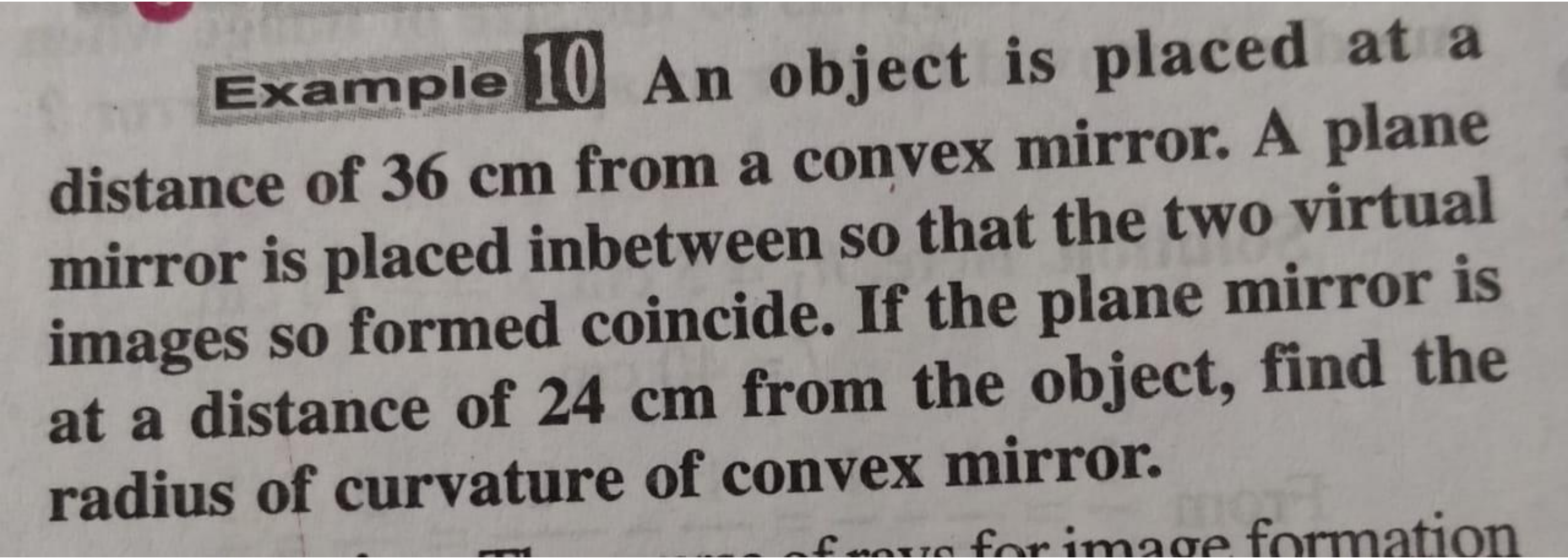
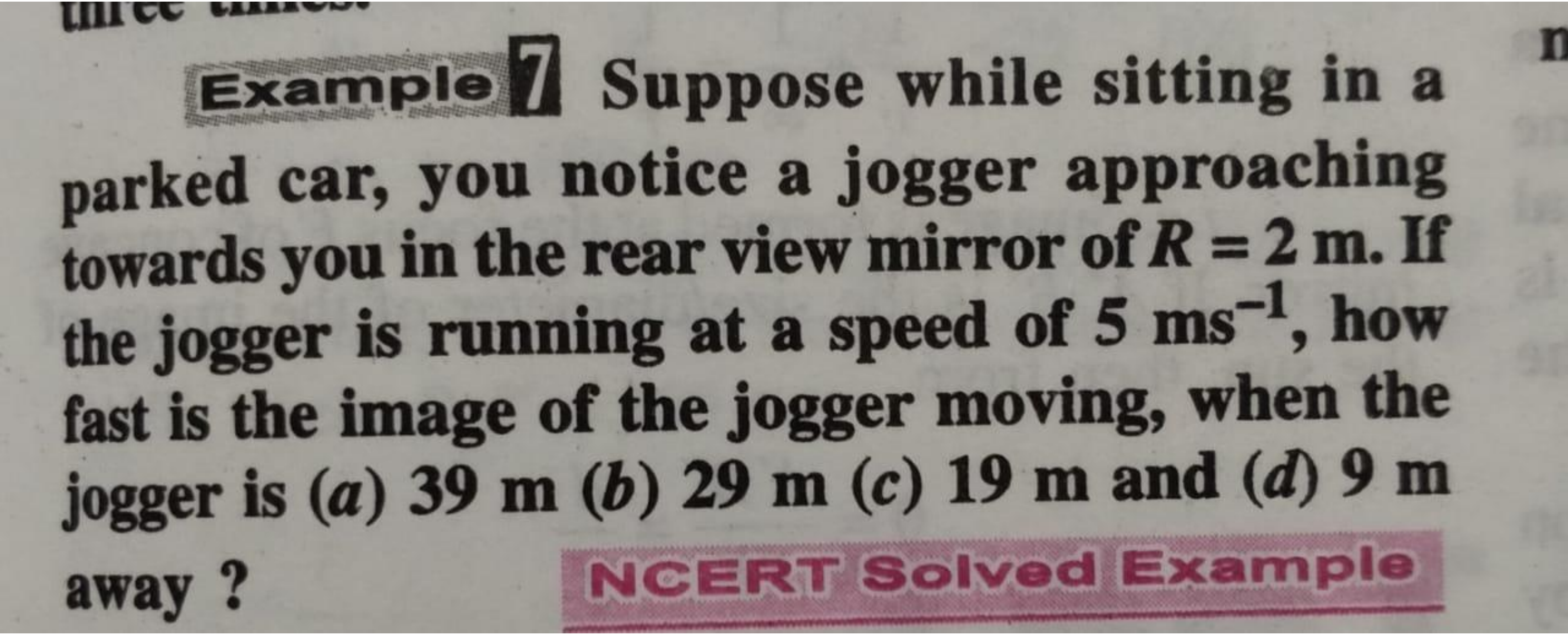
Session 26: Ray Optics – Optical Instruments

- Recap
- Optical Instruments
  - Microscopes
    - Simple
    - Compound
  - Telescopes
    - Astronomical
    - Terrestrial
    - Galilean
    - Cassegrain’s



Example 10 An object is placed at a distance of 36 cm from a convex mirror. A plane mirror is placed inbetween so that the two virtual images so formed coincide. If the plane mirror is at a distance of 24 cm from the object, find the radius of curvature of convex mirror.

of rays for image formation

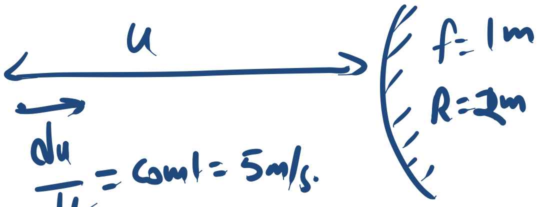


three times.

Example 7 Suppose while sitting in a parked car, you notice a jogger approaching towards you in the rear view mirror of $R = 2$ m. If the jogger is running at a speed of 5 ms^{-1}, how fast is the image of the jogger moving, when the jogger is (*a*) 39 m (*b*) 29 m (*c*) 19 m and (*d*) 9 m away ?

NCERT Solved Example

Ex 2.



$$\frac{du}{dt} = \text{const} = 5 m/s.$$

Rear View Mirror

$$\frac{dv}{dt} = -m^2 \frac{du}{dt}.$$

$$m = \frac{f}{f-u}$$

$$v = \frac{uf}{u-f}.$$

$u = -39, -29, -19, -9$

$f = +1m.$

$$m_1 = \frac{1}{1+39}, \frac{1}{1+29}, \frac{1}{1+19}, \frac{1}{1+9}$$

$$= \frac{1}{40}, \frac{1}{30}, \frac{1}{20}, \frac{1}{10}.$$

$$\frac{dv}{dt} = -\frac{1}{40^2} \times 5 = \frac{-1}{320} m/s.$$

$$\frac{1}{30^2} \times 5$$

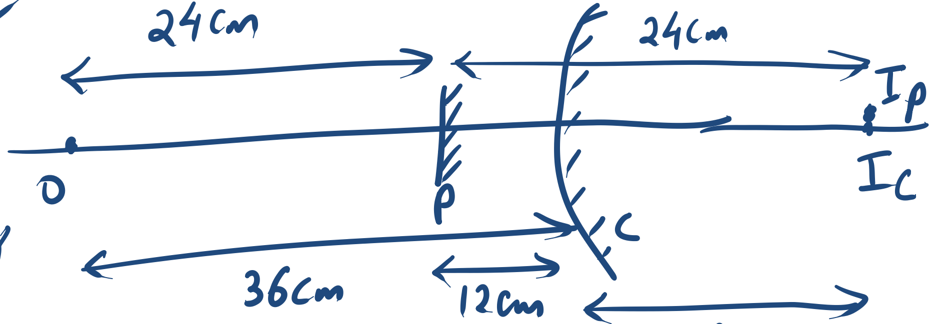
$$\frac{1}{180} m/s$$

16 8

320
280
147
+80
150 5

6

Ex 1



$v_1 < 36cm$

$\boxed{R = 2f}$ R?

$v + 12 = 24$

$v = 12 cm.$

$u = -36cm.$

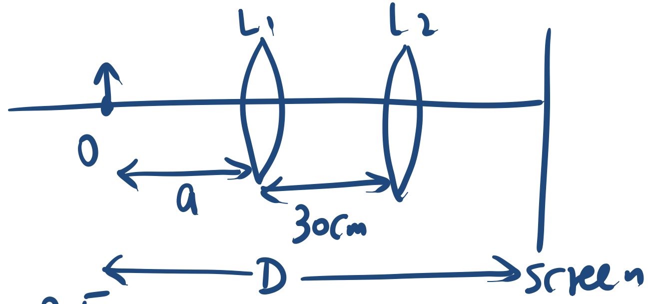
$$f = \frac{uv}{u+v} = \frac{(-36) \times 12}{-36+12} = \frac{+36 \times 12}{+24}$$

6 3

$= 18cm$

$\boxed{R = 36cm}$.

Ex 3



$m = 2.5$

$f = ?$

$m_1 m_2 = 1$

$m_1 = \frac{5}{2}$

$m_2 = 2/5$

$d = 30cm.$

$$f = \frac{D^2 - d^2}{4D}$$

for L2. $-\frac{2}{5} = \frac{D-30-a}{-(30+a)}$

for L1 $-\frac{5}{2} = \frac{D-a}{-a}$

$+5a = 2D - 2a$

$2D = +7a.$

$2(30+a) = 5(D-30-a)$

$60 + 2a = 5D - 150 - 5a$

$7a = 5D - 210$

$2D = 5D - 210$

$\boxed{D = 70}$

$a = \frac{2 \times 70}{7} = 20cm$

$$f = \frac{70^2 - 30^2}{4 \times 70}$$

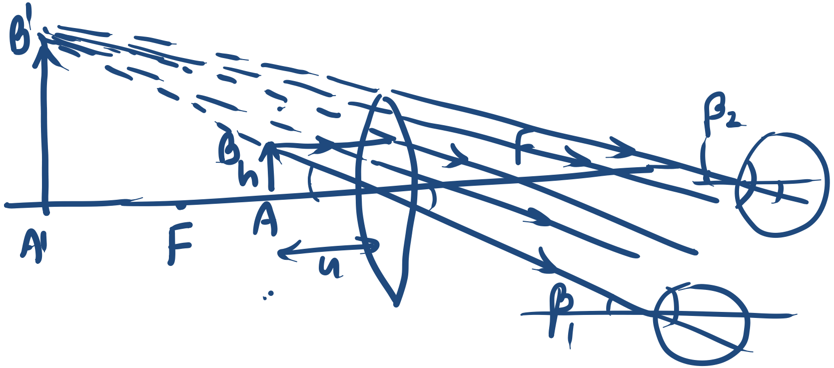
$= 14.3cm$

Microscopes

→ It is used magnify tiny objects or increase the visual angle of the object.

Simple (Only one convex lens)

Compound (Two or more than two convex lenses).



$\beta_1 \gtrless \beta_2$

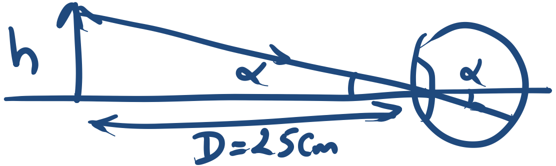
?

$\beta_1 \rightarrow$ Max^m visual angle of all others.

Ex. Visual angle will be more in which case?

obj

$-\infty$ $-D$.



Max^m visual angle ~~for~~ naked eye = $\alpha \simeq \frac{h}{D}$

Max^m " " with Simple microscope = $\beta_1 = \frac{h}{|u|}$

Magnifying power = M.P. = $\frac{\beta}{\alpha}$

$$= \frac{\text{Max}^{m}\text{ visual angle with an instrument}}{\text{Max}^{m}\text{ visual " with naked eye.}}$$

$$\boxed{\begin{aligned} D &= 25\text{cm} \\ &= \text{LDDV} \end{aligned}}$$

$\beta_{max} = \frac{h}{|u|}$ $\alpha_{max} = \frac{h}{D}$.

(M.P.) Simple Microscope $= \frac{h/|u|}{h/D} = \frac{D}{|u|}$.

↳ +ve. (∵ virtual erect img).

A'B' image → 1). when image @ $-\infty$., $u = -|u|$, $v = -\infty$, $f = f$

$-\infty$ $-D$.

$$\frac{1}{-\infty} - \frac{1}{-|u|} = \frac{1}{f}$$

$$\frac{1}{|u|} = \frac{1}{f} \Rightarrow \boxed{M.P. = \frac{D}{f}}$$

2). when image @ $-D$, $u = -|u|$, $v = -D$, $f = f$

$$\frac{1}{-D} - \frac{1}{-|u|} = \frac{1}{f}$$

$$\frac{1}{|u|} = \frac{1}{D} + \frac{1}{f} \Rightarrow \boxed{M.P. = 1 + \frac{D}{f}}$$

Compound Microscope :- Used to get even more magnified image of small object.

- Two lenses are used
- both are convex
  - objective lens
  - eyepiece lens
  - both the lenses have small focal lengths & small aperture.

M.P. = (Linear magnification of obj lens) × (Angular Magnification of eye piece lens)

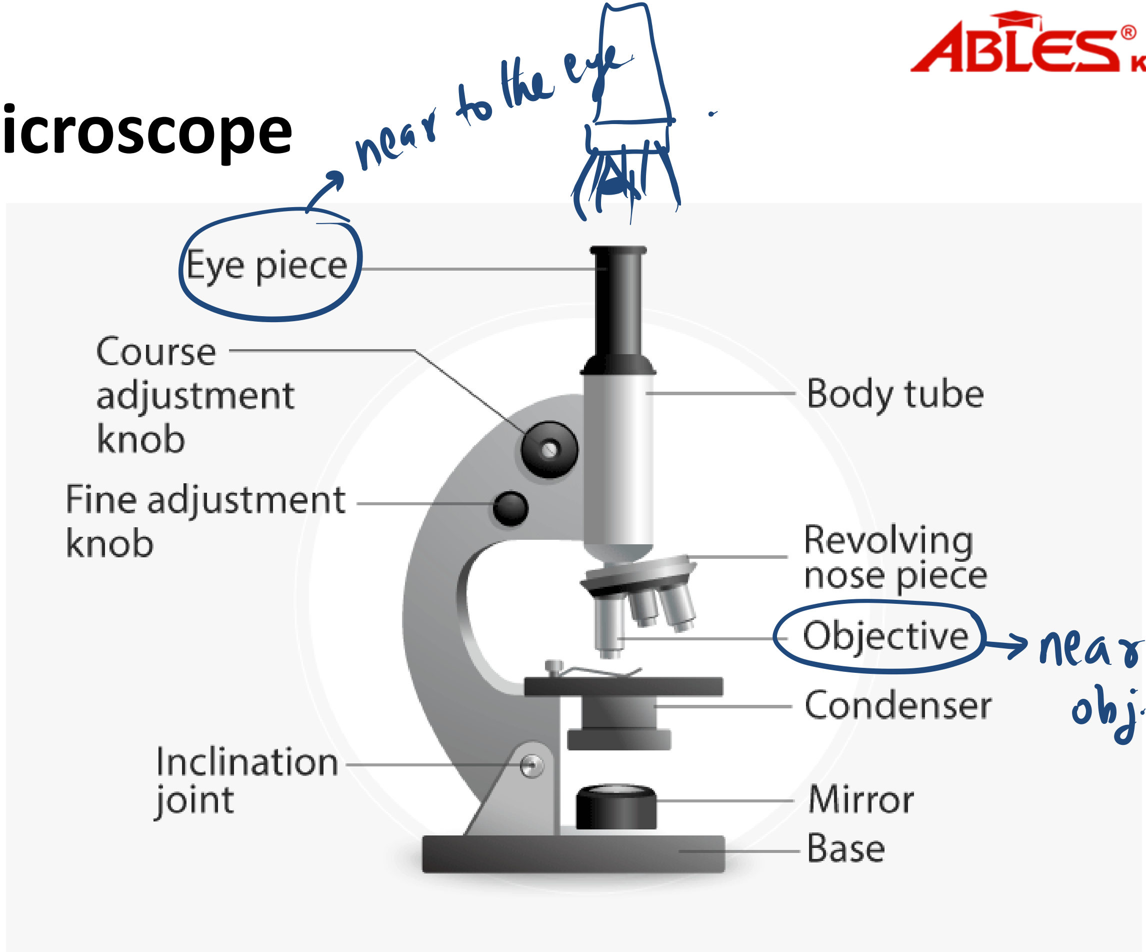
M.P. → Angular Magnification (−ve).

$$\underbrace{\left(\frac{v_0}{u_0}\right)}_{(-ve)} \times \underbrace{\left(\frac{\beta}{\alpha}\right)}_{(+ve).} = \frac{v_0}{u_0}\left(\frac{D}{|u_e|}\right)$$

$\xrightarrow{}$ img @ $-\infty \rightarrow \frac{v_0}{u_0}\left(D/f_e\right)$

$\xrightarrow{}$ img @ $-D \rightarrow \frac{v_0}{u_0}\left(1 + D/f_e\right)$.

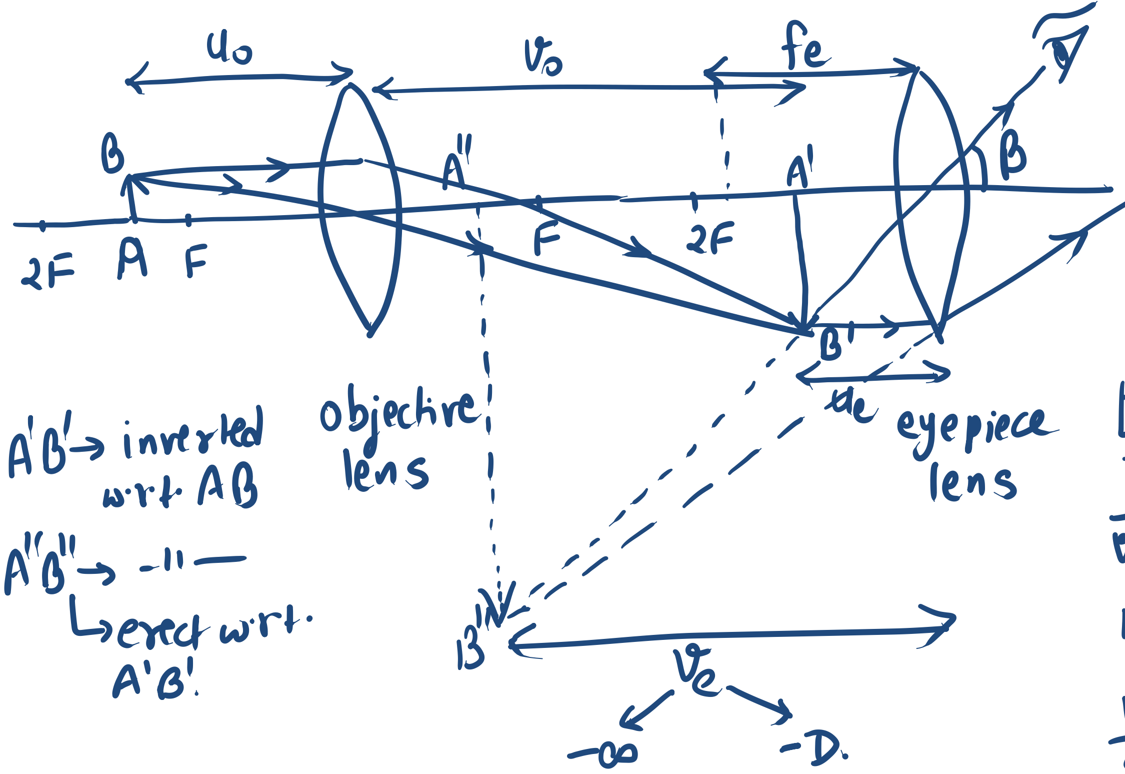
Compound Microscope



near to the eye

near to obj.

Compound Microscope - Ray Diagram



A'B' → inverted w.r.t. AB

A''B'' → -‖—
↳ erect w.r.t. A'B'.

$$\boxed{M.P. = \frac{v_o}{u_o} \times \frac{D}{|u_e|}}$$

A''B'' @ ∞

$$\boxed{M.P. = \frac{v_o}{u_o}\left(\frac{D}{f_e}\right)}$$

A''B'' @ -D

$$\boxed{M.P. = \frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)}$$

Lens formula for obj lens

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

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

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

Estimate

$v_o >> f_o$

$\Rightarrow |v_o/f_o| >> 1$

$\Rightarrow \frac{v_o}{u_o} \simeq -\frac{v_o}{f_o}$

v_o is almost equal to the (L) length of tube (f_e is small)
& $v_o \in (2F, \infty)$

$$\boxed{\text{As } f_e\downarrow \;\&\; f_o\downarrow \;\; \text{M.P.}\uparrow}$$

$$\frac{v_o}{u_o} \approx -\frac{v_o}{f_o} \approx -\frac{L}{f_o}$$

$$L = v_o + f_e$$

$$\begin{tikzcd} \text{M.P.} = \left(-\frac{L}{f_o}\right)\frac{D}{|u_e|} \arrow[r, "\text{img @ } -\infty"] \arrow[dr, "\text{img @ } -D"'] & \boxed{-\frac{LD}{f_o f_e}} \\ & \boxed{-\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)} \end{tikzcd}$$

$$L = v_o + |u_e|$$

$$\boxed{L = v_o + \frac{f_e D}{f_e + D}} \checkmark$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Big\} \text{ for eyepiece.}$$

$$\left.\begin{aligned} v &= -D \\ u &= -|u_e| \\ f &= f_e \end{aligned}\right\} \Rightarrow |u_e| = \frac{fv}{f-v} = \frac{f_e(-D)}{f_e+D}$$

$$= \left|\frac{-f_e D}{f_e + D}\right|$$