CHAPTER 20

Optical Instruments

INTRODUCTION 20.1

The application of artificial lenses and mirrors is widespread; however, one of the most important natural optical instruments is the human eye. But it, too, like the human body itself, has its defects and limitations. The eye not only can have inherent defects, but its performance can change with age. It is also unable to see fine detail or make observations of distant events. For these reasons scientists have developed many complex instruments that assist the eye in overcoming these limitations.

Other animals also have inherent eye defects. For example:

- chickens' eyes contain only cones thus making them unable to adapt to the dark
- owls' eyes contain only rods, which enables them to see well at night but they blink all day long. Can owls recognise colours?

NOVEL CHALLENGE

The word **pupil** comes from the Latin *pupilla* = 'a doll'. When you look at a reflection of yourself in someone's eye you see a small doll-like image of yourself. Now someone was really creative with language. *Quick now, is the image upright or inverted?*

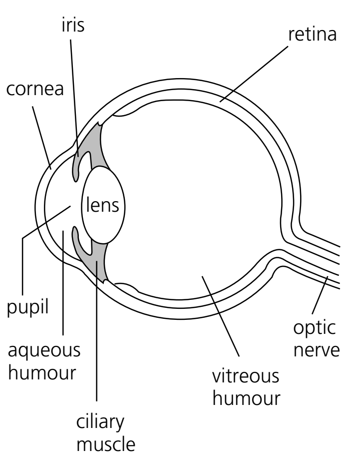
THE HUMAN EYE 20.2

It was not until the Middle Ages that the human eye was studied in any scientific sense. Around the year 1000, an Arabian scholar, Abu Alhazen, investigated the complementary colour of after-images. (Stare at an object then close your eyes to see an image of the complementary colour.) In the early 1600s Johannes Kepler described the eye in terms of a pinhole camera but this left the world puzzled about how we saw things the right way up. Rene Descartes in 1640 proved that the eye produces inverted images (which the brain re-inverts), by experimenting with the eyes of dead oxen. From then on, theories of human vision developed rapidly.

The main function of the human eye is to form images on the **retina**. Light enters the eye through the transparent **cornea** and passes through the **lens system** to be focused onto the light-sensitive retina, which responds by sending signals to the brain via the **optic nerve**.

The amount of light entering the eye through the pupil is controlled by a diaphragm, the **iris**, which reacts to the amount of light available. In very bright daylight the iris allows little light though the pupil, which may be as small as 2.0 mm. At night the iris opens up, enlarging the pupil, which may become as big as 6.0 mm. The iris gives a person's characteristic eye colour.

Figure 20.1
A schematic diagram of the eye.



Activity 20.1 PUPILS LOOK INSIDE THE EYE

EI

The best way to study the optics of an eye is to cut it open. For this activity you'll need a bull's eye, scalpel, forceps, gloves and scissors.

1. Examine the eye (Photo 20.1**(a)**) and look for the optic nerve tube among the white fat and tissue at the back. Remove as much of this white stuff as you can.
2. Use a scalpel to puncture the eyeball and watch the vitreous humour ooze out.

3 Cut the eye open completely and note the bright blue iridescent retina. Locate the optic nerve spot. (Photo 20.1**(b)**.)

4 Cut out the lens and cornea (Photo 20.1**(c)**) and place it over some newspaper to reveal the magnification. Estimate the magnification.

5 Remove the lens and note how hard it is. Can you cut it?

(a) (b) (c)

Photo 20.1
(a) A bull's eye — as supplied by the abattoir.
(b) The retina turned inside out. The optic nerve is visible as a dark spot in the middle.
(c) A bull's eye lens and cornea with the black rim of the iris visible. The letters are magnified about 1.7 times.

The lens system

Light from objects is focused onto the retina by refraction, which takes place at the cornea, the lens, and to a lesser extent in the liquid between the pupil and the cornea — the **aqueous humour** — and the liquid between the lens and the retina — **the vitreous humour**. In fact, the curved cornea, which has an optical power of 40 D, does most of the refracting. However, it is the lens, with a power of 20 D, that allows us to focus on distant objects as well as near objects. The shape and focal length of the lens is controlled by the **ciliary muscles**. When an object is at a large distance the muscles contract, making the lens long and thin and of long focal length, which brings the object into focus on the retina. The furthest distance that objects can be seen in focus is the **far point**. This point varies from person to person and changes with age. It can be from several metres to hundreds of metres. As an object moves closer the muscles relax making the lens shorter and thicker and decreasing the focal length. The closest point at which a sharp image is formed on the retina is the **near point**. If the object is brought closer than this a blurred image is seen. For most people the near point lies between 10 cm and 25 cm. This ability of the lens to adjust, thus enabling humans to see far and near, is called **accommodation**.

NOVEL CHALLENGE

Two eyes are better than one for depth perception.
Would three be better?
Why or why not?

EI Activity 20.2 THE NEAR POINT

1 Hold this book at arm's length.

2 With one eye closed, focus on one word and slowly bring the book towards you stopping when the word starts to become blurred. This is your near point.

3 Have a partner measure this distance.

4 Repeat this with your other eye. Which eye is better?

5 What did you find about the near point for students in your class?

Light rays focus on the retina, which contains light-sensitive cells called rods and cones. The **rods** react to the level of brightness whereas the **cones** react to colour as well as brightness. The cone cells are concentrated near the centre of the retina and are thought to contain three separate receptors, one each for red, green, and blue light. The rods are more concentrated on the outside of the retina, which makes colour identification in peripheral vision poor.

Cones are more active in daylight and cannot identify colour in dim light. Rods are more active in dim light. In dim light the rods secrete a light-sensitive chemical, **visual purple**, which surrounds the tips of the rods and makes them extremely sensitive to dim light. However, it is destroyed by all but red light and therefore can only accumulate in the dark. This allows people over a period of half-an-hour or so to adapt to poor light conditions.

NOVEL CHALLENGE

You blink on average once every 5 seconds while you are awake. *How many megablinks per annum is this? When you go into a shopping centre your blink rate falls to one every 12 seconds. Propose a reason for this.*

NOVEL CHALLENGE

There are three forms of colour blindness: *protanopia*, *deuteranopia* and *total*. Find out what they mean then propose a reason for the names based on the meaning of the prefixes: pro = one, deut = 2.

NEI

Activity 20.3 RODS AND CONES

1 Research:
   (a) whether other animals' eyes contain rods and/or cones
   (b) whether it is true that dogs are colour-blind. Do their eyes contain rods only?
2 Check yourself. A colour blindness test card is reproduced on the inside back cover. Cards such as these are used by optometrists to assess colour blindness.

The optic nerve carries signals from the retinal cells to the brain, which has to interpret these signals as the image formed on the retina is inverted and turned from left to right. However, there are no cells at the point where the optic nerve leaves the eyeball, which results in a blind spot.

EI

Activity 20.4 THE BLIND SPOT

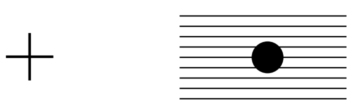
Figure 20.2
Find the blind spot of the eye.

1 Close your left eye, keeping your right eye open.
2 Look at the '+' in Figure 20.2 with your right eye while holding the book at arm's length.
3 Gradually bring the book toward you while you keep looking at the '+' .
4 You will arrive at a distance at which the '•' disappears out of the corner of your eye because light rays from this point hit the retina at the blind spot — the point where the optic nerve leaves the retina.
5 Try this again looking at the '+' in Figure 20.3 this time.
6 What do you notice about the '•' and the lines when the dot is focused on your blind spot?

EI

Activity 20.5 FLOATERS

Figure 20.3
Demonstrating how the brain tries to overcome the blind spot.



Floaters are bits of debris that come away from the inside surface of your eye.

1 Stare at something light coloured and notice the circular blobs that drift around. They tend to move upward. Why is this?
2 Stare at the ceiling and you may notice the floaters congregating at the centre. This happens as they drift into your fovea. New floaters can indicate a retinal tear.

Eye defects

Long-sightedness (Hypermetropia)

Long-sightedness is being able to see distant objects but unable to focus on near objects. It comes from Greek *hyper* = 'beyond', *metros* = 'to measure'. It is due either to the eyeball being too short, or to the inability of the lens to relax enough, so the focal length is too long and the image is formed behind the retina. (See Figure 20.4.)

This can be corrected by using a converging lens, which brings the rays closer together before passing through the eye's lens.

INVESTIGATING

Close your eyes and press an eyelid at the edge close to your nose.
How do you explain the big black circle with a yellow outline on the other corner of your eye? Hmmm!

Short-sightedness (Myopia)

This occurs when people can focus on close objects but distant objects are blurred. This is due either to the eyeball being too long, or to the inability of the muscles to contract sufficiently, making the focal length too short. The image is formed in front of the retina. (See Figure 20.5.)

It can be corrected using a diverging lens, which spreads the light rays out.

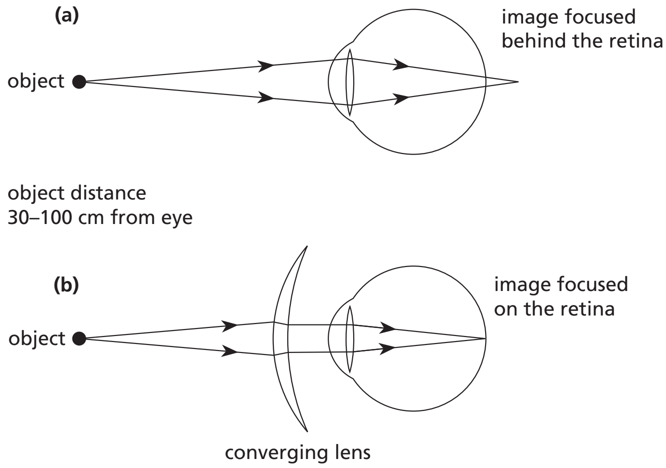


Figure 20.4
In hypermetropia the image is formed behind the retina **(a)**. This can be corrected by the use of a convex lens **(b)**.

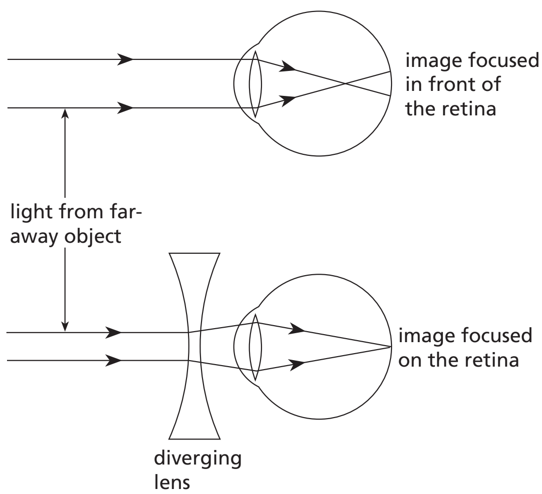
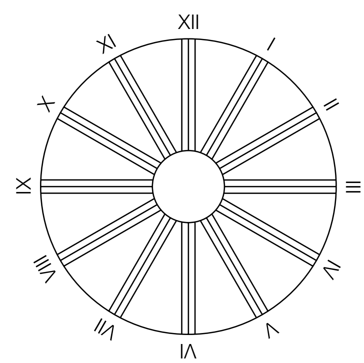


Figure 20.5
In myopia the image is formed in front of the retina **(a)**. This can be corrected by the use of a concave lens **(b)**.

Figure 20.6
If you have astigmatism some lines are blurred while others are sharp.



Presbyopia

Presbyopia is the inability to focus on distant or close objects — a mixture of hypermetropia and myopia. This commonly occurs with the deterioration of eyesight with age. *Presby* is Latin for 'old'. The lens is unable to change shape as the ciliary muscles weaken. Bifocals, where the top half of the spectacles are diverging lenses and the bottom half are converging lenses, are needed to correct this.

Astigmatism

This occurs if the cornea is not spherical. *Stigma* is Greek for 'point'. If the cornea is more curved in one direction than another, a person may find objects or parts of an object blurred in a particular direction whereas other parts are in focus. This can be corrected by specially shaped lenses that correct the variable curvature of the cornea.

EI Activity 20.6 ASTIGMATISM

You can check to see if you have astigmatism by looking at Figure 20.6. If one line appears sharp and the others are blurred then you may have this defect.

Did you know that a Central American fish, the Anableps, has two retinas per eyeball and egg-shaped lenses? This fish swims just below the surface of the water with its large eyeballs protruding half above and half under the water. Because of the difference in refraction that occurs when light passes from air to the eye, and from water to the eye, images occur at different distances from the lens, requiring retinas at different positions.

NOVEL CHALLENGE

In 1970 Dr Fyodorov of the Soviet Union treated a near-sighted man who had glass slivers in his eyes. After the operation his near-sightedness had been cured. Propose what the 'radial keratomy' operation did.

Questions

1 **(a)** Explain why the human eye has a blind spot.
(b) What does the brain do to overcome the non-formation of an image at the blind spot?
(c) Do you think other animals would also have blind spots in their eye? (Would insects, for example flies, have many blind spots?)

2 How could you decide whether a person is long-sighted or short-sighted by examining their spectacles?

3 In the following examples state, with reasons, the likely defect of the eye, and indicate how it can be overcome.
(a) A person needs to move a book to 50 cm to be able to read it but can read street signs, etc. clearly.
(b) A student looking at a blackboard sees vertical lines in focus but horizontal lines are blurred.
(c) An older person needs to move the morning paper a long distance from his eyes to read it, and needs to sit close to the picture screen to see a movie.

4 What is the difference between the medical professionals known as an optometrist, an ophthalmologist and an orthoptist. To which of these people would you go for **(a)** spectacles, **(b)** detached retina symptoms, **(c)** lazy eye, **(d)** cataracts, **(e)** glaucoma, **(f)** conjunctivitis ?

Activity 20.7 VISION EFFECTS

'See' if you can answer these questions.

1 Why does your vision persist on your retina for longer than a blink (0.1 s)?

2 Press the inside corner of your eye when closed and you will see a circular image in the other corner. You have just cut off blood flow to the retina, but why the circular image?

3 If you are long-sighted and hence need reading glasses, you may find that squinting makes close-up things clearer. Does this work by narrowing the effective pupil size and giving you a 'pinhole effect' or does the pressure on your eyeball change its shape somewhat so that it temporarily corrects the defect?

4 The fovea has an enormous number of cells (about 250 000). Why is this?

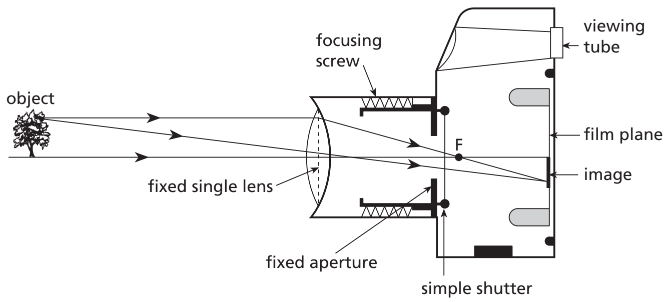
5 Contact lenses are used mainly for short-sightedness. For long-sightedness you would need a concave contact lens. Can you design one that fits the curve of the eyeball?

6 The eye disease 'prosopagnosia' has a strange effect. If you look at a hollow face mask on a rotating table it appears to be rotating the wrong way when its inside surface is viewed. Prosopagnosia prevents this. Can you find an explanation for this effect?

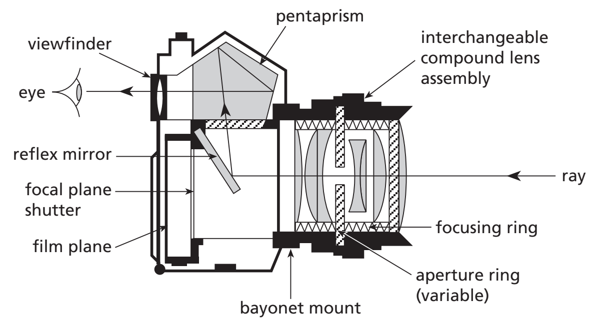
CAMERAS 20.3

A camera works in a similar fashion to the eye. Light from the object enters through the lens system and is focused onto the film containing light-sensitive chemicals (silver halides), which are changed by the image-forming light rays. This is called making an **exposure**. A correct exposure is made when sufficient light is allowed to enter the camera and cause the correct amount of chemical change in the film. This is controlled by both shutter speed and aperture diameter.

(a) Schematic diagram of a simple camera



(b) A more complex SLR camera



Unlike the **lens** of the eye, the lens of the camera cannot change its focal length. Therefore, to form a sharp image of objects at various distances the lens is movable. When objects are far away, the distance between the lens and the film is the focal length. As a distant object moves nearer, the lens has to be moved further from the film to keep the object in focus. This is achieved by use of the **focusing screw**. However, there is a limit to the closeness an object can reach while still in focus, for each particular type of camera and lens. Single lens reflex cameras have the ability to easily change lens systems. These lens systems often have a range of focal lengths over which they can operate. They are called **zoom** lenses. Camera lenses are made from glass in good-quality cameras, but in cheaper ones plastic (usually Perspex) is used.

(c)

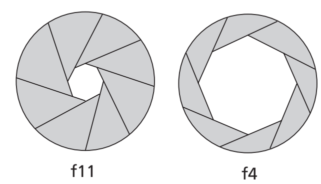


Figure 20.7
A schematic diagram of a simple camera **(a)**; and a more complex SLR camera **(b)**; **(c)** the variable aperture ring.

The **shutter** controls the amount of light entering the camera. If objects are moving quickly then it is necessary to catch the object in one position otherwise the image will be blurred. Therefore, the time interval that the shutter is open needs to be very short, maybe 1/500 second. Because less light is entering the camera this will necessitate the use of a 'fast' film. These films are more sensitive to light than 'slow' films, which can be used when the shutter speed can be longer, allowing more light to enter the camera. However, 'fast' film may not give the picture quality of 'slow' film. It is usually more grainy. The speed of any film is stated as its ISO rating. An ISO400 film is four times as fast as an ISO100 film. In modern films the ISO rating is coded onto the film canister to be 'read' by the camera.

All cameras are fitted with an **aperture**, which restricts the area through which light can pass. Simple cameras have fixed apertures, but other cameras have a variable iris diaphragm (corresponding to the iris of the eye) in the lens system. As the aperture is nearly circular, its area is proportional to the square of its diameter. So when you double the diameter, you let through four times as much light; when you halve it, you let through one-quarter the amount of light.

Apertures are denoted by f-stops or f/numbers, calculated by dividing the focal length of the lens by the 'effective aperture'. The effective aperture is the width of the light beam that must enter the lens to fill the real aperture (or 'stop') completely. It is generally not the same as the diameter of the aperture itself, as most lens front elements are positive and therefore converge a beam of light to fill the aperture. The f/number series is as follows: f1, f1.4, f2, f2.8, f4, f5.6, f8, f11, f22, f32, and f45. Each number admits twice as much light as the next higher one, and half as much as the next lower. The bigger the number, the smaller the aperture, and vice versa. Most lenses allow you to set half-stops, although the f/number is not shown, unless the camera is an electronic type with an LCD panel or the f/stop is the maximum aperture.

Under the same lighting conditions, all lenses, regardless of focal length, produce the same image brightness at the same f/number.

Photo 20.2

The aperture setting and the shutter speed affect the photo produced.

Lenses are described by two parameters: their focal length and their maximum aperture. So you might have a 35 mm f2.8 lens, or a 28–70 mm f3.5–4.5 zoom. Note that the maximum aperture of the zoom has changed with focal length, and the numbers quoted here are not full stops.

It's common to talk about 'the speed of the lens', which is pretty confusing, as it has nothing to do with shutter speed. The speed of the lens is its maximum aperture; a fast lens is one with a big maximum aperture for its focal length (maximum apertures tend to become smaller as the focal length increases). So the so-called 'sports lenses' are 300 mm f2.8 telephotos and are usually very expensive.

The size of the aperture also controls the **depth of focus** or **depth of field**. If a small aperture is used objects from far and near will be in focus at the same time, giving a large depth of field. If a large aperture is used then a small depth of field is obtained, with near objects being in focus while background objects are blurred. (Compare the two photos.) When you use the lens's maximum aperture you are said to be shooting 'wide open', and when using its minimum you are shooting 'stopped down'.

For correct exposure when taking photographs, the shutter time and aperture settings will depend on:

- the brightness of the object
- the sensitivity of the film
- the effect or depth of field desired.

The correct exposure will be determined by the camera's light meter.

NEI

Activity 20.8 CAMERAS AND FILM TYPES

1 Using an encyclopaedia or other reference, find out how a pentaprism in a camera works and make a drawing to illustrate.

2 Use the library or Internet to research **(a)** types of films; **(b)** types of camera systems: compact, SLRs, TLRs, medium format, view cameras, digital cameras.

Questions

5 For a simple camera to produce a photo of a distant object:
(a) state whether the lens will be moved closer to or further from the film;
(b) give an indication of the aperture size required for a good depth of field.

6 Aperture settings of cameras are in terms of f/numbers or f-stops.
(a) What do these numbers marked on the lens indicate?
(b) What is the size of the effective aperture of a 10 cm focal length camera lens if the setting is f4?
(c) An exposure of $\frac{1}{125}$ s at f8 would be equivalent to an exposure of $\frac{1}{250}$ s at what aperture, assuming that film of the same speed is used for both?

7 A lens of a simple camera has a focal length of 12 cm. What is the distance needed between the lens and the film to produce a sharp image when the object is at **(a)** infinity; **(b)** 40 cm; **(c)** 6.0 cm?

TELESCOPES 20.4

Controversy exists over the actual inventor of the telescope although it is usually attributed to a Dutch spectacle maker, Hans Lippershey, in 1608. However, it was Galileo who quickly made his own version in Venice in 1610 and turned it toward the heavens. The modern science of astronomy was born. As Venice was a glassmaking city, the developments of lenses became rapid. The microscope was invented soon after.

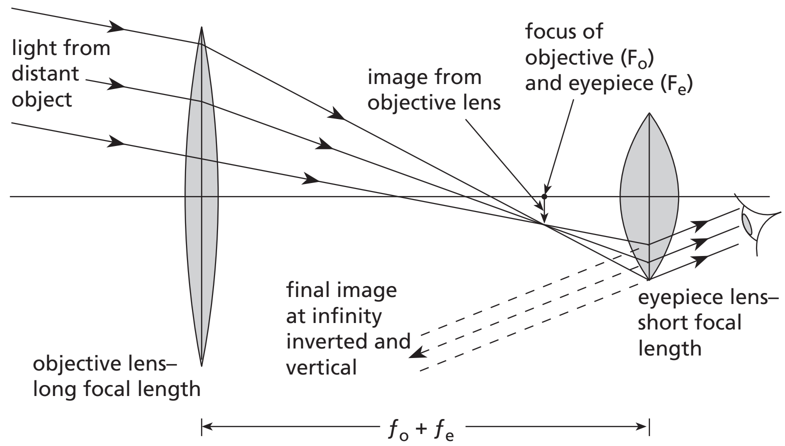


Figure 20.8
A refracting telescope contains a long focal length objective lens and a short focal length eyepiece lens.

INVESTIGATING

Binoculars solve one problem inherent in the design of telescopes. What is it?

This type of telescope consists of two convex lenses. The objective lens has a long focal length and the eyepiece lens has a short focal length. These lenses are set up so their focal points coincide (Figure 20.8). Parallel light from a distant object, after being refracted by the objective lens, forms an inverted image at the focal point of the eyepiece lens. This produces a final image at infinity. The eye uses its own lens to bring the parallel rays to focus on the retina. Notice that the image is inverted, but astronomers are accustomed to this. The magnification of a telescope is given by the formula:

$$M = \frac{f_o}{f_e}$$

where f_o is the focal length of the objective lens, and f_e is the focal length of the eyepiece lens.

The length of the telescope is also controlled by the focal lengths. The telescope has a minimum length of $f_o + f_e$.

Terrestrial telescopes (in Latin *terra* = 'Earth') are a lot smaller than astronomical telescopes and have an extra lens to produce an upright image, which is important when observing earthly things such as a cricket match or while bird watching (Figure 20.9).

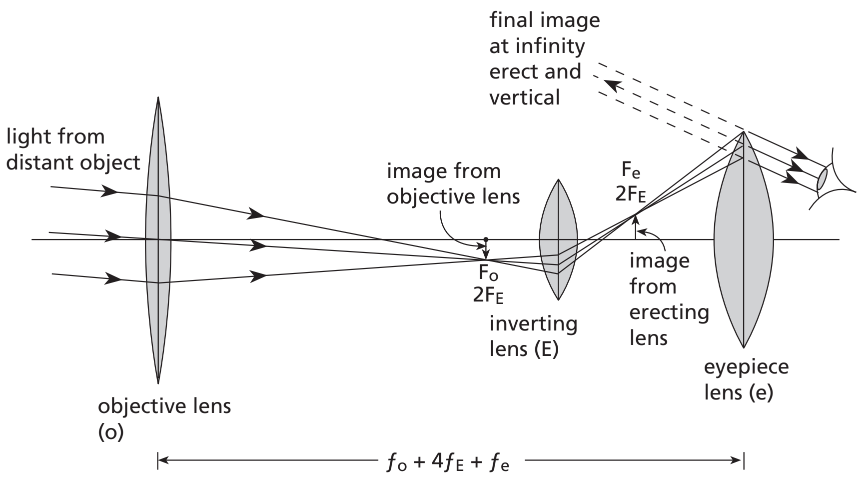


Figure 20.9
Terrestrial telescopes have an extra lens so images are upright.

Galilean telescopes use a diverging lens as the eyepiece, which in effect makes the length smaller and produces an upright image.

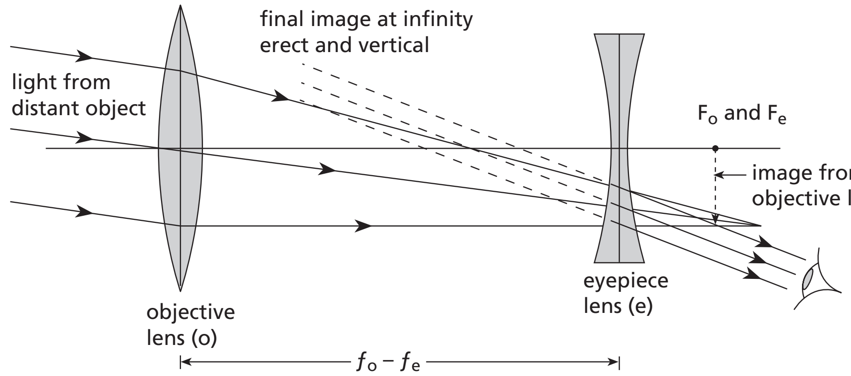


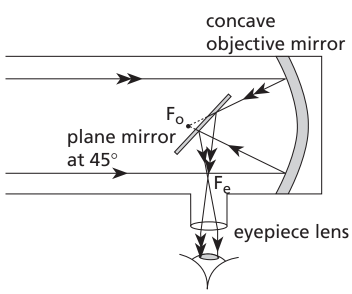
Figure 20.10
A Galilean telescope's eyepiece is a concave lens. This produces upright images but gives a narrower field of view.

However, astronomical telescopes are normally not refracting telescopes as the large lenses required tend to sag and it is very expensive to manufacture good quality, large focal length lenses. Astronomical telescopes are normally reflecting telescopes.

Reflecting telescopes

One of the problems associated with large refracting telescopes is chromatic aberration. Isaac Newton realised that it would be difficult to avoid, so in 1665 he developed a reflecting telescope. It used a large concave mirror to collect light from distant objects. This light converged onto a plane mirror tilted at 45°; this reflected the light to the focal point of the eyepiece, which acted in the same way as that of an astronomical telescope. These telescopes have an advantage in that mirrors are less costly than lenses and can be supported at their backs, therefore they can be very large.

Figure 20.11
Reflecting telescopes use large concave mirrors as the objectives. This allows them to collect much more light than refracting telescopes.



The world's largest optical mirror, polished to the highest perfection, has a diameter of 8.2 m, a surface of more than 50 m^2, and weighs 23.5 t. It was built in 1995 and put in place on 17 April 1998 at the first Very Large Telescope Unit (VLT-UT1) at the Paranal Observatory located on Cerro Paranal in the Atacama Desert, Northern Chile. The VLT now consists of four 8 m telescopes which can work independently or in combined mode, providing the total light-collecting power of a 16 m single telescope, currently making it the largest optical telescope in the world. The VLT is strong enough to detect a glow-worm at 10 000 km. Compared with this, the largest objective lens used in a refracting telescope is quite small — 1.34 m in diameter. Because of the very large diameter mirrors used in reflecting telescopes, they are able to collect large amounts of light, allowing astronomers to see fainter objects in the heavens.

Questions

8 Copy and complete Table 20.1, which indicates the focal lengths of the objective and eyepiece lenses, and the magnification obtained by a refracting astronomical telescope.

Table 20.1

	FOCAL LENGTH OF OBJECTIVE LENS	FOCAL LENGTH OF EYEPIECE LENS	MAGNIFICATION	LENGTH OF THE TELESCOPE
(a)	4.0 m	10 cm		
(b)		5.0 cm	10	
(c)	3.0 m		60	
(d)		2.0 cm		2.0 m

9 Give reasons for most astronomical telescopes being reflecting rather than refracting telescopes.

20.5 MICROSCOPES

A **simple microscope** consists of a single convex lens or magnifying glass. When the object is placed inside the focal length a large upright image is produced. The lens is moved until the largest sharpest image is seen. This occurs when the image is at the 'near point' of the eye.

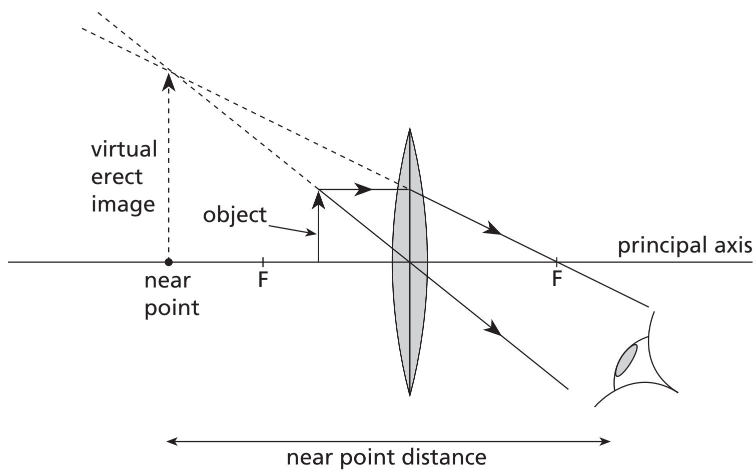


Figure 20.12
A simple microscope produces magnified, upright images at the near point of the eye.

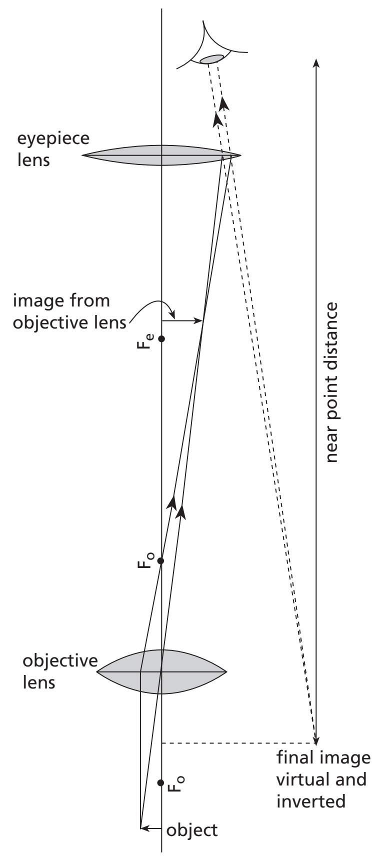
The magnification of the magnifying glass is expressed as the ratio of the near point distance to the focal length of the lens. In general, the near point is taken as 25 cm.

$$M = \frac{25}{f}$$

For example the magnification of a convex lens of 10 cm focal length, when used as a simple microscope, is $\frac{25}{10}$ = 2.5.

A **compound microscope** consists of a converging lens of short focal length (5.0–10 cm) and an eyepiece lens of longer focal length. The light from the object, which is illuminated by reflected light from a mirror or by direct light, passes through the objective lens, which is positioned so that the object is just outside its focal point. This produces a large inverted real image just inside the focus of the eyepiece lens, which acts like a magnifying glass. A large inverted, virtual image is thus produced at the near point of the eye. Since both lenses magnify, magnification of 400 or more can be obtained. Microscopes usually have a variety of objective lenses to produce a range of magnifications and good-quality microscopes contain achromatic lenses to eliminate chromatic aberration.

Figure 20.13
A compound microscope uses a short focal length objective lens and a long focal length eyepiece lens to produce upright, magnified images at the near point of the eye.



Questions

10 Find the magnification of a convex lens when it is used as a simple microscope if the focal length is **(a)** 20 cm; **(b)** 2.0 cm; **(c)** 100 cm; **(d)** 5.0 cm.

11 Cheap microscopes produce images with coloured fringes. Explain why this occurs and how it is overcome in more expensive microscopes.

PROJECTORS AND ENLARGERS 20.6

A **slide projector** (Figure 20.14) consisting of a system of mirrors and lenses produces a real, magnified, inverted image of a piece of photographic slide on a screen. As light leaves the lamp in all directions, the concave mirror reflects the light backward through the slide, intensifying the light through the slide. The **condenser** lens spreads the light evenly over the surface of the slide. The movable **projector lens** focuses a sharp, magnified, inverted image onto a screen. Because the image is inverted, the slide has to be placed in the projector upside-down.

Figure 20.14
A schematic diagram of a slide projector.

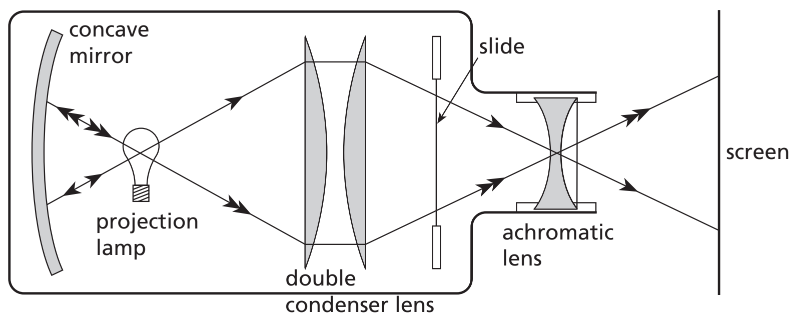
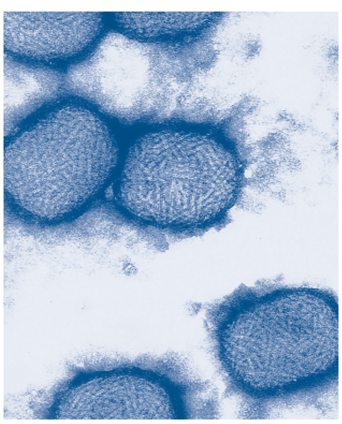


Photo 20.3
Really high magnifications can only be obtained using a scanning electron microscope. This photo shows a Pigeon Pox Virus at 160 000× magnification. Each viron is 200 nm across so you'd fit 1/4 million across the width of this photo. Taken by Mr Howard Prior at the Animal Research Institute, Yeerongpilly, Brisbane.



A **photographic enlarger** is very similar to the slide projector with the slide replaced by a film negative and the screen replaced by a piece of photographic paper containing light-sensitive chemicals, which change when light falls on them. The amount of light emerging from the enlarger can be controlled by adjusting the aperture (the f/number).

The latest versions of these instruments are referred to as **data projectors**. You might like to look back at Chapter 16 (section 16.10) to find out about the electronics and optics in these devices using LEDs and DLPs.

NEI Activity 20.9 OVERHEAD PROJECTOR

1. If you have access to an OHP, examine the optics and draw a diagram to show the way an image is produced.
2. Locate the Fresnel lens and describe its construction.
3. State one safety feature incorporated into the OHP.

Practice questions

The relative difficulty of these questions is indicated by the number of stars beside each question number: * = low; ** = medium; *** = high.

Review — applying principles and problem solving

***12** Why do you think doctors shine a light in your eyes to see if you are conscious?

***13** With age, as the muscles weaken, what do you think happens to the far point?

***14** Draw a well labelled diagram of the human eye.

***15** **(a)** What is hypermetropia?
(b) Explain how this defect of the eye might be caused.
(c) Indicate how it can be overcome.

***16** For the human eye what controls:
- **(a)** the focusing of an image on the retina;
- **(b)** the focal length of the lens;
- **(c)** the amount of light entering the eye;
- **(d)** whether you can see in dim light?

***17** **(a)** Explain the operation of the shutter and the aperture in allowing light into a camera in order to control exposure.
- **(b)** Explain the difference between film speed and lens speed in photography.

***18** Compare the similarities and differences between an eye and a camera by copying and completing Table 20.2.

Table 20.2

FEATURE	EYE	CAMERA
Detects an image		
Focuses light to produce an image		
Controls the amount of light entering		
Controls mechanism to produce a field of view		
Sensing apparatus/material that produces the image		

***19** What would happen to the length and magnification of a refracting telescope if the objective lens was replaced by one of shorter length?

***20** The focal length of the eyepiece lens of an astronomical refracting telescope is 4.0 cm. What focal length objective lens is required to give the telescope a magnification of 10?

***21** What is the focal length of a magnifying glass whose magnification is **(a)** 25; **(b)** 50; **(c)** 10?

***22** Compare the similarities and differences between a refracting astronomical telescope and a microscope.

***23** Specify whether the following use a concave or a convex lens.
- **(a)** The eye.
- **(b)** Spectacles to correct myopia.
- **(c)** The projector.
- **(d)** The terrestrial telescope.
- **(e)** The microscope.

***24** Why must a slide be placed upside-down in a slide projector?

***25** In an enlarger what is the purpose of **(a)** the concave mirror; **(b)** the condenser; **(c)** the lens?

****26** A slide projector contains a lens of 5.0 cm focal length. The distance between the slide and the lens can be adjusted from 5.1 cm to 6.0 cm.
- **(a)** Calculate the minimum distance between the lens and the screen that produces a sharp image on the screen.
- **(b)** Calculate the maximum distance between the lens and the screen that produces a sharp image.
- **(c)** If the size of the slide is 7.8 cm^2, calculate the maximum size of the sharp image produced.

NOVEL CHALLENGE

A searchlight lights up the sky when used on Earth. What would you see if you did the same thing on the moon?

****27** Which of the following form virtual images when in normal use?
(a) The eye.
(b) The camera.
(c) The refracting telescope.
(d) A Galilean telescope.
(e) An enlarger.
(f) A microscope.

****28** Several eye defects are now being treated by the use of lasers. Research the use of lasers in modifying the cornea to enable people to see without spectacles.

****29** If you wanted to start a fire without matches you could use your friend's spectacles to concentrate rays of light from the sun. Is this possible if your friend has **(a)** hypermetropia; **(b)** myopia; **(c)** presbyopia? Explain each answer!

****30** Figure 20.15 can be used in determining the correct exposure when taking photos using a fast film. Use this figure to determine (with explanation) what an appropriate setting would be when the camera is used to take a photo of:
(a) a fast moving car in bright sunlight;
(b) a bird sitting in the branches of a tree;
(c) a flower in the field on an overcast day;
(d) a wedding couple on a bright sunny day.

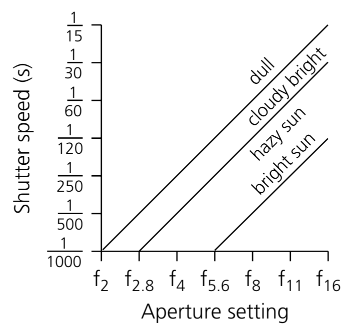


Figure 20.15
For question 30.

****31** In William Golding's *Lord of the Flies* the character Piggy uses his glasses to start a fire. Later the boys break Piggy's glasses but he cannot identify them at close range because he is short-sighted. Find the flaw in this narrative.

Extension — complex, challenging and novel

*****32** A coin collector wants to examine some old coins using a magnifying glass. If the magnifying glass has a focal length of 10 cm, where must the eye and coin be positioned to produce the largest sharpest image?

*****33** A student who is far-sighted needed to hold a book at a distance of 50 cm to be able to read. What focal length corrective lens is required to enable this student to read the book at the normal near point of 25 cm? Assume the distance between the lens and the eye is negligible.

*****34** Figure 20.16 shows the schematic diagram of an 'episcope' used to produce an image of a page of a book on a screen. Analyse the figure and explain how it operates.

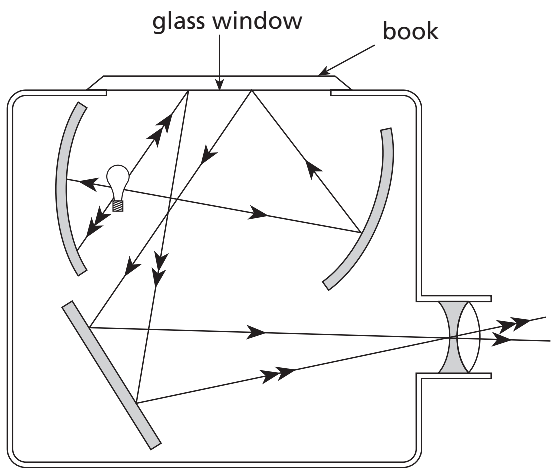


Figure 20.16
For question 34.

*****35** When you hold a pinhead close to your eye and let it be illuminated by light from a pinhole in some paper (see Figure 20.17) you see a strange image. The image is dark, magnified and inverted. Try it and offer some explanations.

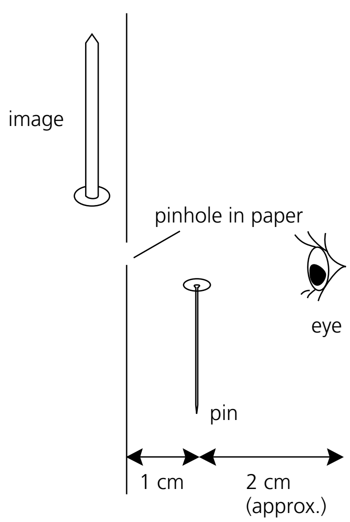


Figure 20.17
For question 35.