Answers to Coursebook questions – Chapter A1

1 **a** See page 472 in *Physics for the IB Diploma*. It must include, at least, the components iris, pupil, cornea, eye lens and retina.

b See pages 472–473 in *Physics for the IB Diploma*.

2 **a** The refractive index of the cornea (where most of the refraction in the eye takes place) is about the same as that of the surrounding water and so no refraction (and hence focusing) can take place.

b With a diving mask there is now air in between the eye and the water and so refraction takes place.

3 **a** Cone and rod cells are the light-sensitive cells that are responsible for vision. Cones are responsible for colour vision and detail and are used in high-intensity light. Rods are responsible for overall shape, are used in low-intensity light and cannot distinguish colour or much detail.

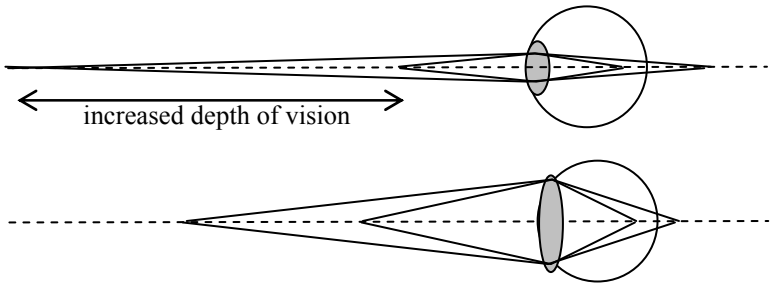
b Cones are found predominantly near where the principal axis of the eye meets the retina, whereas rods are found far from the principal axis.

4 An advantage is that the nerve can respond to low-intensity light (sine light is collected by very many rods). A disadvantage is the lack of detail in the image.

5 **a** **i** Depth of vision is the range of distances of objects from the eye within which the eye can focus relatively clearly without too much straining.

ii Accommodation is the ability of the eye to focus on objects at different distances by changing the focal length of the eye.

b The main reason is that with a smaller aperture the extreme rays (see figure) make smaller angles as they enter the eye.



c With an increase in the intensity of light the pupil diameter will decrease and so the depth of vision will increase.

6 **a** Vision under conditions of reduced light intensity.

b Vision under conditions of high light intensity.

7 With low-intensity light rods are the predominant light receptors. The rods, although they have a different response at different wavelengths, cannot convey this information to the brain in a way that can be interpreted as different colour. This is done by the cone cells which create an electrical voltage that is sent to the brain as a result of chemical changes in the pigment molecules found in cone cells. There are no such molecules in the rods and so no electrical voltage that can be interpreted as colour is created.

8 In high-intensity light the vision is mainly through the cone cells, and the majority of these are found along on the retina where it meets the principal axis of the eye, i.e. when an object is viewed directly.
In low-intensity light the rods are used and the large numbers of rod are found away from the principal axis, i.e. an object has to be viewed a bit 'sideways'.

9 **a** The inability of the eye to interpret differences in a coloured object.

b Colour blindness is associated with damaged cone cells since it is cone cells that are responsible for colour vision.

10 **a** The area of the fovea is about $\pi\frac{0.25^2}{4} = 0.0491\ \text{mm}^2$
and in this area there are $150000 \times 0.0491 = 7365$ cones
and so the area taken by one cone cell is about $\frac{0.0491}{7365} = 6.667\times10^{-6}\ \text{mm}^2$.
If R is the radius of a cone cell, then $\pi R^2 = 6.667\times10^{-6}\ \text{mm}^2 \Rightarrow R \approx 1.5\times10^{-6}\ \text{m}$.
The separation of cones then (centre to centre) is twice the radius,
i.e. $3.0\times10^{-6}\ \text{m}$.

b The angle is $\frac{3.0\times10^{-6}}{2.5\times10^{-2}} = 1.2\times10^{-4}\ \text{rad}$.

c $\theta = \frac{1.22\lambda}{d} = \frac{1.22\times5.5\times10^{-7}}{1.5\times10^{-3}} = 4.5\times10^{-4}\ \text{rad}$.

d The angular separation is smaller than the diffraction angle.
Even if the cones were closer to each other, diffraction would limit the ability of the eye to resolve objects very close to each other.

11 **a** See **Q5b**.

b Because as the hole gets smaller and smaller, diffraction will soon come into play.

12 **a** See **Figure A1.7** on page 476 in *Physics for the IB Diploma*.

b Reducing the intensity of light means using the rod cells. The rod cells are most sensitive for low wavelengths.

13 **a** The minimum number of colours which when mixed produces (almost) any other colour.

b With three primary colours almost all colours may be produced.

c Many other choices of other sets of three colours gives almost all other colours upon mixing.

14 **a** At a wavelength of 420 nm the spectral curve that has the highest response is that for blue cones; hence this creates the sensation of 'blue'.

b At a wavelength of 680 nm it is the red cones that respond the most, giving the sensation of 'red'.

15 **a** Colour addition means mixing different colours in order to produce a new colour.

b Colour subtraction refers (usually) to white light that has one or more colour components removed when transmitted though as filter.

16 **a** $C = B + G$ and $Y = R + G$,
so $C + Y = (B + G) + (R + G) = (B + G + R) + G = W + G = G$, i.e. green.

b $C = B + G$ and $M = B + R$,
so $C + M = (B + G) + (B + R) = (B + G + R) + B = W + B = B$, i.e. blue.

17 Magenta subtracts green and cyan subtracts red,
so the light will be $B + G + R - G - R = B$, i.e. blue.

18 We need to subtract blue and red so we need a yellow filter and a cyan filter.

19 **a** $C = B + G$, $Y = R + G$ and $M = B + R$,
so $Y + C + M = R + G + B + G + B + R = W$.

b Nothing will get transmitted, i.e. black.

20 This is up to you!

21 Also up to you!

22 They do not look equally bright even though they are. This shows that the response of the eye depends on the background the object finds itself in. (Rod cells contain a photosensitive pigment called rhodopsin which breaks down when the rod cells receive high intensities of light. With essentially all of the rhodopsin in the rods broken down, the rods will not respond to any **further** increase in intensity. By contrast, in low-intensity light there is still unbroken-down rhodopsin and so the rods can still respond to a further change in intensity. This means that the rods adjust to the **prevailing conditions of light intensity** and respond differently depending on what the background is.)

