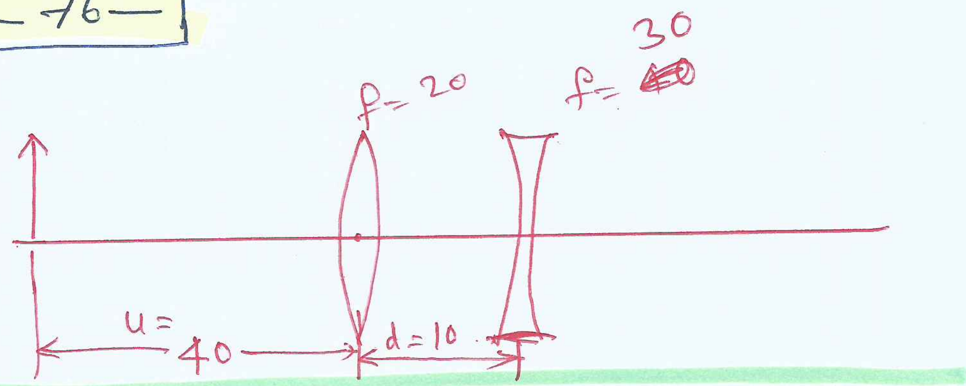
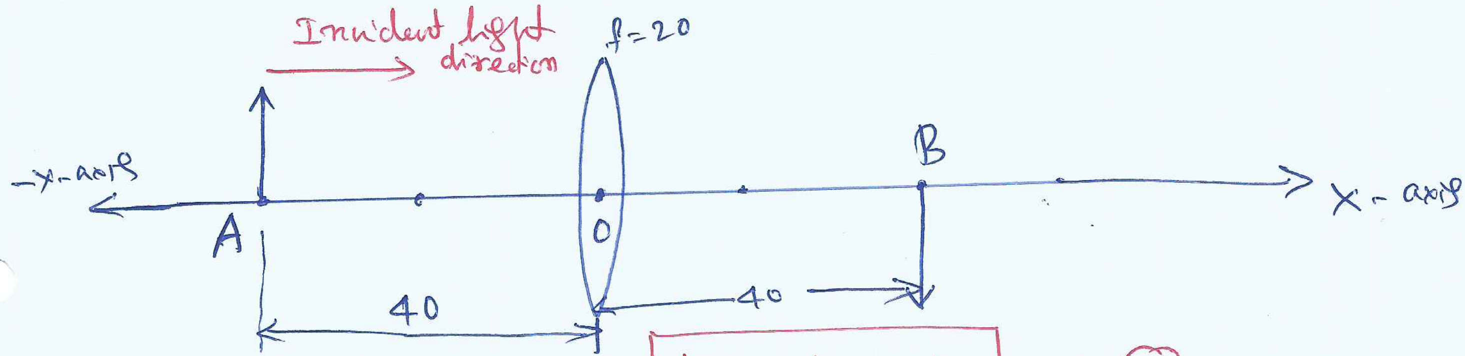
problem :

Where is the image ?



Solution: Take first (Convex) lens and analyse



Formula ~~for~~ thin lens : $\boxed{\frac{1}{v} = \frac{1}{f} + \frac{1}{u}} \longrightarrow (1)$

For eqn (1), we need to assign sign convention.

(a) Given $f = 20 = +20$ (∵ Since it is Convex lens)

(b) Given $u = 40 = -40$

IMP

Note that distances are measured from optical centre of lens towards object / image distance on x-axis. Here distance is measured from O to A. $O \longrightarrow A = OA$ which is opposite to the incident light direction, hence $u = -40$

$$\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} - \frac{1}{40} = \frac{1}{40} \qquad \therefore \boxed{v = +40}$$

$\therefore v = +40 \longrightarrow$ on the positive x-axis; Since ~~OB~~ measured from optical centre $\Rightarrow OB = v \rightarrow$ in the same direction as the incident light, therefore $v = +40$ which automatically is arrived when solving the problem.

[Magnification $= \frac{h_i}{h_o} = \frac{v}{u} = \frac{40}{-40}$ $\therefore m = -1$

⇓ implies

→ Inverted

→ Same height as object.

P.T.O.

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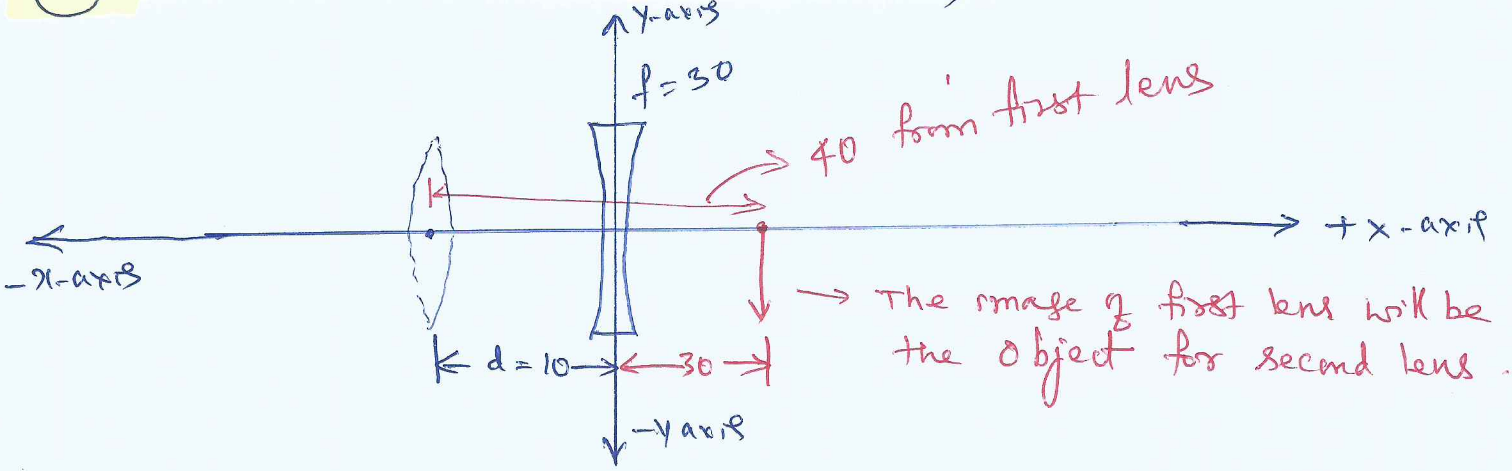
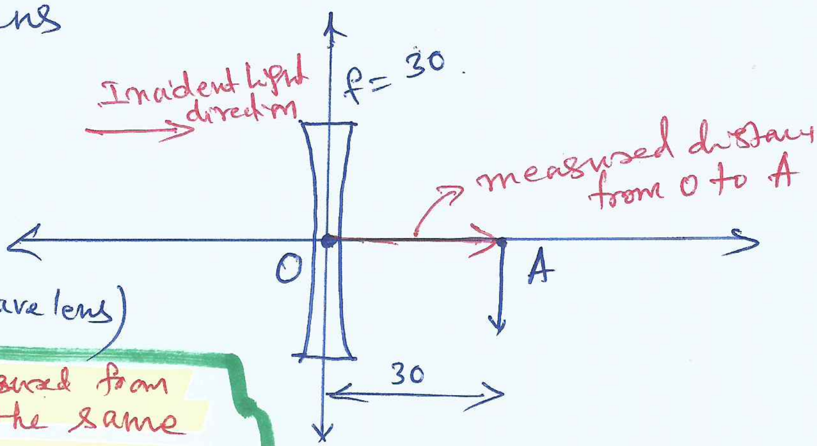
② Take second lens (Concave lens)



→ The image of first lens will be the object for second lens.

So, take only second lens

Formula $\boxed{\frac{1}{v} = \frac{1}{f} + \frac{1}{u}}$



Assign sign convention

ⓐ $f = \cancel{+}30 = -30$ (Since concave lens)

ⓑ $u = 30 = +30$ [distance measured from O to A is in the same direction as incident light, hence $u = +30$]

IMP

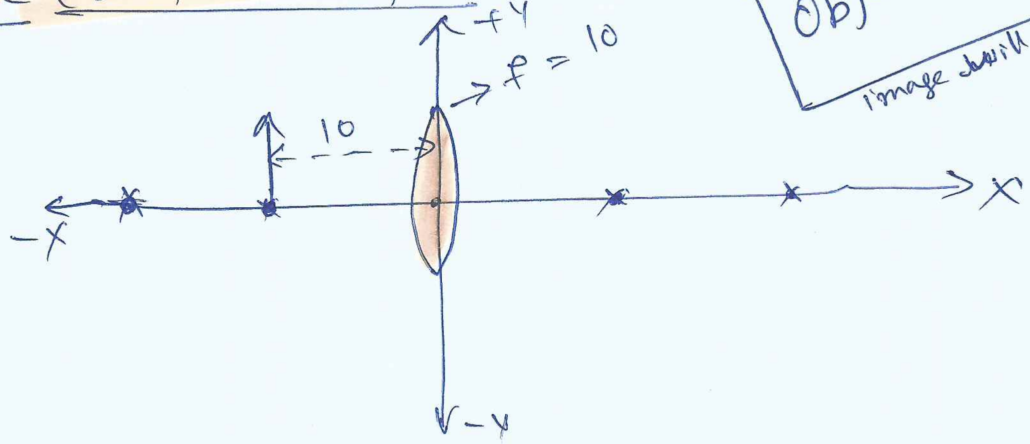
$\therefore \frac{1}{v} = \frac{1}{\cancel{-30}} + \frac{1}{\cancel{30}} = 0 \qquad \therefore v = \infty$ image formed by concave lens at infinity.

$\boxed{v = \infty \rightarrow \text{image at infinity at the } +x\text{-axis side}}$

Magnification $m = \frac{v}{u} = \infty \Rightarrow$ Very large object at infinity.

Example (Simple examples)

Object at ~~Focus~~ Focus
image should be at ∞



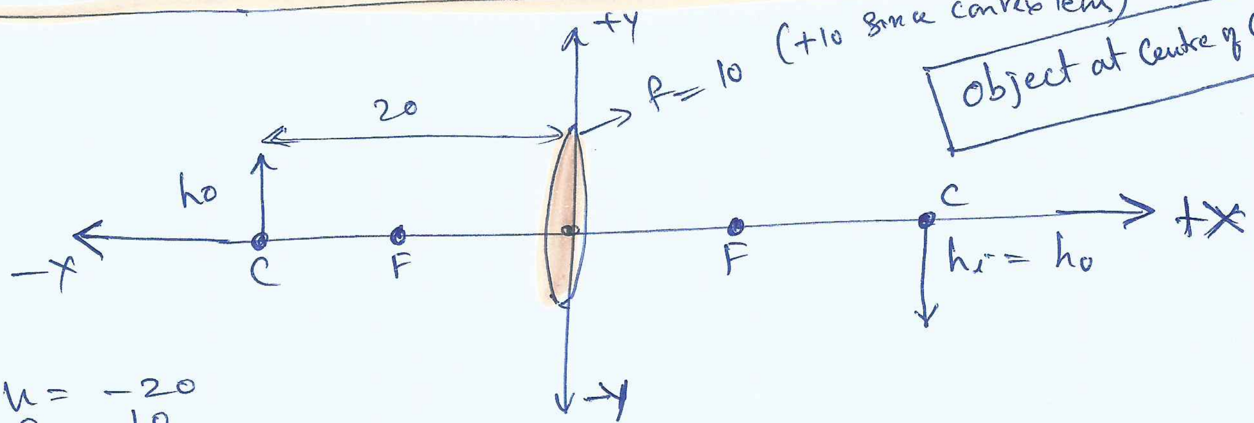
$u = -10$
$f = 10$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{10}$

$\therefore v = \infty$ image at infinity.

magnification $m = \frac{v}{u} = \frac{\infty}{-10} = \infty$

object at Centre of Curvature



$u = -20$
$f = 10$

$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{20}$

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

$v = 20$ (since +ve, it is on the +x-axis)

$m = \frac{v}{u} = \frac{20}{-20} = -1$

⇒ - no magnification
- Inverted image

In above example

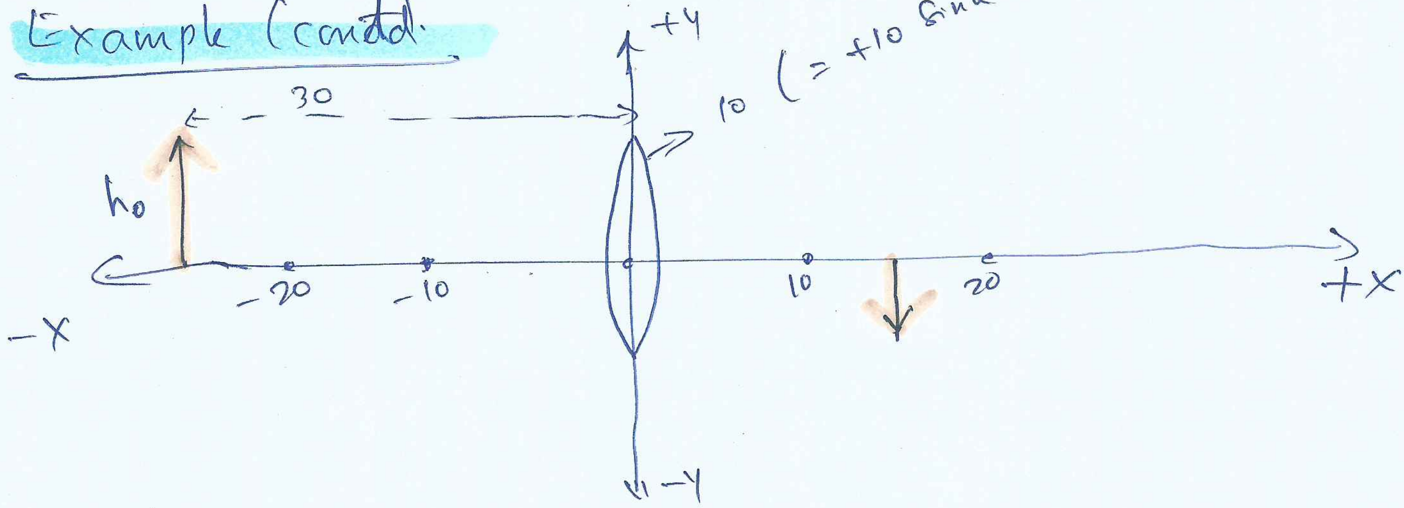
Image properties are determined after solving using Lens's formula and Magnification formula.

→ Lens formula Solution gives whether the image is on +ve x-axis or -ve x-axis (Real or Virtual)

→ Magnification m solution gives
⇒ where image is magnified or not or attenuated
→ Inverted or Erect

P.T.O

Example (contd.)



$u = -30$
$f = +10$

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = -\frac{1}{30} + \frac{1}{10}$$

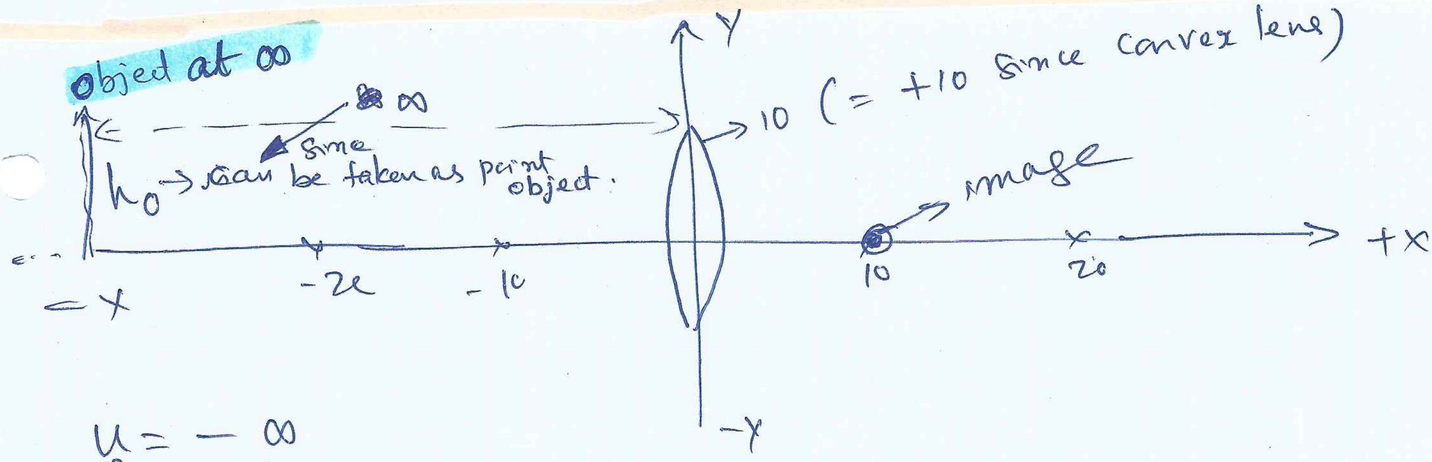
$$\frac{1}{v} = \frac{3-1}{30} = \frac{2}{30} = \frac{1}{15}$$

$\therefore \boxed{v = 15} \longrightarrow$ Real image

$$m = \frac{v}{u} = \frac{15}{-30} = -\frac{1}{2}$$

image $\Rightarrow$ • inverted
• attenuated

object at ∞



$u = -\infty$
$f = 10$

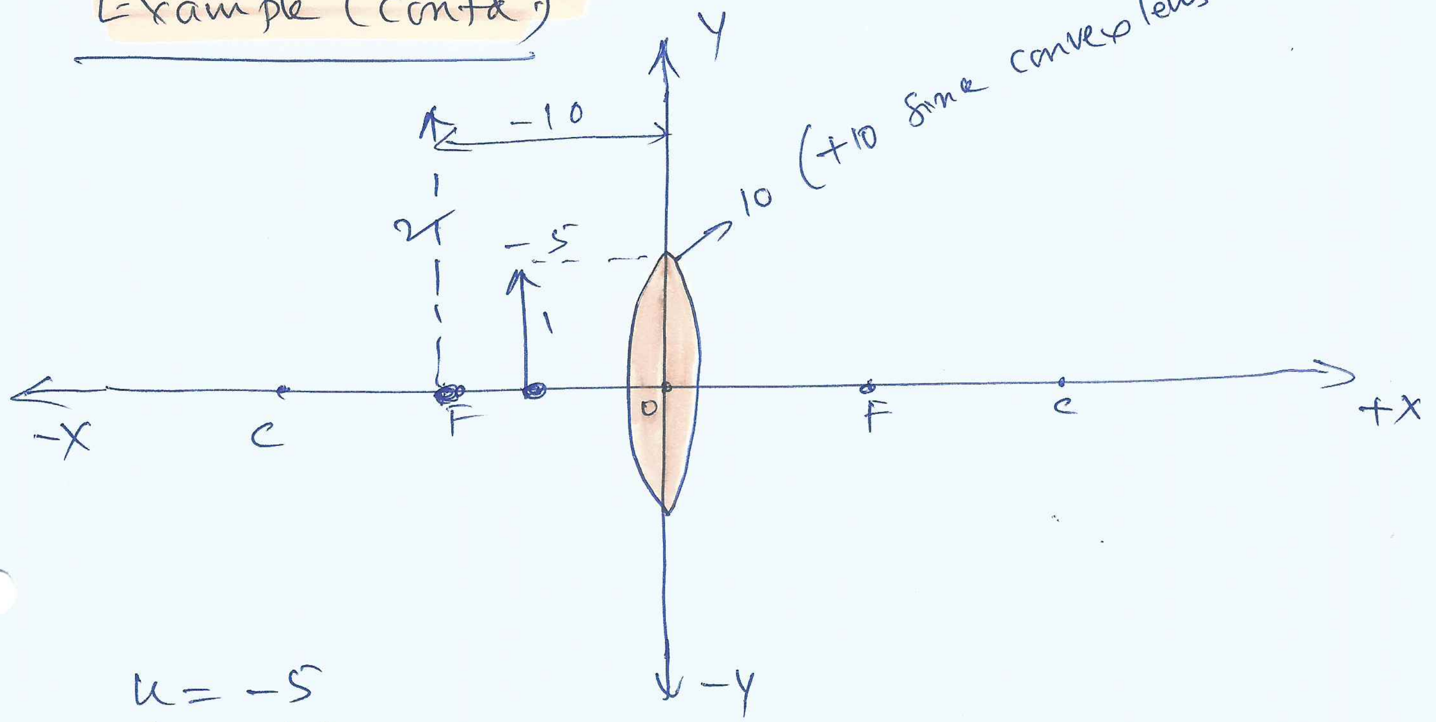
$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{\infty}$$

$\boxed{v = 10} \longrightarrow$ Real image

$$m = \frac{v}{u} = \frac{10}{-\infty} = 0 \longrightarrow$$

- image on focus
- image is real
- image is a point

Example (contd.)



$u = -5$
$f = +10$

$$1/v = \frac{1}{f} + \frac{1}{u} = \left(\frac{1}{10} - \frac{1}{5}\right) = \frac{1-2}{10} = \frac{-1}{10} = \cancel{-0.1}$$

$$\frac{1}{v} = -\frac{1}{10}$$

$\boxed{v = \cancel{-0.1}\ -10}$ → this indicates virtual image

$$m = \frac{v}{u} = \frac{-10}{-5} = 2$$ → this indicates image is
→ magnified
→ erect (+ve Y-axis)

So, use Cartesian Co-ordinate System

→ for u and v signs (if solution of v or u turns out as
+ve → real image
-ve → virtual image)

→ for u and v height signs $\left(m = \frac{h_i}{h_o} = \frac{v}{u}\right)$
- if u or v height comes as +ve, image is erect
- if u or v ——————— -ve, —— inverted

→ magnification decides whether image is magnified or attenuated or no change.

→ For convex lens 'f' is taken as +ve, for concave lens, f is taken as -ve.

80 a | problem #19 2nd pre-board exam

Len's problem

A double convex lens of glass of $\mu = 1.5$ has its both surfaces of equal radii of curvature of 20 cm each. An object of height 5 cm is placed at a dist. of 15 cm from the lens, Calculate the size of the image formed.

Ans: Given Double convex lens with $\mu = 1.5$, $u = 15\,cm$, $h_o = 5\,cm$

$R_1 = 20\,cm$ and $R_2 = 20\,cms$. $h_i = ?$

- To find $h_i \rightarrow$ there are 2 parts in this problem.

(a) To find focal length of lens $\rightarrow$ use len's maker's formula.

$$\boxed{\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]}$$

Given ~~double~~ convex lens, ~~hence~~ ~~with~~ hence $R_1 = +20\,cm$, $R_2 = -20\,cm$ & $\mu = 1.5$

$$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{20} + \frac{1}{20}\right) = 0.5 \times \frac{1}{10} = \frac{5}{100} = \frac{1}{20} \quad \therefore \boxed{f = 20\,cm} \longrightarrow 1$$

(b) To find image distance ~~ds~~ $v \rightarrow$ use Len's formula

$$\boxed{\frac{1}{v} = \frac{1}{f} + \frac{1}{u}}$$

$u = -15\,cm$ (due to new Cartesian convention)

$f = +20\,cm$ (due to convex lens convention)

$$\frac{1}{v} = \frac{1}{20} - \frac{1}{15} \Rightarrow \frac{20}{v} = 1 - \frac{20^{4}}{15_{3}} = \frac{3-4}{3} = -\frac{1}{3}$$

$$\therefore \boxed{v = -60\,cm} \longrightarrow 2$$

(c) To find h_i:

formula $\boxed{\frac{h_i}{h_o} = \frac{v}{u}}$ $\qquad h_i = \frac{v}{u} \times h_o$

Given $u = -15\,cm$

Given $h_o = +5\,cm$

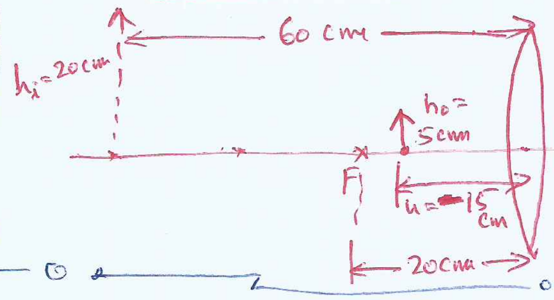
found out $v = -60\,cm$

$$h_i = \frac{-60^{4}}{-15} \times 5 = 20\,cm \qquad \therefore \boxed{h_i = 20\,cm} \longrightarrow 3$$

Since v is $-ve$, image is Virtual, h_i ~~is~~ is $+ve$, image is erect

$m = \frac{h_i}{h_o} = \frac{20}{5} = 4$ enlarged.

Size of image = 20 cm



Tips:

- If focal length is not given, in order to find f, use Lens maker's formula $\boxed{\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$ formula is same for both convex & concave lenses.

$\longrightarrow$ where μ = refractive index of glass w.r.t air

$\longrightarrow R_1, R_2 \rightarrow$ radii of curvature of its two surfaces

$\longrightarrow$ when R_1 and R_2 values are given, for double convex lens R_1 is $+ve$, R_2 is $-ve$; for double concave lens R_1 is $-ve$; R_2 is $+ve$.

$\longrightarrow$ General Formula is $\frac{1}{f} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; when ~~$\mu_2$ ... the~~ $\mu_{21} = \frac{\mu_2}{\mu_1}$,

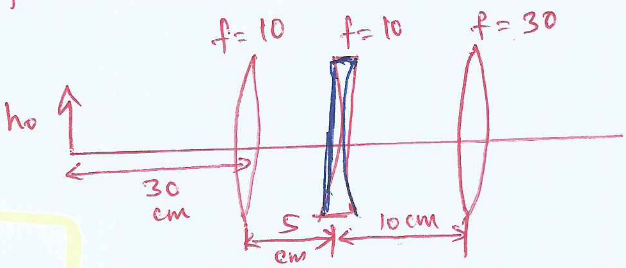
$\mu_2 \rightarrow$ refractive index of glass (in the above example)

$\mu_1 \rightarrow$ —— do —— of air = 1 (in the above example)

$\longrightarrow$ If full expt is done in water, μ_2 = ref. index of glass, μ_1 = ref. index of water = 1.33

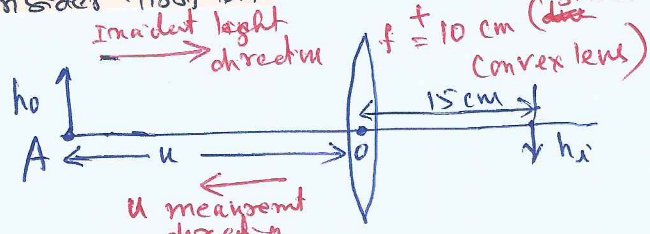
problem:

Find the position of the image formed by the lens combination as given below



Solution:

I Consider first lens



∴ $u = -30$ cm

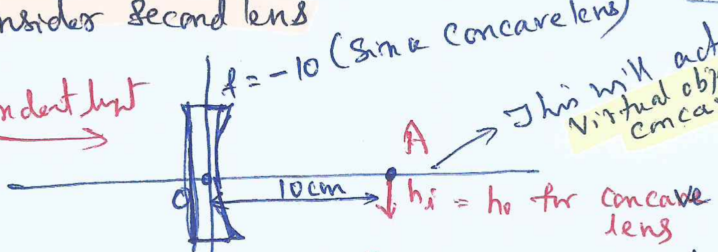
$$\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{30} = \frac{2}{30} = \frac{1}{15}$$

$$\boxed{v = +15\text{ cm}}$$

positive sign has come due to solving the problem hence it is on + x-axis in the same direction of incident light.

$$m = \frac{v}{u} = \frac{15}{-30} = -0.5$$

II Consider second lens



(measured dist OA = u = + 10 cm
same as incident light
hence positive sign for u)

$$\boxed{\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-10} + \frac{1}{10}}$$

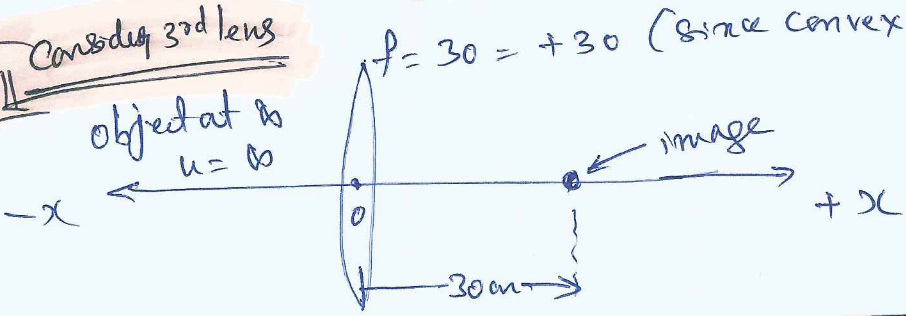
$$= \frac{1}{10} - \frac{1}{10} = 0$$

$$\boxed{v = \infty}$$

$$\boxed{m = \frac{v}{u} = \infty}$$

$v = \infty \implies$ the virtual image is formed at an infinite distance to the left of the second lens (concave lens). This virtual image acts as an object for the third lens.

III Consider 3rd lens



$$\therefore \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = 0 + \frac{1}{30} \qquad \therefore \boxed{v = +30\text{ cm}}$$

$$m = \frac{v}{u} = \frac{30}{\infty} = 0$$

$\implies$ point image.

$v = +30$ cm implies:

The final point image is formed ~~at the~~ to the right of the third lens (at a distance 30 cm from third lens) on the ~~focal plane~~ focus of the third lens.