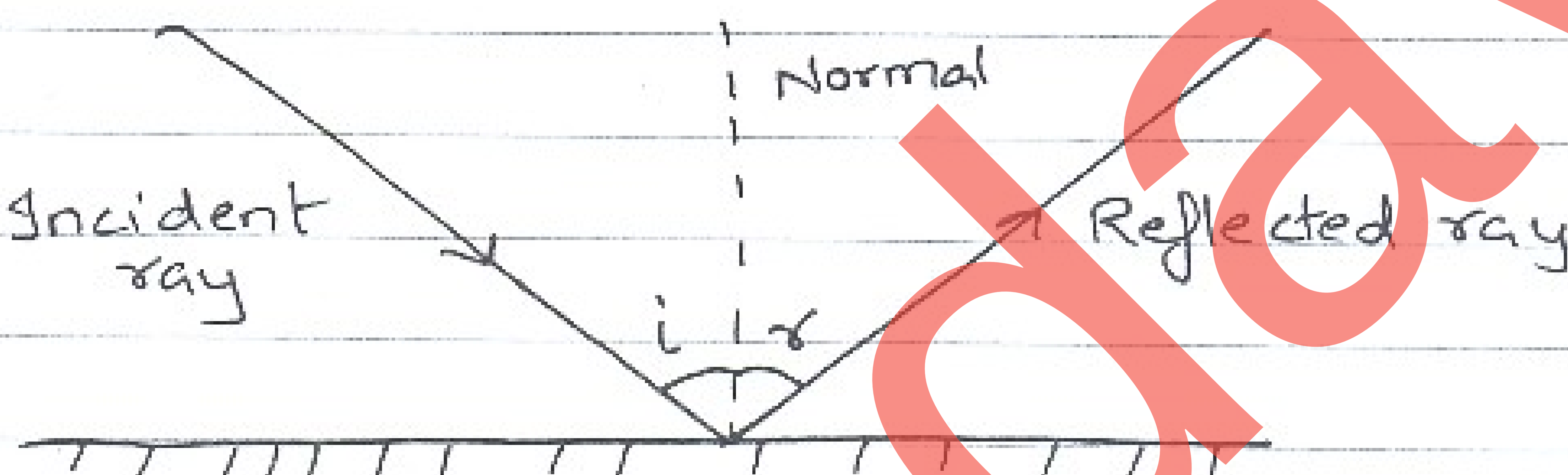
Reflection Of Light

Reflection

It is the change in path of light without any change in medium



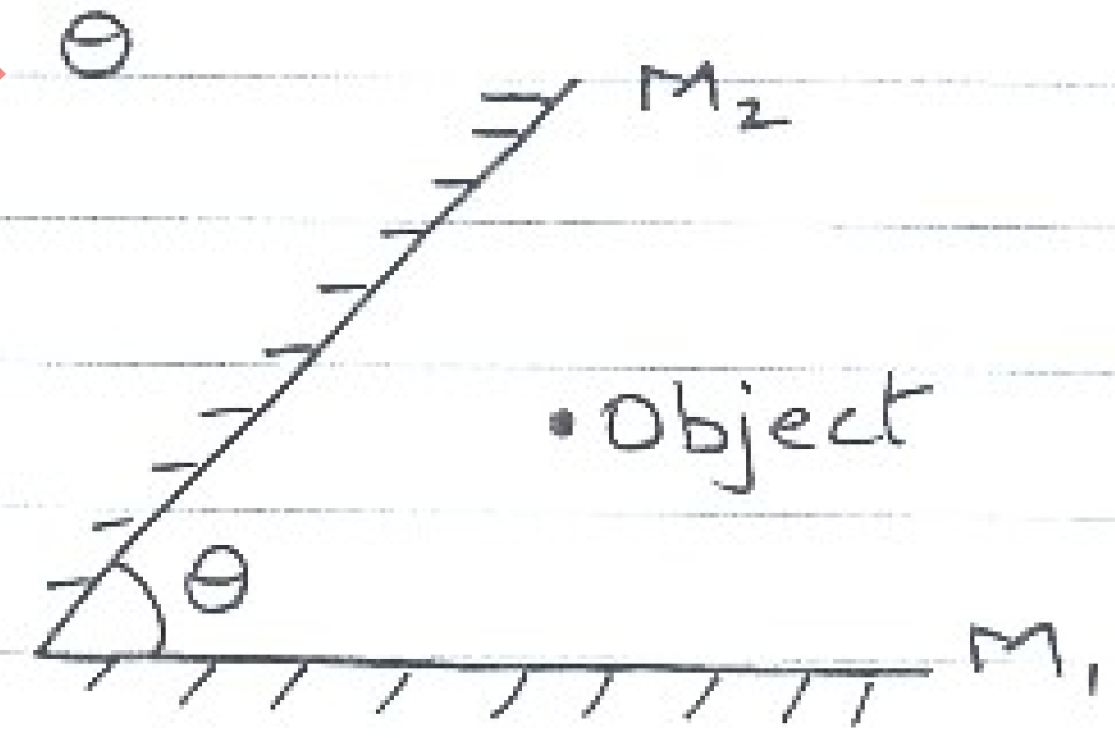
Laws of reflection

(1) The incident ray, the reflected ray & the normal lie in the same plane.

(2) Angle of incidence = Angle of reflection

* For normal incidence $i = 0^\circ$ & $r = 0^\circ$

* When an object is held betn 2 plane mirrors at an angle θ



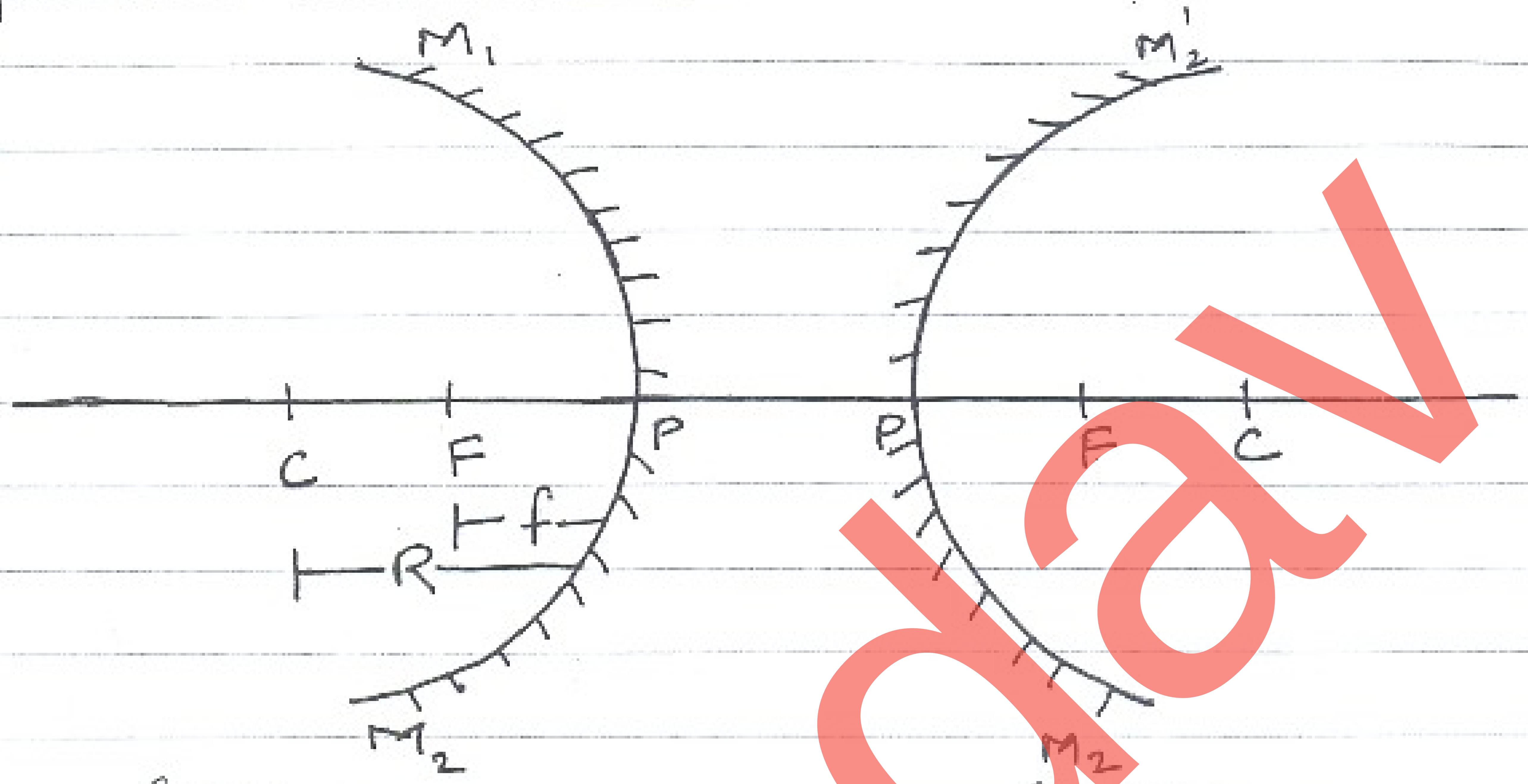
Total no. of images formed $\boxed{n = \frac{360^\circ}{\theta} - 1}$ if $\frac{360^\circ}{\theta}$ (even)

$\boxed{n = \frac{360^\circ}{\theta}}$ if $\frac{360^\circ}{\theta}$ (odd)

eg $\theta = 60^\circ$, $n = \frac{360}{60} - 1 = 6 - 1 = 5$

$= 40^\circ$, $n = \frac{360}{} = 9$

Spherical mirrors

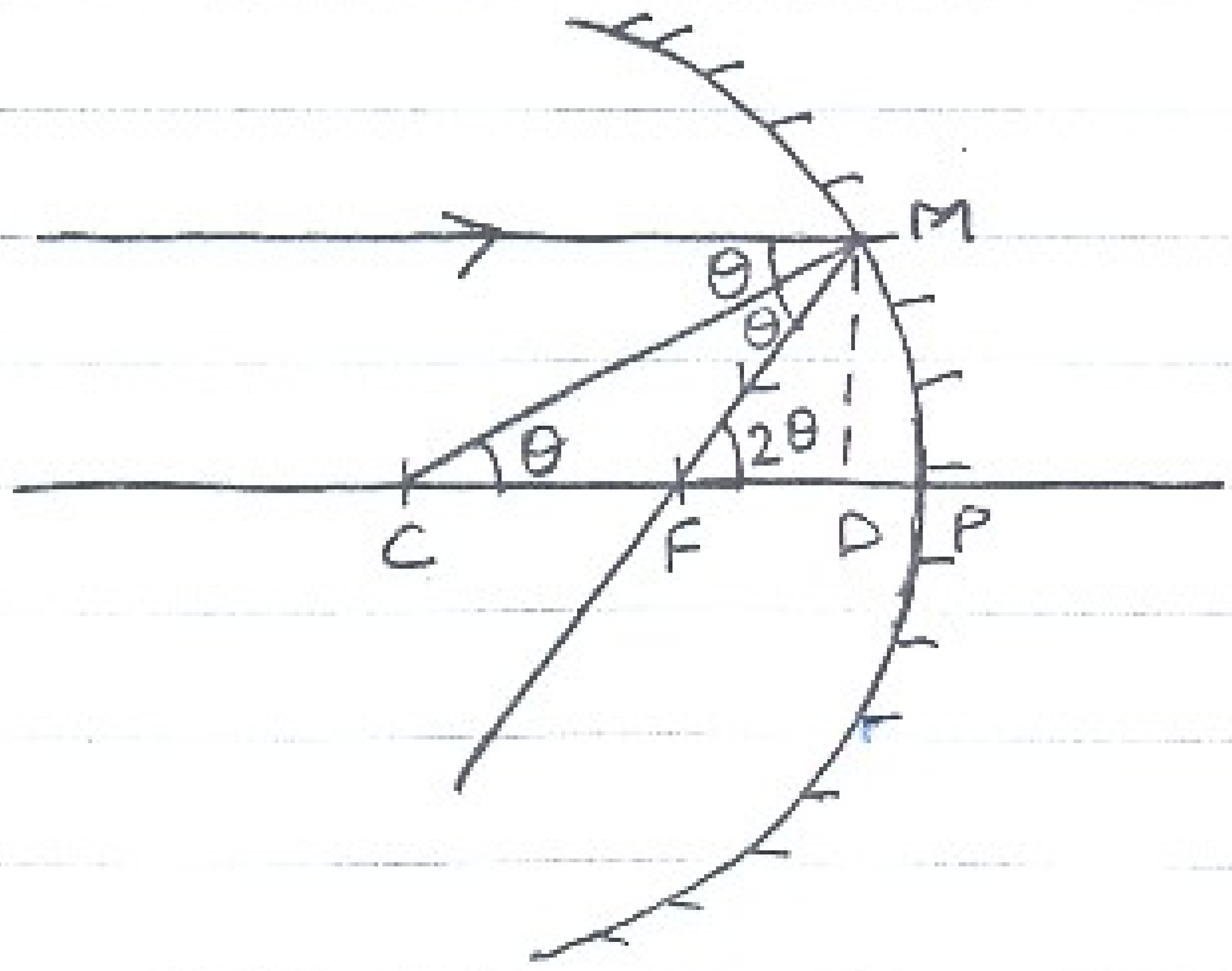


Concave Convex

M_1M_2 - aperature
P - pole
C - centre of curvature
PC (=R) = Radius of curvature
PF (=f) = focal length
F - focus

Relation betn R & f

(a) Concave mirror



Consider a ray parallel to principal axis striking the mirrot at M.
CM is $\perp^r$ to mirror at M

$\angle MCP = \theta$, $\angle MFP = 2\theta$

$\tan\theta = \frac{MD}{CD}$, $\tan 2\theta = \frac{MD}{FD}$

$\theta = \frac{MD}{CD}$, $2\theta = \frac{MD}{FD}$ [For small θ, tan ≈ θ]

$$\frac{2\cancel{MD}}{CD} = \frac{\cancel{MD}}{FD}$$

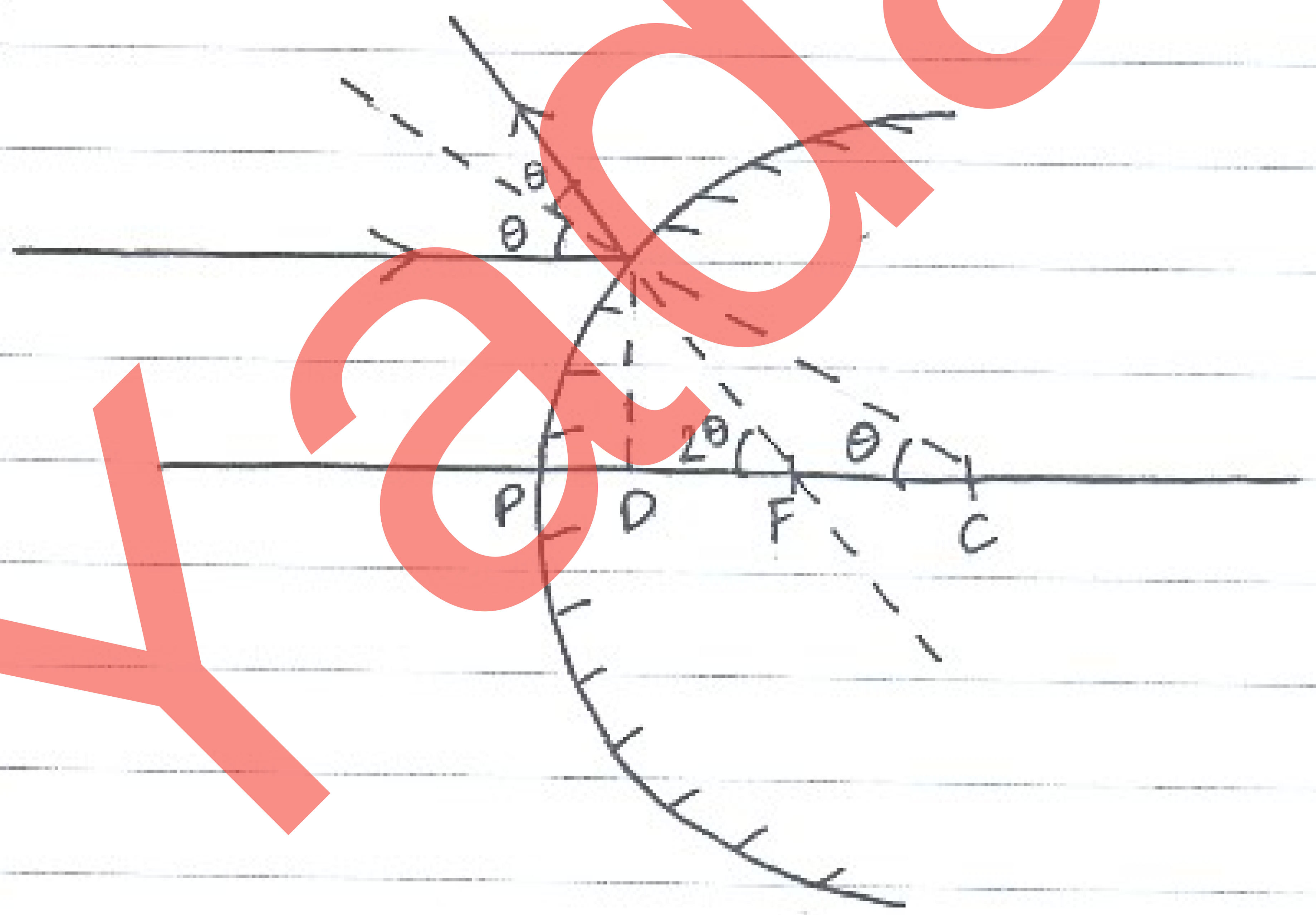
$$FD = \frac{CD}{2}$$

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

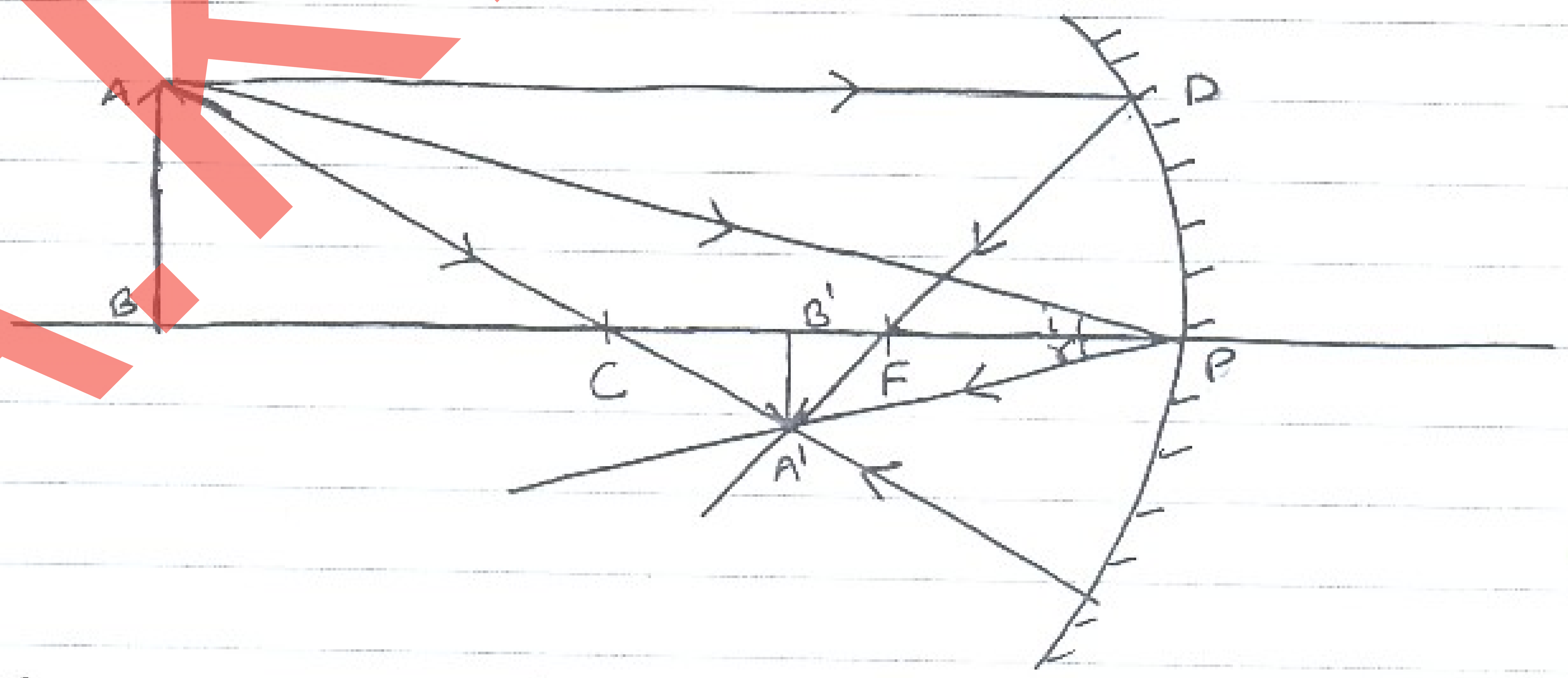
[D lies very close to P so
$CD \approx CP (= R)$
$FD \approx FP (= f)$]

(b) Convex mirror

Same derivation



Mirror Formula



Consider an object AB placed beyond C of a concave mirror. Three rays namely AD, AP & AC are reflected from the mirror, they meet at pt. A' & image (inverted) A'B' is formed.

$\Delta ABC \sim \Delta A'B'C$

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \quad \text{—} (1)$$

$\Delta ABP \sim \Delta A'B'P$

$$\frac{AB}{A'B'} = \frac{BP}{B'P} \quad \text{—} (2)$$

from (1) & (2)

$$\frac{CB}{CB'} = \frac{BP}{B'P}$$

$$\frac{BP - CP}{CP - B'P} = \frac{BP}{B'P}$$

Now, $BP = -u$

$CP = -R$

$B'P = -v$

$$\therefore \frac{-u + R}{-R + v} = \frac{-u}{-v}$$

$$-uv + vR = -uR + uv$$

$$uR + vR = 2uv$$

Dividing both sides by uvR

$$\frac{uR}{uvR} + \frac{vR}{uvR} = \frac{2uv}{uvR}$$

$$\frac{1}{v} + \frac{1}{u} = \frac{2}{R}$$

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

Linear magnification (m)

It is the ratio of the size of image formed by the mirror to the size of the object.

$$m = \frac{\text{height of image } (h_2)}{\text{height of object } (h_1)}$$

so, $m = \frac{A'B'}{AB}$

from fig. $\frac{A'B'}{AB} = \frac{B'P}{BP}$

$$\frac{-h_2}{h_1} = \frac{-v}{u}$$

$$\therefore \boxed{m = \frac{h_2}{h_1} = \frac{-v}{u}}$$

* Derive the mirror formula for
(i) virtual image in concave mirror
(ii) image formed by a convex mirror
by proceeding in the same way (as done above) but with appropriate ray diagrams.
(Note - Take the same triangle pairs)

Relation betn speed of object & image formed by a spherical mirror

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad (1)$$

differentiating both sides

$$\frac{d}{dt}(v^{-1}) + \frac{d}{dt}(u^{-1}) = \frac{d}{dt}(f^{-1})$$

$$-v^{-2}\frac{dv}{dt} - u^{-2}\frac{du}{dt} = 0 \qquad [\because f - \text{const.}]$$

$$\frac{1}{v^2}\frac{dv}{dt} = -\frac{1}{u^2}\frac{du}{dt}$$

$$\frac{dv}{dt} = -\left(\frac{v}{u}\right)^2 \frac{du}{dt}$$

$$\boxed{V_i = -\left(\frac{v}{u}\right)^2 V_o} \qquad \left[\begin{array}{l}\because V_i - \text{speed of image} \\ V_o - \text{" " object}\end{array}\right]$$

from ① $\frac{v}{u} = \frac{f}{u-f}$

$$\therefore \boxed{V_i = -\left(\frac{f}{u-f}\right)^2 V_o}$$

Uses of concave mirror

(i) Shaving mirror
(ii) Headlights of vehicles
(iii) Ophthalmoscope (for reflecting light on retina)
(iv) Reflector in search lights.

Uses of convex mirror

(i) Reflector in street lamps
(ii) Rear-view mirror in vehicles because
(a) always form virtual image
(b) covers large area as image is diminished.

Refraction Of Light

Refraction – Bending of light while moving from one medium to another

Laws of refraction

1. The incident ray, the refracted ray and the normal lie in the same plane.
2. Snell's law
   The product of refractive index and sine of angle of incidence/refraction at a point in a medium is constant.

$$\mu \times \sin i = \text{constant}$$

or, $\mu_1 \sin i = \mu_2 \sin r$

$$\boxed{\mu_{21} = \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}}$$

μ_{21} - r.i of 2 w.r.t 1

Refractive Index (μ)

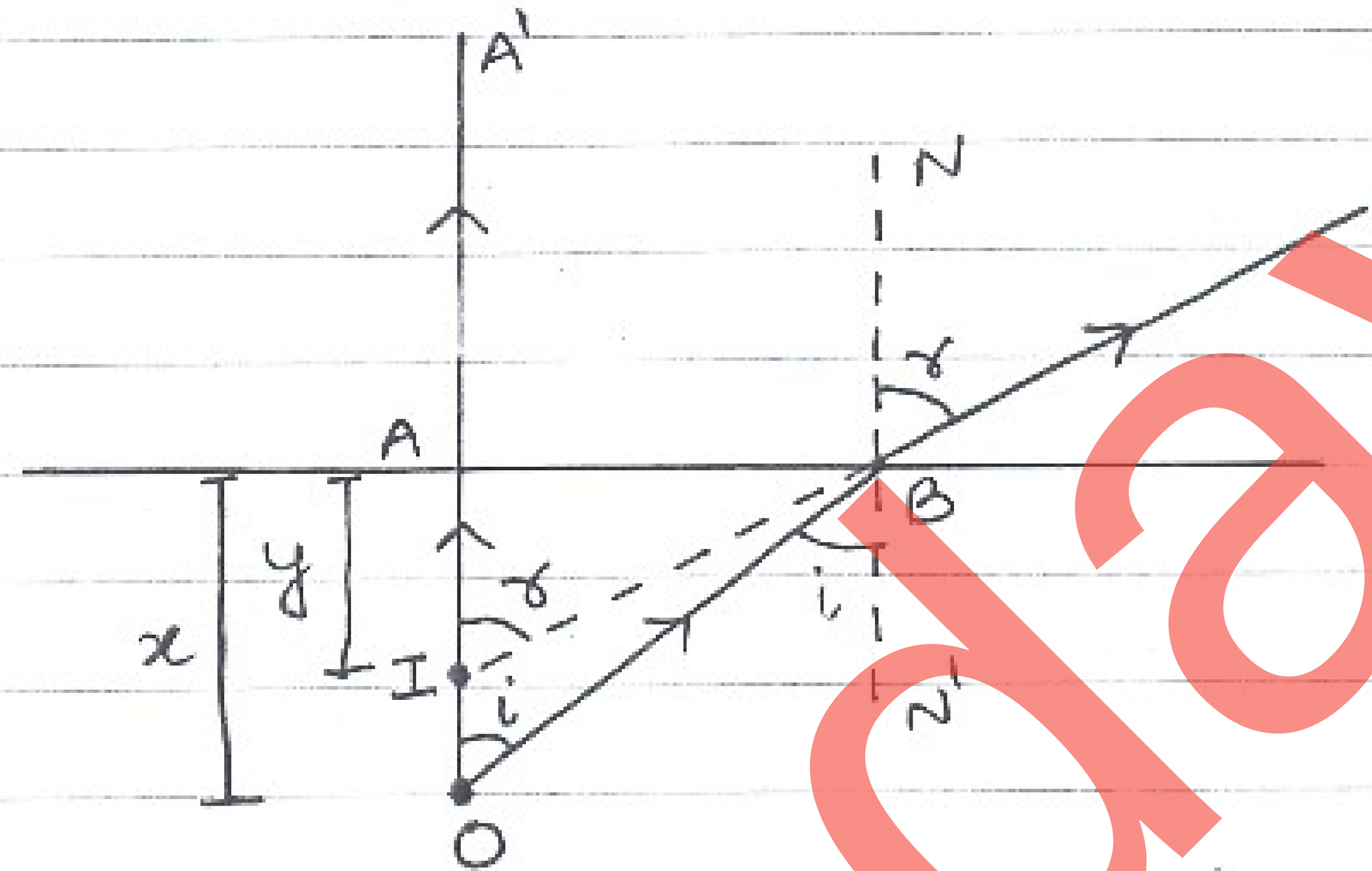
It is the ratio of speed of light in 2 different media

$$\mu_{21} = \frac{\text{speed of light in med 1. } (v_1)}{\text{speed of light in med. 2 } (v_2)}$$

$$\boxed{\mu_{21} = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}}$$

$$\boxed{\mu_{21} = \frac{1}{\mu_{12}}}$$

Real & Apparent Depth of a tank



$\angle AOB = \angle OBN' = i$ (alternate int. angles)

$\angle AIB = \angle NBC = r$ (corresponding ")

In $\triangle OAB$, $\sin i = \frac{AB}{OB}$

$\triangle IAB$, $\sin r = \frac{AB}{IB}$

Now, $\mu_w \sin i = \mu_a \sin r$

$$\frac{\mu_w}{\mu_a} = \frac{\sin r}{\sin i}$$

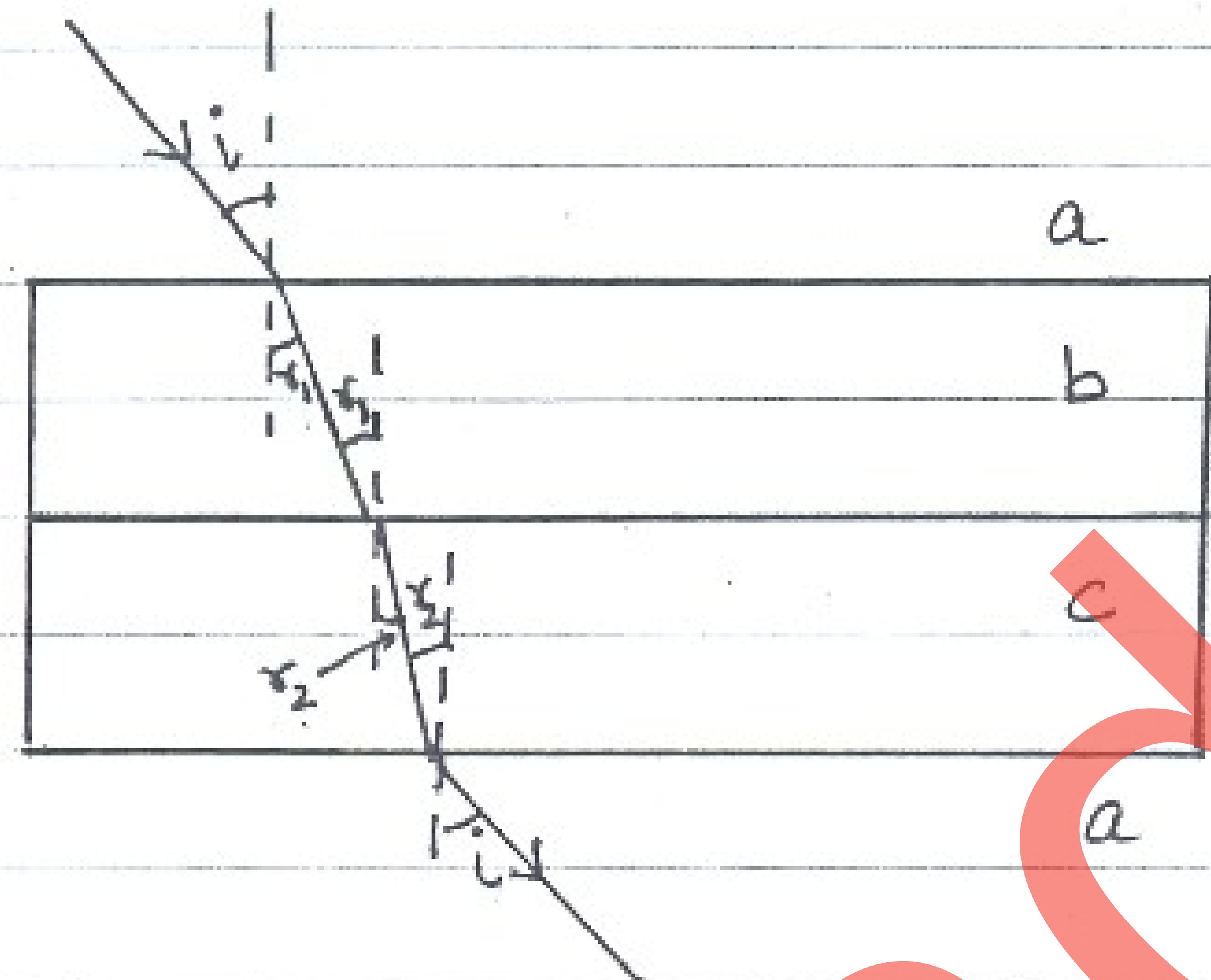
$$\mu_{wa} = \frac{\cancel{AB}}{IB} \times \frac{OB}{\cancel{AB}} = \frac{OB}{IB}$$

When angles are small, B is closer to A

$$\therefore \boxed{\mu_{wa} = \frac{OA}{IA} = \frac{x}{y}}$$

$$\boxed{\mu_{wa} = \frac{\text{real depth}}{\text{apparent depth}}}$$

Refraction of Light through a compound plate



$$^{a}\mu_{b} = \frac{\sin i}{\sin r_1} \quad , \quad ^{b}\mu_{c} = \frac{\sin r_1}{\sin r_2} \quad , \quad ^{c}\mu_{a} = \frac{\sin r_2}{\sin i}$$

$$^{a}\mu_{b} \times {^{b}\mu_{c}} \times {^{c}\mu_{a}} = \frac{\sin i}{\sin r_1} \times \frac{\sin r_1}{\sin r_2} \times \frac{\sin r_2}{\sin i}$$

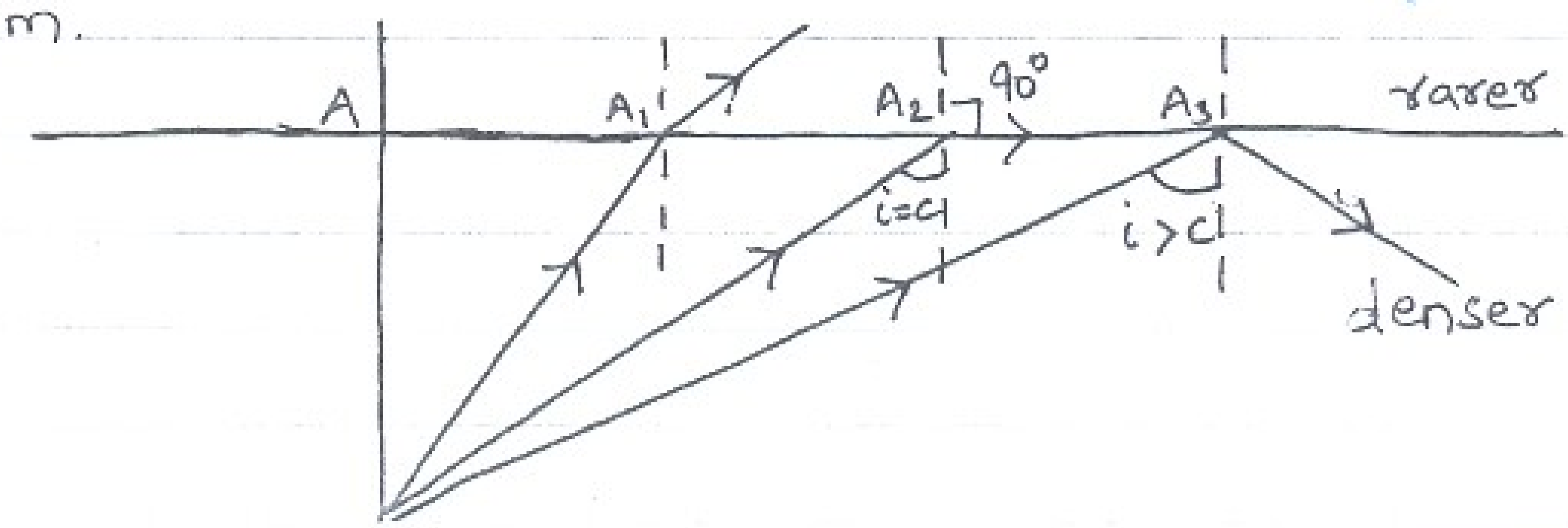
$$^{a}\mu_{b} \times {^{b}\mu_{c}} \times {^{c}\mu_{a}} = 1$$

[$\because$ $^{a}\mu_{b}$ - r.i of b w.r.t a]

$$\boxed{^{a}\mu_{b} \times {^{b}\mu_{c}} = \frac{1}{^{c}\mu_{a}} = {^{a}\mu_{c}}}$$

Total Internal Reflection

The phenomenon of reflection of light into a denser medium from the interface of denser & rarer medium.



At. A_3 - T.I.R.

Essential conditions for T.I.R

(a) Light should travel from a denser medium to a rarer medium.

(b) Angle of incidence in denser medium should be greater than critical angle.

Critical angle (C)

It is that angle of incidence in a denser medium for which angle of refraction is 90°.

$$\mu_b \sin C = \mu_a \sin 90^\circ$$

$$\boxed{\mu_{ba} = \frac{\mu_b}{\mu_a} = \frac{1}{\sin C}}$$

* As μ depends on λ, so C is different for different colours for the same pair of media in contact.

Applications of T.I.R

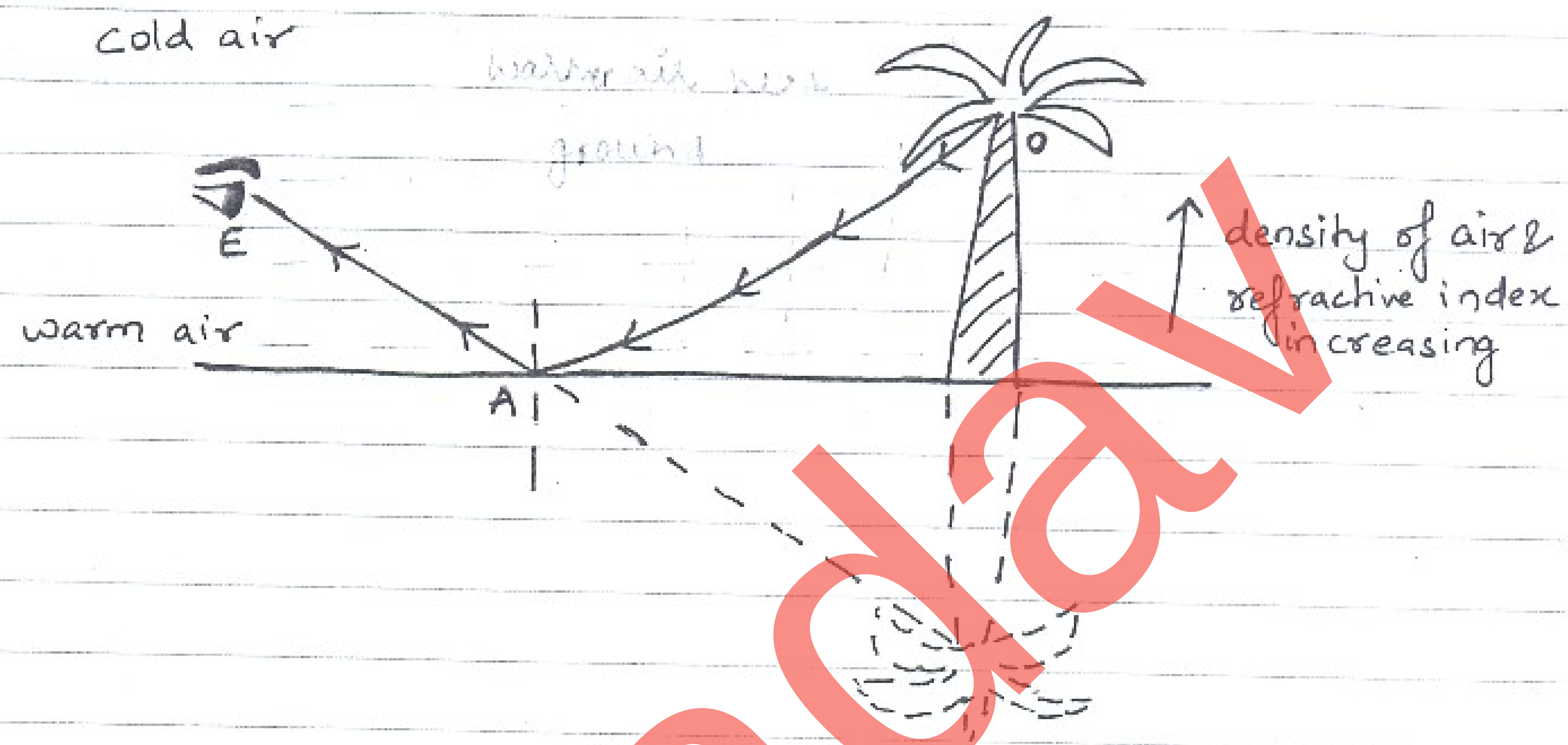
(a) **Brilliance of diamond**

For diamond $\mu = 2.42$ so $C = 24.4^\circ$

- The diamond is cut suitably so that light entering the diamond from any face falls at an angle greater than 24.4°.
- So, it suffers multiple T.I.Rs at various faces & remains within the diamond & hence sparkles.

(b) **Mirage**

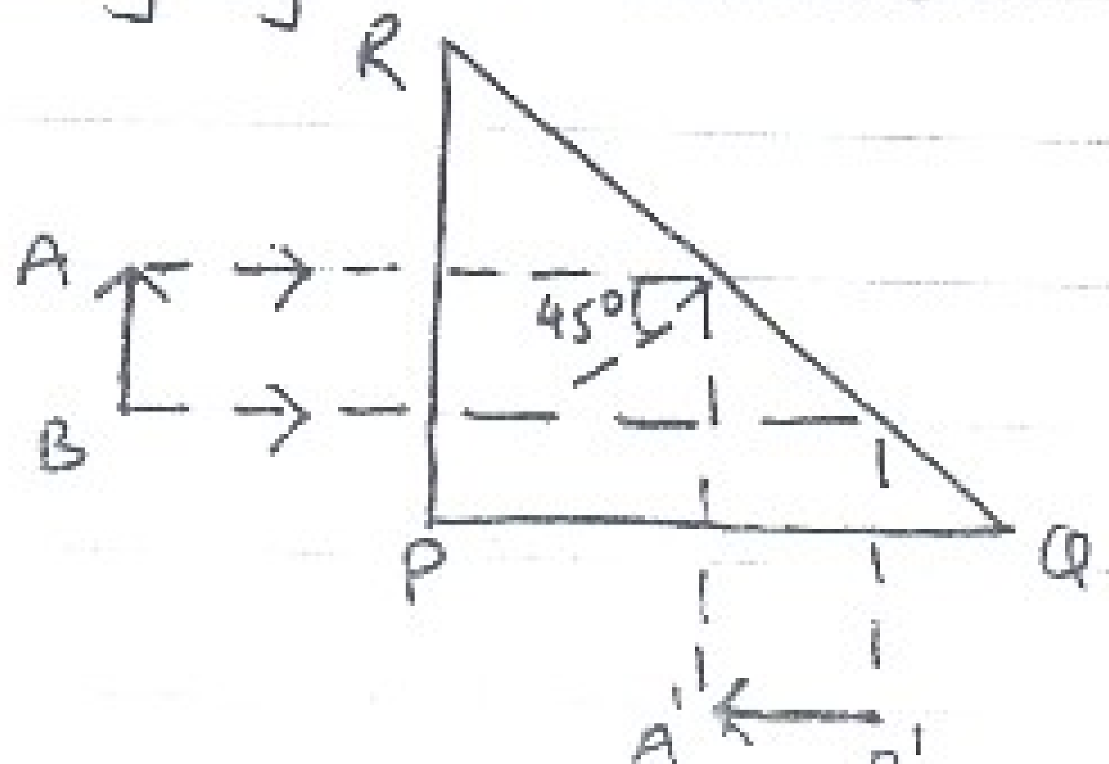
It is an optical illusion which occurs usually in deserts on hot summer days. The object such as a tree appears to be inverted, as if the tree is on the bank of a pond of water.

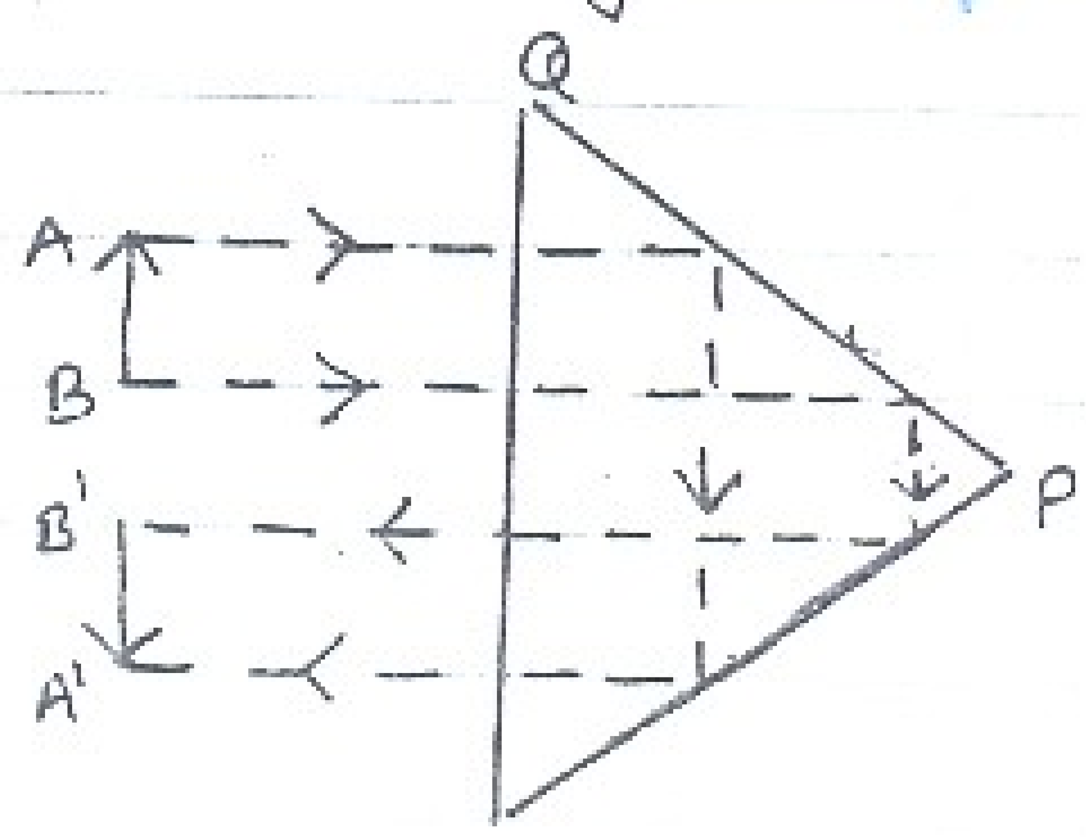


- On a hot summer day, tem. of air near the surface of earth is max.
- So, the density & refractive index of air goes on increasing slightly with height.
- A ray of light from O (top of the tree) goes from denser to rarer medium bending successfully away from normal.
- At a particular layer $i > c$ & T.I.R occurs & the totally reflected rays reaches the observer along AE appearing to come from I.

(c) <u>Totally reflecting glass prisms</u>

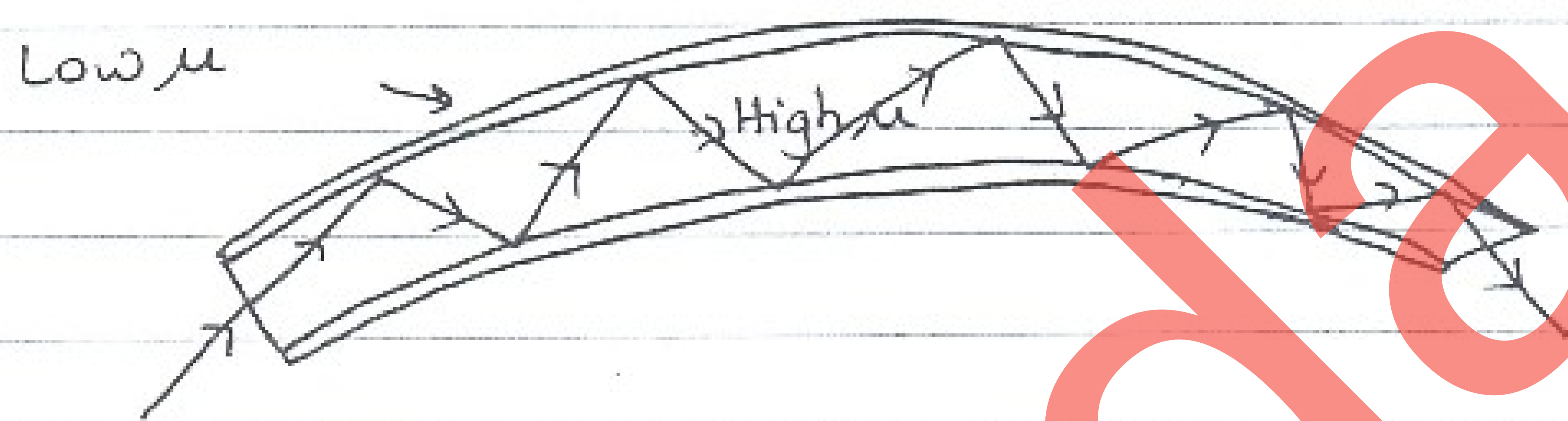
- Prisms designed to bend light by 90° or 180° use T.I.R concept
- Such prism is also used to invert images without changing their size.





(d) Optical fibres

- It consists of several thousands of very long fine quality fibres of glass ($\mu = 1.5$)
- The fibres are coated with a thin layer of material of lower refractive index ($\mu = 1.48$)



- Light incident on one end of the fibre at small angle enters the fibre after refraction and undergoes repeated T.I.Rs inside the fibre.
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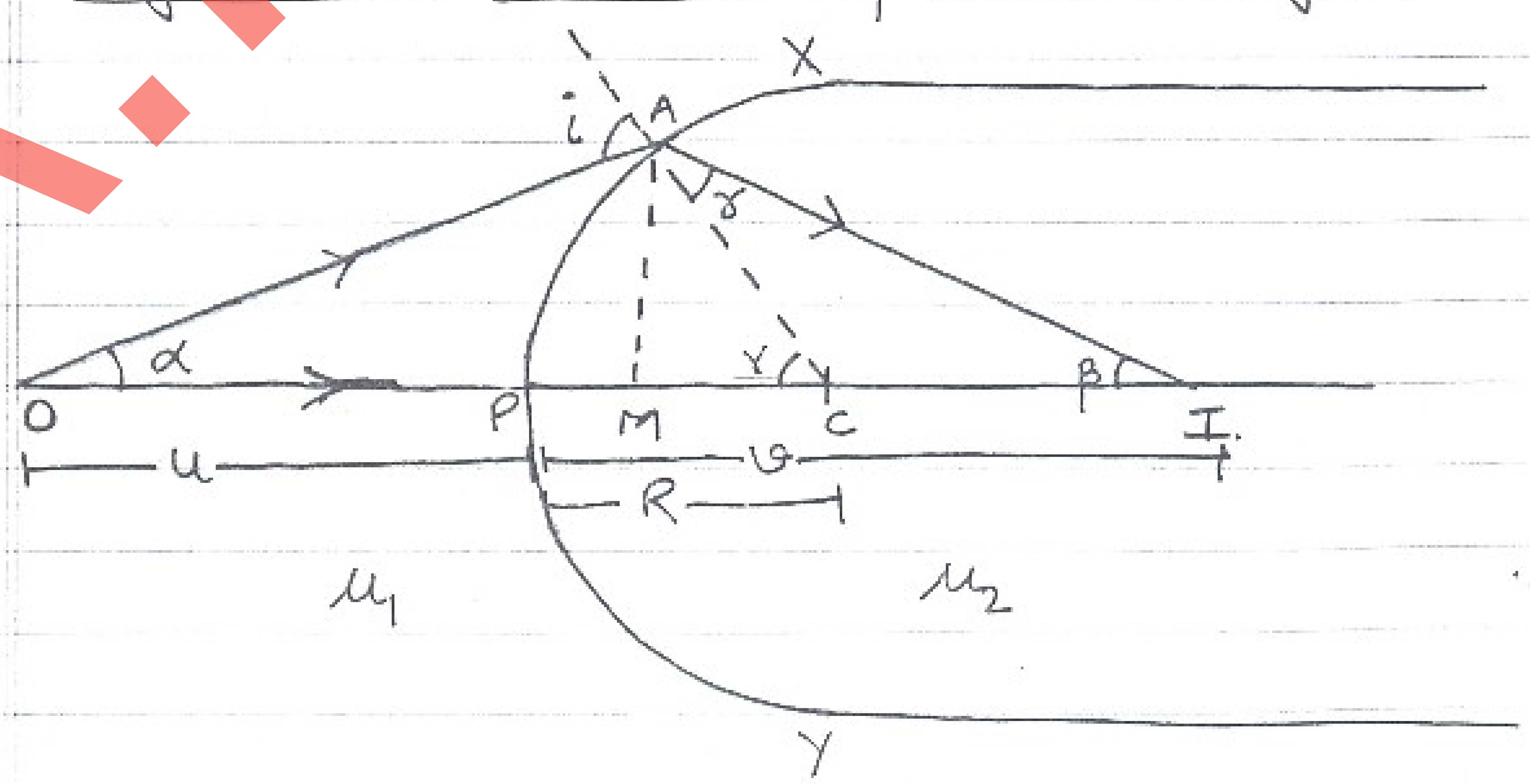
Applications of optical fibres

(i) Endoscopy - A bundle of optical fibres called light is used to transmit images from inaccessible parts of human body.

(ii) Transmission & reception of electrical signals.

(iii) Used in telephone & other transmitting cables.

Refraction from a spherical surface



Consider a pt. object O lying on principal axis at a distance 'u'.
A ray of light incident normally on XY along OP passes straight
Another ray of light incident along OA at $\angle i$ is refracted along AI at $\angle r$.
The 2 refracted rays actually meet at I (real image

Draw AM $\perp$ OI
Let $\angle AOM = \alpha$, $\angle AIM = \beta$, $\angle ACM = \gamma$

In ΔIAC, $r = \gamma - \beta$ $[\because \gamma = r + \beta]$
ΔOAC, $i = \alpha + \gamma$

Now, $\mu_1 \sin i = \mu_2 \sin r$ [Snell's law]
$\mu_1 i = \mu_2 r$ [$\because$ angles small]
$\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$
$$\mu_1 \left(\frac{AM}{OM} + \frac{AM}{MC} \right) = \mu_2 \left(\frac{AM}{MC} - \frac{AM}{MI} \right)$$

As aperature is small, M is close to P, so
MO $\approx$ PO , MI $\approx$ PI , MC $\approx$ PC

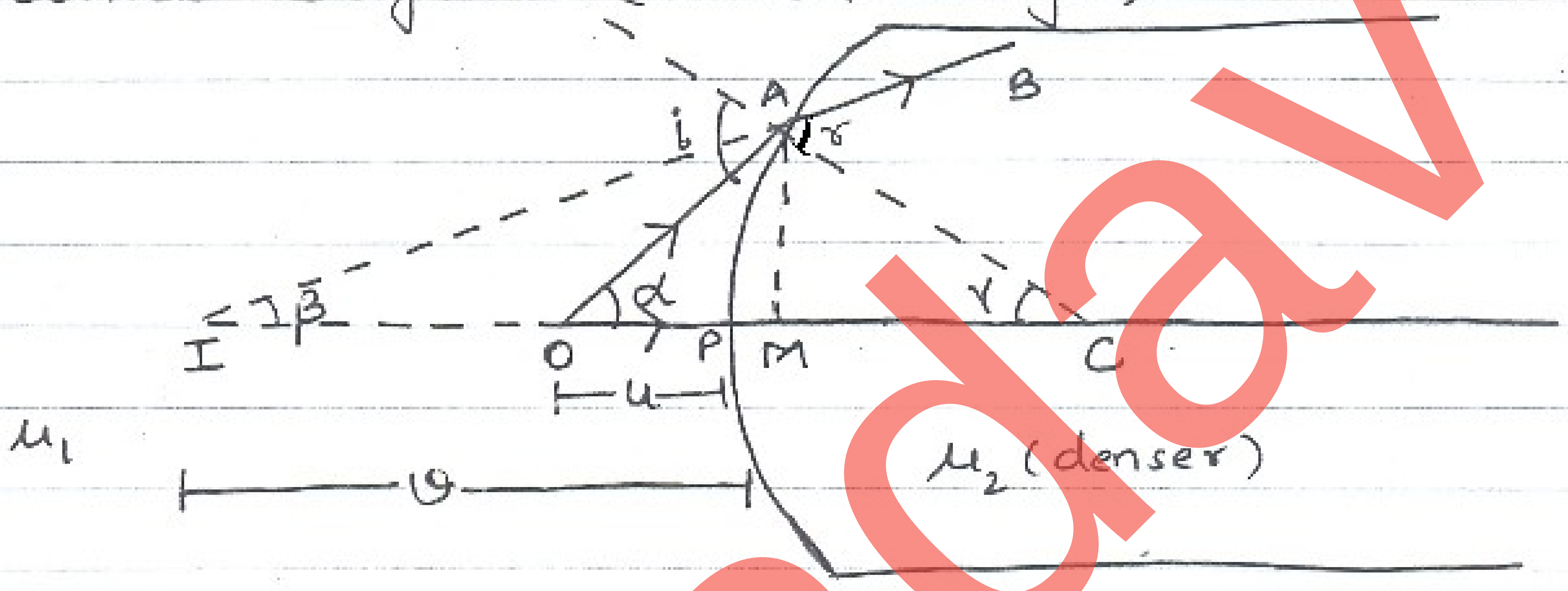
$$\therefore \mu_1 \left[\frac{1}{PO} + \frac{1}{PC} \right] = \mu_2 \left[\frac{1}{PC} - \frac{1}{PI} \right]$$

$$\frac{\mu_1}{PO} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

$$\boxed{\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}}$$

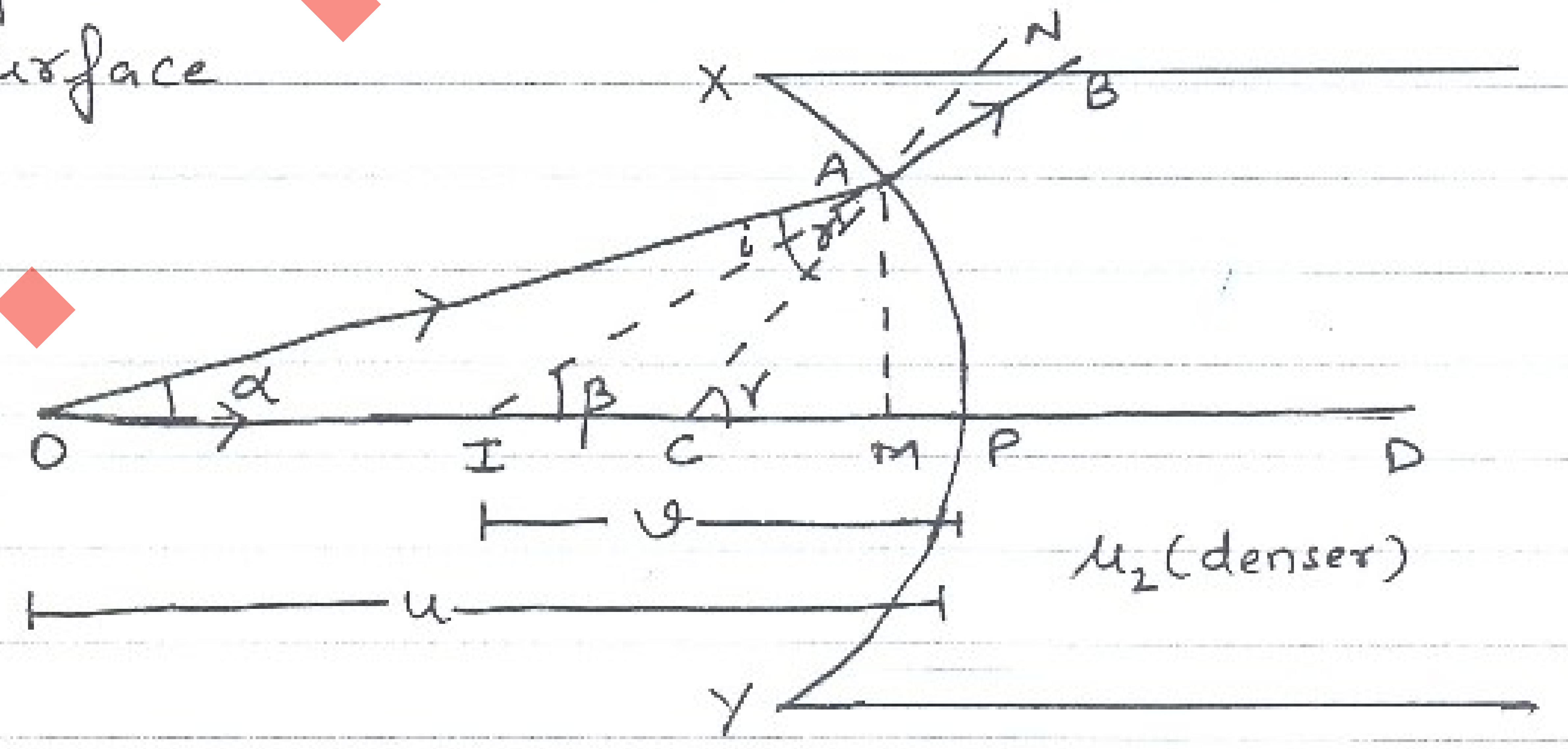
* Pay Attention

1. Refraction from rarer to denser medium at a convex surface (virtual image)



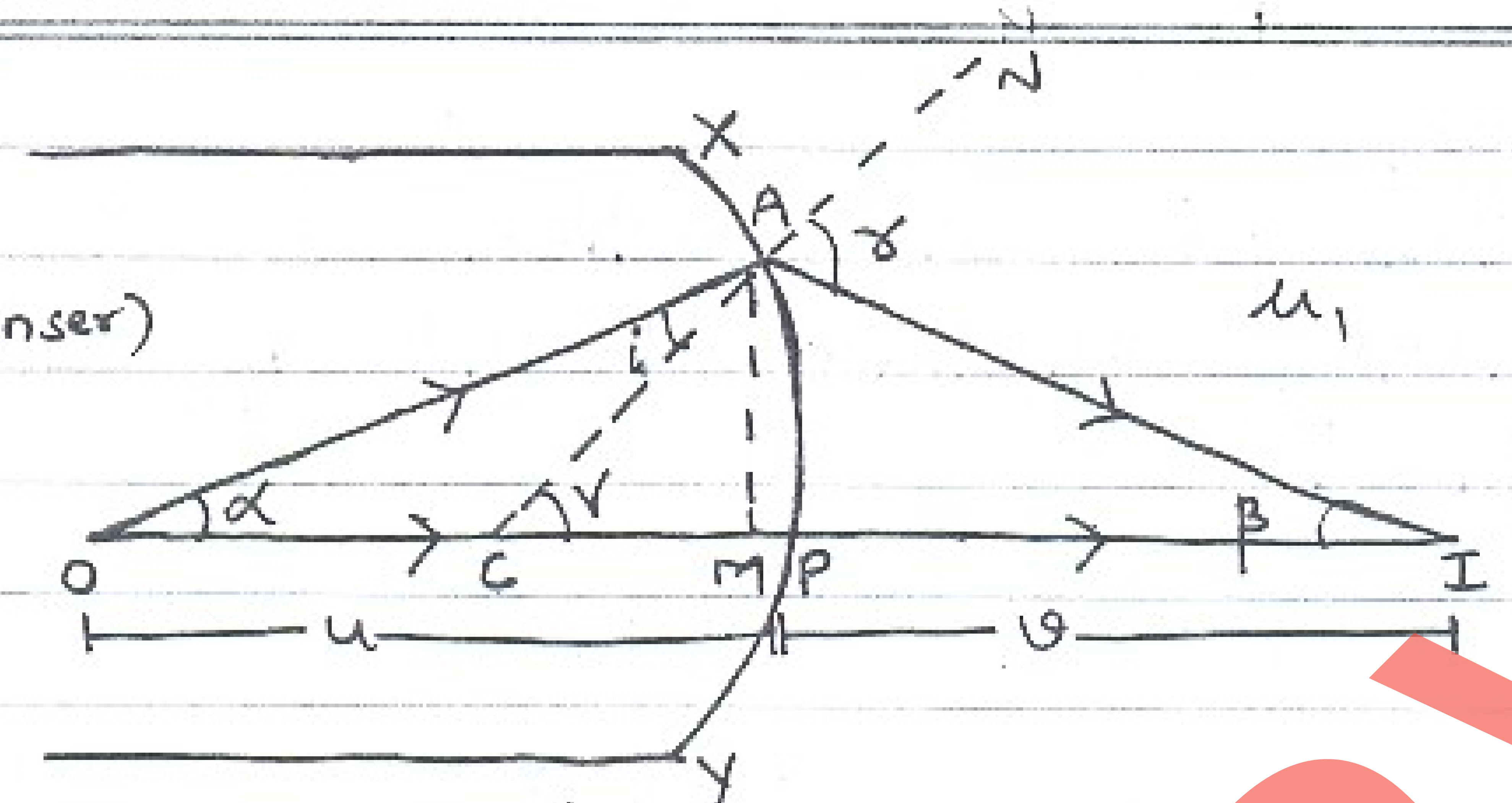
same derivation except $i = \gamma + \alpha$
$r = \gamma + \beta$

2. Refraction from rarer to denser medium at a concave surface



same derivation except $i = \gamma - \alpha$
$r = \gamma - \beta$

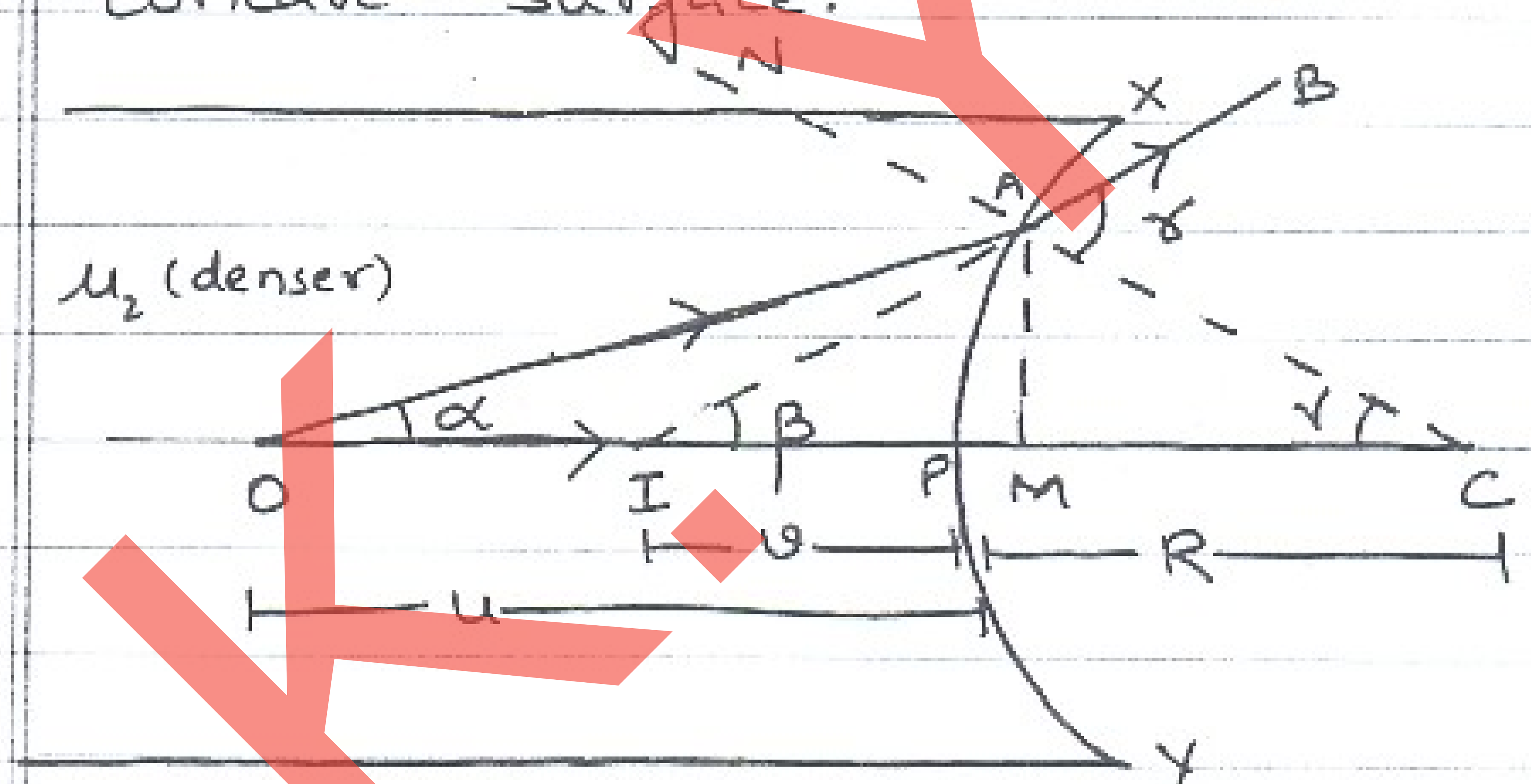
3. Refraction from denser to rarer medium at a convex surface



Proceed as ~~usually~~ previously with $\left.\begin{array}{l} i = r - \alpha \\ r = r + \beta \end{array}\right\}$ to get

$$\boxed{\frac{\mu_2}{-u} + \frac{\mu_1}{v} = \frac{\mu_2 - \mu_1}{-R} = \frac{\mu_1 - \mu_2}{R}}$$

4. Refraction from denser to rarer medium at a concave surface.



Proceed as previously with $\left.\begin{array}{l} i = r + \alpha \\ r = r + \beta \end{array}\right\}$ to get

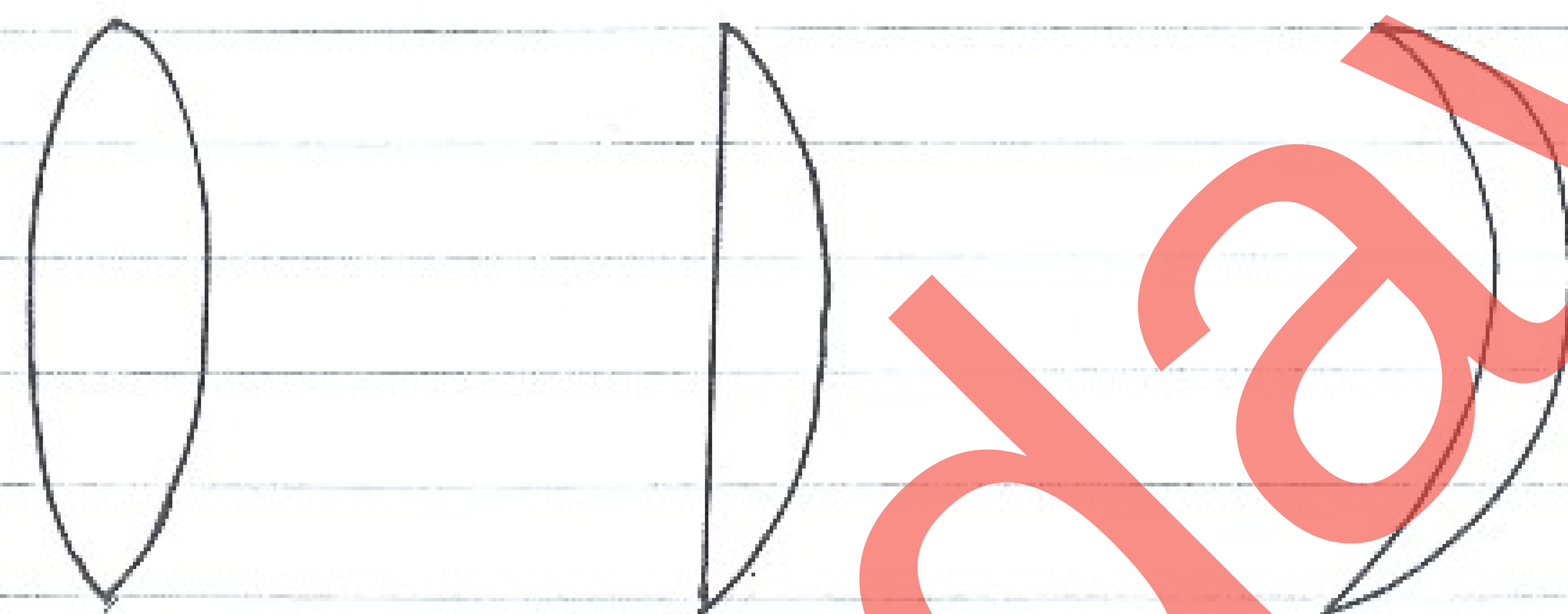
$$\frac{\mu_2}{-u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R}$$

5. In 1 & 2 result is same as derived previously, just change the values of i & r & the situational sign conventions.

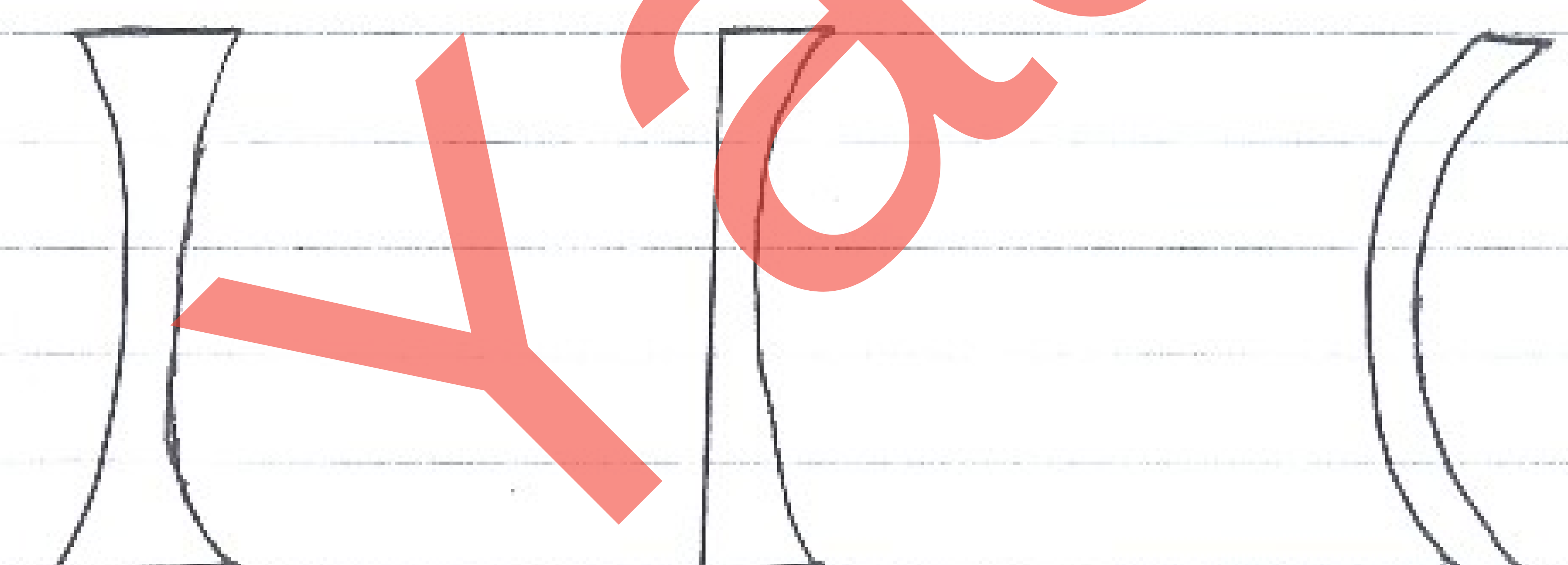
(Steps) Method is same in all the cases.

Lenses

A lens is a portion of a transparent refracting medium bound by 2 spherical surfaces.

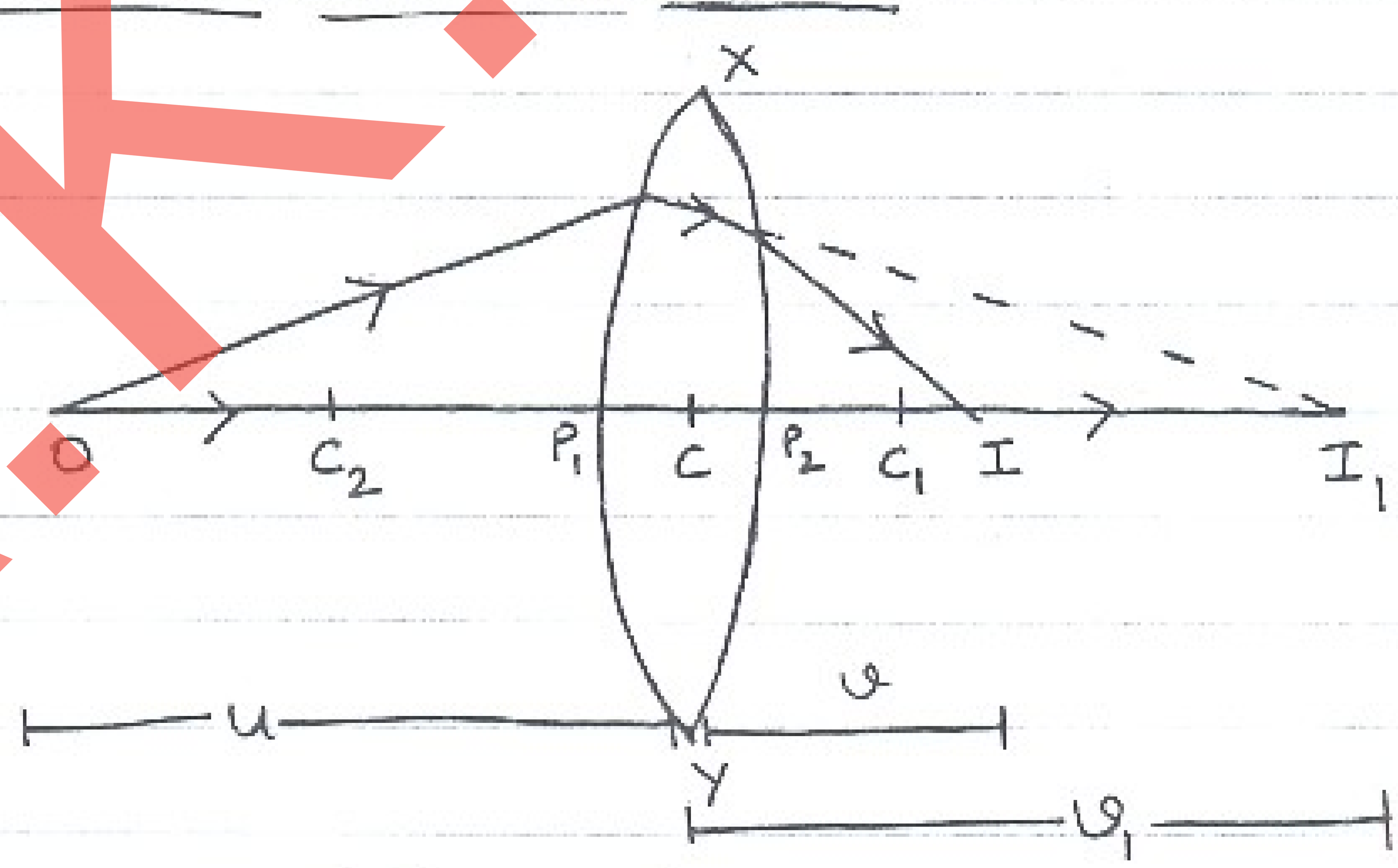


Double convex   Plano convex   Concavo convex



Double concave   Plano concave   Convexo concave

Len's Maker Formula



Here. P_1, P_2 - poles

C_1, C_2 - centres of curvatures

μ_1 - refractive index of rarer medium around the lens

μ_2 - " " " material of lens

Consider a point Object 'O' lying on the principal axis of the lens.
A ray of light incident normally on the surface XP_1Y along OP_1 goes undeviated.
Another ray incident along OA is refracted along AB.

If the lens material was continuous (i.e. no boundary surface XP_2Y), then refracted ray AB would meet 1st ray at I_1.
(i.e. I_1 would have been real image of O)
So,

$$-\frac{\mu_1}{u} + \frac{\mu_2}{v_1} = \frac{\mu_2 - \mu_1}{R} \quad \text{--- (1)} \qquad [\because v = v_1]$$

But the lens material is not continuous so, AB suffers further refraction at B & emerges along BI.
[i.e. I is the final real image of O]

For refraction at XP_2Y we regard I_1 as virtual object whose real image is formed at I.

$\therefore$ $u = CI_1 = v_1$
$v = CI = v$
R – r. o. curvature of 2nd surface of lens.

As refraction is taking from denser to rarer medium so,

$$-\frac{\mu_2}{v_1} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R_2} \quad \text{--- (2)} \qquad \left[\because \frac{\mu_2}{-u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R}\right]$$

(1) + (2)

$$-\frac{\mu_1}{u} + \frac{\mu_1}{v} = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\mu_1\left[\frac{1}{v} - \frac{1}{u}\right] = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

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

When $u = \infty$, $v = f$

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

Power of a lens

It is the degree of convergence or divergence of a lens.

$$P = \frac{1}{f}$$

S.I. unit - Dioptre

1 Dioptre - It is the power of a lens of focal length 1m.

Combination of thin lenses in contact

In various optical instruments, 2 or more lenses are combined to -

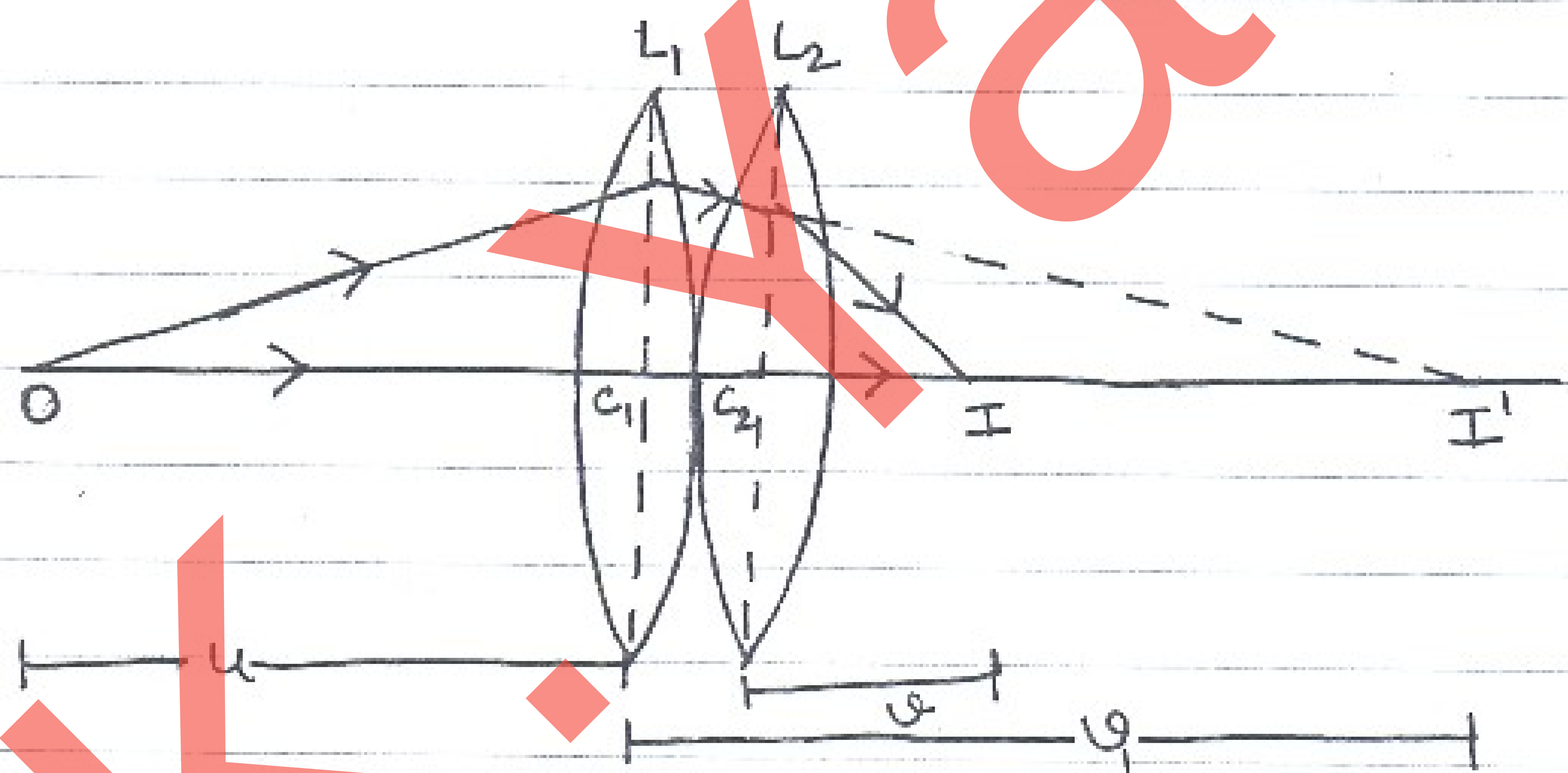
(i) increase the magnification of image

(ii) make the final image erect w.r.t the object.

(iii) reduce defect of images by single lens.

Focal length of equivalent Lens

(a) Both the lenses are convex



Let C_1, C_2 be the optical centres of 2 thin convex lenses L_1 & L_2 held co-axially in contact with each other in air.

Let a point object O be placed on the common principal axis at $OC_1 = u$

L_1 alone would form its image at I' ($C_1I' = v'$)

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad \text{—(1)}$$

Now, I' serves as a virtual object for L_2 which forms a final image I at $C_2 I = v$

So, $\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2}$ — (2)

(1) + (2)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{— (3)}$$

Let the 2 lenses be replaced by a single lens of focal length F, which forms image I at distance v, of an object placed at a distance 'u' from the lens, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \quad \text{— (4)}$$

from (3) & (4)

$$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$$

(b) One lens is convex & the other is concave

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{-f_2} = \frac{1}{f_1} - \frac{1}{f_2}$$

<u>Special cases</u>

(a) $f_1 = f_2 \Rightarrow F = \infty$, combination behaves like plane mirror

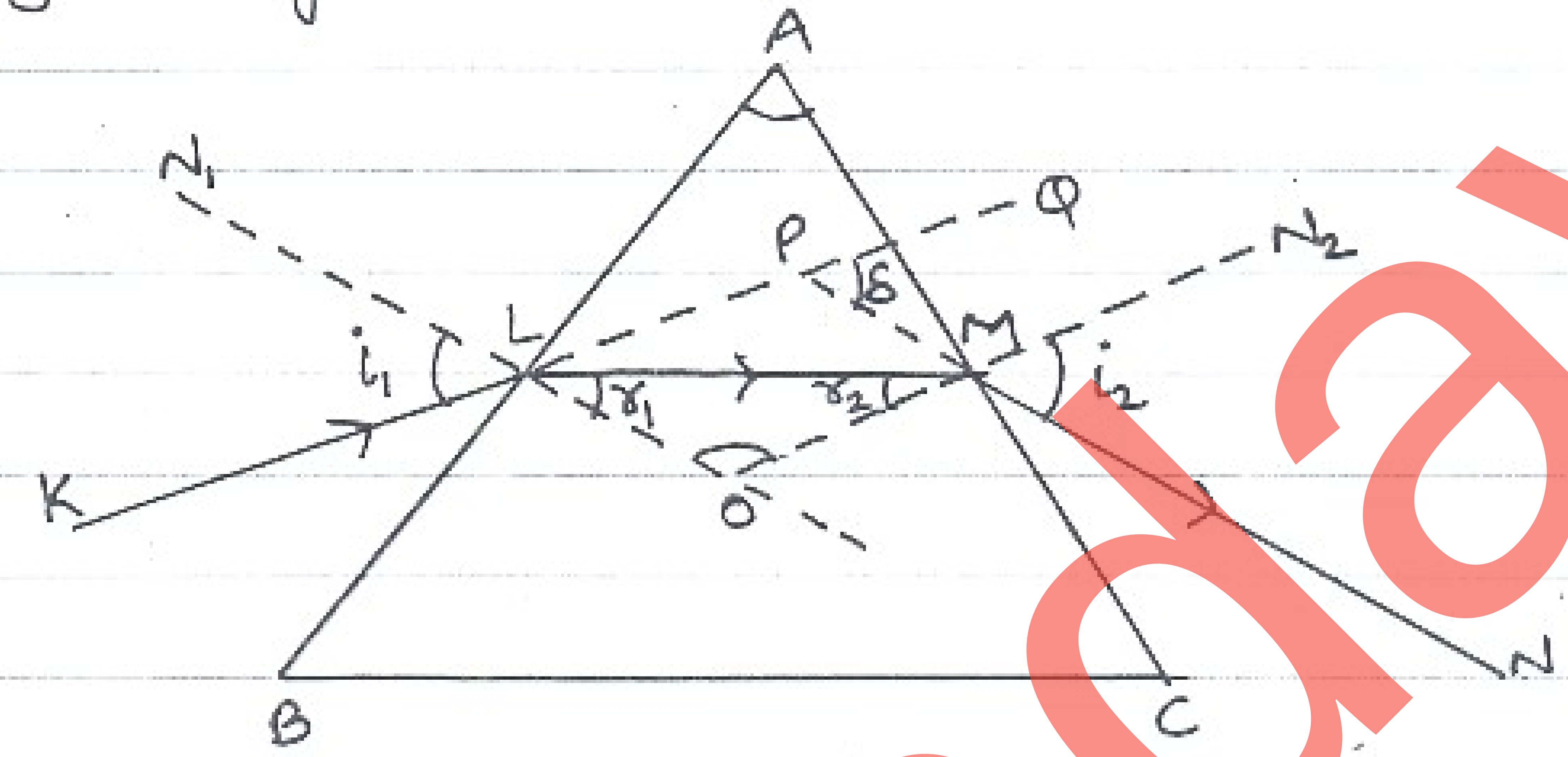
(b) $f_1 > f_2 \Rightarrow F = -ve$, " " " concave lens

(c) $f_1 < f_2 \Rightarrow F = +ve$, " " " convex

Dispersion of Light

Refraction through a prism

(a) Angle of deviation (δ)



- Incident ray KL strikes AB at $\angle i_1$, bends towards normal (N_1O) & is refracted along LM at $\angle r_1$.
- Refracted ray LM is incident at $\angle r_2$ on AC, bends away from normal (N_2O) & emerges along MN at $\angle i_2$.
- In passing through prism, ray KL suffers 2 refractions & has turned through $\angle QPN = \delta$

In ΔPLM, $\delta = \angle PLM + \angle PML$

$= (i_1 - r_1) + (i_2 - r_2)$

$= (i_1 + i_2) - (r_1 + r_2)$ — (1)

In ΔOLM, $\angle O + r_1 + r_2 = 180°$ — (2)

In qud. ALOM, $A + \angle O = 180°$ — (3)

from (2) & (3) $\boxed{r_1 + r_2 = A}$

eqn (1) becomes $\boxed{\delta = (i_1 + i_2) - A}$

If μ is the refractive index of the material of the prism, then

$$\mu = \frac{\sin i_1}{\sin r_1}$$

$$\mu = \frac{i_1}{r_1} \qquad \text{[when angles are small]}$$

$$\therefore \quad i_1 = \mu r_1$$

Similarly, $i_2 = \mu r_2$

$$\therefore \quad \delta = \mu(r_1 + r_2) - A$$
$$= \mu A - A$$

$$\boxed{\delta = (\mu - 1)A}$$

(b) Prism formula

$$\delta = (i_1 + i_2) - A$$
$$= (\sqrt{i_1})^2 + (\sqrt{i_2})^2 - A$$
$$= (\sqrt{i_1})^2 + (\sqrt{i_2})^2 - 2\sqrt{i_1 i_2} + 2\sqrt{i_1 i_2} - A$$
$$= (\sqrt{i_1} - \sqrt{i_2})^2 + 2\sqrt{i_1 i_2} - A$$

δ will be minimum, if $(\sqrt{i_1} - \sqrt{i_2})^2 = 0$

$$\sqrt{i_1} = \sqrt{i_2}$$

$$i_1 = i_2$$

Thus in minimum deviation position

$$i_1 = i_2 = i$$

As $i_1 = i_2$, so, $r_1 = r_2 = r$

Now, $r + r = A$

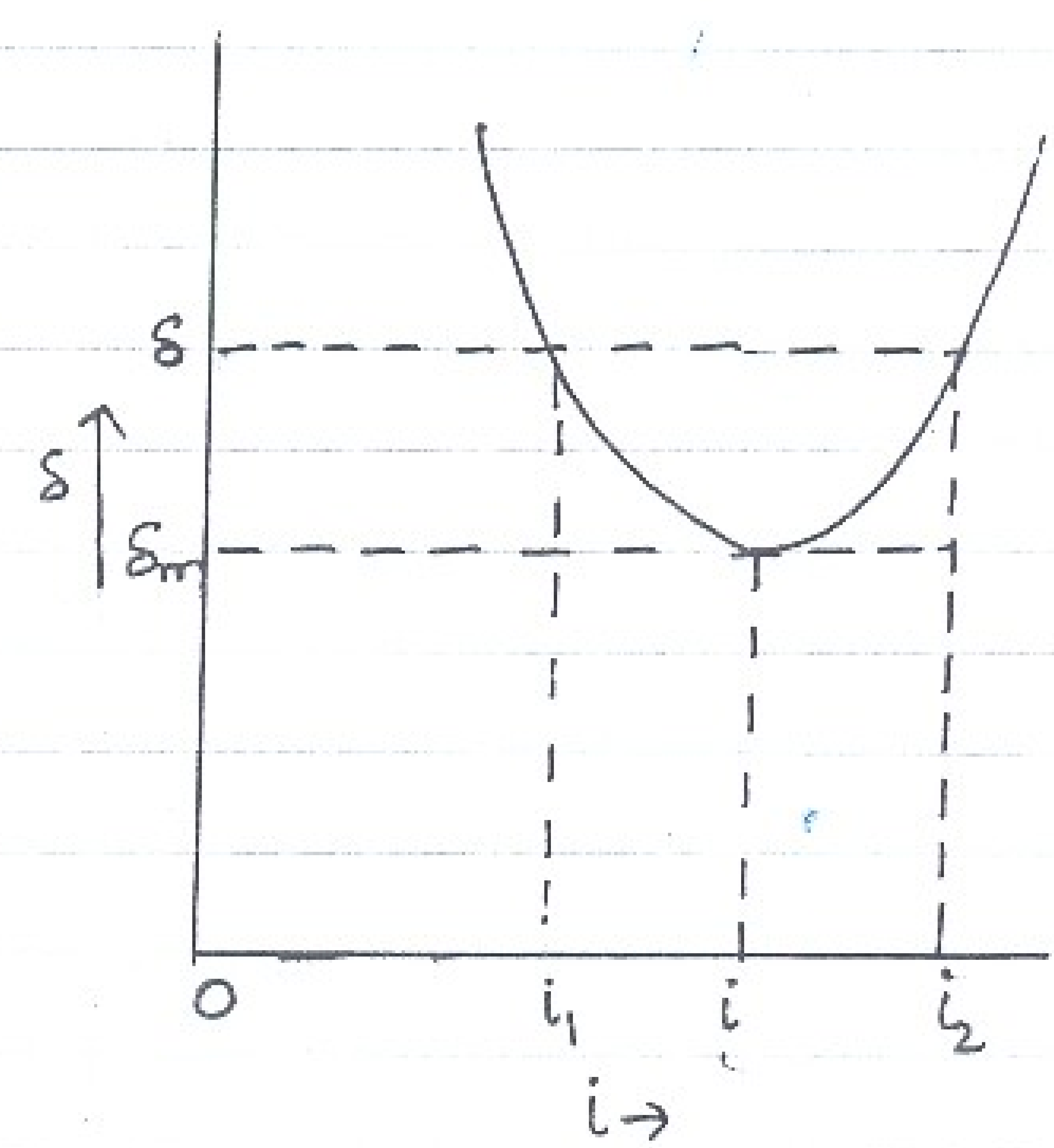
$$\therefore r = A/2$$

So, $\delta_m = i + i - A$

$$i = \frac{A + \delta_m}{2}$$

Now, $$\boxed{\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}}$$

Graphically



→ When i is increased δ decreases, reaches a minimum & increases again.

→ For one value of δ, there are 2 angles of incidence i_1 & i_2

→ But at minimum deviation

$$\delta = \delta_m$$

$$i_1 = i_2$$

[i.e. incident ray & emergent ray are symmetrical w.r.t refracting faces]

Dispersion of light

It is the phenomenon of splitting of white light into its constituent colours on passing through a prism.

Cause of dispersion

- Each colour has its own wavelength
- μ (prism material) different for different colours.
- So, different colours deviate through different angles on passing through the prism and are seen as separate.

$$\lambda_{violet} < \lambda_{red}$$

$$\mu_{violet} > \mu_{red} \qquad \left[\because \mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \dots\right]$$

$$\boxed{\delta_{violet} > \delta_{red}}$$

So, violet is at the lower end & red at upper end of spectrum.

Scattering of light

Rayleigh scattering

Amount of scattering is inversely proportional to the 4th power of wavelength.

$$\boxed{I_s \propto \frac{1}{\lambda^4}}$$

Important factor in scattering is the relative size of wavelength of light (λ) & ~~wavelength~~ size of scatterer (a)

if $a << \lambda$, Rayleigh scattering is valid

$a >> \lambda$, " " " not valid & all wavelengths are equally scattered

Applications of scattering of light

1 Blue colour of sky

- Sunlight while travelling through earth's atmosphere gets scattered by large no. of molecules present in the atmosphere
- As $a << \lambda$, Rayleigh scattering is valid so,

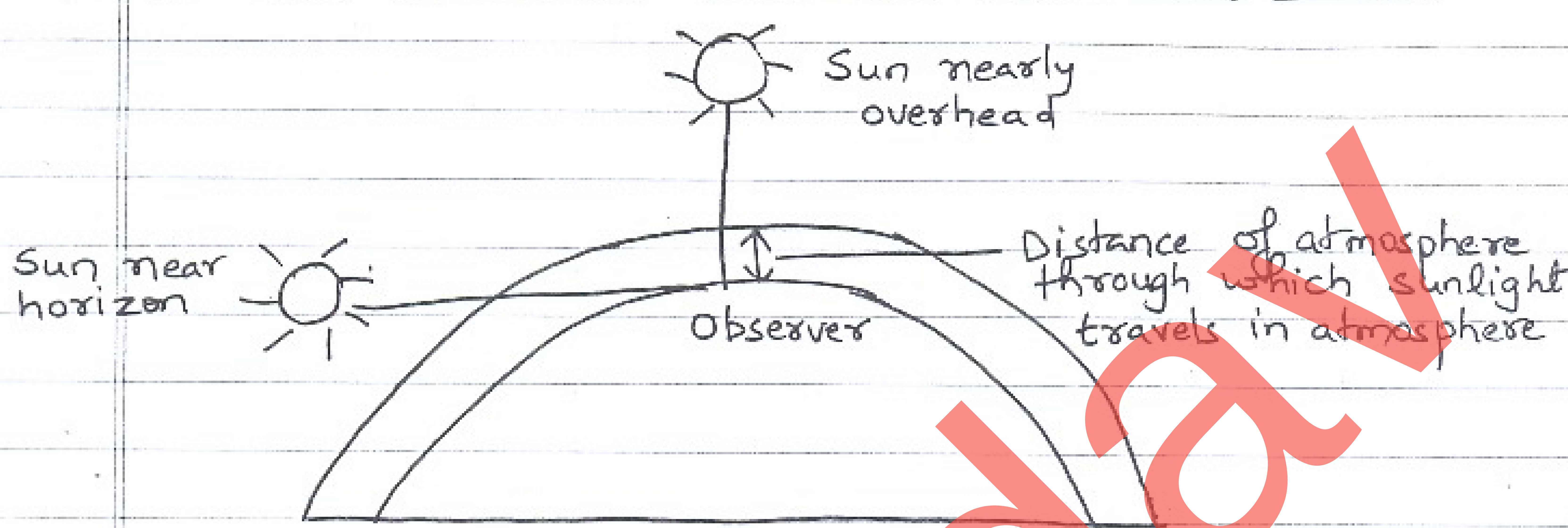
$$I_s \propto \frac{1}{\lambda^4}$$

- As blue colour has a shorter wavelength than red, so blue colour is scattered more strongly.
- So, the sky looks blue.

2 White colour of clouds

- Clouds are at much lower height.
- They are seen due to scattering from lower parts of atmosphere which contains large dust particles, water droplets etc.
- Here $a >> \lambda$, Rayleigh scattering not valid
- So, all wavelengths are equally scattered which gives the sensation of white colour.

③ Sun looks reddish at sunrise and sunset



- At sunset and sunrise, sun is near horizon.
- So, sun's rays has to pass through a large distance in the atmosphere.
- Most of the blue & other shorter wavelengths are removed by scattering.
- The least scattered colour (i.e. red) reaches our eyes & so the reddish appearance of sun.

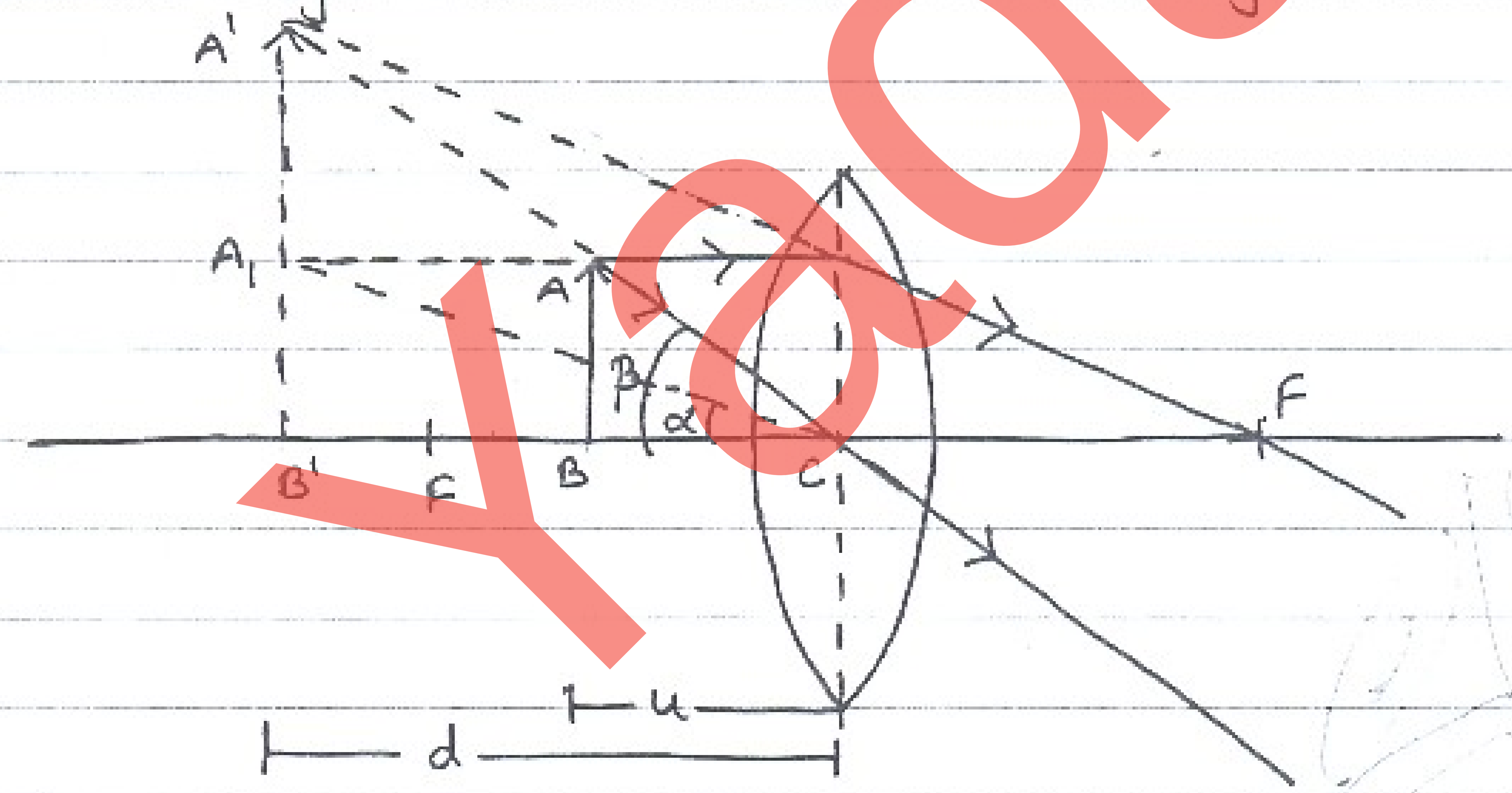
④ Danger signals are red

Red colour is least scattered (λ-large, I-small) & can be seen from large distance.

Optical Instruments

Simple microscope

- It is used for observing magnified images of tiny objects.
- It consists of a converging lens of small focal length.
- A virtual, erect and magnified image of the object is formed at the least distance of distinct vision from the eye held close to the eye.



When an object AB is held betⁿ F & C (optical centre) then a virtual, erect & enlarged image A'B' is formed.
The eye is held close to the lens & CB' = d
i.e. the image is at least distance of distinct vision.

Magnifying power of a simple microscope

It is defined as the ratio of the angles subtended by the image & the object on the eye, when both are at the least distance of distinct vision from the eye.

Imagine the object AB to be displaced to A_1B' at distance d.

Let $\angle A'CB' = \beta$ & $\angle A_1CB' = \alpha$

$\therefore \quad m = \frac{\beta}{\alpha}$

For small angles, $\tan\theta \approx \theta$

So, $m = \frac{\tan\beta}{\tan\alpha}$

In ΔABC, $\tan\beta = \frac{AB}{CB}$

In $\Delta A_1B'C$, $\tan\alpha = \frac{A_1B'}{CB'} = \frac{AB}{CB'}$

$= \frac{AB}{CB} \times \frac{CB'}{AB}$

$= \frac{CB'}{CB}$

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

From lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$1 - \frac{v}{u} = \frac{v}{f}$

$1 - m = \frac{v}{f}$

$m = 1 - \frac{v}{f}$

$$\boxed{m = 1 + \frac{d}{f}}$$

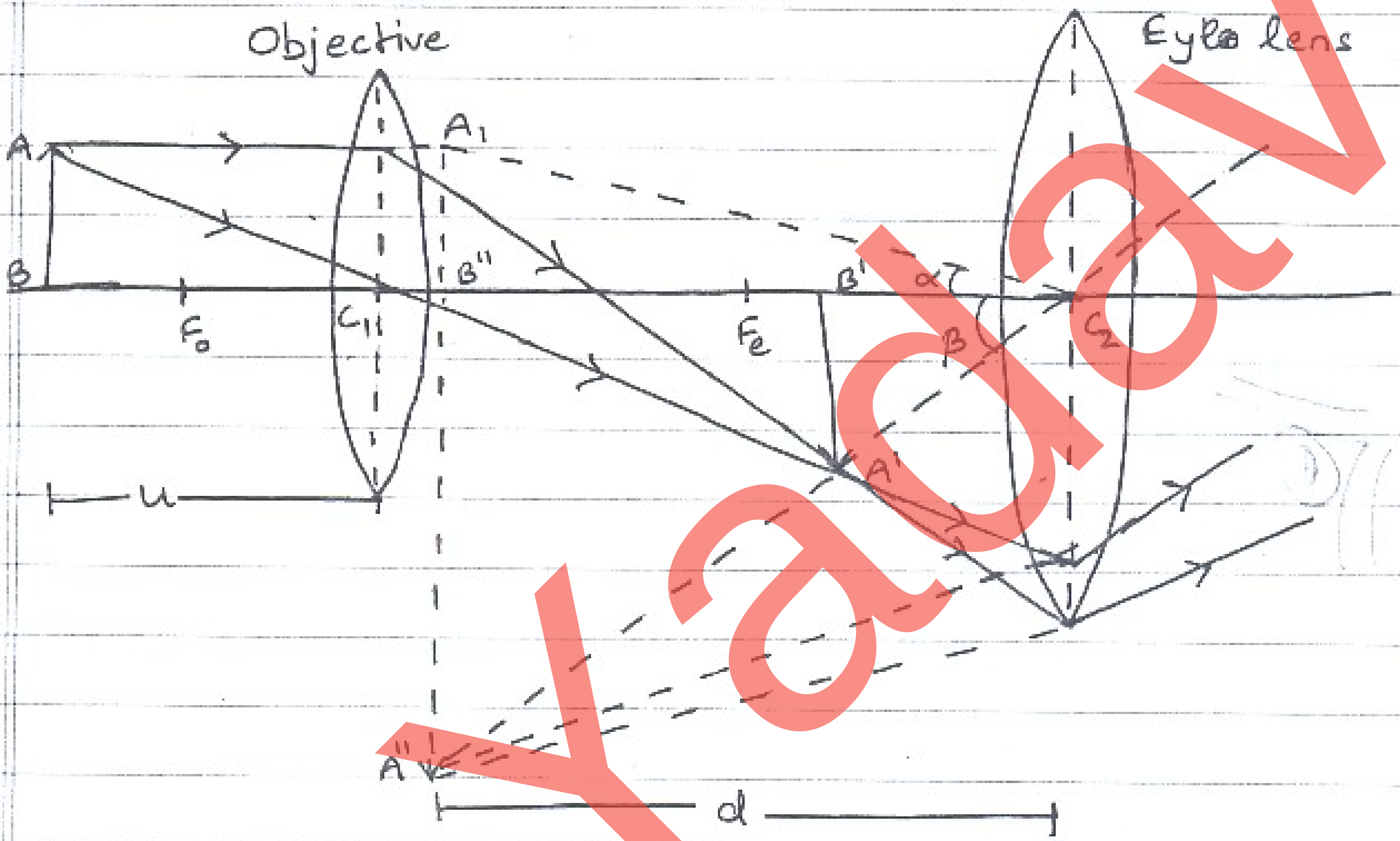
$\because v = -d$

Uses of simple microscope

1. By watch makers & jewellers
2. By students in labs for reading vernier scale etc.

Compound Microscope

It is an optical instrument used for observing highly magnified images of tiny objects.



- Object AB is placed beyond the focus F_o of the objective lens.
- A real, inverted & enlarged image $A'B'$ is formed.
- The position of $A'B'$ is so adjusted that it lies betⁿ C_2 & F_e (i.e. it serves as a object).
- A virtual & enlarged image $A''B''$ is formed & is seen by the eye held close to eye lens.
- Adjustments are so made that $A''B''$ is at the least distance of distinct vision from eye.

Magnifying power of compound microscope

It is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image & the object are situated at the least distance of distinct vision from the eye.

Image AB to be shifted to A_1B'' so that it is at distance 'd' from the eye

Now, $m = \frac{\beta}{\alpha}$

$= \frac{\tan\beta}{\tan\alpha}$ $\quad$ | $\because$ for small angles $\tan\theta \approx \theta$

$= \frac{A''B''}{C_2B''} \times \frac{C_2B''}{AB}$ $\quad$ | In $\Delta A''B''C_2$, $\tan\beta = \frac{A''B''}{C_2B''}$

In $\Delta A_1B''C_2$, $\tan\alpha = \frac{A_1B''}{C_2B''} = \frac{AB}{C_2B''}$

$$m = \frac{A''B''}{AB} = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB}$$

$$\boxed{m = m_e \times m_o}$$

Now, $m_e = 1 + \frac{d}{f_e}$

$$m_o = \frac{A'B'}{AB} = \frac{\text{distance of } A'B' \text{ from } C_1}{\text{distance of } AB \text{ from } C_1} = \frac{C_1B'}{C_1B} = \frac{v_o}{-u_o}$$

$$\therefore \boxed{m = \frac{v_o}{-u_o}\left(1 + \frac{d}{f_e}\right)}$$

As AB lies very close to F_o so,
$u_o = C_1B \approx C_1F_o = f_o$

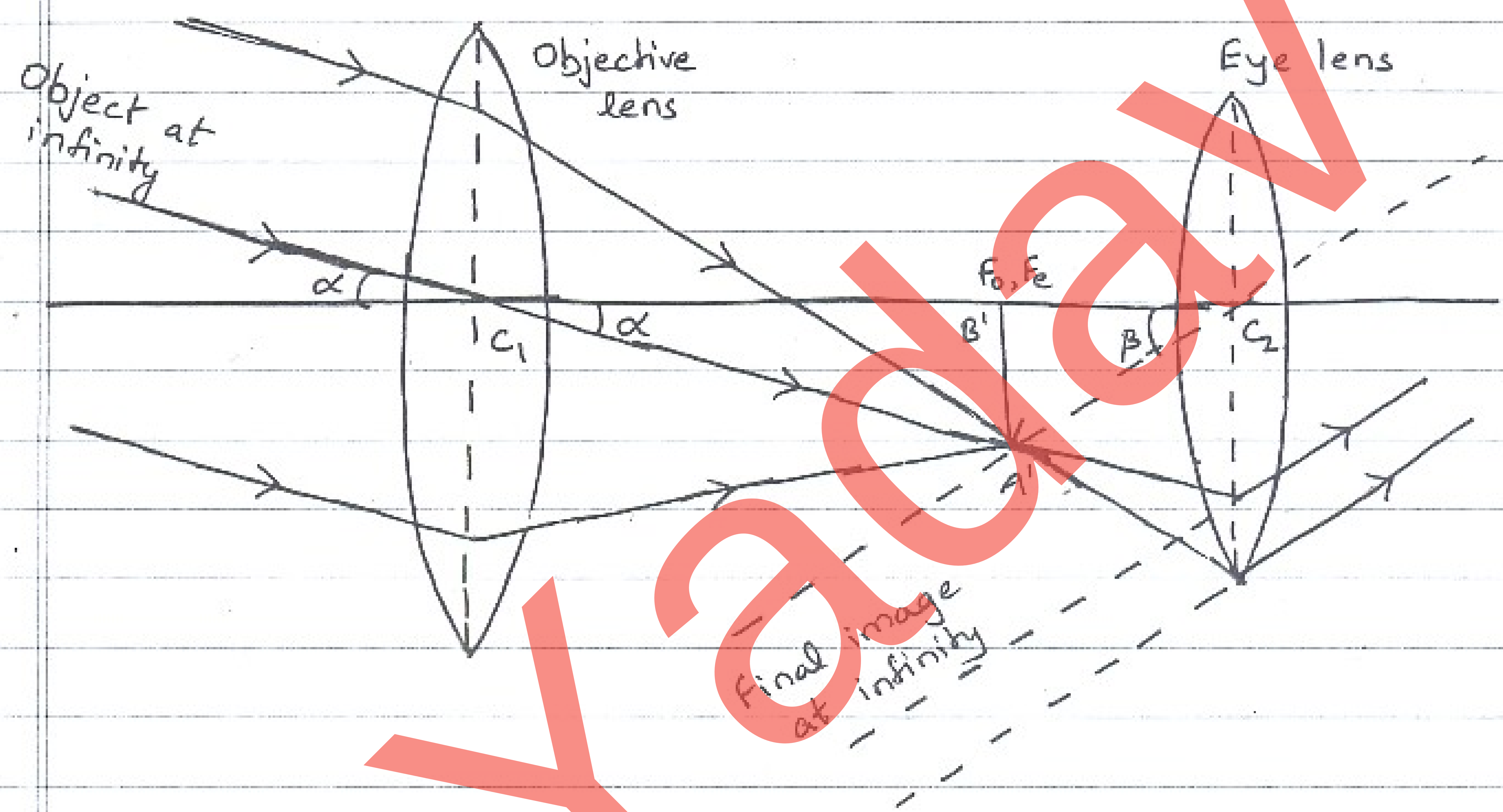
As $A'B'$ is formed very close to eye lens so,
$v_o = C_1B' \approx C_1C_2 = L$ (length of microscope tube)

$$\therefore \boxed{m = \frac{L}{-f_o}\left(1 + \frac{d}{f_e}\right)}$$

5

Astronomical Telescope

It is an optical instrument which is used for observing distinct images of heavenly bodies.



- A parallel beam of light from an astronomical object at ∞ is made to fall on the objective lens of telescope.
- It forms a real, inverted & diminished image $A'B'$ of the object.
- The eye piece is so adjusted that $A'B'$ lies just at the focus of eye piece.
- A final highly magnified image is formed at infinity
- The final image is erect w.r.t $A'B'$ & inverted w.r.t obj

Magnifying power

It is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye, by the object directly, when the final image & the object both lie at infinite distance from the eye.

$$m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$$ [∵ for small angles $\theta \approx \tan\theta$]

$$= \frac{A'B'}{C_2B'} \times \frac{C_1B'}{A'B'}$$

In $\Delta A'B'C_2$, $\tan\beta = \frac{A'B'}{C_2B'}$

In $\Delta A'B'C_1$, $\tan\alpha = \frac{A'B'}{C_1B'}$

$$\boxed{m = \frac{f_o}{-f_e}}$$

-ve sign indicates final image is inverted

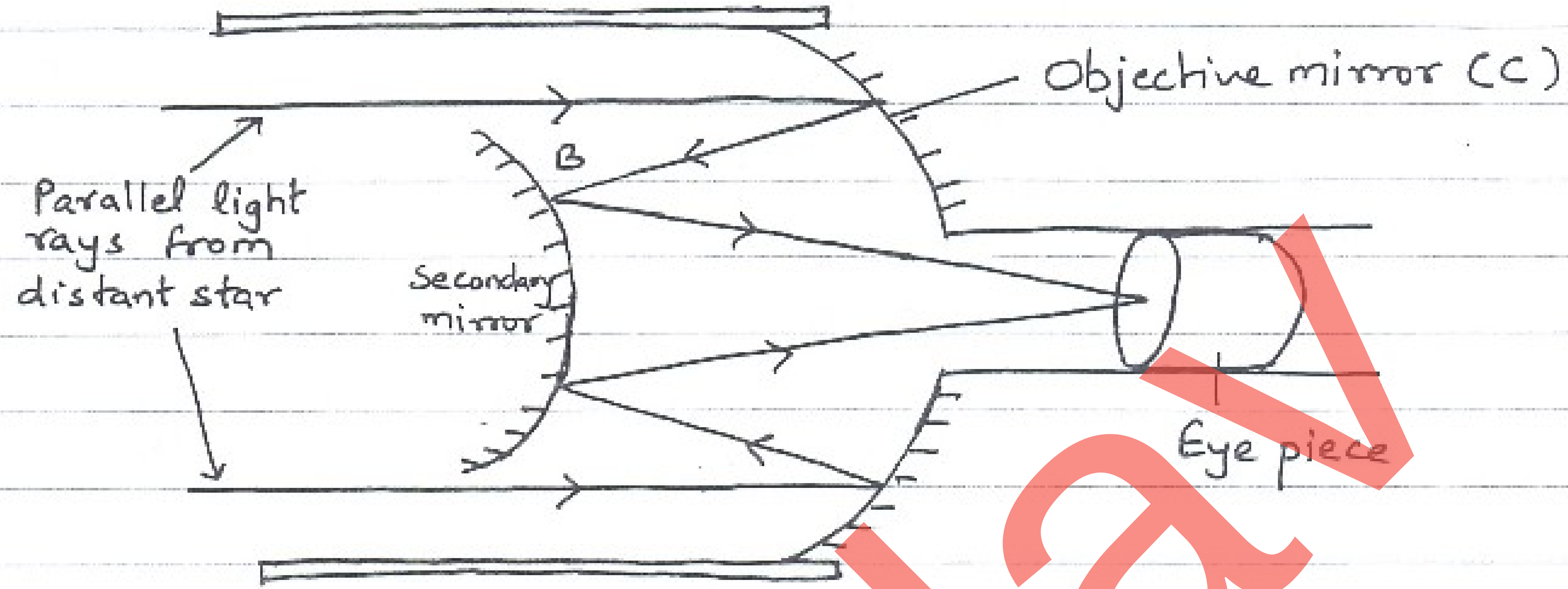
So, to increase 'm' of an astronomical telescope in normal adjustment, f_o should be large & f_e should be small.

Reflecting Type Telescope (Cassegrainian Telescope)

- It is an improvement over the refracting type astronomical telescope.
- Here, the objective lens is replaced by a concave parabolic mirror of large aperture (200 in
- Image formed is much brighter.

Advantages

1. No chromatic aberration as objective is a mirror.
2. Image is brighter compared to that in a refracting type telescope.
3. High resolution is achieved by using a mirror of large aperture.
4. Spherical aberration is reduced by using mirror objective in the form of a paraboloid.



- Parallel light rays from a distant star enter the telescope in a direction parallel to the principal axis of the mirror and are reflected.
- These reflected rays are again reflected by a secondary convex mirror B to the eye piece.
- The final image is seen through the eye piece.

* magnifying power of reflecting type telescope

$$m = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

<u>Resolving Power</u>

It is the power or ability of an instrument to produce distinctly separate images of two close objects.

<u>Limit of resolution (d)</u>

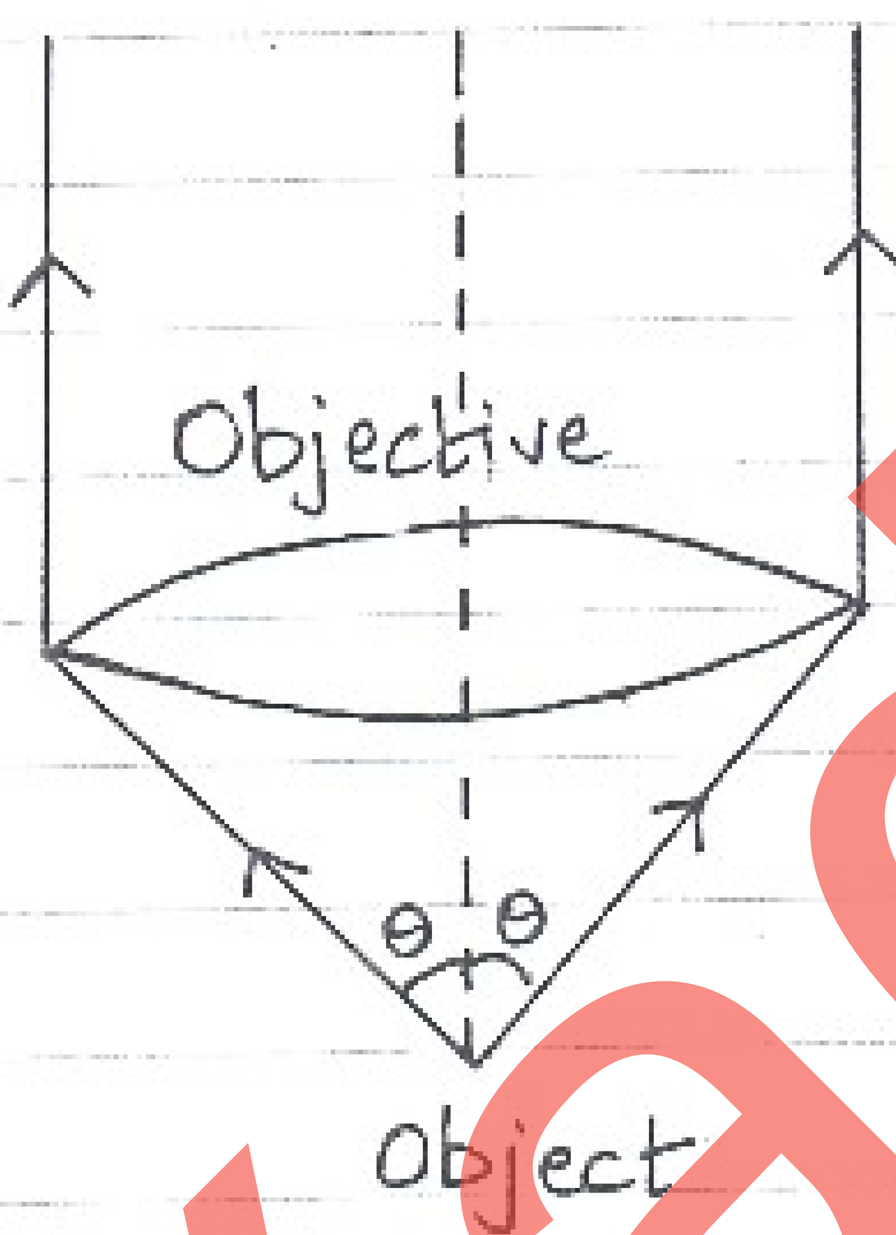
The minimum distance betⁿ 2 objects which can just be seen as separate by the optical instrument.

- Smaller the value of d, greater is its R.P.
- Resolving power of human eye is 1 min or $\frac{1}{60}$ degree.

It means that if 2 distant objects

Resolving power of microscope

It is the ability of the microscope to show, as separate, the images of 2 point objects lying close to each other.



The limit of resolution is measured by the min. distance (d) betⁿ 2 point objects, whose images in the microscope are just seen as separate.

Now $d \propto \lambda$ (wavelength of light used)

$d \propto \frac{1}{2\theta}$ (cone angle of light rays)

So, $d \propto \frac{\lambda}{2\theta} \Rightarrow d = \frac{\lambda}{2\sin\theta}$

If medium betⁿ the object & objective lens of microscope is a transparent medium of refractive index μ, then

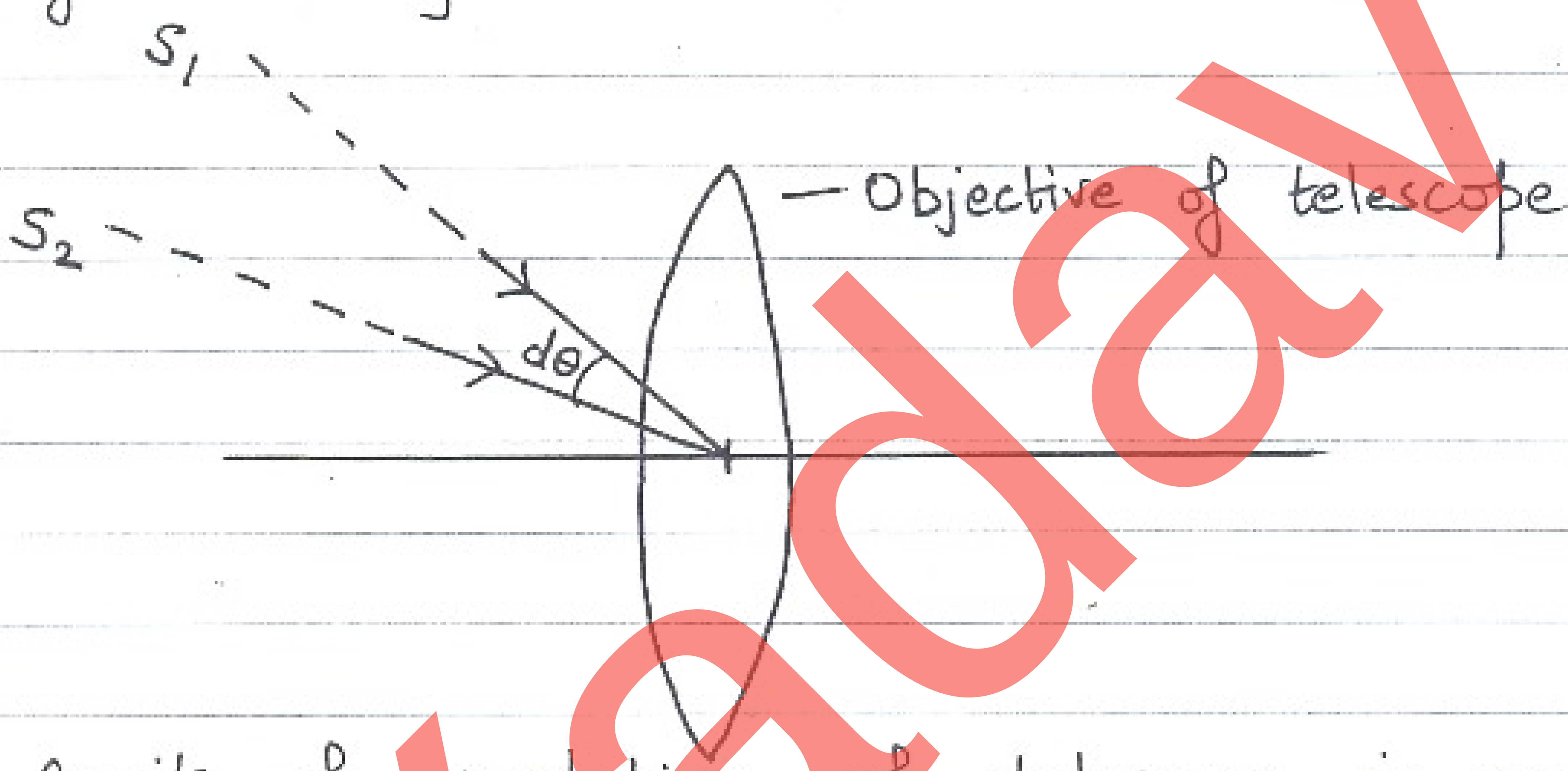
$$\boxed{d = \frac{\lambda}{2\mu\sin\theta}}$$

$$\boxed{\text{R.P. of microscope} = \frac{1}{d} = \frac{2\mu\sin\theta}{\lambda}}$$

$\mu\sin\theta$ - numeric aperture of microscope

Resolving power of Telescope

It is the ability of the telescope to show distinctly the images of 2 distant objects lying closeby.



The limit of resolution of telescope is measured by the angle ($d\theta$) subtended at its objective by 2 distant objects.

$d\theta \propto \lambda$ (wavelength of light used)

$d\theta \propto \frac{1}{D}$ (aperture of objective lens) | aperture = diam

$\therefore \; d\theta \propto \frac{\lambda}{D}$

$$\boxed{d\theta = \frac{1.22\lambda}{D}}$$

$$\boxed{\text{R.P. of telescope} = \frac{1}{d\theta} = \frac{D}{1.22\lambda}}$$

- Here we can't change λ (normally sunlight used so λ is out of bounds) so we have to change D.
- Extremely far away stars can be seen with telescope of large aperture (D).