# CHAPTER 19

## Lenses

#### 19.1

#### INTRODUCTION

Did you know that the earliest eyeglasses were thick convex lenses, which reminded their makers of lentils, hence the term 'lens', from the Latin for 'lentil beans'?

Lenses play a major part in everyday life and in the scientific world. They are present in spectacles, contact lenses, microscopes, telescopes, overhead projectors, and photocopiers, to name a few. Simple lenses are used in science classes for mineral identification and for map reading in geography.

Lenses are transparent devices that refract light. Differently shaped lenses refract light differently. Once they were made of glass but now, to reduce the weight, many lenses are made of plastic. Magnetic lenses are used to focus charged particles in particle physics. Eyes of animals contain lenses made of organic material that can change shape to produce a range of depth of vision.

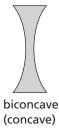
At the end of this chapter you may be able to answer questions such as these:

- What devices around me rely on lenses of various types?
- If lenses refract light why don't we see colours when using spectacles due to the fact that each colour of light is refracted differently?

#### 19.2

#### SHAPE OF LENSES

Lenses are curved pieces of glass or plastic in many shapes, although they all serve a similar purpose — they refract or bend light in one way or another. Several shapes are shown in Figure 19.1. However, the ones most commonly used are **biconcave** (concave) or **biconvex** (convex) lenses.



biconvex (convex)

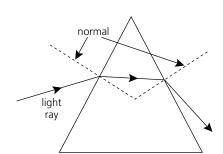


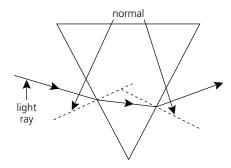


Figure 19.1
Some of the different shapes of lenses.

One common feature of all lenses is that light incident on the lens always bends toward the thickest part. Recall the refraction of light through a prism (Figure 19.2). Light is refracted toward the normal at the first surface and away from the normal at the second surface. The overall effect is that light always bends toward the thickest part of the prism.

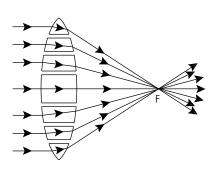
Figure 19.2 Light through a prism always refracts toward the thickest part of the prism.

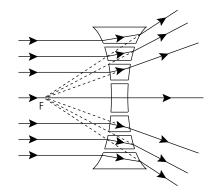




We can regard a lens as being a system of tiny prisms of slightly different shapes, so that light rays are refracted at both sides of the lens, which results in the bending of light rays toward the thickest part. This makes light rays incident on a convex lens bend toward the centre, thus focusing or converging the light. This type of lens is therefore also called a converging lens. Light incident on a concave lens spreads or diverges the light. This lens is also called a **diverging lens** (Figure 19.3).

Figure 19.3 Lenses can be considered to be made up of tiny prisms, thus light will always refract to the thickest part of the lens.





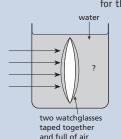
Other shaped lenses produce effects that depend on their shape. Note: refraction occurs at both sides of the lens but to simplify the drawing of ray diagrams we will draw a line through the centre of the lens and have all refraction occur at this line.

### FEATURES OF LENSES

19.3

#### **NOVEL CHALLENGE**

You have made an air lens by taping two watchglasses together. This does nothing in air but what will it do underwater? 'Myopic people see better underwater' account for this.



Similar terms to those associated with mirrors are used in describing lenses. Each face of the lens can be drawn using a compass. The centre of the circle that produces the curved surface is called the centre of curvature. Each face can have a different curvature. However, for our discussions we will use lenses whose sides have the same radius of curvature. The line joining the centre of curvature through the optical centre of the lens is called the **principal axis**. If rays of light parallel to the principal axis are incident on a convex lens the rays converge to a point on the other side of the lens — the **principal focus** (F). Since lenses can be used either way around they have two focal points, one on either side of the lens. If rays of light parallel to the principal axis are incident on a concave lens they diverge. However, if these rays are traced back they appear to come from a point on the same side of the lens as the light originates. This is a virtual focus. The distance from the focal point to the optical centre of the lens is the **focal length** (f). More powerful lenses have shorter focal lengths and are much thicker (Figures 19.4 and 19.5).

Lens makers use the unit of the **dioptre** (D) to define the **optical power** of a lens. This is equivalent to the reciprocal of the focal length (in metres). For example, the optical power of a 20 cm focal length convex lens is 1/0.20, which equals +5 D. For a concave lens this becomes 1/-0.20 = -5 D. The term power in this case refers to the ability of the lens to refract light. High power lenses will refract light to a greater degree than low power lenses.

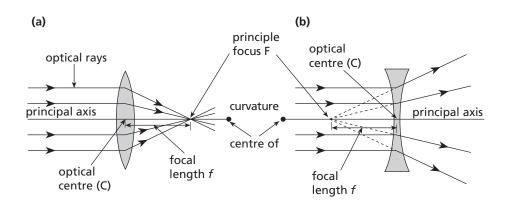


Figure 19.4
Features of convex (a) and concave (b) lenses.

19.4

#### RAY DIAGRAMS AND IMAGES

If you look through a magnifying glass (a convex lens) at an object you can see the object. In actual fact you are only seeing the image of the object. This can be easily verified if you look at an object a long distance away while holding the lens at arm's length. The image is upside-down.

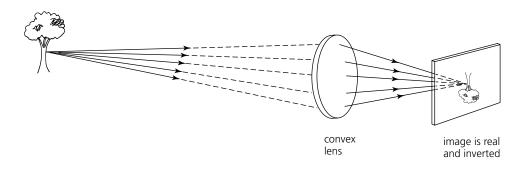


Figure 19.5
Thick lenses have smaller focal lengths than thin lenses and are more powerful.

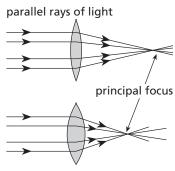
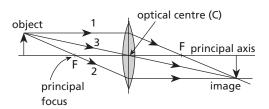


Figure 19.6
Images of distant objects are inverted, indicating that when you look through a lens you are observing the image and not the object itself.

## — Ray diagrams

Ray diagrams can be drawn to find the position and nature of an image. Again, any number of rays can be drawn to determine the position and nature of the image but many would require the use of protractors, many calculations, and measurements of the angles of refraction at both surfaces to produce an accurate ray diagram. However, three easily drawn rays are most commonly used to simplify the drawing of ray diagrams (Figure 19.7).



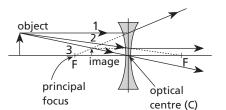


Figure 19.7
The three rays that are used to find the image produced by a lens: one parallel to the principle axis (1), one through the focal point (2), and one through the optical centre of the lens (3).