(22)

$$\frac{1}{f_{eff}} = \frac{1}{f_1} + \frac{1}{f_2}$$

- $L_1 : +f_1 \quad L_2 : -f_2$

$$\frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{f_1} \Rightarrow \frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1}$$

$$s_2 = -\frac{1}{s_1'} \;//\; -\frac{1}{s_1'} + \frac{1}{s_2'} = \frac{1}{f_2}$$

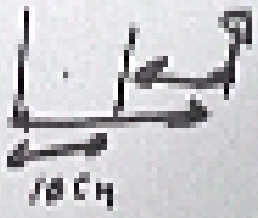
$$-\frac{1}{f_1} + \frac{1}{s_1} + \frac{1}{s_2'} = \frac{1}{f_2}$$

$$\frac{1}{s_1} + \frac{1}{s_2'} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f_{eff}}$$

$$\frac{1}{f_{eff}} = \frac{1}{f_1} + \frac{1}{f_2}$$

L_1: $+10\,cm = f_1$

L_2: $-10\,cm = f_2$



s_1' ; trans $L_2 \rightarrow s_2 : s_2'$

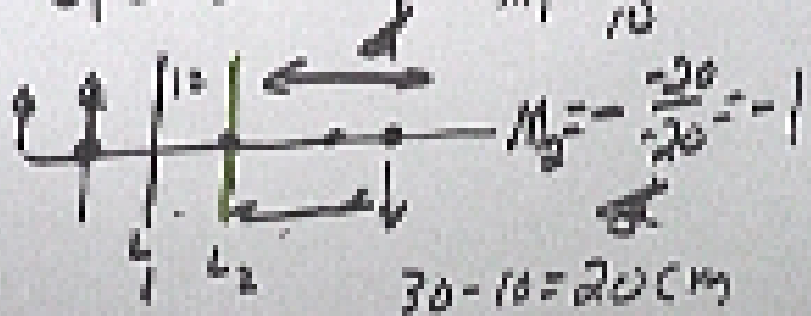
$s_1 = 15$ $\qquad \frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1}$

s_1' ; trans $L_2 \Rightarrow s_2 : s_2'$

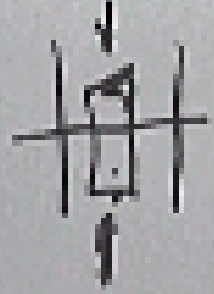
$s_1 = 15$ $\qquad \frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1}$

$$\frac{1}{s_1'} = \frac{1}{+10} - \frac{1}{+15} = \frac{3}{30} - \frac{2}{30} = \frac{1}{30}$$

$s_1' = +30$ $\qquad M_1 = -\frac{30}{10} = -3$



$30 - 10 = 20$ cm



$s_2 = -20$

$$s_2' = \frac{1}{f_2} - \frac{1}{-20} = \frac{1}{-10} + \frac{1}{20}$$

$$= -\frac{2}{20} + \frac{1}{20} = -\frac{1}{20}$$

$s_2' = -20$

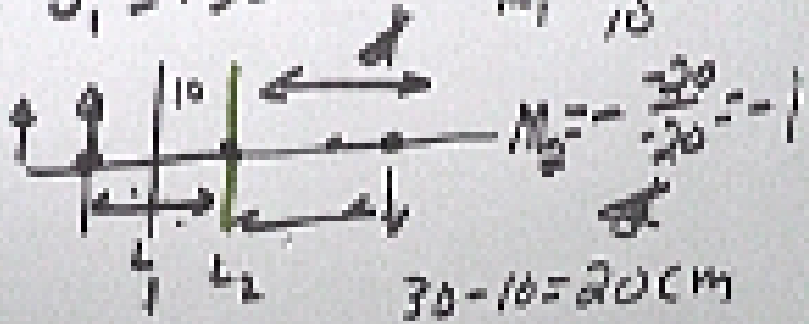
$M = M_1 M_2$ $\qquad M = (-3)(-1) = +3$

S_1' ; trans $L_2 \Rightarrow S_2 : S_2'$

$S_1 = 15$ $\qquad \frac{1}{S_1'} = \frac{1}{f_1} - \frac{1}{S_1}$

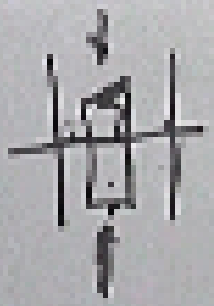
$$\frac{1}{S_1'} = \frac{1}{+10} - \frac{1}{+15} = \frac{3}{30} - \frac{2}{30} = \frac{1}{30}$$

$S_1' = +30$ $\qquad M_1 = -\frac{30}{10} = -3$



$30 - 10 = 20\,cm$

$S_2 = -20$



$$S_2' = \frac{1}{f_2} - \frac{1}{-20} = \frac{1}{-10} + \frac{1}{20}$$

$$= -\frac{2}{20} + \frac{1}{20} = -\frac{1}{20}$$

$S_2' = -20$

$M = M_1 M_2$ $\qquad M = (-3)(-1) = +3$

$f_1 = +10\,cm$ $\quad f_2 = -20\,cm$

$$\frac{1}{f_{eff}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{10} + \frac{1}{-20}$$

$$= \frac{2}{20} - \frac{1}{20} = \frac{1}{20}$$

$$f_{eff} = +20$$

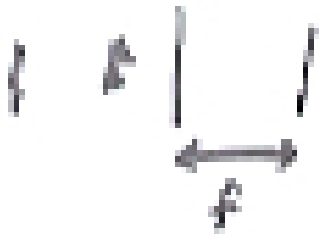
$$\frac{1}{s'} = \frac{1}{f_{eff}} - \frac{1}{s} = \frac{1}{20} - \frac{1}{10}$$

$$= \frac{1-2}{20} = -\frac{1}{20} \Rightarrow s' = -20$$

$$M = -\frac{-20}{+10} = +2$$

virtual; enlarged; upright

L_1: $f_1 = +f$ $\quad L_2$: $f_2 = -f$



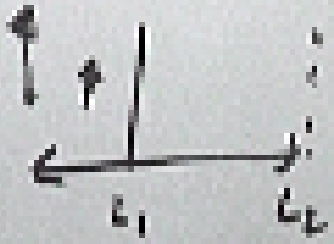
$s_1 = +\frac{1}{2}f$

$$\frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1} = \frac{1}{f} - \frac{2}{f}$$

$$= -\frac{1}{f} \Rightarrow s_1' = -f$$

$$M = -\frac{s_1'}{s_1} = -\frac{-f}{\frac{1}{2}f}$$

$$= +2$$

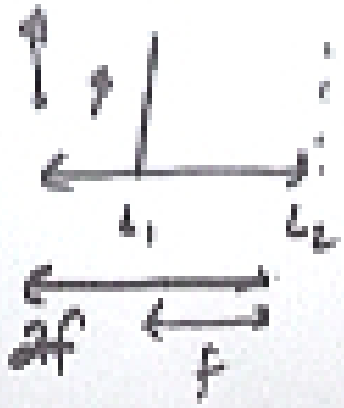


$$\frac{1}{s_1'} = \frac{1}{f_1} - \frac{1}{s_1} = \frac{1}{f} - \frac{2}{f}$$

$$= -\frac{1}{f} \Rightarrow s_1' = -f$$

$$M = -\frac{s_1'}{s_1} = -\frac{-f}{2f}$$

$$= +\frac{1}{2}$$



$$s_2 = +2f$$

$$s_2': \quad \frac{1}{s_2'} = \frac{1}{f_2} - \frac{1}{s_2}$$

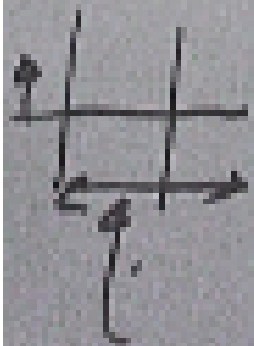
$$= \frac{1}{-f} - \frac{1}{2f}$$

$$= \frac{-2}{2f} - \frac{1}{2f} = -\frac{3}{2f}$$

$$s_2' = -\frac{2f}{3} \qquad M_2 = -\frac{-\frac{2f}{3}}{2f}$$

$$= \frac{1}{3} \qquad M = M_1 M_2$$

$$= \frac{1}{2}$$



$$\frac{1}{s_1'} \quad \frac{1}{f_1} \quad \frac{1}{s_1} \quad \frac{1}{f} \quad \frac{1}{f}$$

$$= -\frac{1}{f} \Rightarrow s_1' = -f$$

$$M = -\frac{s_1'}{s_1} = -\frac{-f}{2f}$$

$$= +2$$

$$s_2 = +2f$$

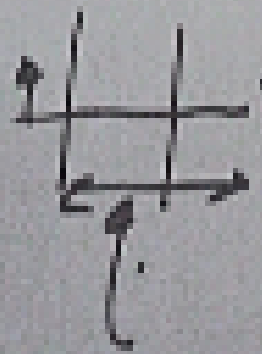
$$s_2': \quad \frac{1}{s_2'} = \frac{1}{f_2} - \frac{1}{s_2}$$

$$= \frac{1}{-f} - \frac{1}{2f}$$

$$= \frac{-2}{2f} - \frac{1}{2f} = \frac{-3}{2f}$$

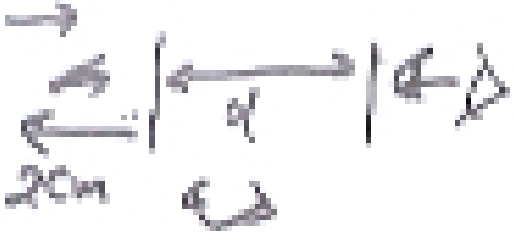
$$s_2' = -\frac{2f}{3} \qquad M_2 = -\frac{-2f}{3} = \frac{3}{2f}$$

$$= \frac{1}{3} \qquad M = M_1 M_2 = \frac{2}{3}$$

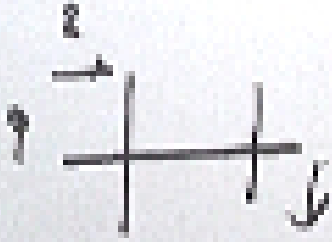


$f + 2f = 3f$

L_1: (f+) L_2: (f-)



L_1: +1cm = f L_2: -1cm = f



$d = \frac{1}{2}$ cm

$s_1 = +2$ cm

$$\frac{1}{s_1'} = \frac{1}{1} - \frac{1}{2} = +\frac{1}{2}$$

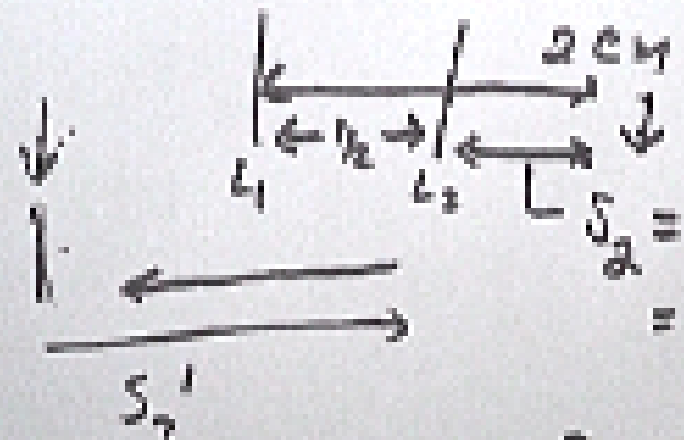
$s_1' = +2$.

$$M = -\frac{s_1'}{s_1} = -\frac{2}{2} = -1$$

$\frac{1}{s_1'} = \frac{1}{1} - \frac{1}{2} = +\frac{1}{2}$

$M = -\frac{s_1'}{s_1} = -\frac{2}{2}$ $\quad s_1' = +2$

$= -1$



$s_2 = 2 - \frac{1}{2}$

$= \frac{4}{2} - \frac{1}{2} = \frac{3}{2}$ cm

$f_2 = -\frac{3}{2}$ cm

$\frac{1}{s_2'} = \frac{1}{f_2} - \frac{1}{s_2} = -\frac{1}{1} - \frac{1}{-3/2}$

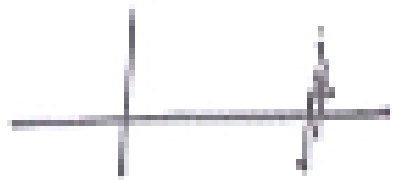
$= -\frac{1}{1} + \frac{2}{3} = -\frac{3}{3} + \frac{2}{3} = -\frac{1}{3}$

$s_2' = -3$ $\quad M = -\frac{-3}{3/2}$

$= +2$

$3 - \frac{1}{2} = \frac{6}{2} - \frac{1}{2} = \frac{5}{2}$

L_1 = f_1 $\quad$ L_2 = f_1



L_1 $\quad$ L_2

d $\quad$ e

$$\frac{1}{S_1} + \frac{1}{S_1'} = \frac{1}{f}$$

$$\frac{1}{S_1} = \frac{1}{f} - \frac{1}{d}$$

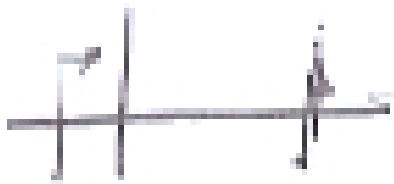
$$\frac{1}{S_1} = \frac{1}{f} - \frac{1}{e}$$

$f = .5$ cm $\quad$ $d = 1$ cm

$$\frac{1}{S_1} = \frac{1}{.5} - \frac{1}{1} = \frac{2}{1} - \frac{1}{1} = \frac{1}{1} = 1$$

$S_1 = 1$

$L_1 = f_1$ $\quad$ $L_2 = f_1$



$$\frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{f}$$

$$\frac{1}{s_1} = \frac{1}{f} - \frac{1}{d}$$

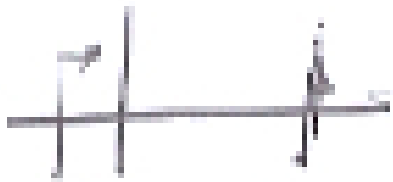
$$\frac{1}{s_1} = \frac{1}{f} - \frac{1}{e}$$

$f = .5$ cm $\quad$ $d = 1$ cm

$$\frac{1}{s_1} = \frac{1}{.5} - \frac{1}{1} = \frac{2}{1} - \frac{1}{1} = \frac{1}{1} = 1$$

$s_1 = +1$

$L_1 = f_1$ $\quad$ $L_2 = f_1$



$$\frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{f}$$

$$\frac{1}{s_1} = \frac{1}{f} - \frac{1}{d}$$

$$\frac{1}{s_1} = \frac{1}{f} - \frac{1}{e}$$

$f = .5$ cm $\quad$ $d = 1$ cm

$$\frac{1}{s_1} = \frac{1}{.5} - \frac{1}{1} = \frac{2}{1} - \frac{1}{1} = \frac{1}{1} = 1$$

$s_1 = +1$