1. Projector: object between f and $2f$.

a)

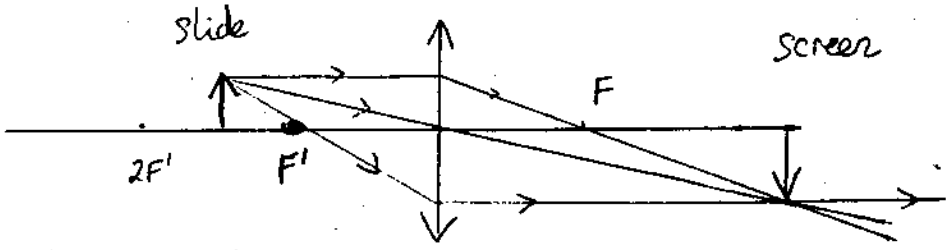


Image is real, inverted, magnified (formed beyond $2F$).

b) $\frac{1}{s_o} = \frac{1}{f} - \frac{1}{s_i}$ with $f = +125\,mm$, $s_i = 3000\,mm$

$\Rightarrow s_o = 130.4\,mm$ (just beyond F' ✓).

c) For slide object height $y_o = 35mm$, image height

$y_i = M_T y_o = (-)\frac{s_i}{s_o} \cdot y_o = -\frac{3000}{130.4} \times 35mm$

i.e. $y_i = (-)805\,mm$.

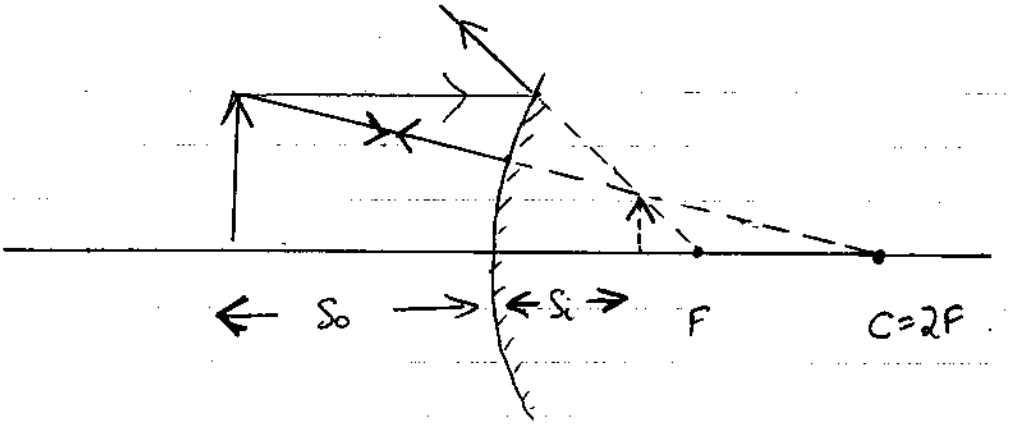
Note: Given a fixed image distance s_i, image height is fixed by the projector's focal length. Some projectors vary focal length by using 2 lenses in series and changing their separation:

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

- see formula in Hecht for f

2

a)



b) We require $M_T = -s_i/s_o = 1/3$ when $s_o = 5m$

So for $s_o = 5m$, $s_i = -5/3\ m$

Then $\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{5} - \frac{3}{5} \Rightarrow f = -2.5m$

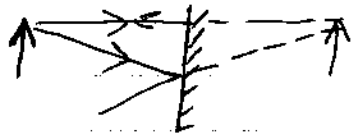
c) Use $s_i = -M_T s_o$ in the mirror equation

i.e. $\frac{1}{-M_T s_o} = \frac{1}{f} - \frac{1}{s_o} = \frac{s_o - f}{f s_o}$

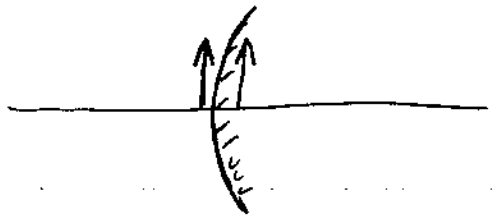
$\rightarrow M_T s_o = \frac{-f s_o}{s_o - f}$ i.e. $\boxed{M_T = \frac{-f}{s_o - f}}$

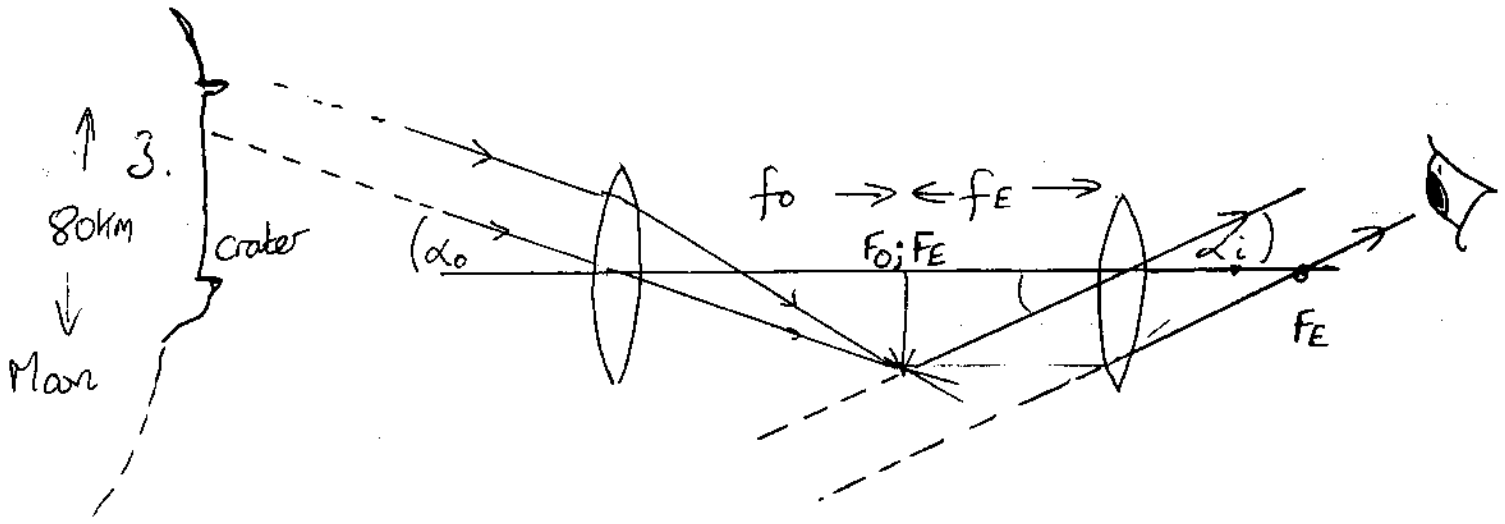
d)

i) As $f \rightarrow -\infty$, $M_T \rightarrow +1$: plane mirror ($R \rightarrow \infty$)



ii) As $s_o \rightarrow 0$, $M_T \rightarrow +1$ again : object touching mirror





a) Length of tube = $f_O + f_E$ when distant object is focussed onto common focal point of objective, eyepiece

$= 1000 + 25 = 1025$ mm

b) For 80km crater at $r = 4\times10^{+5}$ km

$$\alpha \approx \tan\alpha = \frac{80}{4\times10^{5}} = 2\times10^{-4}\ \text{rad}$$

$\times \frac{180}{\pi} = 0.0115$ degrees

c) So angular size at eyepiece $\alpha_i = \frac{f_O}{f_E}\alpha_O$

$$= \underbrace{\left(\frac{1000}{25}\right)}_{80\times} 0.0115 = 0.917^\circ$$

(Note: human eye can discern angular sizes $\gtrsim 0.02^\circ$

so we could not see this crater without a telescope.)

Also, tube diameter must be large enough to accommodate the intermediate image formed by the objective, i.e.

$> y_i = f_O \tan\alpha_O$ or ≥ 10 mm for Moon ($\frac{1}{2}^\circ$)