

SOLUTIONS TO CONCEPTS CHAPTER 19

1. The visual angles made by the tree with the eyes can be calculated be below.

$$\theta = \frac{\text{Height of the tree}}{\text{Distance from the eye}} = \frac{AB}{OB} \Rightarrow \theta_A = \frac{2}{50} = 0.04$$

similarly, $\theta_B = 2.5 / 80 = 0.03125$

$$\theta_C = 1.8 / 70 = 0.02571$$

$$\theta_D = 2.8 / 100 = 0.028$$

Since, $\theta_A > \theta_B > \theta_D > \theta_C$, the arrangement in decreasing order is given by A, B, D and C.

2. For the given simple microscope,

$$f = 12 \text{ cm and } D = 25 \text{ cm}$$

For maximum angular magnification, the image should be produced at least distance of clear vision.

$$\text{So, } v = -D = -25 \text{ cm}$$

$$\text{Now, } \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{u} = \frac{1}{v} - \frac{1}{f} = \frac{1}{-25} - \frac{1}{12} = -\frac{37}{300}$$

$$\Rightarrow u = -8.1 \text{ cm}$$

So, the object should be placed 8.1 cm away from the lens.

3. The simple microscope has, $m = 3$, when image is formed at $D = 25 \text{ cm}$

$$\text{a) } m = 1 + \frac{D}{f} \Rightarrow 3 = 1 + \frac{25}{f}$$

$$\Rightarrow f = 25/2 = 12.5 \text{ cm}$$

- b) When the image is formed at infinity (normal adjustment)

$$\text{Magnifying power} = \frac{D}{f} = \frac{25}{12.5} = 2.0$$

4. The child has $D = 10 \text{ cm}$ and $f = 10 \text{ cm}$

The maximum angular magnification is obtained when the image is formed at near point.

$$m = 1 + \frac{D}{f} = 1 + \frac{10}{10} = 1 + 1 = 2$$

5. The simple microscope has magnification of 5 for normal relaxed eye ($D = 25 \text{ cm}$).

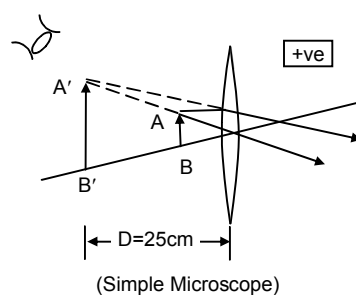
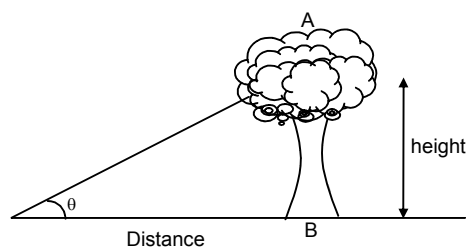
Because, the eye is relaxed the image is formed at infinity (normal adjustment)

$$\text{So, } m = 5 = \frac{D}{f} = \frac{25}{f} \Rightarrow f = 5 \text{ cm}$$

For the relaxed farsighted eye, $D = 40 \text{ cm}$

$$\text{So, } m = \frac{D}{f} = \frac{40}{5} = 8$$

So, its magnifying power is 8X.



6. For the given compound microscope

$$f_o = \frac{1}{25 \text{ diopter}} = 0.04 \text{ m} = 4 \text{ cm}, f_e = \frac{1}{5 \text{ diopter}} = 0.2 \text{ m} = 20 \text{ cm}$$

$D = 25 \text{ cm}$, separation between objective and eyepiece = 30 cm

The magnifying power is maximum when the image is formed by the eye piece at least distance of clear vision i.e. $D = 25 \text{ cm}$

for the eye piece, $v_e = -25 \text{ cm}$, $f_e = 20 \text{ cm}$

For lens formula, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$$\Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} \Rightarrow \frac{1}{-25} - \frac{1}{20} \Rightarrow u_e = 11.11 \text{ cm}$$

So, for the objective lens, the image distance should be

$$v_o = 30 - (11.11) = 18.89 \text{ cm}$$

Now, for the objective lens,

$$v_o = +18.89 \text{ cm} \text{ (because real image is produced)}$$

$$f_o = 4 \text{ cm}$$

$$\text{So, } \frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} \Rightarrow \frac{1}{18.89} - \frac{1}{4} = 0.053 - 0.25 = -0.197$$

$$\Rightarrow u_o = -5.07 \text{ cm}$$

So, the maximum magnifying power is given by

$$m = -\frac{v_o}{u_o} \left[1 + \frac{D}{f_e} \right] = -\frac{18.89}{-5.07} \left[1 + \frac{25}{20} \right] = 3.7225 \times 2.25 = 8.376$$

7. For the given compound microscope

$$f_o = 1 \text{ cm}, f_e = 6 \text{ cm}, D = 24 \text{ cm}$$

For the eye piece, $v_e = -24 \text{ cm}$, $f_e = 6 \text{ cm}$

Now, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$$\Rightarrow \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} \Rightarrow -\left[\frac{1}{24} + \frac{1}{6} \right] = -\frac{5}{24}$$

$$\Rightarrow u_e = -4.8 \text{ cm}$$

- a) When the separation between objective and eye piece is 9.8 cm , the image distance for the objective lens must be $(9.8) - (4.8) = 5.0 \text{ cm}$

Now, $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$

$$\Rightarrow \frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{5} - \frac{1}{1} = -\frac{4}{5}$$

$$\Rightarrow u_o = -\frac{5}{4} = -1.25 \text{ cm}$$

So, the magnifying power is given by,

$$m = \frac{v_o}{u_o} \left[1 + \frac{D}{f_e} \right] = \frac{-5}{-1.25} \left[1 + \frac{24}{6} \right] = 4 \times 5 = 20$$

- (b) When the separation is 11.8 cm ,

$$v_o = 11.8 - 4.8 = 7.0 \text{ cm}, f_o = 1 \text{ cm}$$

$$\Rightarrow \frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{7} - \frac{1}{1} = -\frac{6}{7}$$

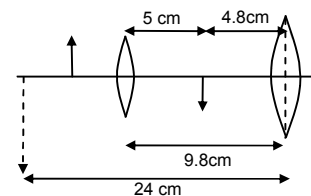
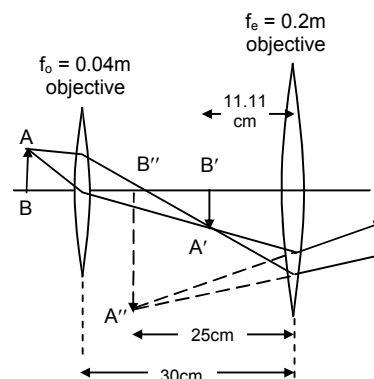


Fig-A

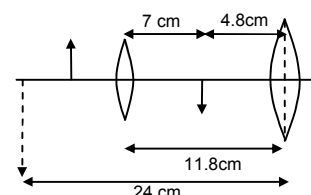


Fig-B

$$\text{So, } m = -\frac{v_0}{u_0} \left[1 + \frac{D}{f} \right] = \frac{-7}{-\left(\frac{7}{6}\right)} \left[1 + \frac{24}{6} \right] = 6 \times 5 = 30$$

So, the range of magnifying power will be 20 to 30.

8. For the given compound microscope.

$$f_0 = \frac{1}{20D} = 0.05 \text{ m} = 5 \text{ cm}, \quad f_e = \frac{1}{10D} = 0.1 \text{ m} = 10 \text{ cm}.$$

$D = 25 \text{ cm}$, separation between objective & eyepiece = 20 cm

For the minimum separation between two points which can be distinguished by eye using the microscope, the magnifying power should be maximum.

For the eyepiece, $v_e = -25 \text{ cm}$, $f_e = 10 \text{ cm}$

$$\text{So, } \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{10} = -\left[\frac{2+5}{50}\right] \Rightarrow u_e = -\frac{50}{7} \text{ cm}$$

So, the image distance for the objective lens should be,

$$V_0 = 20 - \frac{50}{7} = \frac{90}{7} \text{ cm}$$

Now, for the objective lens,

$$\frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{7}{90} - \frac{1}{5} = -\frac{11}{90}$$

$$\Rightarrow u_0 = -\frac{90}{11} \text{ cm}$$

So, the maximum magnifying power is given by,

$$m = \frac{-v_0}{u_0} \left[1 + \frac{D}{f_e} \right]$$

$$= \frac{\left(\frac{90}{7}\right)}{\left(-\frac{90}{11}\right)} \left[1 + \frac{25}{10} \right]$$

$$= \frac{11}{7} \times 3.5 = 5.5$$

Thus, minimum separation eye can distinguish = $\frac{0.22}{5.5} \text{ mm} = 0.04 \text{ mm}$

9. For the give compound microscope,

$f_0 = 0.5 \text{ cm}$, tube length = 6.5 cm

magnifying power = 100 (normal adjustment)

Since, the image is formed at infinity, the real image produced by the objective lens should lie on the focus of the eye piece.

So, $v_0 + f_e = 6.5 \text{ cm}$... (1)

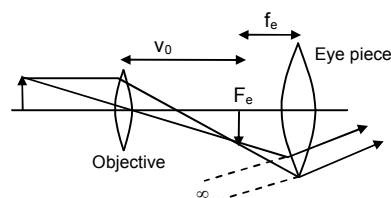
Again, magnifying power = $\frac{v_0}{u_0} \times \frac{D}{f_e}$ [for normal adjustment]

$$\Rightarrow m = -\left[1 - \frac{v_0}{f_0} \right] \frac{D}{f_e} \quad \left[\because \frac{v_0}{u_0} = 1 - \frac{v_0}{f_0} \right]$$

$$\Rightarrow 100 = -\left[1 - \frac{v_0}{0.5} \right] \times \frac{25}{f_e} \quad [\text{Taking } D = 25 \text{ cm}]$$

$$\Rightarrow 100 f_e = -(1 - 2v_0) \times 25$$

$$\Rightarrow 2v_0 - 4f_e = 1 \quad \dots (2)$$



Solving equation (1) and (2) we can get,

$$V_0 = 4.5 \text{ cm and } f_e = 2 \text{ cm}$$

So, the focal length of the eye piece is 2cm.

10. Given that,

$$f_o = 1 \text{ cm, } f_e = 5 \text{ cm, } u_o = 0.5 \text{ cm, } v_e = 30 \text{ cm}$$

For the objective lens, $u_o = -0.5 \text{ cm, } f_o = 1 \text{ cm}$.

From lens formula,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{v_o} = \frac{1}{u_o} + \frac{1}{f_o} = \frac{1}{-0.5} + \frac{1}{1} = -1$$

$$\Rightarrow v_o = -1 \text{ cm}$$

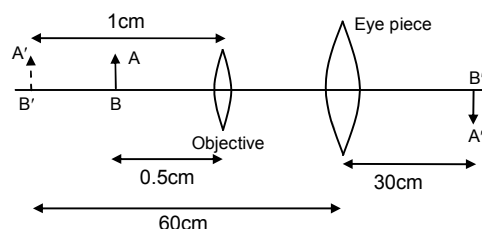
So, a virtual image is formed by the objective on the same side as that of the object at a distance of 1 cm from the objective lens. This image acts as a virtual object for the eyepiece.

For the eyepiece,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{30} - \frac{1}{5} = \frac{-5}{30} = \frac{-1}{6} \Rightarrow u_o = -6 \text{ cm}$$

So, as shown in figure,

$$\text{Separation between the lenses} = u_o - v_o = 6 - 1 = 5 \text{ cm}$$



11. The optical instrument has

$$f_o = \frac{1}{25D} = 0.04 \text{ m} = 4 \text{ cm}$$

$$f_e = \frac{1}{20D} = 0.05 \text{ m} = 5 \text{ cm}$$

tube length = 25 cm (normal adjustment)

(a) The instrument must be a microscope as $f_o < f_e$

(b) Since the final image is formed at infinity, the image produced by the objective should lie on the focal plane of the eye piece.

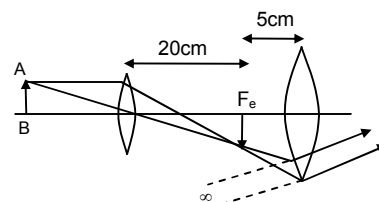
So, image distance for objective = $v_o = 25 - 5 = 20 \text{ cm}$

Now, using lens formula.

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{20} - \frac{1}{4} = \frac{-4}{20} = \frac{-1}{5} \Rightarrow u_o = -5 \text{ cm}$$

$$\text{So, angular magnification} = m = -\frac{v_o}{u_o} \times \frac{D}{f_e} \quad [\text{Taking } D = 25 \text{ cm}]$$

$$= -\frac{20}{-5} \times \frac{25}{5} = 20$$



12. For the astronomical telescope in normal adjustment.

Magnifying power = $m = 50$, length of the tube = $L = 102 \text{ cm}$

Let f_o and f_e be the focal length of objective and eye piece respectively.

$$m = \frac{f_o}{f_e} = 50 \Rightarrow f_o = 50 f_e \quad \dots(1)$$

$$\text{and, } L = f_o + f_e = 102 \text{ cm} \quad \dots(2)$$

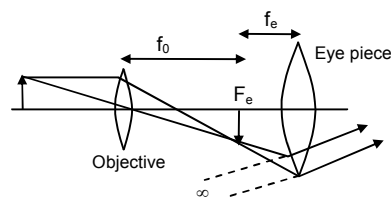
Putting the value of f_o from equation (1) in (2), we get,

$$f_o + f_e = 102 \Rightarrow 51f_e = 102 \Rightarrow f_e = 2 \text{ cm} = 0.02 \text{ m}$$

$$\text{So, } f_o = 100 \text{ cm} = 1 \text{ m}$$

$$\therefore \text{Power of the objective lens} = \frac{1}{f_o} = 1D$$

$$\text{And Power of the eye piece lens} = \frac{1}{f_e} = \frac{1}{0.02} = 50D$$



13. For the given astronomical telescope in normal adjustment,
 $F_e = 10 \text{ cm}$, $L = 1 \text{ m} = 100 \text{ cm}$
 $S_0, f_0 = L - f_e = 100 - 10 = 90 \text{ cm}$
 and, magnifying power $= \frac{f_0}{f_e} = \frac{90}{10} = 9$
14. For the given Galilean telescope, (When the image is formed at infinity)
 $f_0 = 30 \text{ cm}$, $L = 27 \text{ cm}$
 Since $L = f_0 - |f_e|$
 [Since, concave eyepiece lens is used in Galilean Telescope]
 $\Rightarrow f_e = f_0 - L = 30 - 27 = 3 \text{ cm}$
15. For the far sighted person,
 $u = -20 \text{ cm}$, $v = -50 \text{ cm}$
 from lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
 $\frac{1}{f} = \frac{1}{-50} - \frac{1}{-20} = \frac{1}{20} - \frac{1}{50} = \frac{3}{100} \quad \Rightarrow f = \frac{100}{3} \text{ cm} = \frac{1}{3} \text{ m}$
 So, power of the lens $= \frac{1}{f} = 3 \text{ Diopter}$
16. For the near sighted person,
 $u = \infty$ and $v = -200 \text{ cm} = -2 \text{ m}$
 So, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-2} - \frac{1}{\infty} = -\frac{1}{2} = -0.5$
 So, power of the lens is -0.5 D
17. The person wears glasses of power -2.5 D
 So, the person must be near sighted.
 $u = \infty$, $v = \text{far point}$, $f = \frac{1}{-2.5} = -0.4 \text{ m} = -40 \text{ cm}$
 Now, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
 $\Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = 0 + \frac{1}{-40} \Rightarrow v = -40 \text{ cm}$
 So, the far point of the person is 40 cm
18. On the 50th birthday, he reads the card at a distance 25 cm using a glass of $+2.5 \text{ D}$.
 Ten years later, his near point must have changed.
 So after ten years,
 $u = -50 \text{ cm}$, $f = \frac{1}{2.5 \text{ D}} = 0.4 \text{ m} = 40 \text{ cm}$ $v = \text{near point}$
 Now, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{-50} + \frac{1}{40} = \frac{1}{200}$
 So, near point $= v = 200 \text{ cm}$
 To read the farewell letter at a distance of 25 cm ,
 $U = -25 \text{ cm}$
 For lens formula,
 $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{200} - \frac{1}{-25} = \frac{1}{200} + \frac{1}{25} = \frac{9}{200} \Rightarrow f = \frac{200}{9} \text{ cm} = \frac{2}{9} \text{ m}$
 $\Rightarrow \text{Power of the lens} = \frac{1}{f} = \frac{9}{2} = 4.5 \text{ D}$
 \therefore He has to use a lens of power $+4.5 \text{ D}$.

19. Since, the retina is 2 cm behind the eye-lens

$$v = 2\text{cm}$$

- (a) When the eye-lens is fully relaxed

$$u = \infty, \quad v = 2\text{cm} = 0.02 \text{ m}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.02} - \frac{1}{\infty} = 50\text{D}$$

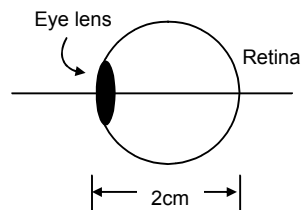
So, in this condition power of the eye-lens is 50D

- (b) When the eye-lens is most strained,

$$u = -25 \text{ cm} = -0.25 \text{ m}, \quad v = +2 \text{ cm} = +0.02 \text{ m}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.02} - \frac{1}{-0.25} = 50 + 4 = 54\text{D}$$

In this condition power of the eye lens is 54D.



20. The child has near point and far point 10 cm and 100 cm respectively.

Since, the retina is 2 cm behind the eye-lens, $v = 2\text{cm}$

For near point $u = -10 \text{ cm} = -0.1 \text{ m}$, $v = 2 \text{ cm} = 0.02 \text{ m}$

$$\text{So, } \frac{1}{f_{\text{near}}} = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.02} - \frac{1}{-0.1} = 50 + 10 = 60\text{D}$$

For far point, $u = -100 \text{ cm} = -1 \text{ m}$, $v = 2 \text{ cm} = 0.02 \text{ m}$

$$\text{So, } \frac{1}{f_{\text{far}}} = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.02} - \frac{1}{-1} = 50 + 1 = 51\text{D}$$

So, the range of power of the eye-lens is +60D to +51D

21. For the near sighted person,

v = distance of image from glass

= distance of image from eye – separation between glass and eye

$$= 25 \text{ cm} - 1\text{cm} = 24 \text{ cm} = 0.24\text{m}$$

So, for the glass, $u = \infty$ and $v = -24 \text{ cm} = -0.24\text{m}$

$$\text{So, } \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-0.24} - \frac{1}{\infty} = -4.2 \text{ D}$$

22. The person has near point 100 cm. It is needed to read at a distance of 20cm.

- (a) When contact lens is used,

$$u = -20 \text{ cm} = -0.2\text{m}, \quad v = -100 \text{ cm} = -1 \text{ m}$$

$$\text{So, } \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-1} - \frac{1}{-0.2} = -1 + 5 = +4\text{D}$$

- (b) When spectacles are used,

$$u = -(20 - 2) = -18 \text{ cm} = -0.18\text{m}, \quad v = -100 \text{ cm} = -1 \text{ m}$$

$$\text{So, } \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-1} - \frac{1}{-0.18} = -1 + 5.55 = +4.5\text{D}$$

23. The lady uses +1.5D glasses to have normal vision at 25 cm.

So, with the glasses, her least distance of clear vision = $D = 25 \text{ cm}$

$$\text{Focal length of the glasses} = \frac{1}{1.5} \text{ m} = \frac{100}{1.5} \text{ cm}$$

So, without the glasses her least distance of distinct vision should be more

$$\text{If, } u = -25\text{cm}, \quad f = \frac{100}{1.5} \text{ cm}$$

$$\text{Now, } \frac{1}{v} - \frac{1}{u} = \frac{1}{f} = \frac{1.5}{100} - \frac{1}{25} = \frac{1.5 - 4}{100} = \frac{-2.5}{100} \Rightarrow v = -40\text{cm} = \text{near point without glasses.}$$

$$\text{Focal length of magnifying glass} = \frac{1}{20} \text{ m} = 0.05\text{m} = 5 \text{ cm} = f$$

(a) The maximum magnifying power with glasses

$$m = 1 + \frac{D}{f} = 1 + \frac{25}{5} = 6 \quad [\because D = 25\text{cm}]$$

(b) Without the glasses, $D = 40\text{cm}$

$$\text{So, } m = 1 + \frac{D}{f} = 1 + \frac{40}{5} = 9$$

24. The lady can not see objects closer than 40 cm from the left eye and 100 cm from the right eye.

For the left glass lens,

$$v = -40 \text{ cm}, \quad u = -25 \text{ cm}$$

$$\therefore \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-40} - \frac{1}{-25} = \frac{1}{25} - \frac{1}{40} = \frac{3}{200} \quad \Rightarrow f = \frac{200}{3} \text{ cm}$$

For the right glass lens,

$$v = -100 \text{ cm}, \quad u = -25 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-100} - \frac{1}{-25} = \frac{1}{25} - \frac{1}{100} = \frac{3}{100} \quad \Rightarrow f = \frac{100}{3} \text{ cm}$$

(a) For an astronomical telescope, the eye piece lens should have smaller focal length. So, she should use the right lens ($f = \frac{100}{3} \text{ cm}$) as the eye piece lens.

(b) With relaxed eye, (normal adjustment)

$$f_o = \frac{200}{3} \text{ cm}, \quad f_e = \frac{100}{3} \text{ cm}$$

$$\text{magnification} = m = \frac{f_o}{f_e} = \frac{(200/3)}{(100/3)} = 2$$

