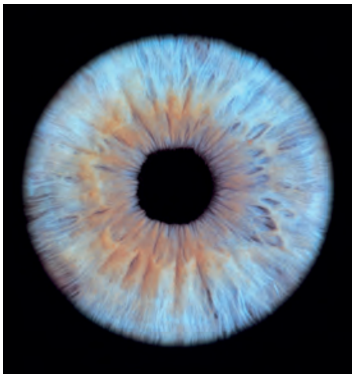
Appendix (Option A)

The eye and sight

Assessment statements

A.1.1 Describe the basic structure of the human eye.
A.1.2 State and explain the process of depth of vision and accommodation.
A.1.3 State that the retina contains rods and cones, and describe the variation in density across the surface of the retina.
A.1.4 Describe the function of the rods and of the cones in photopic and scotopic vision.
A.1.5 Describe colour mixing of light by addition and subtraction.
A.1.6 Discuss the effect of light and dark, and colour, on the perception of objects.



The coloured part of the eye is called the *iris* and it consists of a ring of muscle fibres that contract and relax to alter the amount of light entering the eye through the pupil.

When the human eye is viewed from the front, the pupil looks black. In fact it is a circular hole in the centre of the iris, and the black colour comes from a layer inside the eye that prevents internal reflections. If the intensity of incident light is high, then the iris reduces the size of the pupil; in low intensity light, the pupil dilates to allow more light to enter.

The front of the eye is covered with a layer of transparent skin called the *cornea*. The lens and the cornea both play a part in focusing light onto the retina at the back of the eye. The retina is the light-sensitive layer and it sends messages to the brain through the optic nerve.

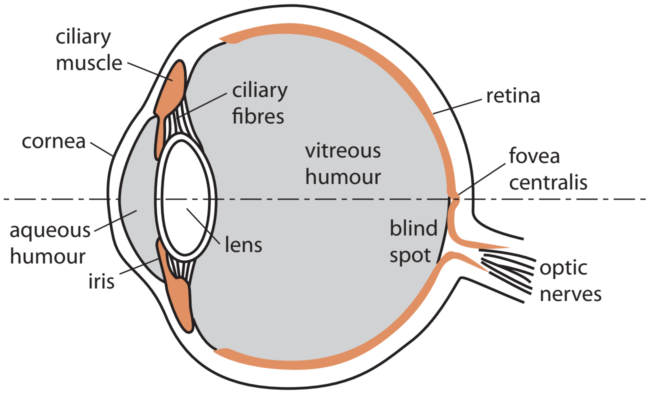


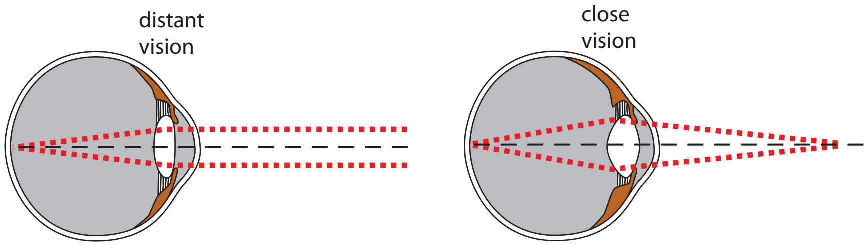
Figure 1 The human eye. The humours are transparent jellies that nourish the eye and keep its shape. The blind spot is where the optic nerve exits the eye and there is no retina. The fovea is directly opposite the centre of the lens and is sometimes called the yellow spot.

The lens in our eyes can change shape to enable us to focus on both near and far objects.

This process is called *accommodation*. When we look at a distant object, the ciliary muscles relax and the taut fibres make the lens longer and thinner. When we focus on something close to our eyes, the ciliary muscles contract and the lens changes shape to become shorter and thicker.

Modern laser surgery can reshape the cornea to correct many defects of vision and remove the need for glasses or contact lenses.

Figure 2 Rays of light from a distant object arrive at the eye effectively parallel, and so need less refraction than rays from an object close to the eye.



The near point is defined as the position where an object can be seen most clearly. As you are reading this page you are automatically holding it at your near point. If you hold it closer to your eyes it will appear blurred and if you hold it further away the writing will appear smaller and so more difficult to read.

The range over which the eye can focus is from the *near point* to the *far point*. For a normal eye, the far point is at infinity; we focus on the far point when the ciliary muscles are completely relaxed and the eye is not accommodating. The near point varies from person to person but is taken to be 25 centimetres.

Depth of vision

Depth of vision is the ability to see things in three dimensions. It is the perception of depth th at enables us to judge how far away things are, and this is crucially important when playing ball games or driving a car.

Using only one eye we can get some information about depth of vision. This is based on our previous experience and from cues we get from relative sizes of objects, perspective and relative motion between objects.

If the image from an object falls on the blind spot, it cannot be detected by the brain. With two eyes one compensates for the other, so we do not lose sight of things.

With two eyes we are able to obtain two images of the same thing and the brain is then able to judge distances and motion far more accurately. This is particularly important for nearby objects; for things that are far away there will not be a big difference in the images received by each eye.

Colour vision

People in different parts of the world literally see things differently. The indigenous peoples of the Australian and Kalahari deserts have been found to have exceptional long distance vision; useful when scanning the horizon for moving animals. People who have spent their whole life in the rainforest have been found to lack depth perspective. When they see animals at a distance on the plains, they simply assume that the animals are very small; they have no other means of making a judgement.

The retina contains two types of receptor cells called *rods* and *cones*. The rods detect motion, enable us to see in low light intensity and are responsible for peripheral vision (seeing things from the corner of our eyes). The cones are responsible for colour vision and also visual acuity. We need good visual acuity for reading the very small letters at the bottom of opticians' charts.

The fovea or yellow spot, located in the centre of the retina, consists entirely of cones. This is the part of the retina where our vision is most acute. Just a few degrees from the fovea, the concentration of rods is at a maximum and the rods spread out all around the rest of the retina with a gradually decreasing concentration.

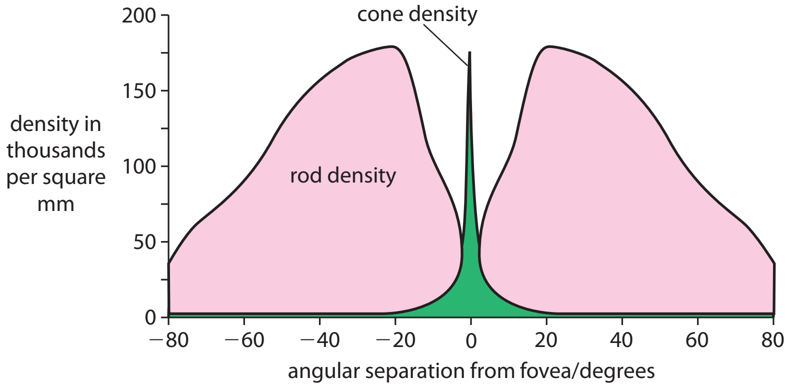


Figure 3 Variation in density of rods and cones across the retina. The diagram shows high density of cones in the fovea but low density elsewhere. There are no rods in the fovea but they are highly dense in other parts of the retina.

In each eye we have about 120 million rods but only about 6 million cones.

Experiments show that we have three types of cones in our retina. They are known as *blue*, *green* and *red* or as S, M and L which stands for short, medium and long, referring to the wavelength of light to which they are most sensitive.

There is overlap between the wavelengths to which each of the three types of cone responds and this enables the brain to perceive the full spectrum of colours. You can see from the diagram that both green and red cones respond to yellow light, but the blue cones do not respond to yellow or red light.

Photopic vision refers to colour vision under normal lighting and is the function of the cones. Scotopic vision refers to our ability to see in dim light, it is completely lacking in colour and is the function of the rods.

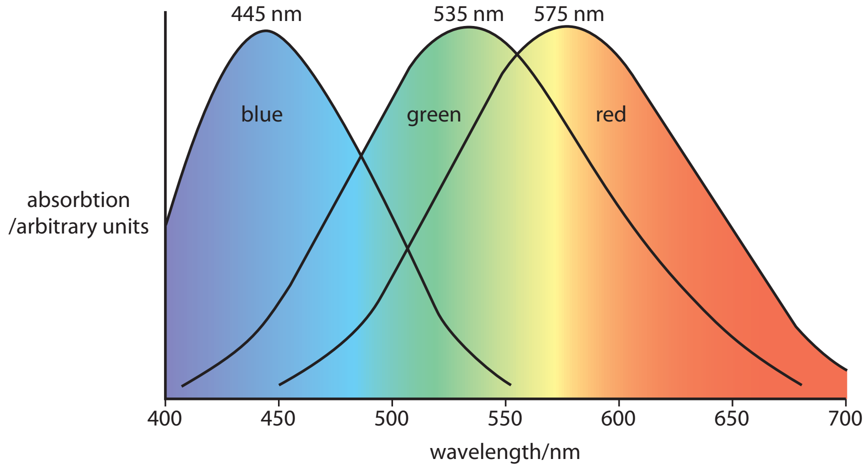


Figure 4 Spectral response curves for cones: each of the three types of cone responds to a different region of the visible spectrum.

Only 2% of our 6 million cones are for seeing blue, but since we appear to see equally well in the short end of the visible spectrum, the blue cones must be more sensitive.

- **Examiner's hint:** You need to be able to sketch and interpret this type of graph.

People who are colour-blind have difficulty in distinguishing between different colours. The most common type is red-green colour-blindness and is inherited. It stems from problems in the green and red cones and involves an inability to properly distinguish between reds, yellows and greens. There are other types of colour blindness but they are quite rare.

Some apes also have been found to have three types of cones, so they see colours in a similar way to us. Other animals see things very differently; the vision of bees extends into the ultraviolet region of the electromagnetic spectrum, while some snakes can see infrared. Sharks are apparently unable to detect any colours.

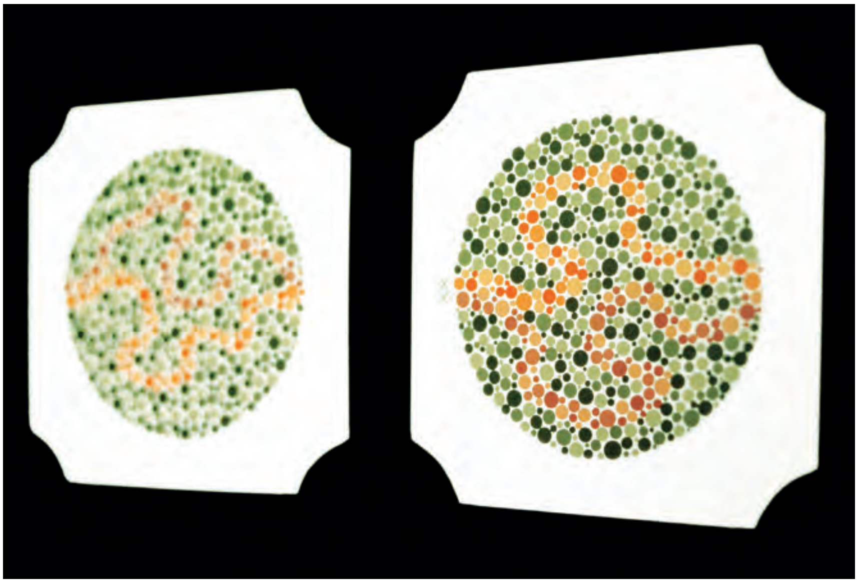
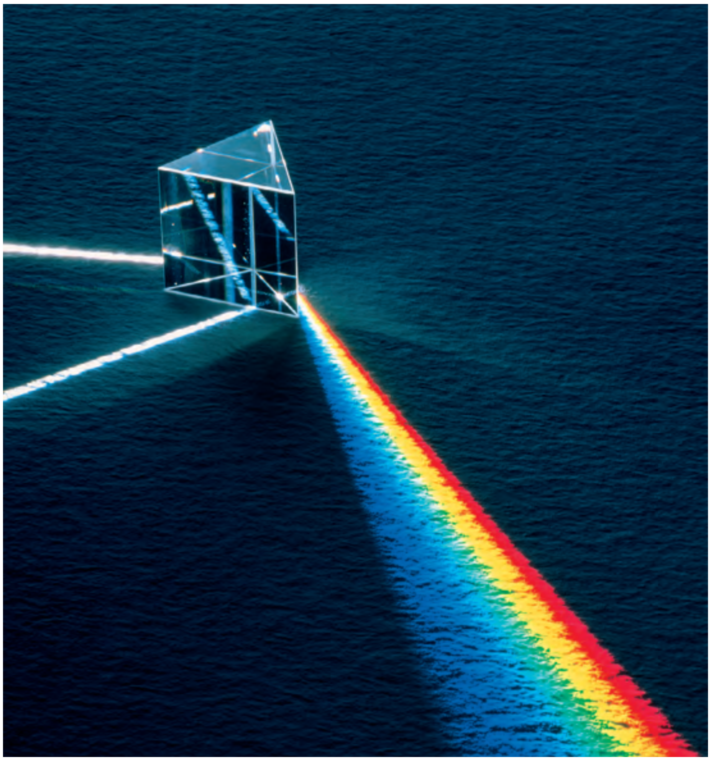


Figure 5 This is an example of a test used to see if people are colour-blind. A person with normal colour vision will be able to trace both the orange and red lines. A person who is colour-blind will find one line easier to follow than the other.



The white light is dispersed into the colours of the spectrum because different colours of light travel at different speeds in glass.

Colour mixing of light

White light is a mixture of all the colours of the visible spectrum. A prism can separate the colours by a process called *dispersion*.

If three projectors are arranged to shine red, green and blue light of the correct intensity onto a screen, the result will appear white. It is for this reason that these colours are called *primary colours*.

Mixing the three primary colours in pairs gives us the three secondary colours.

Colours of light can be subtracted by absorption using filters. The colour of light that is transmitted by the filter is the same as the colour of the filter itself. For example, if white light is shone through a red filter, then all the wavelengths will be absorbed except for red; only red light will be transmitted.

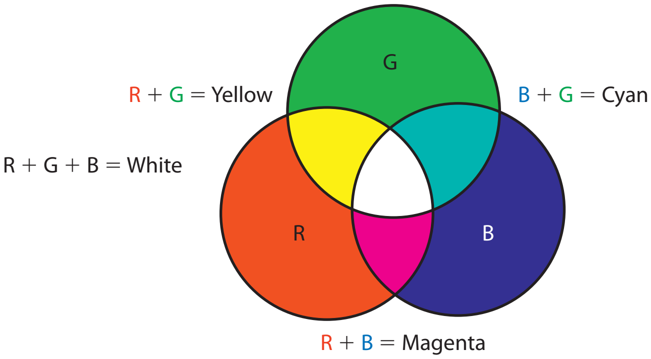


Figure 6 Adding red to green makes yellow. Adding red to blue makes magenta. Adding blue to green makes cyan. Adding all three together makes white. This is called additive colour mixing.

Red, green and blue are the primary colours of light.

Yellow, magenta and cyan are the secondary colours of light.

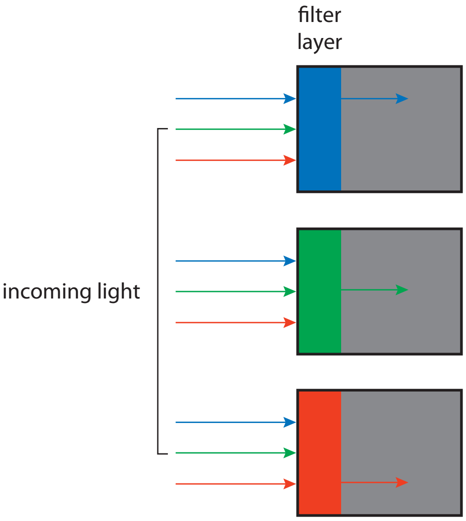


Figure 7 If a second green or blue filter is placed after the red filter, it will block the red light and then no light will be visible.

When white light passes through filters of the secondary colours, the wavelengths absorbed depend on the make up of the secondary colour. For example, magenta is made up of red and blue, so magenta transmits red and blue.

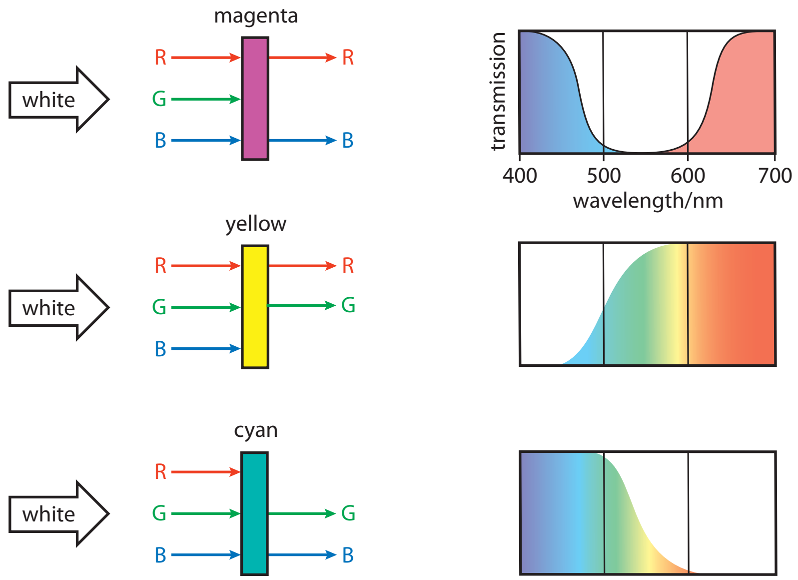


Figure 8 If another secondary filter is placed after the first one, then one primary colour will still be transmitted.

To view a fun simulation 'Color vision and filters', visit www.heinemann.co.uk/hotlinks, enter the express code 4426P and click on Weblink A.1.

Perception

Information collected by the eye is sent to the brain for processing. There is so much information coming in all the time that the brain must select what is relevant. Perception involves collection, selection and also organization and interpretation of the sensory input.

Light, shade and colour are used by artists, designers and architects to deliberately influence, and even alter, our perception of reality. For example, deep shadow in a painting, or in a church, can give the impression of massiveness.

Blue is perceived as a cold colour, orange and red glow can give the impression of warmth. A room can be made to appear bigger and lighter by the careful placing of mirrors and it can be made to appear higher by a light-coloured ceiling.

Sense perception is one of the ways of knowing. To what extent do our eyes give us knowledge of the world as it really is?

Exercises

1 Explain the process of accommodation in the human eye.

2 Distinguish between photopic and scotopic vision.

3 Sketch and label a graph to show the spectral response of cones in the human eye.