Physics 122
Chapter 25
Problem Solutions

Q4 A young normal or normally corrected eye has sufficient accommodation to focus close enough to the face to obviate the need for further correction. An older lens, being stiffer, allows for less accommodation and so even a normal eye cannot focus closely enough for many everyday tasks such as reading. If the eye is already being corrected for myopia or hyperopia, a second correction may be needed for near vision.

Q7 Squinting reduces the aperture of the lens thereby reducing the circle of confusion and sharpening the image. See page 699 for a diagram and explanation of circle of confusion.

Q12 If the plane surface is toward the distant object the light rays will be nearly parallel to that surface and they will pass through with very little refraction. If the lens is turned around the rays will be refracted toward the optical axis by the first (curved) surface and they will then refract when they encounter the flat surface.

The angle through which a given ray bends at the curved surface is unchanged by the orientation of the lens but if the curved side is encountered first then there will be some refraction at the flat surface. This means that the focal length gets shorter when the curved surface is toward the incident light.

If we compare two lenses that each have the same focal length where one has the flat side toward the incoming light and the second has the curved side toward the incoming light we will see that each individual refraction in the second lens will be something like half the size of the refraction at the curved surface in the first lens. The curvature of the first lens would have to be greater to get the larger refraction and so the spherical aberration will be worse.

Q14 The law of refraction (Snell's Law) includes a dependence on the index of refraction which in turn depends upon wavelength. (See Q13 in chapter 24) Thus there is chromatic aberration in lenses. The law of reflection has no reference to wavelength and so treats all wavelengths equally.

P11 The difference here is the extra 2cm from contact lens to the uncorrected far point compared to the distance from the lens in the glasses. See the worked out example on page 703. With this change, the focal length of the contect lens will be -17cm instead of -15cm for the glasses.

For the near point calculation, replace the focal length with -17cm, and the image distance with 12cm (the actual near point distance rather than the glasses-near point distance). The new near point is 41cm. This is worse than the 32cm for the glasses.

P20 This is rather similar to problem 11. The focal length of the lens contact lens is -25cm. (Why is that[*]?) The contact lens will form a virtual image from the object some distance away. If this image is between 10cm and 20cm from the eye we will be able to focus it onto the retina. As the object moves farther from the eye the virtual image, formed by the contact lens, will move away as well. The farthest the object can be moved will be its location when the resulting virtual image is 20cm from the eye.

So, the new far point distance is found by letting the image distance be the old (uncorrected) far point distance and solving for the object distance. Keep in mind that the image distance is negative. The near point distance works in just the same way. The far point distance with correction is 100cm. The near point distance with correction is 17cm.

P28 Begin by finding the focal length of the lens. You will need a standard near point distance to do this. It is generally taken to be 25cm.

$$M_{Standard} = \frac{NP_{Standard}}{f}$$

$$f = \frac{NP_{Standard}}{M_{Standard}}$$

Now find the magnifications for the new near point distances.

$$\begin{aligned} M_{55} &= \frac{NP_{55}}{f} \\ &= M_{Standard}\left(\frac{NP_{55}}{NP_{Standard}}\right) \\ &= 3.0\left(\frac{55cm}{25cm}\right) \\ &= 6.6 \end{aligned}$$

Similarly, the magnification for a near point distance of 16cm is 1.9.

P29 The magnification for a telescope is given by $-\frac{f_{Objective}}{f_{Eyepiece}}$. For these focal lengths that is -27.

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[*] See page 648 paragraph 3.

The telescope is focused at infinity when the focal points of the lenses overlap. The tube length is the sum of the focal lengths or 78.8cm.

P37 If we write down the magnification and the tube length for the telescope (see problem 29) we will have two equations in the two focal lengths and so we can find them.

$$M = -\frac{f_{Obj}}{f_{EP}} \qquad \text{(P37-1)}$$

$$L_{Tube} = f_{Obj} + f_{EP} \qquad \text{(P37-2)}$$

Solve (P37-1) for the f_{Obj} ,

$$f_{Obf} = -M \cdot f_{EP} \qquad \text{(P37-3)}$$

substitute into (P37-2), and solve for the focal length of the eyepiece.

$$L_{Tube} = f_{EP}\left(1 - M\right)$$

$$f_{EP} = \frac{L_{Tube}}{1 - M}$$

Now use this result with (P37-3) to get the focal length of the objective.

$$f_{Obj} = \frac{-M \cdot L_{Tube}}{1 - M}$$

Notice that the magnification is taken to be -170 as this type of telescope gives an inverted image. The focal length of the eyepiece is 7.31mm and that of the objective is 124.3cm.

P43 We know that the image formed by the objective lens is to fall on the focal point of the eyepiece. Let *l* be the length of the tube. Then we want the image distance to be this minus the focal length of the eyepiece. Thus

$$d_o = \frac{f_{Obj} \cdot d_i}{d_i - f_{Obj}}$$

becomes

$$d_o = \frac{f_{Obj}(l - f_{EP})}{(l - f_{EP}) - f_{Obj}}$$

Inserting the supplied values gives an object distance of 8.5mm. The magnification is given by the product of the magnifications of the two lenses.

The approximate magnification uses the tube length for the image distance of the objective lens and the focal length of the objective lens for the object distance.

$$M \cong \frac{NP \cdot l}{f_{Obj} \cdot f_{EP}}$$

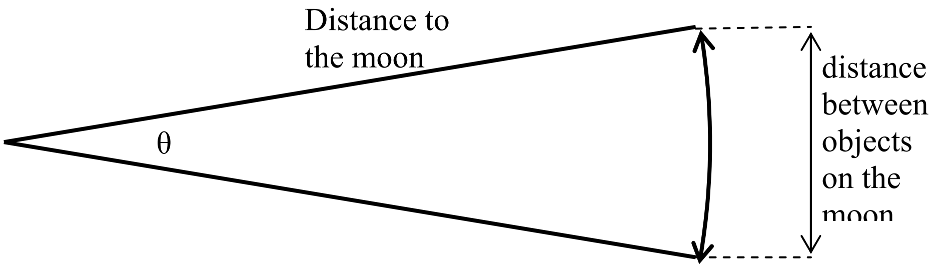
With the supplied values this is 278.

P70 Using the Rayleigh criterion[†] for resolution of objects we have an angular separation of

$$\theta = 1.22\frac{\lambda}{D}$$

We have been told that the wavelength to consider is $550 \cdot 10^{-9}$m and that the diameter of the telescope is 2.4m. This gives us an angular resolution limit of $2.8 \cdot 10^{-7}$ radians.

How far apart are two object on the moon if, from Earth, they have that angular separation?



For a very small angle, the arc length is nearly the same as distance between the objects. The arc length is just the angle in radians times the distance to the moon[‡].

The object separation on the moon for resolvable objects is 10.7cm.

[†] See section 25-7.

[‡] See the inside front cover of your book.