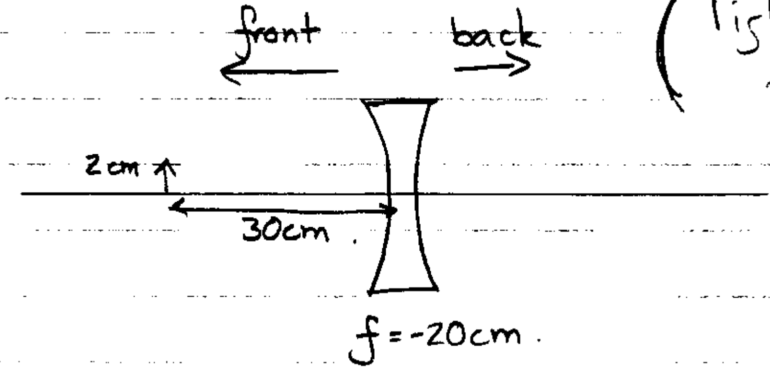
# Geometric Optics. - Examples.

## #1 Image from diverging lens.




(light **always** travels from left to right!)

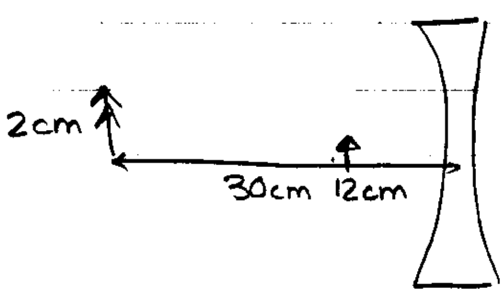
A diverging lens w/ $f = -20\text{cm}$. Object 2cm in height is placed 30 cm in **front** of the lens. Locate position of image.

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

$f = -20\text{cm}$
$s = 30\text{cm}$ (because it is in front)

$$\frac{1}{30\text{cm}} + \frac{1}{s'} = \frac{-1}{20\text{cm}} \Rightarrow s' = -12\text{cm}.$$

$\therefore$ $s' < 0 \Rightarrow$ virtual image $\Rightarrow$ it is in **front** of lens.



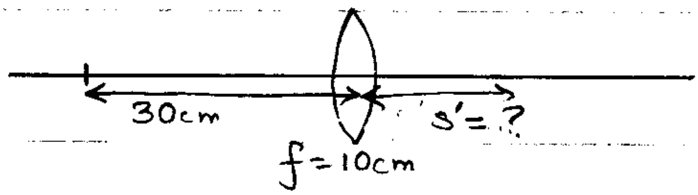

$$M = -\frac{s'}{s} = \frac{-(-12)}{30} = 0.4$$

$$h' = M \cdot h = 0.8\text{cm}.$$

$\Rightarrow$ Image is virtual, reduced and upright.

#2 Converging lens. w/ focal length $f = 10\,cm$. Image is formed w/ an object placed at (a) 30cm, (b) 10cm, (c) 5cm from the lens. Find image distance and describe image in each case.

(a)




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

$$\frac{1}{30} - \frac{1}{10} = -\frac{1}{s'}$$

$$M = \frac{-s'}{s} = -\frac{15}{30} = -0.5$$

$$s' = -\left(\frac{10 \cdot 30}{10-30}\right) = \underline{\underline{15\,cm}}$$

$s' = 15\,cm \Rightarrow$ to the right of the lens ∴ real image
$M = -0.5 \Rightarrow$ inverted, reduced in size by one half.

(b) -- $s = 10\,cm \Rightarrow s' = \infty$ (definition of focal length)
when object is placed at focal length, image is formed at $\infty$.

(c) $s = 5\,cm$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad \frac{1}{5\,cm} + \frac{1}{s'} = \frac{1}{10\,cm}$$

$$s' = -\left(\frac{5 \cdot 10}{10-5}\right) = -10\,cm.$$

$$M = \frac{-s'}{s} = 2.$$

Picture

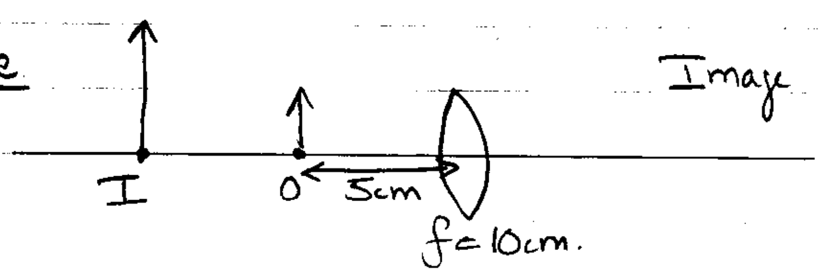
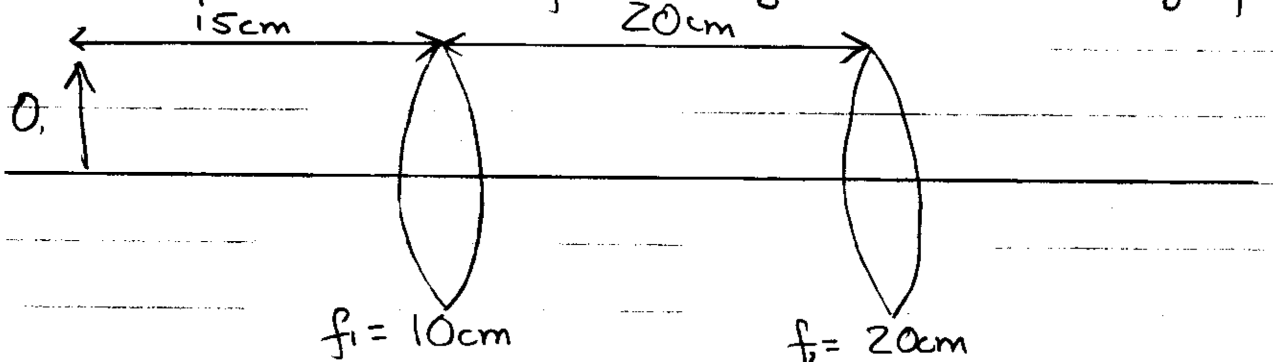



Image is virtual, magnefied and upright.

Note, $s > f \Rightarrow$ real, inverted, smaller ; $s < f \Rightarrow$ virtual, upright, magnified

#3 Two lens problem

Two thin lens of $f = 10cm$ and $f = 20cm$ are separated by 20 cm. An object is placed 15 cm in front of first lens. Find the position of the final image. Find its magnification




First lens. $\frac{1}{s} + \frac{1}{s_1'} = \frac{1}{f_1}$ $\quad s = 15cm \Rightarrow s' = -\left(\frac{15 \cdot 10}{10-15}\right) = +30cm.$

$\Rightarrow$ s' is to the right of $l_1$ and <u>also</u> to the right of $l_2$ by 10 cm.

$M_1 = -\frac{s'}{s} = \frac{-30}{15} = \underline{\underline{-2}}.$

Second lens.

Object is image from first lens.

$\Rightarrow s_2 = -10$ cm.

$$\frac{1}{s_2} + \frac{1}{s_2'} = \frac{1}{f_2}$$

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

$$\frac{1}{s_2'} = \frac{1}{20} + \frac{1}{10} \Rightarrow s_2' = \frac{200}{30} = \frac{20}{3} \text{ cm}.$$

$\Rightarrow$ Image is real, upright

#3 Con't.

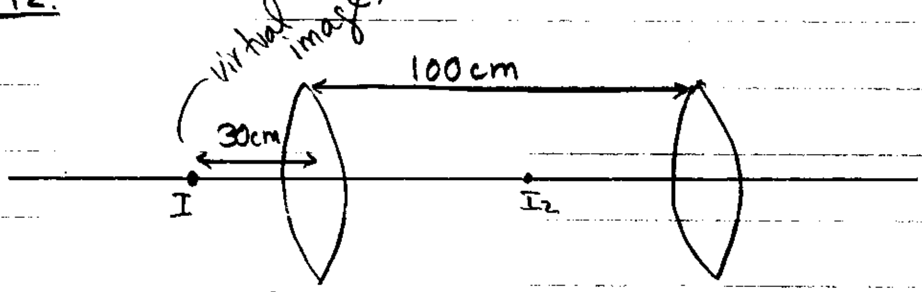
$$M_2 = \frac{-s_2'}{s_2} = \frac{-(20/3)}{-10} = \frac{2}{3}.$$

Notice $s_2' > 0$ ⇒ Image is to the right of $l_2$

Total Magnification $M = M_1 \cdot M_2 = -\frac{4}{3}.$

⟹ Final image is real ($s_2' > 0$), inverted and enlarged.

Problem 1.12.




$s_2' = -130\text{ cm}$  $f_2 = 70\text{ cm}.$

$$\frac{1}{s_2} + \frac{1}{s_2'} = \frac{1}{f_2}$$

$$\Rightarrow \frac{1}{s_2} = \frac{1}{70\text{cm}} - \frac{1}{-130\text{cm}} \Rightarrow s_2 = \left(\frac{70 \cdot 130}{70+130}\right) = 45.5\text{cm}$$

⇒ $s_2$ is 45.5 cm to the left of $s_2$

∴ $s_1' = 100\text{ cm} - 45.5\text{cm} = 54.5\text{ cm}.$  $l_1$ has a real image

$$\frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{f_1} \qquad \frac{1}{s_1} = \frac{1}{50\text{cm}} - \frac{1}{54.5\text{cm}}.$$

$$s_1 = \left(\frac{50 \cdot 54.5}{50 - 54.5}\right) = \underline{\underline{-605.5\text{ cm}}}.$$

Object is to the right of $l_1$ by 605.5 cm.
$\Rightarrow$ Virtual object.