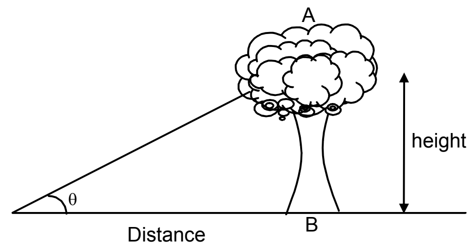
SOLUTIONS TO CONCEPTS
CHAPTER 19

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



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

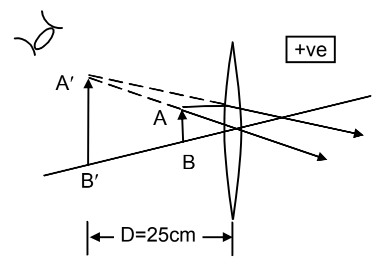
similarly, θ_B = 2.5 / 80 = 0.03125

θ_C = 1.8 / 70 = 0.02571

θ_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,



(Simple Microscope)

f = 12 cm and D = 25 cm

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

So, v = – D = –25 cm

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 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 cm

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

$\Rightarrow$ f = 25/2 = 12.5 cm

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

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

4. The child has D = 10 cm and f = 10 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 cm).

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

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

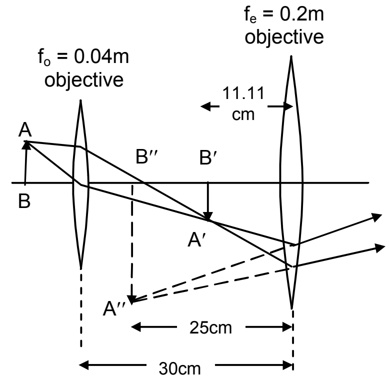
For the relaxed farsighted eye, D = 40 cm

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

So, its magnifying power is 8X.

6. For the given compound microscope

$f_0 = \frac{1}{25 \text{ diopter}} = 0.04 \text{ m} = 4 \text{ cm}$, $f_e = \frac{1}{5 \text{ diopter}} = 0.2 \text{ m} = 20 \text{ cm}$



D = 25 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 cm

for the eye piece, v_e = –25 cm, f_e = 20 cm

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

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

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

v_0 = 30 – (11.11) = 18.89 cm

Now, for the objective lens,

v_0 = +18.89 cm (because real image is produced)

f_0 = 4 cm

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 cm

So, the maximum magnificent 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 cm, f_e = 6 cm, D = 24 cm

For the eye piece, v_e = –24 cm, f_e = 6 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 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 cm

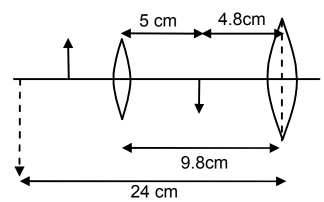


Fig-A

Now, $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\Rightarrow \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{5} - \frac{1}{1} = -\frac{4}{5}$

$\Rightarrow u_0 = -\frac{5}{4} = -1.25 \text{ cm}$

So, the magnifying power is given by,

$m = \frac{v_0}{u_0}\left[1 + \frac{D}{f}\right] = \frac{-5}{-1.25}\left[1 + \frac{24}{6}\right] = 4 \times 5 = 20$

(b) When the separation is 11.8 cm,

v_0 = 11.8 – 4.8 = 7.0 cm, f_0 = 1 cm

$\Rightarrow \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{7} - \frac{1}{1} = -\frac{6}{7}$

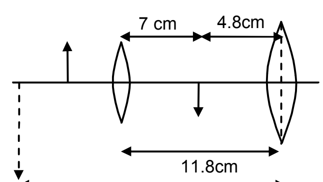


Fig-B

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

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 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, $v_0 = -25$ cm, $f_e = 10$ cm

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

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

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

Now, for the objective lens,

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

$\Rightarrow u_0 = -\frac{90}{11}$ 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 = $\frac{0.22}{5.5}$ mm = 0.04 mm

9. For the give compound microscope,

f_0 = 0.5cm, tube length = 6.5cm

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, $v_0 + f_e = 6.5$ cm …(1)

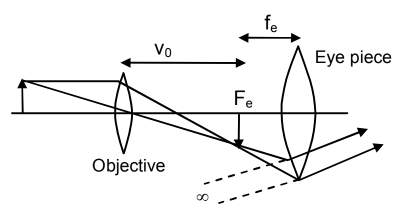
Again, magnifying power= $\frac{v_0}{u_0} \times \frac{D}{f_e}$ [for normal adjustment]

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

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

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

$\Rightarrow 2v_0 - 4f_e = 1$ …(2)



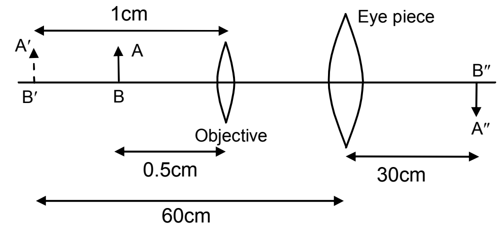
Solving equation (1) and (2) we can get,

V_0 = 4.5 cm and f_e = 2 cm

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

10. Given that,

f_o = = 1 cm, f_e = 5 cm, u_0 = 0.5 cm, v_e = 30 cm



For the objective lens, u_0 = – 0.5 cm, f_0 = 1 cm.

From lens formula,

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \quad \Rightarrow \frac{1}{v_0} = \frac{1}{u_0} + \frac{1}{f_0} = \frac{1}{-0.5} + \frac{1}{1} = -1$$

$\Rightarrow v_0 = -1$ 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,

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \quad \Rightarrow \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{30} - \frac{1}{5} = \frac{-5}{30} = \frac{-1}{6} \quad \Rightarrow u_0 = -6 \text{ cm}$$

So, as shown in figure,

Separation between the lenses = $u_0 - v_0$ = 6 – 1 = 5 cm

11. The optical instrument has

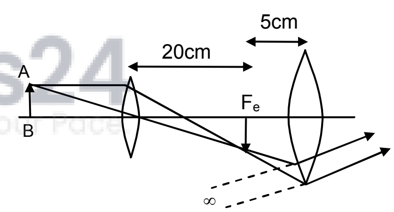
$$f_0 = \frac{1}{25D} = 0.04 \text{ m} = 4 \text{ cm}$$

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

tube length = 25 cm (normal adjustment)

(a) The instrument must be a microscope as $f_0 < f_e$

(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_0 = 25 – 5 = 20 cm

Now, using lens formula.

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \quad \Rightarrow \frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0} = \frac{1}{20} - \frac{1}{4} = \frac{-4}{20} = \frac{-1}{5} \quad \Rightarrow u_0 = -5 \text{ cm}$$

So, angular magnification = $m = -\frac{v_0}{u_0} \times \frac{D}{f_e}$ [Taking D = 25 cm]

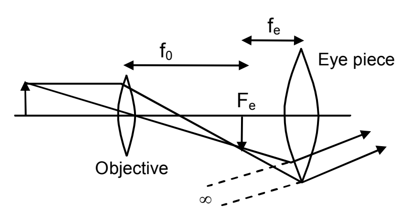
$$= -\frac{20}{-5} \times \frac{25}{5} = 20$$

12. For the astronomical telescope in normal adjustment.

Magnifying power = m = 50, length of the tube = L = 102 cm

Let f_0 and f_e be the focal length of objective and eye piece respectively.

$$m = \frac{f_0}{f_e} = 50 \Rightarrow f_0 = 50 f_e \quad \ldots(1)$$



and, L = $f_0 + f_e$ = 102 cm …(2)

Putting the value of f_0 from equation (1) in (2), we get,

$f_0 + f_e = 102 \Rightarrow 51f_e = 102 \Rightarrow f_e$ = 2 cm = 0.02 m

So, f_0 = 100 cm = 1 m

$$\therefore \text{ Power of the objective lens} = \frac{1}{f_0} = 1D$$

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

13. For the given astronomical telescope in normal adjustment,
F_e = 10 cm, L = 1 m = 100cm
S0, $f_0 = L - f_e = 100 - 10 = 90$ 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 cm, L = 27 cm
Since $L = f_0 - |f_e|$
[Since, concave eyepiece lens is used in Galilean Telescope]
$\Rightarrow f_e = f_0 - L = 30 - 27 = 3$ cm

15. For the far sighted person,
u = – 20 cm, v = – 50 cm
from lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
$\frac{1}{f} = \frac{1}{-50} - \frac{1}{-20} = \frac{1}{20} - \frac{1}{50} = \frac{3}{100}$ $\Rightarrow f = \frac{100}{3}$ cm = $\frac{1}{3}$ m
So, power of the lens = $\frac{1}{f}$ = 3 Diopter

16. For the near sighted person,
u = ∞ and v = – 200 cm = – 2m
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 –0.5D

17. The person wears glasses of power –2.5D
So, the person must be near sighted.
u = ∞, v = far point, $f = \frac{1}{-2.5}$ = – 0.4m = – 40 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 cm
So, the far point of the person is 40 cm

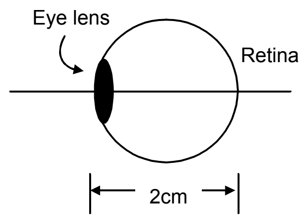
18. On the 50^{th} birthday, he reads the card at a distance 25cm using a glass of +2.5D.
Ten years later, his near point must have changed.
So after ten years,
u = – 50 cm, $f = \frac{1}{2.5D}$ = 0.4m = 40 cm v = near point
Now, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{-50} + \frac{1}{40} = \frac{1}{200}$
So, near point = v = 200cm
To read the farewell letter at a distance of 25 cm,
U = – 25 cm
For lens formula,
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{200} - \frac{-}{-25} = \frac{1}{200} + \frac{1}{25} = \frac{9}{200}$ $\Rightarrow f = \frac{200}{9}$ cm = $\frac{2}{9}$ m
$\Rightarrow$ Power of the lens = $\frac{1}{f} = \frac{9}{2}$ = 4.5D
$\therefore$ He has to use a lens of power +4.5D.

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

$v = 2cm$

(a) When the eye-lens is fully relaxed

$u = \infty$, $v = 2cm = 0.02$ m



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

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

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

$u = -25$ cm $= -0.25$ m, $v = +2$ cm $= +0.02$ m

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

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 = 2cm

For near point $u = -10$ cm $= -0.1$ m, $v = 2$ cm $= 0.02$ m

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

For far point, $u = -100$ cm $= -1$ m, $v = 2$ cm $= 0.02$ m

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

So, the rage 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 cm – 1cm = 24 cm = 0.24m

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

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

$u = -20$ cm $= -0.2$m, $v = -100$ cm $= -1$ m

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

(b) When spectacles are used,

$u = -(20 - 2) = -18$ cm $= -0.18$m, $v = -100$ cm $= -1$ m

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

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 cm

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

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

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

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

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

(a) The maximum magnifying power with glasses

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

(b) Without the glasses, D = 40cm

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 cm, u = – 25 cm

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

For the right glass lens,

v = – 100 cm, u = – 25 cm

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

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

(b) With relaxed eye, (normal adjustment)

$f_0 = \frac{200}{3}$ cm, $f_e = \frac{100}{3}$ cm

magnification = $m = \frac{f_0}{f_e} = \frac{(200/3)}{(100/3)} = 2$

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