CHAPTER 15

Light — A Wave?

15.1 INTRODUCTION

Have you ever wondered about the following things concerning light?

- If a camera lens is made of clear glass, why does it look purple?
- Why do soap bubbles look so colourful?
- If you had a powerful enough microscope, could you see a single atom?
- How can light be both a wave and a particle? Surely it is one or the other?

In Chapter 14 we investigated the properties of two-dimensional waves; in particular, water waves. The reason for this was that they are easier to observe and investigate in the laboratory. It is now time to investigate the properties of light; in particular, visible light. However, visible light, the light that enables us to see objects, is just a small part of all the electromagnetic waves that are around us. Radio waves, microwaves, infrared waves, for example, all travel through space at the speed of 3×10^8 m s^{-1} and make up a part of that group of waves called electromagnetic waves.

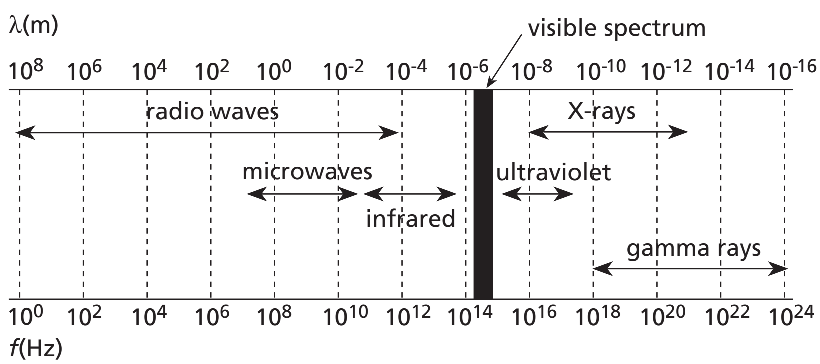
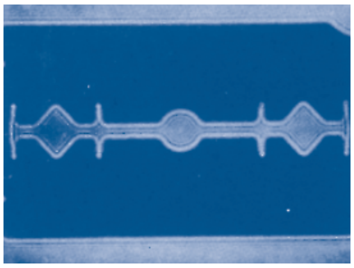


Figure 15.1
The electromagnetic spectrum.

But we seem to be jumping the gun. We are assuming that light travels through space by means of wave motion and not as particles. The particle nature of light is another issue and will be taken up in a later chapter. However, we can show that light does exhibit wave characteristics similar to those of water waves. Again, it is impossible to investigate the properties of all electromagnetic waves in a school laboratory, but we can investigate visible light waves as several of their effects can be seen with the unaided eye.

THE PROPERTIES OF LIGHT WAVES 15.2

Photo 15.1
Diffraction of light through a razor blade — the diffraction of light occurs around the edges of objects and through small apertures.



Light is a form of energy that propagates (travels) through empty space. The propagation of this energy does not require a medium, as proven by light energy from the Sun being able to reach us here on Earth where it can be converted to other forms such as heat used in solar hot water systems, or to electrical energy used by solar powered cars to race across the Northern Territory.

Several of those properties of water waves investigated in Chapter 14 can be applied to light and observed in the laboratory but this requires detailed observation as the wavelength of visible light waves ranges from 4×10^{-7} m to 7×10^{-7} m. These waves are much too small to be seen with the unaided eye.

Light waves or light rays can, like water waves, be reflected and refracted. This can very easily be seen in the laboratory using a laser or light boxes. However, these properties are not exclusive to wave characteristics and will be discussed in Chapters 17 and 18, where physical optics, such as the uses of mirrors, prisms, and lenses, are investigated.

In this chapter we will investigate the properties of light with respect to two distinct wave characteristics — **diffraction** and **interference**. If light has wave characteristics then the diffraction and interference of light waves should be observable.

DIFFRACTION OF LIGHT 15.3

Photo 15.2
The interference pattern produced by the diffraction of white light through a narrow slit.

Recall that diffraction is the bending of waves as they pass through an aperture or around the edge of an object in their path. This bending of waves is more noticeable if the wavelength of the waves is comparable to the size of the aperture. Also, if an object is placed in the path of the waves a 'shadow' is produced if the object is of the same size as the wavelength. (Revise Section 14.4.) Can this effect be observed with light? Remember, to observe this effect the slit or the object in front of the waves has to be of the same size as the wavelength of the waves, and light waves have very short wavelengths. However, this effect can be observed! Light does bend around the edges of objects to produce diffraction fringes. Objects seem to be blurred at the edges when light shone on them is focused on a screen. Photo 15.1 shows the diffraction fringes produced by white light passing the edges of a razor blade. The edges of the blade appear blurred and dark bands appear in the small apertures in the blade.

Diffraction of light can also be produced when light passes through a very narrow slit. Photo 15.2 shows the diffraction pattern produced on a screen when white light passes through a very narrow slit.

Photo 15.3
The diffraction pattern produced by a single slit using monochromatic (red) light from a laser.

Activity 15.1 FINGER FRINGES

1. Place your index and middle fingers very close together.
2. Put these fingers up close to one eye, close the other and look at a distant light.
3. Slowly start to separate these fingers and you will notice that black lines appear between your thinly separated two fingers. These are diffraction fringes.

You may have noticed at night in rainy weather how scratches on a car's windscreen produce long shafts of light, sometimes with black bands across them. This too is diffraction.

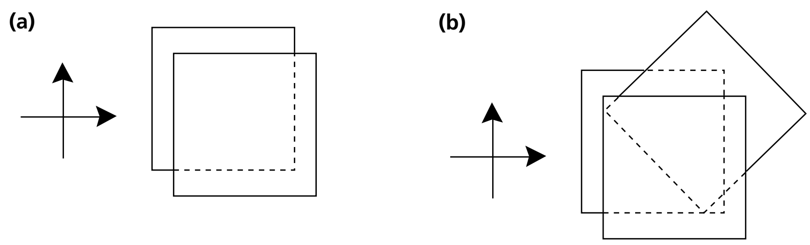
This pattern can be seen much more clearly if a laser and a commercially prepared narrow slit are used.

If different colours of light are used the pattern changes. If red light is used the pattern spreads out more than when blue light is used. Recall the diffraction of water waves. The larger the wavelength compared with the slit, the more the pattern spreads out and is noticeable. This would suggest that the wavelength of red light is larger than that of blue light. The reason these diffraction bands occur will be analysed in Section 15.5.

Activity 15.10 SUNGLASSES

If you have an old pair of Polaroid sunglasses, pop the lenses out and place them together. When they are rotated as shown in Figure 15.27 the amount of light passing through will vary.

1. Cut one of the lenses in half — now you have three pieces.
2. Cross one pair so that they go black (Figure 15.27 **(a)**).
3. Slide the third one in at an angle and note what happens (Figure 15.27 **(b)**). How on earth can this happen?
4. Try it in front and behind the crossed polarisers. What happens?



INVESTIGATING

The nematic crystals used in liquid crystal displays (e.g. your calculator) melt like all crystals. Put your calculator in the sun and watch the display go black. *At what temperature did this happen?*

Figure 15.27
For Activity 15.10.

Polaroid sunglasses

When wearing Polaroid sunglasses, annoying reflections from horizontal surfaces, such as shiny floors, wet roads, car bonnets, the ocean and the beach are eliminated. When sunlight reflects from these surfaces it becomes horizontally polarised because most of the other components are scattered. Polaroid sunglasses have their polarising plane vertical so as to block these reflections.

Camera filters

To reduce the brightness of light entering a camera, photographers sometimes use Polaroid filters which have polarisers that can be rotated. Light intensity can be reduced by rotating one of the polarisers. By doing this instead of closing the aperture down, the depth of field of the lens is not affected. The polarising filter is also used to reduce unwanted reflections from glass or water surfaces.

Liquid crystal display

The sort of display used in calculators and digital watches uses two pieces of Polaroid that are crossed. Room light passes through the top polariser, where it is then rotated through 90° by the liquid crystals before it strikes the bottom polariser. The bottom polariser is crossed with respect to the top polariser but because the liquid crystals have rotated the light through 90° the light passes through. Underneath the bottom layer is a mirror which reflects the room light back to the user. (See Figure 15.28.) When a voltage is applied to the crystals they stop rotating the light so it is blocked, and appears black. If you have a broken calculator check that it has Polaroid and mirrors in it.

Figure 15.28
Liquid crystal displays in calculators and digital watches use polarising filters. A voltage applied to the liquid controls the amount of light reflected back to the user.