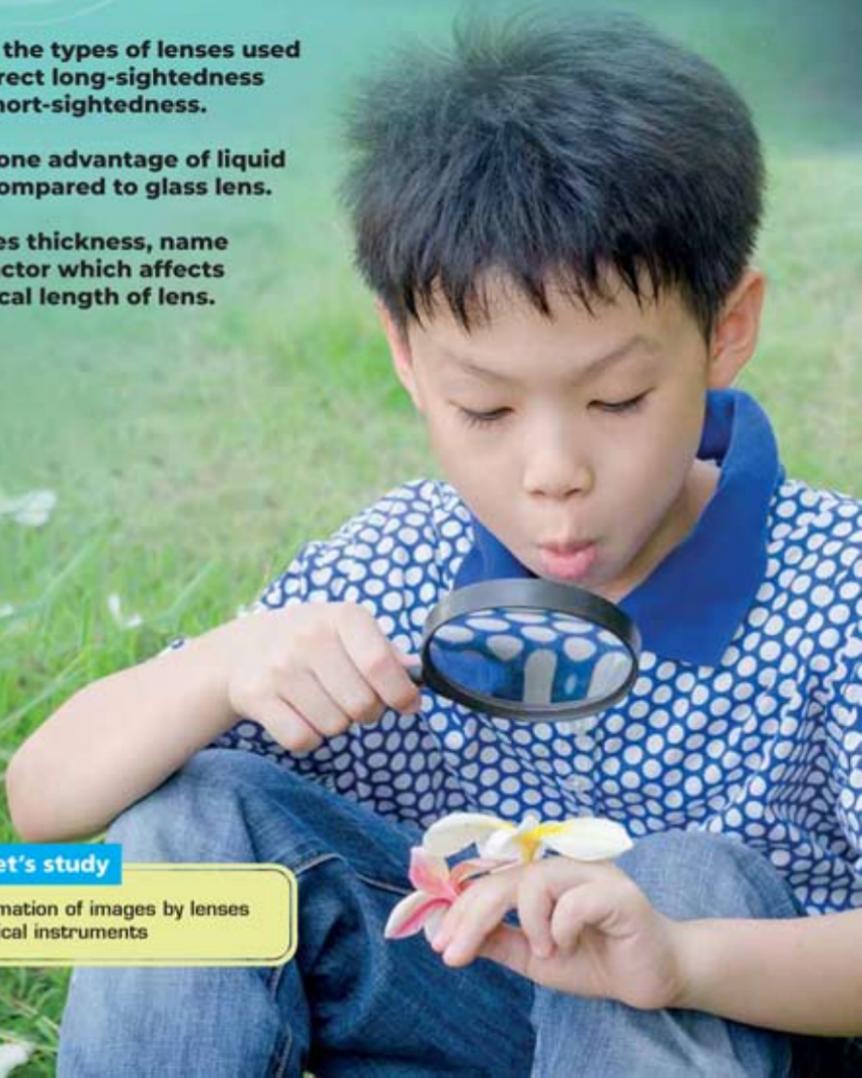


Name the types of lenses used to correct long-sightedness and short-sightedness.

State one advantage of liquid lens compared to glass lens.

Besides thickness, name one factor which affects the focal length of lens.



Let's study

- Formation of images by lenses
- Optical instruments



Nowadays, the use of lenses in optical instruments is expanding. For example, the telephone which was originally an audio communication device has been developed into a smartphone which can function as an audio-visual communication device using a camera to take photographs and videos.

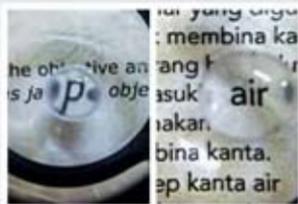


Handphone without camera



Smartphone with five cameras

Camera quality is normally related to the type or quality of lens attached to the camera. This is because the image in the camera is formed by the lens. Besides transparent glass and plastic, any transparent material including water can be used to make lenses. The concept of liquid lens is shown in the photograph below.



Concept of liquid lens

Keywords

- Convex lens
- Converging lens
- Concave lens
- Diverging lens
- Focal point
- Focal length
- Ray diagram
- Principal axis
- Optical centre
- Object distance
- Image distance
- Microscope
- Magnifying power
- Telescope
- Normal adjustment
- CCTV
- Lenses in optical instruments

7.1

Formation of Images by Lenses

Convex Lens and Concave Lens

A lens is a transparent medium such as glass which has one or two curved surfaces. Lenses are divided into two types, **convex lens** and **concave lens** as shown in Figure 7.1.

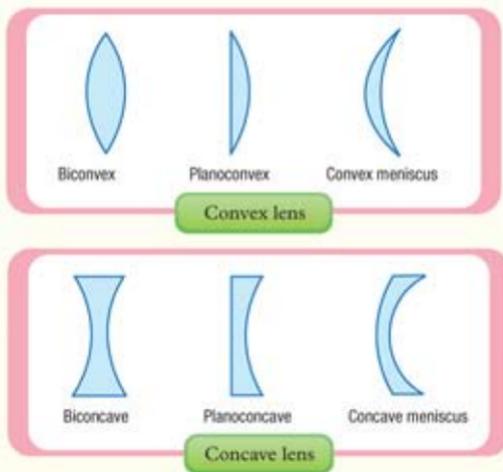


Figure 7.1 Convex lens and concave lens

Figure 7.2 shows the path of light rays before and after passing through a convex lens and a concave lens. What happens to the light rays after passing through these lenses?

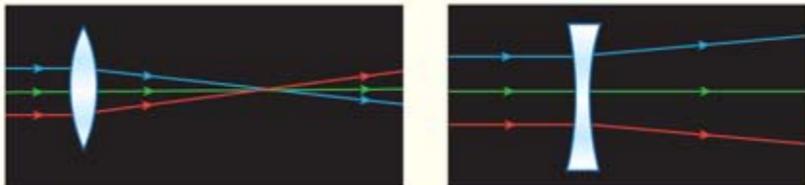


Figure 7.2 Refraction of light rays after passing through a convex lens and a concave lens

Based on Figure 7.2, light rays converge after passing through a convex lens while light rays diverge after passing through a concave lens. Therefore, a convex lens is known as a **converging lens** while a concave lens is known as a **diverging lens**.

For convex lenses, the **focal point**, F is a point where light rays parallel to the principal axis converge after passing through the convex lens (Figure 7.3(a)).

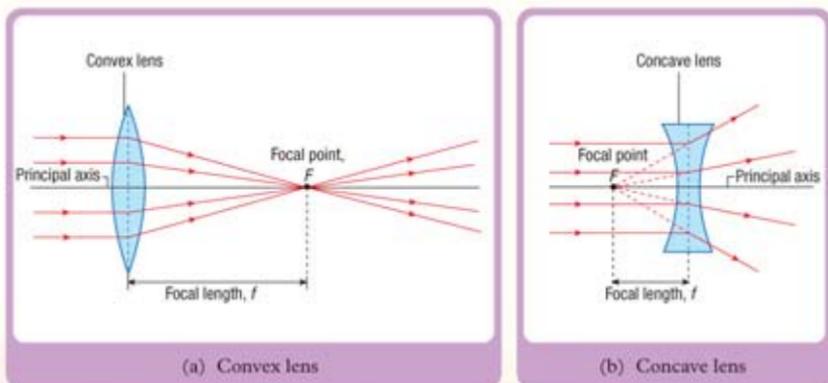


Figure 7.3 Focal point and focal length for convex lens and concave lens

When light rays which diverge after passing through a concave lens are extrapolated backwards, the light rays will intersect at a point. This point is the **focal point**, F for the concave lens (Figure 7.3(b)).

Let us carry out Activity 7.1 to study some properties of convex lenses and concave lenses using an Optical Ray Kit.

Activity 7.1

Use the Optical Ray Kit to:

- show the convex lens as a converging lens and the concave lens as a diverging lens
- determine the focal points of convex lenses and concave lenses

Materials

White paper (sized 86 cm \times 86 cm)

Apparatus

Optical Ray Kit containing ray box, cylindrical biconvex lens, cylindrical biconcave lens, triple slit plate, ruler and pencil

Note: This activity is best suited to be carried out in the dark.

21st Century Skills

- TPS
- Inquiry-based activity

Instructions

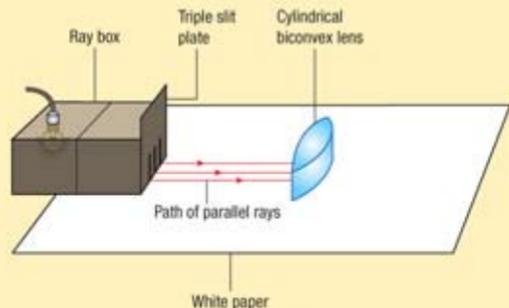
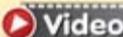


Figure 7.4

1. Prepare the apparatus set-up shown in Figure 7.4.
2. Trace the shape of the convex lens onto a piece of white paper using a pencil. Mark the centre point of the convex lens, that is the optical centre, O on the tracing of the convex lens.
3. Direct three parallel light rays from the ray box in the direction of the convex lens. Observe the path of light rays before and after passing through the convex lens.
4. Make two marks, one near to the lens and another far from the lens, on each path of the light rays before and after passing through the convex lens. Remove the convex lens from the white paper.
5. Draw a straight line using a pencil and ruler to connect the two marks on each path of the light rays before and after passing through the convex lens (Figure 7.3(a)).
6. Mark the point of intersection of the three light rays as the focal point, F for the convex lens.
7. Repeat steps 1 to 5 by replacing the convex lens with a concave lens.
8. Extrapolate the light rays which diverge after passing through the concave lens backwards until a point of intersection (Figure 7.3(b)).
9. Mark the point of intersection of the three light rays as the focal point, F for the concave lens.



Video

Eduweb TV:
Physics – lenses
<http://buku-teks.com/sc5204>
(Medium: bahasa Melayu)



Questions

1. Why is it more suitable for this activity to be carried out in the dark?
2. What happens to light rays after passing through the following lenses?
 - (a) Convex lens
 - (b) Concave lens
3. Describe the observations made in this activity that show the following properties of lenses:
 - (a) convex lens as a converging lens
 - (b) concave lens as a diverging lens

Determining the Focal Length of a Convex Lens

Before carrying out Activity 7.2, let us understand optical terms (Table 7.1).

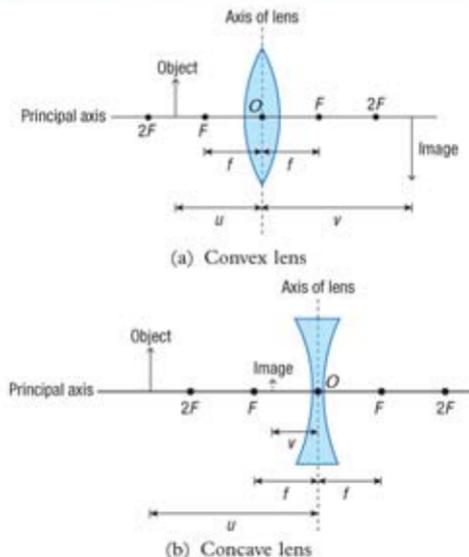


Figure 7.5 Convex lens and concave lens

Table 7.1 Optical terms and their explanations

Optical term	Explanation
Optical centre, O	Point at the centre of the lens. Light rays which pass through the optical centre do not refract.
Principal axis	A straight line which passes through the optical centre of a lens and the focal point, F .
Axis of lens	Straight line which passes through the optical centre and is perpendicular to the principal axis.
Focal point, F (refer to Figure 7.3)	<ul style="list-style-type: none"> For convex lens, the focal point, F is a point on the principal axis, where light rays parallel to the principal axis converge after passing through the lens. For concave lens, the focal point, F is a point on the principal axis, where light rays parallel to the principal axis appear to diverge from it after passing through the lens.
Focal length, f	The distance between the focal point, F and the optical centre.
Object distance, u	The distance between the object and the optical centre.
Image distance, v	The distance between the image and the optical centre.

Let us carry out Activity 7.2 to determine the focal length of a convex lens using a distant object by applying the concept that light rays from a distant object are parallel (Figure 7.6).

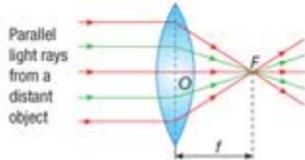


Figure 7.6

Activity 7.2

To determine the focal length of a convex lens using a distant object

Materials

Convex lens, lens holder, white screen and metre rule

Instructions

1. Prepare the apparatus set-up as shown in Figure 7.7.
2. Position the convex lens towards a distant object seen through an open window.
3. Adjust the position of the white screen until a sharp image of the distant object is formed on the screen.
4. Measure and record the distance between the centre of the convex lens and the screen, that is the focal length, f of the convex lens using a metre rule.

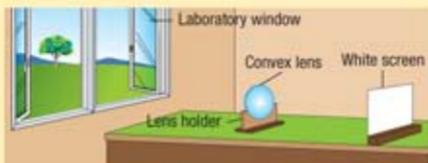


Figure 7.7

Questions

1. Why are laboratory objects not used to determine the focal length of a convex lens in this activity?
2. State the characteristics of the image formed on the white screen.
3. If the convex lens in this activity is replaced with a concave lens, can the focal length of the concave lens be estimated? Explain your answer.

21st Century Skills

- TPS
- Inquiry-based activity

Ray Diagrams to Determine the Characteristics of Images Formed by Convex Lenses and Concave Lenses

Besides carrying out activities using appropriate apparatus such as in Activity 7.2, the position and characteristics of images formed by convex lenses and concave lenses can be determined using ray diagrams.

Study and understand Table 7.2 which explains the method of drawing ray diagrams by drawing two principal light rays to determine the characteristics of the images formed by convex lenses and concave lenses.

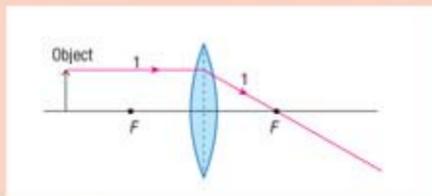
 **Video**

Steps to draw ray diagrams
<http://buku.teks.com/sc5206>
(Medium: bahasa Melayu)

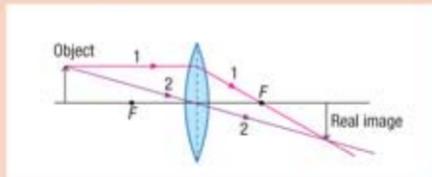


Table 7.2 Method for drawing ray diagrams**Convex lens**

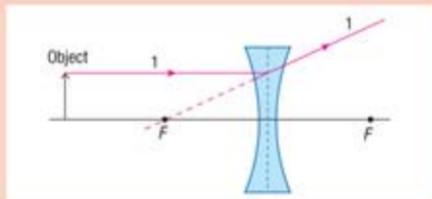
- 1 A light ray parallel to the principal axis refracts and passes through the focal point, F .



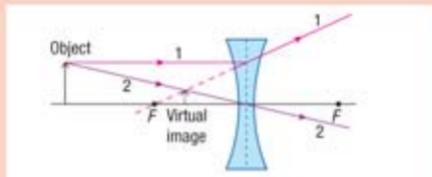
- 2 A light ray heading towards the optical centre continues in a straight line through the optical centre without refracting.

**Concave lens**

- 1 A light ray parallel to the principal axis refracts and appears to come from the focal point, F .



- 2 A light ray heading towards the optical centre continues in a straight line through the optical centre without refracting.



Tables 7.3 and 7.4 show the positions of object, ray diagrams, positions of image and characteristics of images for convex lens and concave lens, respectively.

Table 7.3 Ray diagrams to determine the characteristics of images formed by a convex lens

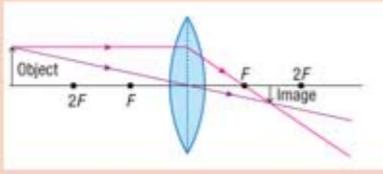
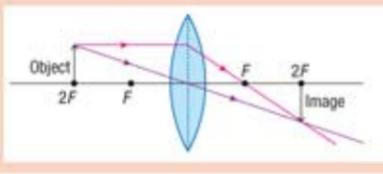
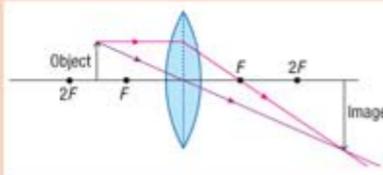
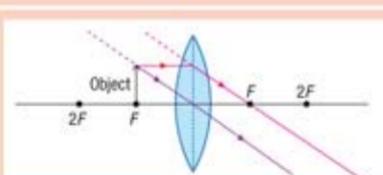
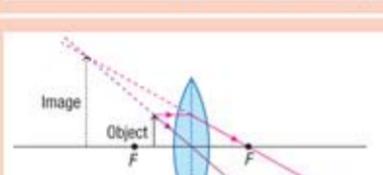
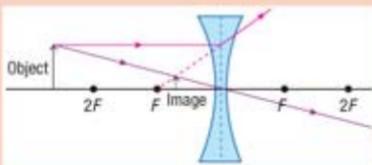
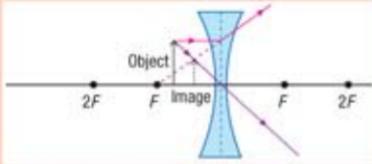
Position of object	Ray diagram	Position of image	Characteristics of image
Object is further than $2F$		Image is between F and $2F$	<ul style="list-style-type: none"> • Real • Inverted • Diminished
Object is at $2F$		Image is at $2F$	<ul style="list-style-type: none"> • Real • Inverted • Same size as object
Object is between F and $2F$		Image is further than $2F$	<ul style="list-style-type: none"> • Real • Inverted • Magnified
Object is at F		Image is at infinity	<ul style="list-style-type: none"> • Virtual • Upright • Magnified
Object is between F and optical centre (Used as a magnifying glass)		Image distance is further than F	<ul style="list-style-type: none"> • Virtual • Upright • Magnified

Table 7.4 Ray diagrams to determine the characteristics of images formed by a concave lens

Position of object	Ray diagram	Position of image	Characteristics of image
Object is further than $2F$		Between optical centre and focal point	<ul style="list-style-type: none"> • Virtual • Upright • Diminished
Object is between F and optical centre		Between optical centre and focal point	<ul style="list-style-type: none"> • Virtual • Upright • Diminished

Note: The characteristics of images formed by concave lenses for **any** object distance are:

- virtual
- upright
- diminished
- positioned between the object and the concave lens

BRAIN TEASER

Reinforcement practice
<http://buku-teks.com/sc5207>



Formative Practice 7.1

1. Name the type of lens found in the human eye.
2. Figure 1 shows two types of lenses.

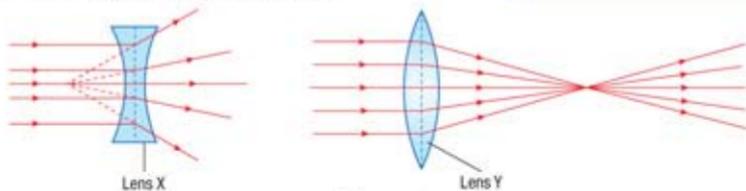


Figure 1

- (a) Name the following types of lenses:
 - (i) Lens X
 - (ii) Lens Y
 - (b) (i) Which lens functions as a diverging lens?
 (ii) Which lens functions as a converging lens?
 - (c) Mark the focal point of lenses X and Y with the letter F .
3. How is the convex lens used as a magnifying glass?

7.2 Optical Instruments

The function of optical instruments is normally related to the type of image, whether real or virtual, and the size of image formed by the lens. The ray diagrams in Tables 7.3 and 7.4 show that the image size formed by a lens depends on the position of the object from the centre of the lens.



Photograph 7.1 Optical instruments

Photograph 7.1 shows three optical instruments. Describe the characteristics of the final image formed by these three optical instruments.

Formation of the Final Image by a Microscope



Study the two ray diagrams in Figure 7.8.

(a) Object is between F and $2F$

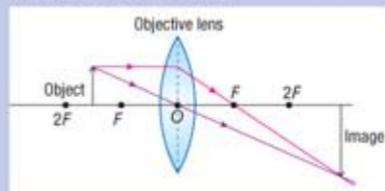


Image position: Image is further than $2F$
Image characteristics:

- Real
- Inverted
- Magnified

(b) Object is between F and the optical centre, O

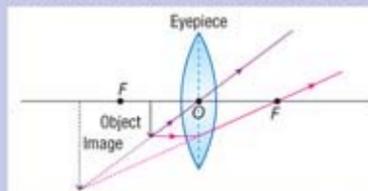


Image position: Image is further than F
Image characteristics:

- Virtual
- Upright
- Magnified

Figure 7.8 Ray diagrams for the images formed by the objective lens and eyepiece of a microscope

Based on your understanding of the two ray diagrams in Figure 7.8, the formation of the final image by a microscope is shown in Figure 7.9.

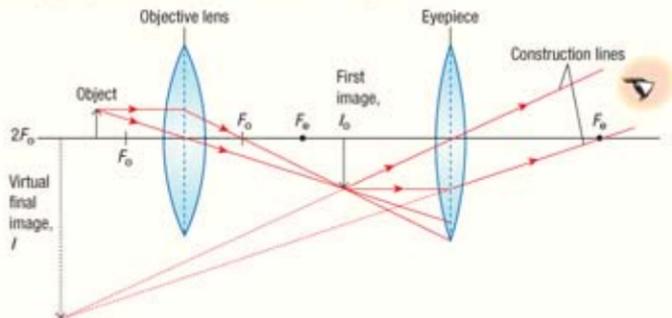


Figure 7.9 Ray diagram showing the formation of the final image in a microscope

Determining the Magnifying Power of a Microscope

Magnifying power of microscope

= Magnifying power of objective lens \times Magnifying power of eyepiece

Example

Photograph 7.2 shows a microscope containing an eyepiece with a magnifying power of 4 times and an objective lens with a magnifying power of 40 times.



Photograph 7.2

Calculate the magnifying power of the microscope.

Solution

Magnifying power of microscope

= Magnifying power of objective lens \times Magnifying power of eyepiece

= 40×4

= 160 times

Science Info

Identify the objective lens and eyepiece of a microscope
<http://buku-teks.com/sc5211>



Formation of the Final Image by a Telescope

Study the two ray diagrams in Figure 7.10.

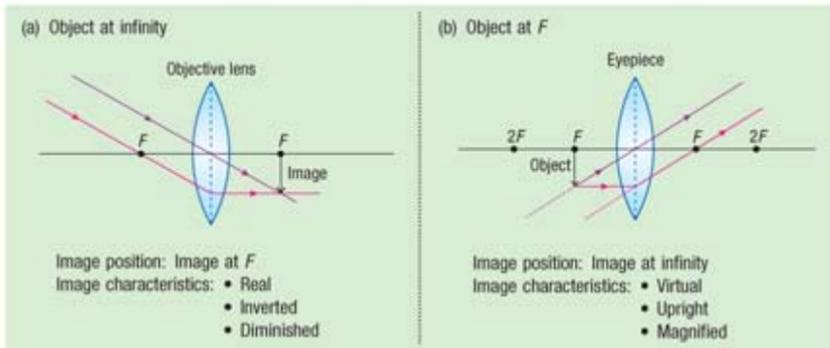


Figure 7.10 Ray diagrams for the images formed by the objective lens and eyepiece of a telescope

Based on your understanding of the two ray diagrams in Figure 7.10, the formation of the final image by a telescope is shown in Figure 7.11.

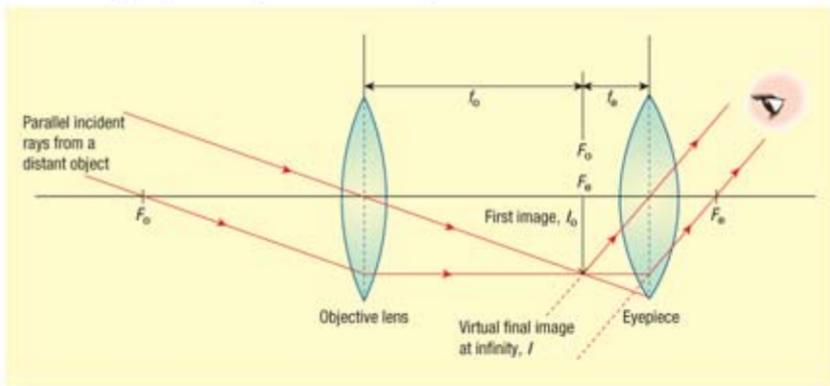


Figure 7.11 Ray diagram showing the formation of the final image in a telescope

In normal adjustment, the distance between the objective lens and eyepiece = $f_o + f_e$ where f_o = focal length of objective lens,
 f_e = focal length of eyepiece
 so that the image can be viewed more comfortably.

Activity 7.3

To build a simple telescope model

Materials

Hollow paper cylinder and cellophane tape

Apparatus

Convex lens with focal length, $f_o \geq 10$ cm, convex lens with focal length, $f_e \leq 2$ cm, ruler, scissors or knife and pencil

Instructions

- Carry out the activity in groups.
- Gather information from the Internet, print media and other electronic media about the following:
 - type, size and function of lenses used in a telescope
 - selection criteria for the objective lens and eyepiece of a telescope which can produce the clearest and brightest image
 - ray diagram to show the formation of image in a simple telescope
- Discuss the information needed to complete the K-W-L Strategic Data Form as a guide to design and build your simple telescope. You can download and print the form from the website given below.

Download K-W-L
Strategic Data Form
[http://buku-teks.com/
sc5213](http://buku-teks.com/sc5213)



K-W-L Strategic Data Form

What students already know, wish to know and will know (K-W-L chart)

Already know (K – Know)	Wish to know (W – Wonder)	Will know (L – Learn)

- Sketch the design of the simple telescope.
- Build your model according to the sketch made.
- Comment on the effectiveness of the design and improve on the design produced.
- Present your group's telescope design and model.

Questions

- Why is the cylinder for the model telescope constructed from materials that are opaque and not transparent or translucent?
- What is the distance between the objective lens and the eyepiece so that the final image can be seen more comfortably?
- What is the name of the condition mentioned in question 2?

21st Century Skills

- ICS, ISS, STEM
- Innovative activity

Application of Lenses in Optical Instruments

Digital single-lens reflex (DSLR) camera with two different lenses



High-resolution closed-circuit television (CCTV)



Spy camera in safety device



Photograph 7.3 Examples of optical instruments using lenses

Technological advancements in the field of optics have enabled lenses used in optical instruments such as smartphones and closed-circuit television (CCTV) to be only several millimetres thick. Optical studies have succeeded in building flat lenses with a thickness of several microns only (1 micron = 0.001 mm). What are the effects of a flat lens on the size and thickness of smartphones?

The focal length of the lens in the DSLR camera affects the field of vision. The shorter the focal length of the lens, the wider the field of vision as shown in Photograph 7.4.

Camera image formed using a lens of focal length 70 mm from a distance of 15 m



Camera image formed using a lens of focal length 24 mm from a distance of 15 m



Photograph 7.4 Images formed using different focal lengths

Activity 7.4

To study the contributions of science and technology towards the invention of optical instruments that can help or overcome the limitations of human sight

21st Century Skills

- ICS, ISS, TPS
- Discussion

Instructions

1. Carry out the activity in groups.
2. Gather information from the Internet, print media and other electronic media on the following:
 - (a) use of lenses in daily instruments such as cameras, smartphones, LCD projectors, spectacles, magnifying glasses and CCTV
 - (b) the thickness and focal length of the camera lens of smartphones
3. Discuss the information gathered.
4. Present the outcome of your group discussion in the form of a multimedia presentation.



Science Info

Photograph 7.5 shows a water lens placed under the sunlight.



Video

A water lens can function as a magnifying glass
<http://buku-teks.com/sc5215>



Photograph 7.5 Water lens

Formative Practice 7.2

1. State the characteristics of the image formed by a magnifying glass.
2. Telescope X consists of an objective lens with a focal length of 30 cm and an eyepiece with a focal length of 5 cm.

What is the separation distance between the objective lens and the eyepiece when telescope X is in normal adjustment? 

Light and Optics

Image formation

by

Convex lens

or

Converging lens

Concave lens

or

Diverging lens

Ray diagrams

Optical instruments

Telescope

Characteristics of the final image:

- virtual
- magnified
- inverted

In normal adjustment, the distance between the objective lens and the eyepiece
 $= f_o + f_e$

Microscope

Characteristics of the final image:

- virtual
- magnified
- inverted

Magnifying power of microscope
 $=$ Magnifying power of objective lens \times Magnifying power of eyepiece

Camera, smartphone, LCD projector, spectacles, magnifying glass, CCTV

to overcome

Limitations of human sight



Self-Reflection

After studying this chapter, you are able to:

7.1 Formation of Images by Lenses

- Describe convex lens as a converging lens and concave lens as a diverging lens.
- Determine the focal length of a convex lens using a distant object.
- Determine the characteristics of images formed by convex and concave lenses using ray diagrams.

7.2 Optical Instruments

- Describe the formation of the final image by telescopes and microscopes.
- Design and build a simple telescope.
- Communicate about the application of lenses in optical instruments.



Summative Practice 7

Answer the following questions:

1. Draw ray diagrams which describe the following characteristics of lenses:
 - (a) convex lens as a converging lens



- (b) concave lens as a diverging lens



Quiz
<http://buku-teks.com/sc5217>



2. Figure 1 shows an object placed in front of a convex lens at a distance less than the focal length, f .

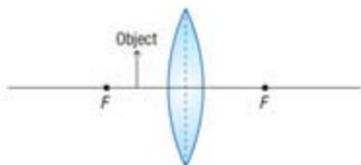


Figure 1

- (a) Draw a ray diagram in Figure 1 to determine the image formed by the convex lens.
- (b) State the characteristics of the image formed by the convex lens in Figure 1.
3. (a) Why do smartphones have several cameras?
- (b) A student carried out an experiment to form a virtual image using a convex lens. Explain how the student formed the virtual image based on the apparatus set-up in Figure 2.

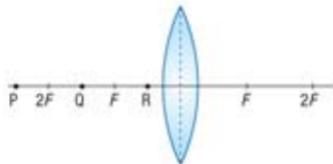


Figure 2

- (i) Write the problem statement.
- (ii) State the position of the object (at P, Q or R).
- (iii) Using an arrow (\uparrow) as the object, draw a ray diagram to show the formation and position of the image. Complete Figure 2 to obtain your answer.
- (iv) State **two** other characteristics of the image formed in 3(b)(iii).



Enrichment Practice

4. Optics is a scientific field that studies the properties of light, interactions between light and substances such as glass, human sight and instruments which use or detect light. Study and understand the contents of the poster in Figure 3.

Convex lens

This convex lens makes my eye appear bigger. Do you know the reason why?

Concave lens

This concave lens makes my eye appear smaller. Do you know the reason why?

How does a lens make an object appear bigger or smaller?

Convex lens

Magnified image of fly

A fly seen through a convex lens will appear larger than its actual size.

Concave lens

Diminished image of fly

A fly seen through a concave lens will appear smaller than its actual size.

Lenses can be combined to make special optical instruments.

Figure 3

How effective is this poster in explaining the concept of image formation by lenses and optical instruments in the study of optics? 🧠