Telescope

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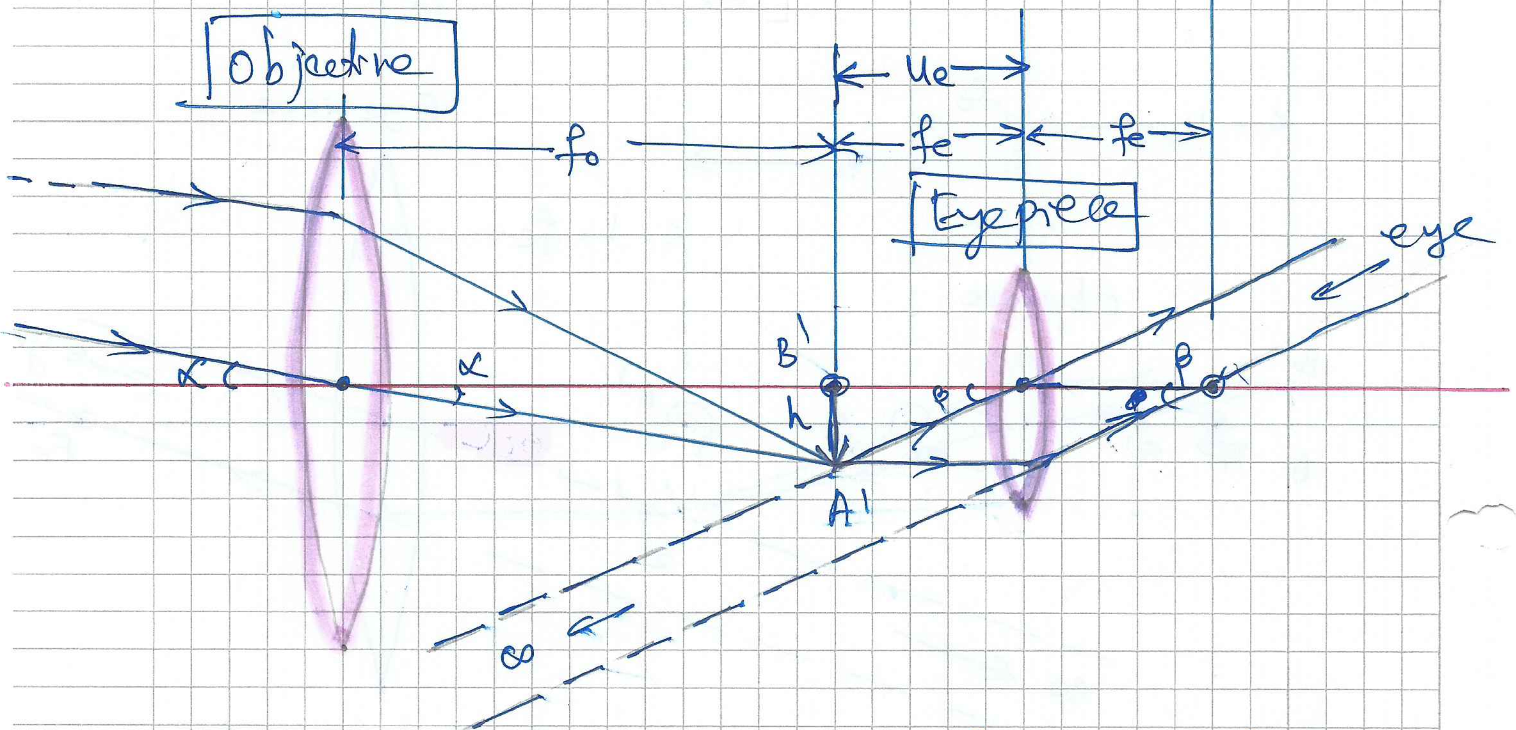
Telescope is used to provide angular magnification of distant objects.



Magnifying power $m = \dfrac{\text{Angle } \beta \text{ subtended by the final image at the eye}}{\text{Angle } \alpha \text{ which the Object subtends at the lens or the eye}}$

$$m = \frac{\beta}{\alpha} \simeq \frac{\tan\beta}{\tan\alpha} = \frac{\cancel{h}}{f_e} \cdot \frac{f_o}{\cancel{h}} = \frac{f_o}{f_e}$$ using sign convention $f_e = -f_e$

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

In this case, length of the telescope tube $= (f_o + f_e)$

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

Negative sign indicates that the final image is inverted.

IMP

For telescopes

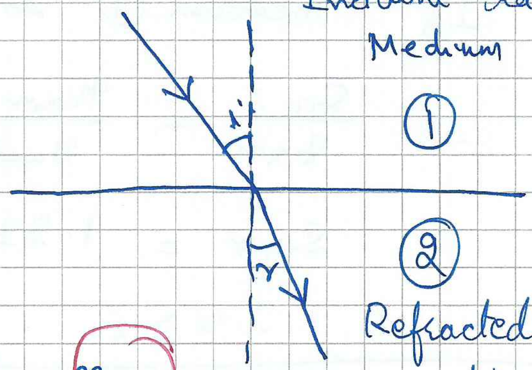
1. objective lens should have large diameter (hence f_o)
2. Since very big "objective" lens will be very cheap, so 'mirror' objectives are used ~~→ they are~~ instead of 'lens' objective. → They are called Reflecting telescopes
3. "Cassegrain" telescope → uses two mirrors – one primary Concave objective mirror and a Convex Secondary mirror

(4) "Resolving power" ~~is the of an optical instrument~~ is the power of an optical instrument to produce distinctly separate images of two close objects.

Limit of resolution	Microscope		Telescope	
Resolving power = $\frac{1}{\text{limit of resolution}}$	Limit of Res. $\frac{1.22\lambda}{2n\sin\alpha}$	Resolving power $\left(\frac{2n\sin\alpha}{1.22\lambda}\right)$	Limit of Res. $\left[1.22\frac{\lambda}{d}\right]$	Resolving power $\frac{d}{1.22\lambda}$
	$\lambda \to$ wavelength of incident light		$\lambda \to$ wavelength of incident light	
	$\alpha \to$ angle of incidence at the objective lens		$d \to$ Aperture (diameter) of objective lens.	
	$n \to$ refractive index of medium			

End

Refraction : Refractive index.



When a light ray travels from medium (1) to medium (2), then according to "Snell's law of refraction"

use this ~~formula~~ convention always.

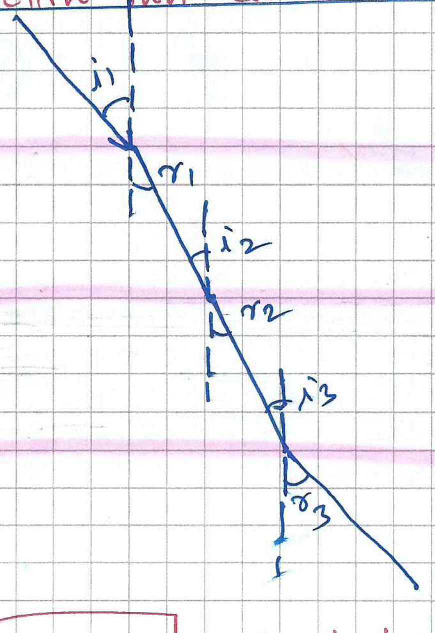
$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \to \text{which is denoted as } \boxed{n_{21}}$$

$\downarrow$ Refractive index of medium (2) w.r.t ~~to~~ medium (1)

$$\therefore \boxed{\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = n_{21}}$$

$\to$ This notation is as per NCERT book. Follow this convention.

eg (1)



$$\frac{\sin i_1}{\sin r_1} = n_{21}$$

$$\frac{\sin i_2}{\sin r_2} = n_{32}$$

$$\frac{\sin i_3}{\sin r_3} = n_{13}$$

$$\frac{\sin i_1}{\sin r_1} \times \frac{\sin i_2}{\sin r_2} \times \frac{\sin i_3}{\sin r_3} = n_{21} \times n_{32} \times n_{13}$$

Since $i_2 = r_1$; $r_2 = i_3$

$$\frac{\sin i_1}{\cancel{\sin r_1}} \times \frac{\cancel{\sin r_1}}{\cancel{\sin r_2}} \times \frac{\cancel{\sin r_2}}{\sin r_3} = \cancel{\frac{n_2}{n_1}} \times \cancel{\frac{n_3}{n_2}} \times \cancel{\frac{n_1}{n_3}}$$

$$\therefore \frac{\sin i_1}{\sin r_3} = 1 \quad \therefore \underline{\sin i_1 = \sin r_3} \quad \therefore \boxed{i_1 = r_3} \quad \therefore \text{Incident ray is parallel to emergent ray.}$$

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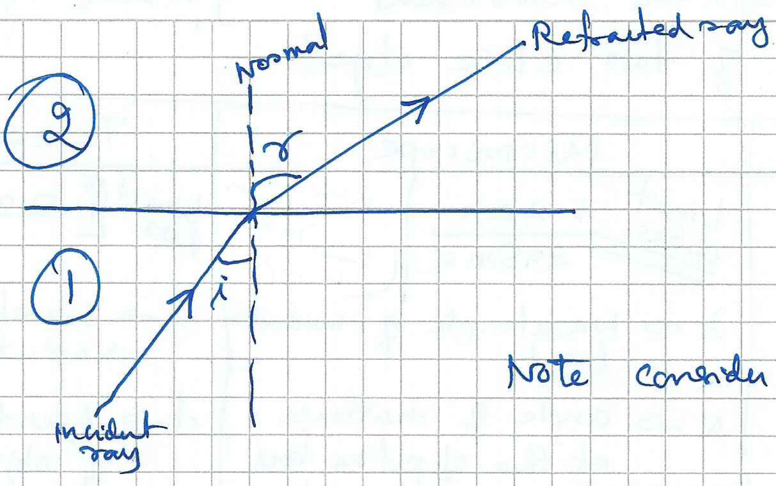
Example (2)



Note consider medium (1) ~~for incident ray~~ → for incident ray

medium (2) ~~for refracted ray~~ → for refracted ray

$$\therefore \frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$$

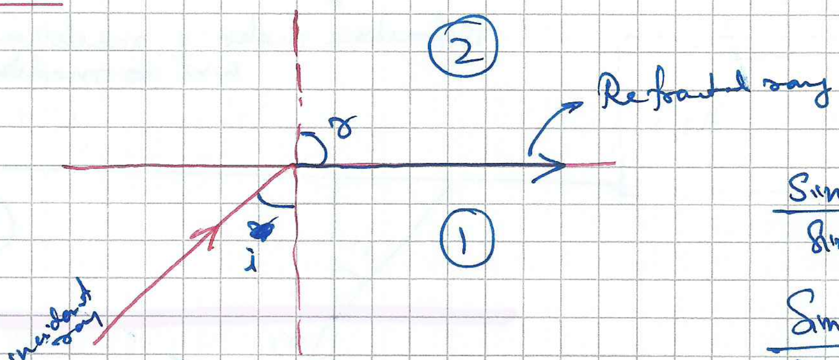
If medium (1) is water ; and (2) is air

$$\frac{\sin i}{\sin r} = \frac{n_{air}}{n_{water}} = \frac{1}{1.33}$$

$$\sin r = 1.33 \sin i$$

$\therefore r > i$ $\therefore$ Refracted ray bends away from normal.

Example (3) :



$$\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$$

$$\frac{\sin i}{\sin r} = \frac{n_{air}}{n_{water}} = \frac{1}{1.33}$$

Since $r = 90^0$, $i = i_c$

$$\frac{\sin i_c}{\sin 90^0} = \frac{1}{1.33} = \frac{n_2}{n_1}$$

$$\sin i_c = \frac{1}{1.33} = \frac{1}{4/3} = \frac{3}{4}$$

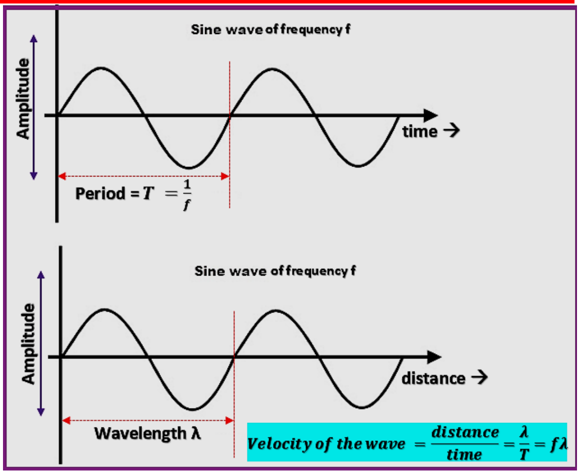
$\sin i_c = 0.75$ $\therefore$ $\boxed{i_c = 48.6^0}$

- 81a - Definition of Wavelength (denoted by λ)

Definition: (use this definition for λ when it is asked to define wavelength of a wave elsewhere.

The wavelength (λ) is the "distance" over which the wave's shape repeats. It is the "distance" between "consecutive corresponding points" of the same "phase on the wave", such as two adjacent 'crests' or 'troughs'.

As given in the definition above, it is also the "distance" between "consecutive corresponding points" of the same "phase on the wave", ***such as zero crossing from the same direction (meaning when crossing from positive side to negative side).***



- Wavelength is the recurrence distance of a periodic signal observed in the spatial domain
- λ is the spatial period of a periodic wave.
- Frequency of a wave f = number of oscillations per second
- Period of a wave T = number of seconds per oscillation ; $f = 1/T$
- Frequency f is the "number of waves" that pass a given reference point per second. In other words, in one second how many waves have crossed a reference point gives the frequency of the wave.
- We know the velocity of e-m wave (eg. light) in vacuum (≈ also in air), denoted by symbol 'c' : **c = fλ**
- **c = 3 x 10^8 m/s in vacuum (or ≈ in air also) [refractive index of vacuum or air = 1]**
- Velocity of "light of a given frequency" decreases when passed through a medium like water, glass having refractive index > 1, however, the frequency (or period) gets unaltered ; what is changed is the "wavelength of the light"

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For any other wave other than light wave (or e-m wave), we should also know the <u>**speed of the wave**</u>, the formula remains same $v = f\lambda$, where v is called the "phase speed" (<u>magnitude of the phase velocity</u>) of the wave. Sometimes, we denote this $v \ as \ v_p$ to indicate that it is the phase speed.

- We can use many forms the above equation such as $v_p = f\lambda$ OR $v_p = \frac{\lambda}{T}$ OR $\boldsymbol{f} = \frac{v_p}{\lambda}$; let us use for convenience $v_p = v$
- "Phase velocity" of a wave is the rate at which the "phase" of the wave "propagates in space". This is the velocity at which the phase of any one frequency component of the wave travels. For such a component, any given phase of the wave (eg: Crest) will appear to travel at the phase velocity. $v = f\lambda \ Or \ v = \frac{\lambda}{T} = \frac{distance}{time\ (T)} \ ; where\ T = \frac{1}{f}$; it is to be noted that v is the phase speed of the wave.
- $\lambda = vT \Rightarrow \ distance\ covered = phase\ speed\ of\ wave * time\ of\ travel.$
- We know that λ is the distance between "consecutive corresponding points" of the same "phase on the wave", such as two adjacent 'crests' or 'troughs'. This implies that when we say two consecutive crests, this is nothing but the "time period T" of the wave. **∴ we can also define the wavelength (λ) of a wave is the "distance" covered by the "wave" in its own time period. However, note that the wave can travel with any speed $\boldsymbol{v}$** (unlike standard speeds for light and sound waves)
  - ∴ Using $\lambda = vT$ ⇒ if the (wave) speed v increases, then <u>for a given time period (say T)</u>, the wave covers more distance (since speed is more), means that the next crest would have travelled more distance wrt the first crest ⇒ So, naturally λ is also more (*to maintain constant T or f*).
  - If the (wave) speed v decreases, then <u>for a given time period (say T)</u>, the wave covers less distance (since speed is less), means that the next crest would have travelled less distance wrt the first crest ⇒ So, naturally λ is also less (*to maintain constant T or f*). This concept will be more clear from the following example:
- **Example: <u>Given a wave with frequency = 100 KHz (∴ T = 1/f = 1/100 KHz = 10ms = 10 x 10^{-3} s)</u>**
  - **When the speed of wave = 10 m/s , then λ = 10 ms^{-1} x [10 x 10^{-3}]s = 0.1 m (note that T and f are unaffected)**
  - **When the speed of wave = 20 m/s , then λ = 20 ms^{-1} x [10 x 10^{-3}]s = 0.2 m (note that T and f are unaffected)**
  - **When speed of wave increases, λ will also increase ; and when speed of wave decreases, λ will also decrease keeping T or f unchanged. ∴ λ is directly proportional to phase velocity of the wave.**

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Info : Velocity is the distance/time = λ/T ; $\therefore v = \frac{\lambda}{T}\ ; since\ \boldsymbol{f} = \frac{1}{T}\ ,\ v = f\lambda$

- Normally, in a problem, the "frequency" of a "standard wave" (eg. audio or light waves) is given and we are asked to calculate λ. We can use the equation $v = f\lambda$ to calculate λ since we know the velocity of the standard waves.
- Eg: Speed of audio waves v_s ≈ 330 m/s and speed of light (in vacuum or air) c = 3 x 10^8 m/s
  - Given f = 20 kHz sound waves, λ = $\frac{v_s}{f} = \frac{330}{2\ x\ 10^4} = 16.5\ x\ 10^{-3} m = 1.65\ cm$
  - Same f = 20 KHz light waves, λ = $\frac{c}{f} = \frac{3\ x\ 10^8}{2\ x\ 10^4} = 1.5\ x\ 10^4 = 15\ km$
- However, for any non-standard wave, we do not know the velocity of the wave, therefore, in that case, the problem should provide both f & v to calculate λ.
- Eg: If we need to calculate the λ of an electron wave, then we need both f and v of the electron. Velocity of electron depends on how much potential that we apply to say electrodes. **Note that the velocity of electron is not equal to velocity of light.**

- 81aa - Relation between μ and velocity of light (for Info)

This page is to be seen as an introduction to the next page, which discusses the phenomenon of dispersion; however what is dispersion in a prism and what is the cause of dispersion ; for such questions, refer next page: What is given in the next page will be THE answer (that you have to write in examination) for "what is dispersion" and "what is the cause of dispersion". This page provides only additional information.

Relation between refractive index of a medium (μ) & velocity (v) of light waves in the medium

- $\boldsymbol{Refractive\ index\ of\ the\ medium} = \mu = \dfrac{\boldsymbol{velocity\ of\ light\ in\ vacuum\ (or \approx air)}}{\boldsymbol{velocity\ of\ light\ in\ the\ medium}} = \dfrac{\boldsymbol{c}}{\boldsymbol{v}} = \dfrac{\boldsymbol{3\ x\ 10^8 ms^{-1}}}{\boldsymbol{v}}$
  - *Note that velocity of light in vacuum (or ≈ air) is denoted by letter* **c**, *which is constant* $= 3\ x\ 10^8\ ms^{-1}$
- $\therefore When\ light\ passes\ through\ a\ given\ medium\ (glass\ or\ water), velocity\ of\ light\ is\ given\ by$: $v = \frac{c}{\mu}$
  - If the medium is vacuum (or ≈air), μ = 1 and $v = c$; velocity of light does not change while passing though vacuum or air
  - For other media like water & glass, the velocity of light decreases when passing through a medium (like water or glass)
    - $(\boldsymbol{eg}: \mu_{\boldsymbol{water}} = \mathbf{1.33}\ ,\ \mu_{\boldsymbol{crown\ glass}} \approx \mathbf{1.5}),\ \ \boldsymbol{v < c}$
- Another important property of the medium (eg: glass) is that its **μ depends on λ on the incident light**. It is the PROPERTY of the material and as per Cauchy's formula $\mu \propto \frac{1}{\lambda^2}$
- Since $\lambda_{red} > \lambda_{violet}$; $\mu_{red} < \mu_{violet}$; $since\ v = \frac{c}{\mu}$; $v_{red} > v_{violet}$; red travels faster compared to violet in the medium (eg: glass)
- As per Snell's law $\frac{sin(i)}{\sin(r)} = \frac{\mu_2}{\mu_1}$; $if\ \mu_2\ is\ higher\ and\ higher, then\ r\ is\ lesser\ and\ lesser\ compared\ to\ i$
- ∴ the refracted ray bends more towards normal ⇒ **μ of a medium indicates the bending power of the medium to light**
- $Greater\ the\ \mu, greater\ is\ the\ bending\ , therefore,\ violet\ color\ bends\ more\ than\ that\ of\ red\ color$. Hence a prism can split white light into different colours. *We will see the exact analysis of cause of dispersion in the next page.*
- ***The key takeaway from the above analysis is the fact that μ & λ are interrelated in a medium like glass, which is the cause for dispersion***

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- As we have seen above, the variation of <u>$\mu\ with\ \lambda$</u> may be more pronounced in some media than the other.
- In vacuum (or ≈ in air), the speed of light is independent of λ. Thus, vacuum (or air) is a <u>non-dispersive medium</u> in which all colors travel with the same speed. Therefore, sunlight reaches us in the form of <u>white light and not as its constituent colors</u>.
- On the other hand, glass is a <u>**dispersive medium**</u> where the material that is used to make glass (crown or flint glass) has a property that results in variation of μ with incident λ of light. It is this property that causes dispersion phenomenon.
  - <u>Dispersion</u> is clearly visible when white light passes through a triangular prism, in which the two refracting surfaces are not parallel.
  - It is harder to observe the dispersion phenomenon (white light spectrum) when the glass is in rectangular shape, in which the two refracting surfaces are parallel.
  - Why this happens → We will discuss this in subsequent pages.

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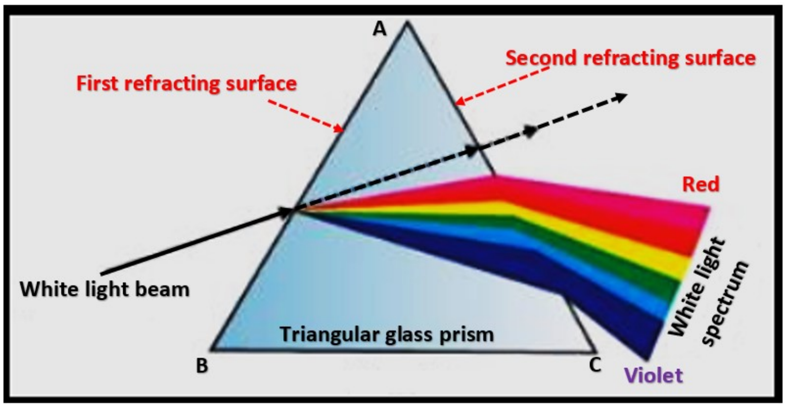
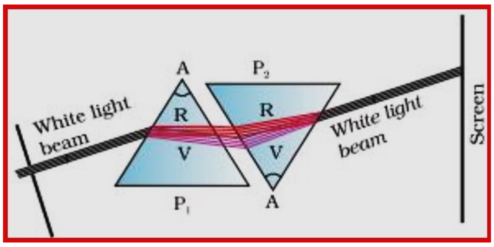
Dispersion of light



Definition:

- Dispersion of light is the phenomenon of splitting of white light into its constituent colors while passing through a prism.
- The band of 7 colors VIBGYOR is called "visible spectrum"
- Prism does not create colors, it only separates colors in the incident white light.
- This was proved by Newton by putting another prism in inverted position as shown in the figure. This experiment proved that it is the property of the prism that **separates** white light into its constituent colours. White light consists of 7 colors and it is the prism that separates these colors. A triangular prism will be very useful to demonstrate this separation clearly due to its shape.



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Causes of dispersion of white light:

"μ" of Crown & Flint glasses for different colors			
Colors	**λ in nm**	μ {Crown}	μ {Flint}
Violet	396.9	1.532	1.663
Blue	486.1	1.523	1.639
Green	546.1	1.519	1.635
Yellow	589.0	1.517	1.627
Red	656.3	1.515	1.622
As λ increases, μ of the material decreases			

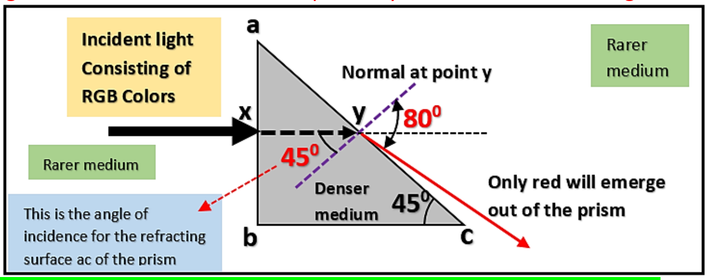
1. It is the inherent property of the **material** of the prism, in which the refractive index (μ) of glass varies with wavelength (λ) of the incident light (see table for crown and flint glasses). As per Cauchy's formula $\mu = a + \frac{b}{\lambda^2} + ..$; $Essentially\ \mu \propto \frac{1}{\lambda^2}$
2. In visible light spectrum, λ is different for different colors. Example
   a. $\lambda_{red} = 656.3\ nm$; $\lambda_{violet} = 396.9\ nm$
   b. $\therefore \lambda_{red} > \lambda_{violet}$ *in the incident white light on to the prism*
3. When this white light falls on a prism surface and due to the property of the prism $\left[\mu \propto \frac{1}{\lambda^2}\ and\ also\ see\ table\right]$, $\mu_{red} < \mu_{violet} ----(1)$
4. We know that the "angle of minimum deviation" by small angled prism is given by $\boldsymbol{\delta_{min} = (\mu_{21} - 1)A \Rightarrow \delta_{min} \propto \mu}$ -------- **(2)**
   a. $\therefore$ *From* $(1)\ \&\ (2)$, *we have* $\delta_{red} < \delta_{violet} -----(3)$
   b. $\therefore$ *Red will deviate the least and the violet will deviate the most when passing through the prism*
   c. *Hence, prism splits white light into its constituent colors.*

****

Why does dispersion takes when light is passed through a prism and not through glass slab?

- In fact, dispersion does occur when light is passed through a glass slab also. It is just harder to observe.
- In prism, light goes through two surfaces, which are not parallel and as a result, every color exiting the prism travels different distances and in a different direction → splitting up clearly over a short surface.
- However, in a glass slab, since the two surfaces are parallel, the direction of any color light is not changed by going through slab. Evert color is offset by a very small amount with respect to each other, and the color separation is only observable at the edges.
  - If one uses a small spot of light and a very thick slab of glass, one can see color separation at the edges.

Q: A beam of light consisting of red, green and blue colors is incident on a right angled isosceles prism as shown in the figure. The refractive indices of the material of the prism for the red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. Which color will emerge out of the prism surface AC?



Given:

- Angle $a\hat{b}c = 90^0$, $a\hat{c}b = 45^0$, $\therefore\ b\hat{a}c = 45^0$
- Refractive index of prism for RED color = $\mu_{red} = 1.39$
- Refractive index of prism for Green color = $\mu_{green} = 1.44$
- Refractive index of prism for Blue color = $\mu_{blue} = 1.47$
- From fig, it is clear that the light is incident perpendicular to refracting face ab at point x
  - ∴ angle of incident $i = 0$, therefore angle of refraction is also = 0. This means the incident beam will not suffer any refraction and will go straight and hit face ac at point y. From figure, it is clear that the beam will make an angle 45⁰ wrt normal. This is the angle of incidence for the refracting surface ac of the prism.
- This is the case of light travelling from denser medium to rarer medium and we need to know whether this angle of incidence (45⁰) is less than or greater than critical angle (C) of the prism for different colors. Face ac will not allow emergence of light if $\boldsymbol{i} > \boldsymbol{C}$.
- Use formula $sinC = \frac{1}{\mu}$; since μ is different for different colors (material specific property), we need to find the critical angles for R, G, B colors.

Colors	μ (given)	Critical angle $C = sin^{-1}\left(\frac{1}{\mu}\right)$	**Since the angle of incidence for the face ac = 45⁰, then**
Red	1.39	**46⁰**	For red color, angle of incidence of 45⁰ < critical angle for red (46⁰), ∴ red color will emerge out of the **prism surface "ac".** {we can calculate the angle of refraction $using\ \frac{sini}{sinr} = \frac{1}{\mu}$, where i = 45⁰, μ = 1.39, then r ≈ 80⁰ , see figure)
Green	1.44	**44⁰**	For green color, angle of incidence of 45⁰ > critical angle for green (44⁰), ∴ green color will not emerge out of the **prism surface "ac" (green will suffer total internal reflection).**
Blue	1.47	**42.9⁰ ≈ 43⁰**	For blue color, angle of incidence of 45⁰ > critical angle for blue (43⁰), ∴ blue color will not emerge out of the **prism surface "ac" (green will suffer total internal reflection).**
			However, green and blue light will come out from the face "bc" of the prism (if face BC is transparent)

(iv) Totally reflecting Prisms

What is a totally reflecting prism ? How can it be used to deviate rays of light through (a) 90° and (b) 180° ? How it can be used to invert the image of an object without changing its size. Also write down the advantages of totally reflecting prisms over the plane mirrors.

A right angled isosceles prism is called ***totally reflecting prism.***

The refractive index of glass is 1·5. Therefore, the critical angle for glass-air interface is given by sin C = 1/1·5 or C = sin⁻¹ (0·6667) = 41·8°. When the ray of light falls on the face of a right angled prism at angle greater than 41·8°, it will suffer total internal reflection.

(a) Right angled prism used to deviate the rays of light through 90°.

The rays of light from an object AB fall perpendicular on the face *ab* of the prism travel undeviated and fall on the face *ac* at an angle of 45°, which is greater than the critical angle (41·8°) of the glass-air interface (Figure 35). Hence, the rays of light suffer total internal reflection at the face *ac*. Therefore, these rays deviate through an angle of 90° after suffering total internal reflection. These rays fall perpendicular on the face *bc* of the prism and come out without deviation. Such *prism is used in the periscope.*

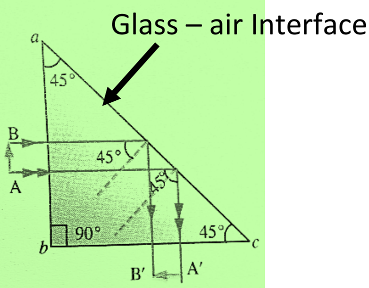


Figure 35

(b) Right angled prism used to deviate the rays of light through 180°.

The rays of light from an object AB fall perpendicular on the face *ac* of the prism travel undeviated and fall on the face *ab* of the prism at an angle of 45°, which is greater than the critical angle (Figure 36). Hence, these rays suffer total internal reflection and fall on face *bc* of the prism at an angle of 45°, greater than the critical angle. Therefore, the rays again suffer total internal reflection at the face *bc* of the prism. These rays then fall perpendicular on the face *ac* of the prism and travel undeviated. The directions of incident rays and emergent rays are opposite to each other. Hence, the prism deviates the rays of light through 180°. The right angled isoscele prism which deviates the rays of light through 180° is called *porro-prism.*

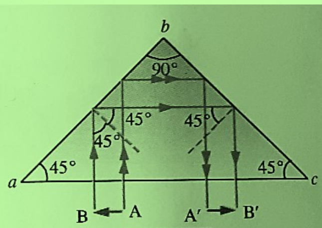


Figure 36

(c) Right angled prism used to invert the image of an object without changing its size.

The rays of light from an object AB fall perpendicular on the face *ab* of the prism travel undeviated and then fall on the face *ac* of the prism at an angle of 45°, which is greater than the critical angle. These rays suffer total internal reflection and fall perpendicular on the face *bc* of the prism (Figure 37). These rays emerge out of the prism undeviated and form an inverted image A′B′ of the same size as that of the object AB. These prisms are called **erecting prisms.** They are used in **binoculars.**

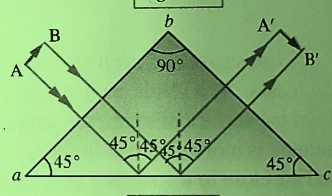
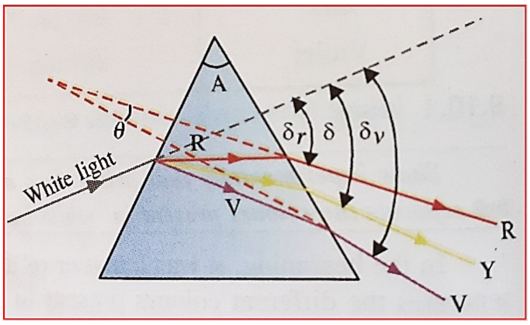


Figure 37

81bbb

Angular dispersion and dispersive power of a medium (not in NCERT syllabus)

Angular dispersion is defined as the difference in the deviations suffered by the two extreme colors (i.e. red and violet) in passing through a prism. It is denoted by θ.



∴ $\theta = \delta_v - \delta_r$ -------- (1) ; need to express this deviation in terms of μ and A

We know the expression for minimum deviation and using small angled prism (A is small) as

$\delta_m = (\mu_{21} - 1)A$; if we consider medium 1 as air ($\mu_1 = 1$) and medium 2 as glass, then

$\delta = (\mu - 1)A$, where μ is the refractive index of glass.

- For red color, $\delta_r = (\mu_r - 1)A$; For violet color $\delta_v = (\mu_v - 1)A$, using eq (1),
- $\theta = (\mu_v - 1)A - (\mu_r - 1)A = \mu_v A - A - \mu_r A + A = (\mu_v - \mu_r)A$
- $\theta = (\mu_v - \mu_r)A$; *unit of angular dispersion is degree or radian.*

Dispersive Power of the material is its ability to disperse the constituent colors of incident white light. Dispersive power is equal to the ratio of the angular dispersion to the mean deviation produced by the prism. It is denoted by ω.

- $\omega = \frac{\theta}{\delta} = \frac{\delta_v - \delta_r}{\delta}$; *here mean deviation δ means the deviation suffered by the yellow light (which is also known as mean light*
- If μ is the mean refractive index of the medium (say glass), it will correspond to yellow color ; ∴ $\delta = (\mu - 1)A$
- $\omega = \frac{\theta}{\delta} = \frac{(\mu_v - \mu_r)A}{(\mu - 1)A} = \frac{(\mu_v - \mu_r)}{(\mu - 1)}$; Dispersive power ω indicates that ...
  - Dispersive power depends only on the nature of the material of the prism
  - Dispersive power is independent of the angle of the prism (A)
  - Dispersive power is the dimensionless quantity and has no unit.
  - Dispersive power is constant for any two colors
  - Since $\mu_v > \mu_r$ and μ > 1 for say glass, dispersive power is always positive number.

****

Angular dispersion and Wavelength:

Angular dispersion θ is also defined as the rate of change of angle of deviation δ with wavelength λ, that is $\boldsymbol{\theta = \frac{d\delta}{d\lambda}}$

- We know that $\delta = (\mu - 1)A = \mu A - A$; *differenting wrt μ, we get*
- $\boldsymbol{\frac{d\delta}{d\mu} = A - - - - (1)}$
- *As per Cauchy's formula,* $\mu = a + \frac{b}{\lambda^2}$, *where a and b are constants. Differntiaing this wrt λ, we get*
- $\boldsymbol{\frac{d\mu}{d\lambda} = -\frac{2b}{\lambda^3} - - - - - (2)}$; ***Multiplying (1) and (2), we get***
- $\boldsymbol{\left[\frac{d\delta}{d\mu}\right]\left[\frac{d\mu}{d\lambda}\right] = A\left[-\frac{2b}{\lambda^3}\right]}$ **or**
- $\boldsymbol{\left[\frac{d\delta}{d\lambda}\right] = A\left[-\frac{2b}{\lambda^3}\right]}$ **; since $\boldsymbol{\theta = \frac{d\delta}{d\lambda}}$ and A, b are constants for a given material, we get**
- $\boldsymbol{\theta \propto \frac{1}{\lambda^3}}$; *Thus, angular dispersion is inversely proportional to the cube of wavelength of the color.*

81c

In optics, the **refractive index** of a **material** is a **dimensionless** number that describes how fast light travels through the **material**. It is defined as $\mu = \frac{c}{v}$; where c is the speed of light in vacuum and v is the phase velocity of light in the medium or material.

- Increasing the refractive index corresponds to decreasing the speed of light in the material.
- For example, μ_{water} is 1.333, meaning that light travels 1.333 times **slower** in water than in a vacuum.
- For example, if μ_{glass} is 1.5, meaning that light travels 1.5 times **slower** in glass than in a vacuum.

From the table, μ_{air} = 1.000293
Speed of light in air = $\frac{c}{1.000293} \approx 2{,}99{,}912\ km\ s^{-1}$
Difference between speed of light in vacuum & air = [3,00,000 – 2,99,912], which is 88 km/s slower than c. This difference in speeds is negligible.
Therefore, μ_{air} is practically taken as 1 and
speed of light in air is practically taken as speed of light in vacuum.

Selected refractive indices at λ=589 nm. For references, see the extended List of refractive indices.

Material	*n*
Vacuum	1
Gases at 0 °C and 1 atm	
Air	1.000 293
Helium	1.000 036
Hydrogen	1.000 132
Carbon dioxide	1.000 45
Liquids at 20 °C	
Water	1.333
Ethanol	1.36
Olive oil	1.47
Solids	
Ice	1.31
Fused silica (quartz)	1.46[11]
PMMA (acrylic, plexiglas, lucite, perspex)	1.49
Window glass	1.52[12]
Polycarbonate (Lexan™)	1.58[13]
Flint glass (typical)	1.69
Sapphire	1.77[14]
Cubic zirconia	2.15
Diamond	2.42
Moissanite	2.65

- If μ_{glass} is given as 1.5, it is to be read as μ of glass is 1.5 wrt vacuum or air.
- $\mu_{glass} = 1.5\ means\ \frac{\mu_{glass}}{\mu_{air}} = 1.5$; It is denoted in NCERT book as μ_{ga}. $\boldsymbol{Remember\ \mu_{ga} = \frac{\mu_{glass}}{\mu_{air}}}$
- The focal length of a lens (***made of glass or plastic***) in air can be calculated from the lens maker's equation

$\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ OR $\frac{1}{f} = [\mu_{ga} - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$; where $\mu_{ga} = \frac{\mu_{glass}}{\mu_{air}}$

- **Convention : For convex lens, f is taken as POSITIVE**
- **Convention : For concave lens, f is taken as NEGATIVE**

- **Note that the nature of a lens depends on the medium surrounding the lens. The lens is generally made of glass or plastic.**
- If the surrounding medium is **air**, then nature of the lens remains the same. That means if it is a convex lens, it behaves as convex lens ; if it is a concave lens, it behaves as concave lens. Since the surrounding medium i.e. air is a rarer medium as compared to glass $[\mu_{air} < \mu_{glass}]$
  - The focal length is given by $\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$
  - Since $[\mu_{glass} > \mu_{air}]$, $\left[\frac{\mu_{glass}}{\mu_{air}} - 1\right] > 0\quad or\ is\ positive$
  - For convex lens, R_1 is positive and R_2 is negative, therefore $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]\ is\ also > 0\ \ or\ is\ positive$
    - So, focal length f is positive → hence convex lens
  - For concave lens, R_1 is negative and R_2 is positive, therefore $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]\ is\ also < 0\ \ or\ is\ negative$
  - So, focal length f is negative → hence concave lens
- If the surrounding medium of glass is a **liquid**, the nature of the lens depends on the μ of the liquid.
- Focal length of such a glass in liquid is given by $\frac{1}{f'} = \left[\frac{\mu_{glass}}{\mu_{liquid}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ OR $\frac{1}{f'} = [\mu_{gl} - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ and is different as compared to when the glass is in air. (as we know, by convention, the focal length of convex lens is taken as positive or that of concave lens is taken as negative).
  - If $\mu_{glass} > \mu_{liquid}$, this is a similar case as in air, $\left[\frac{\mu_{glass}}{\mu_{liquid}} - 1\right]\ is > 0$
  - If lens immersed in liquid is "convex" lens, R_1 is positive and R_2 is negative, and hence $\left[\frac{1}{R_1} - \frac{1}{R_2}\right] > 0$, therefore $f\ is > 0\ \ or\ is\ positive\ ; therefore\ convex\ lens\ behaves\ as\ convex\ lens$
  - If lens immersed in liquid is "concave" lens, R_1 is negative and R_2 is positive, and hence $\left[\frac{1}{R_1} - \frac{1}{R_2}\right] < 0$, therefore $f\ is < 0\ \ or\ is\ negative\ ; therefore\ concave\ lens\ behaves\ as\ concave\ lens$
  - Therefore, there is no change in the nature or behaviour of the lens and it remains the same.

- If $\mu_{glass} < \mu_{liquid}$, then $\left[\frac{\mu_{glass}}{\mu_{liquid}} - 1\right]$ $is < 0$
- If lens immersed in liquid is "convex" lens, R_1 is positive and R_2 is negative, and hence $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ > 0, therefore $f\ is < 0\ \ or\ is\ negative\ ; therefore\ convex\ lens\ behaves\ as\ concave\ lens$
- If lens immersed in liquid is "concave" lens, R_1 is negative and R_2 is positive, and hence $\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ < 0, therefore $f\ is > 0\ \ or\ is\ positive\ ; therefore\ concave\ lens\ behaves\ as\ convex\ lens$
- Therefore, the nature of the lens changes depending on the refractive index.

****

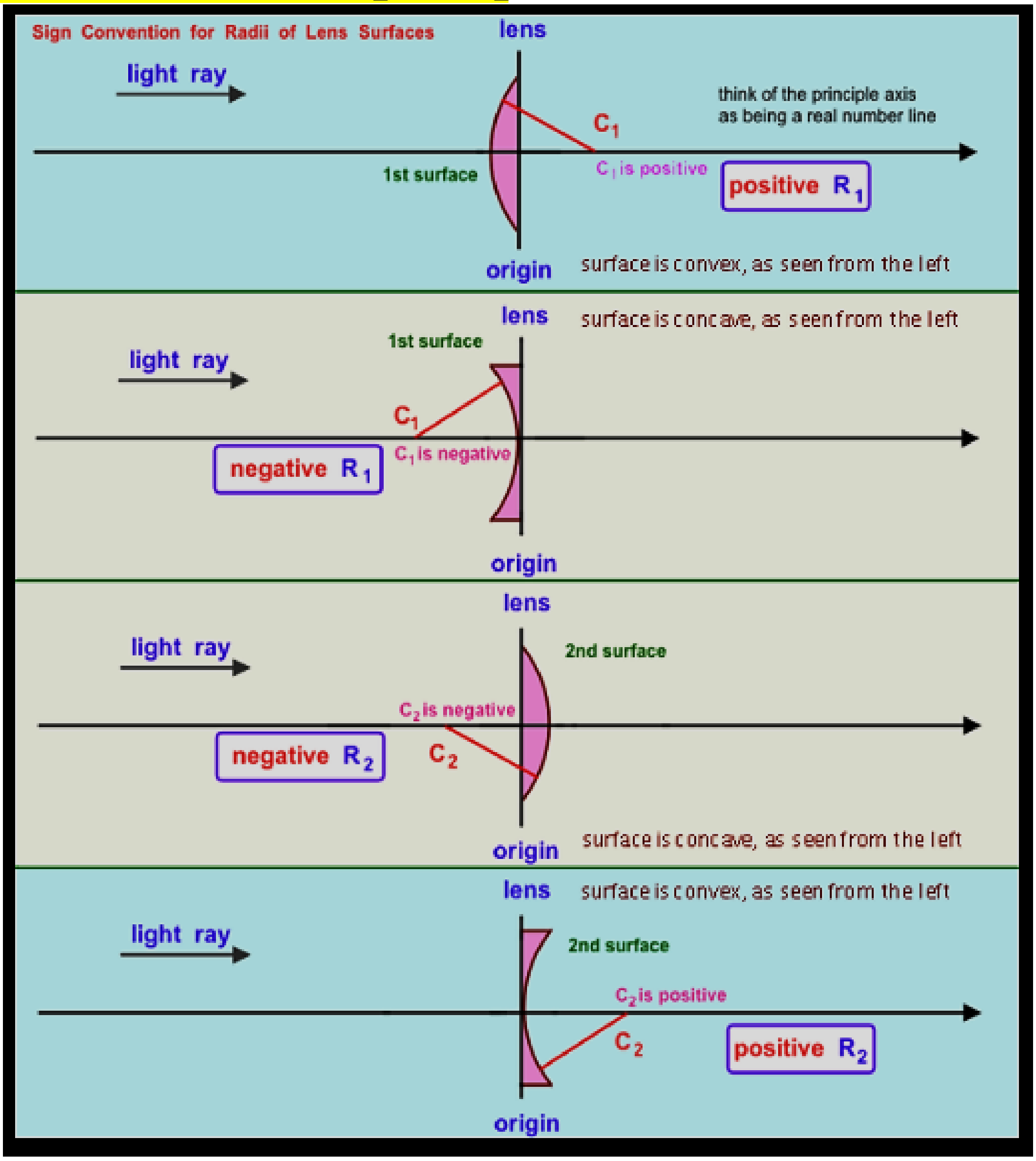
- If $\mu_{glass} = \mu_{liquid}$, then $\left[\frac{\mu_{glass}}{\mu_{liquid}} - 1\right]$ $is = 0$
- Hence, whether the lens is convex or concave, focal length in this case = ∞
- Then the glass lens cannot be distinguished from the liquid. In other words, glass is not visible.

****

Rationale in taking sign convention for R_1 and R_2

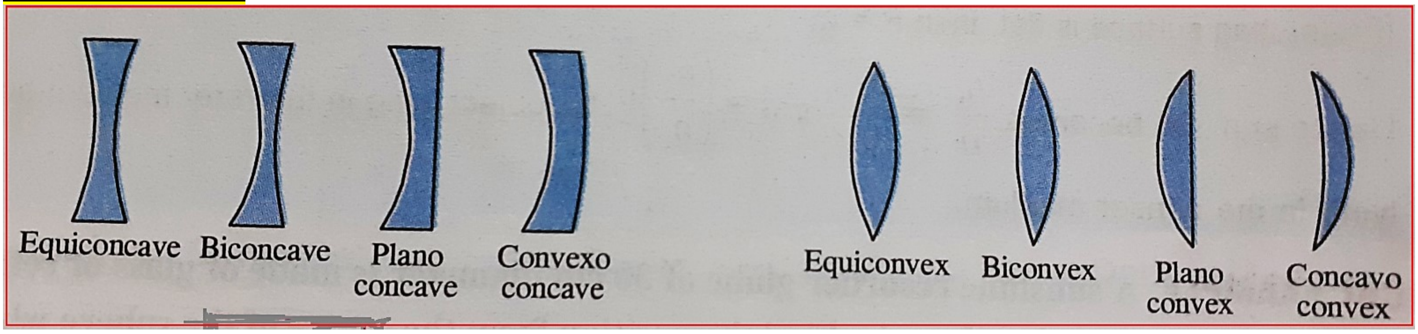
The signs of the lens' radii of curvature indicate whether the corresponding surfaces are convex or concave. The sign convention used to represent this varies, but in this article

- a positive R indicates a surface's center of curvature is further along in the direction of the ray travel (right, in the accompanying diagrams),
- while negative R means that rays reaching the surface have already passed the center of curvature.
- Consequently, for external lens surfaces as diagrammed above, $R_1 > 0$ and $R_2 < 0$ indicate convex surfaces (used to converge light in a positive lens),
- while $R_1 < 0$ and $R_2 > 0$ indicate concave surfaces.



- The reciprocal of the radius of curvature is called the curvature.
- A flat surface has zero curvature, and its radius of curvature is infinity.

Types of Lenses



- Lenses are classified by the curvature of the two optical surfaces. A lens is biconvex (or double convex, or just convex) if both surfaces are convex. If both surfaces have the same radius of curvature, the lens is **equiconvex**.
- A lens with two concave surfaces is biconcave (or just concave).
- If one of the surfaces is flat, the lens is plano-convex or plano-concave depending on the curvature of the other surface.
- A lens with one convex and one concave side is convex-concave or meniscus. It is used in corrective lenses.

A.T. 2. Spherical Aberration in Lenses

Spherical aberration of a lens is defined as its inability to focus all the rays of light falling on it at a single point on the principal axis.

When a wide beam of light, parallel to the principal axis, falls on a lens of large aperture, then the rays travelling close to principal axis (called **paraxial rays**) are focussed at a large distance after refraction than the rays travelling far away from the principal axis (called **marginal rays**) as shown in *figure* 2. Thus, we get an image whose centre is bright but sides are blurred. The size of the image is minimum where marginal rays and paraxial rays cross each other after refraction and is known as **circle of least confusion**.

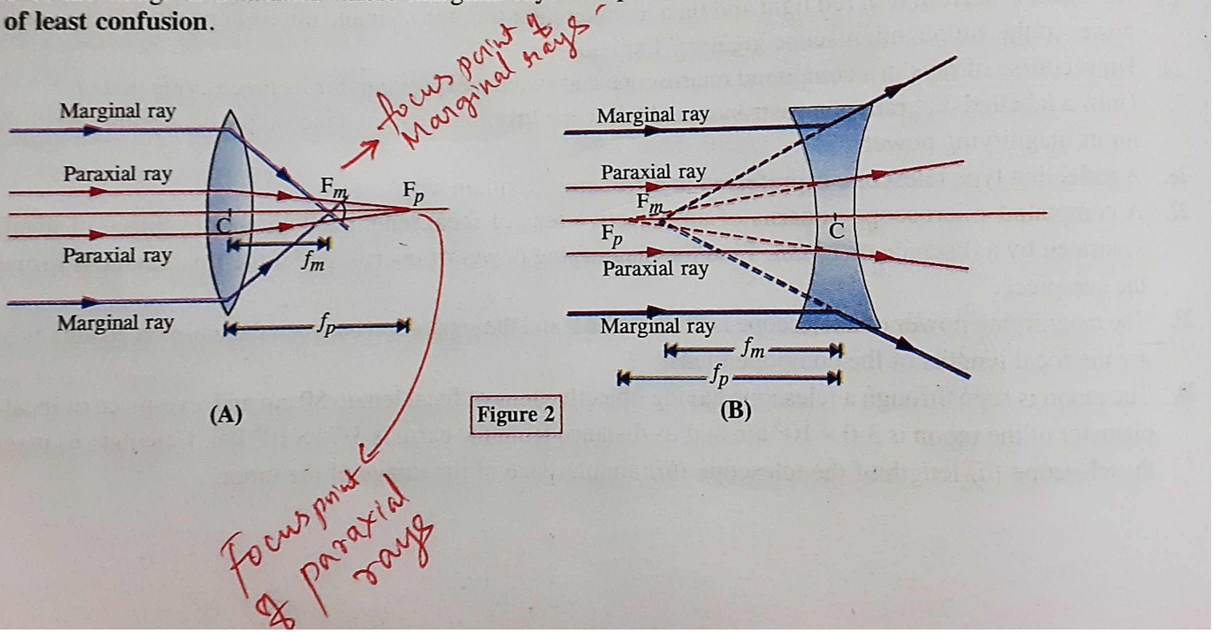


Figure 2

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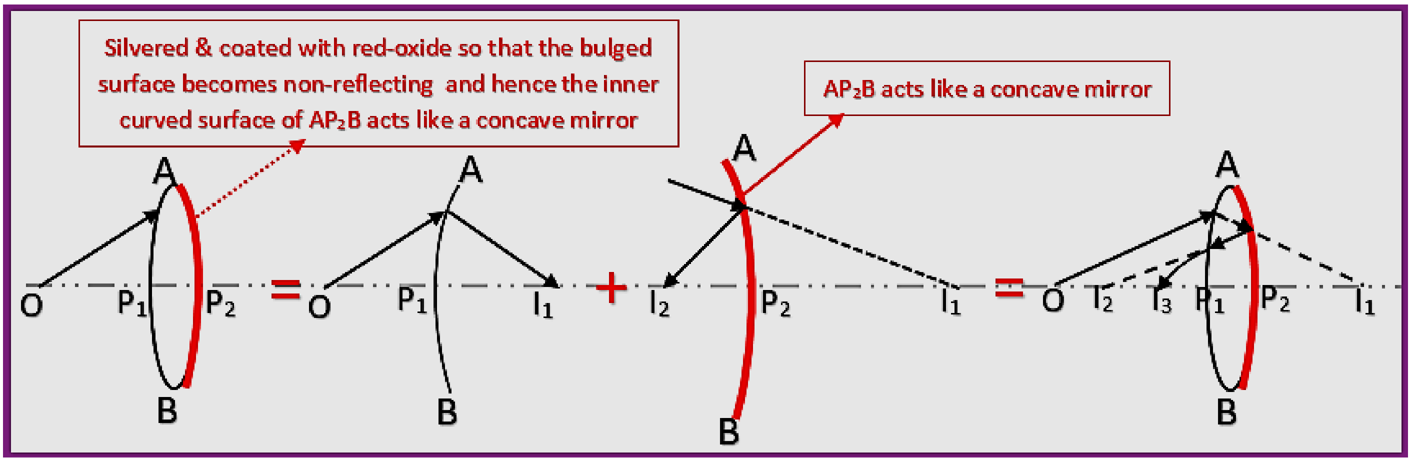
Focal length and power of a lens with one silvered surface

Consider a convex lens whose second surface is silvered (and coated with red oxide → meaning it becomes non-reflecting surface



- The light from object O passes through the first surface AP_1B of the lens and the image would have formed at I_1, if the second (outer) surface AP_2B of the lens were not silvered. (*since the light after passing through the first surface cannot go out of the second surface since it is blocked by silver coating, so the refracted light has to be reflected back from the inner surface of AP_2B that acts like a concave mirror*).
- For analysis purpose, imagine that there is an image formed at I_1, which acts as a virtual object for the surface AP_2B (behind concave mirror) and the resulting image is formed at I_2.
- Now, I_2 acts as a virtual object for the surface AP_1B of the lens and the light is reflected from the surface AP_2B and then passes through again AP_1B and the final image is formed at I_3.

Thus, there are 2 refractions and 1 reflection of light in the system and this system is equivalent to two lenses and one concave mirror. Therefore, the power of the system = $P = P_L + P_M + P_L = 2P_L + P_M$ ----------------------- (1), where

$P_L = \frac{1}{f_L}$ *and* $P_M = -\frac{1}{f_M}$ (minus sign since mirror is concave) , where f_L and f_M is defined as

- $\frac{1}{f_L} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$, which is the Lens maker's formula ; As discussed in previous pages, since we have taken convex lens as an example, R_1 is positive and R_2 is negative. Here, we have considered "air" as the surrounding medium of the "glass" lens
- $f_M = \frac{R_2}{2}$
- $Hence, P = 2\left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] - \frac{2}{R_2} - - - - - - - - - - - - - - - (2)$

Case 1: If the lens is plano-convex with plane surface silvered and object is placed in front of convex surface

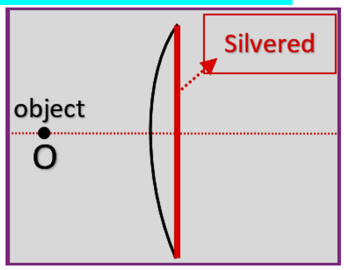
$\frac{1}{f_L} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$; here R_1 is positive = R (say) and $R_2 = \infty$

$\frac{1}{f_L} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R}\right] = \frac{[\mu_{ga}-1]}{R}$ ∴ In this case $\frac{1}{f_L} = \frac{[\mu_{ga}-1]}{R} - - - - - - -(3)$

And also $f_M = \infty$ (since the second surface is a plane surface), therefore, $P_M = 0$

$P = 2P_L + P_M = \frac{2[\mu_{ga}-1]}{R} + 0 = \frac{2[\mu_{ga}-1]}{R}$; $\therefore P = \frac{2[\mu_{ga}-1]}{R}$ and $\therefore F = -\frac{1}{P} = \frac{-R}{2[\mu_{ga}-1]}$

Therefore, the system acts as a concave mirror of focal length $\therefore F = -\frac{R}{2[\mu_{ga}-1]}$



Case 2: If the lens is plano-convex with convex surface silvered and object is placed in front of plane surface

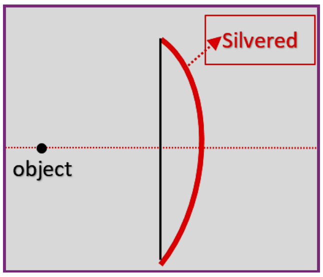
$\frac{1}{f_L} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$; here $R_1 = \infty$ = R (say) and $R_2 = -R$

$\frac{1}{f_L} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R}\right] = \frac{[\mu_{ga}-1]}{R}$ ∴ In this case $\frac{1}{f_L} = \frac{[\mu_{ga}-1]}{R} - - - - - - -(4)$

Also $f_M = \frac{(-R)}{2} = -\frac{R}{2}$ (since the 2nd surface is a conave surface), therefore, $P_M = -\frac{2}{R}$

$P = 2P_L + P_M = \frac{2[\mu_{ga}-1]}{R} + \frac{2}{R} = \frac{2\mu_{ga}}{R}$; $\therefore P = \frac{2\mu_{ga}}{R}$ and $\therefore F = -\frac{1}{P} = \frac{-R}{2\mu_{ga}}$

Therefore, the system acts as a concave mirror of focal length $\therefore F = -\frac{R}{2\mu_{ga}}$



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Problems:

A double concave lens of glass of $\mu = 1.6$ *has radii of curvature of* $40\ cm$ & $60\ cm$. Calculate the focal length of the lens in air

Equation is $\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$; for Concave lens, R_1 is –ve = - 40cm and R_2 is +ve = + 60cm, $\mu_{glass} = 1.6$ *and* $\mu_{air} = 1$

$\frac{1}{f} = \left[\frac{1.6}{1} - 1\right]\left[\frac{1}{-40} - \frac{1}{60}\right] = -0.6\left[\frac{1}{40} + \frac{1}{60}\right] = -\frac{0.6}{20}\left[\frac{1}{2} + \frac{1}{3}\right] = -\frac{0.6}{20}\left[\frac{5}{6}\right] = -\frac{0.1}{40} = -\frac{1}{40}$; focal length = -40 cm

We know that by convention, for concave lens and mirror, focal length is taken as negative. Answer has come –ve, hence verified

A biconvex lens has a focal length 2/3 times the radius of curvature of either surface. Calculate the μ of the lens material

Given: Radius of curvature of the two surfaces of biconvex lens is same, implies it is equiconvex lens. $R_1 = R_2 = R$ (without sign convention)

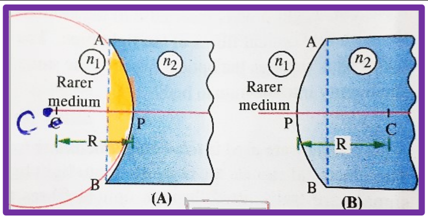
Given $f = \frac{2}{3}R$; in this lens, R_1 is +ve and R_2 is –ve ; ∴ $R_1 = R$ and $R_2 = -R$; Equation is …

$\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R} + \frac{1}{R}\right] = \left[\frac{\mu_{glass}}{1} - 1\right]\left[\frac{2}{R}\right] = \frac{2[\mu_{glass} - 1]}{R}$; given $f = \frac{2}{3}R \longrightarrow \frac{1}{f} = \frac{3}{2R}$

$\frac{3}{2R} = \frac{2[\mu_{glass} - 1]}{R}$; $[\mu_{glass} - 1] = \frac{3}{4}$; $\mu_{glass} = 1 + \frac{3}{4} = 1.75$

What is the aperture of the lens? (very Important)

It is the effective diameter (note that it is not the area of the glass material exposed to light) of the refracting spherical surface exposed to the incident light. In figure, the vertical distance between points A and B is the aperture of the spherical refracting surface.



Assumption : In ray optics, all formulae connected with lens are valid only when aperture is small and for paraxial rays (close to principal axis) ; otherwise, the equations are different. (In 12th standard , we only consider aperture being small and using only paraxial rays ; If we consider rays far away from principal axis (marginal rays), then we will get two (or multiple focal points).

A plano-convex lens has f = 20 cm. What is its new focal length if its plane surface is silvered?

Formula is $\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

- For plano-convex lens $R_1 = R$ and $R_2 = \infty$ ∴ $\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R}\right] \rightarrow \frac{\mu_{ga}-1}{R} = \frac{1}{20}$ OR $20 = \frac{R}{\mu_{ga}-1}$ ---- (1)
- Given that the plane surface is silvered, it acts like a concave mirror of focal length $F = -\frac{1}{2}\frac{R}{(\mu_{ga}-1)}$ ------ (2)
- Comparing (1) and (2), new focal length, 20 = -2F , therefore F = -10cm

A plano-convex lens acts like a concave mirror of 28 cm focal length when its plane surface is silvered and like a concave mirror of 10 cm focal length when its curved surface is silvered. What is the refractive index of the material of the lens?

When the plane surface of plano-convex lens is polished, the formula is $F = -\frac{R}{2[\mu_{ga}-1]}$; where $\mu_{ga} = \frac{\mu_g}{\mu_a} = \mu_g = \mu\ (say) = ?$

- $28 = -\frac{R}{2[\mu-1]}$; R = -56(μ-1) -------------- (1)

When the convex surface of plano-convex lens is polished, the formula is $F = -\frac{R}{2\mu_{ga}}$; where $\mu_{ga} = \frac{\mu_g}{\mu_a} = \mu_g = \mu\ (say) = ?$

- $10 = -\frac{R}{2\mu}$; R = - 20μ ------------------------(2)

Comparing (1) and (2), we get 56(μ-1) = 20μ → 56μ- 56 = 20μ → 36μ = 56 → $\mu = \frac{56}{36} = \frac{14}{9} = 1.55$

A plano-convex lens acts like a concave mirror of 30 cm focal length when its plane surface is silvered and like a concave mirror of 10 cm focal length when its curved surface is silvered. What is the refractive index of the material of the lens?

When the plane surface of plano-convex lens is polished, the formula is $F = -\frac{R}{2[\mu_{ga}-1]}$; where $\mu_{ga} = \frac{\mu_g}{\mu_a} = \mu_g = \mu\ (say) = ?$

- $30 = -\frac{R}{2[\mu-1]}$; R = -60(μ-1) -------------- (1)

When the convex surface of plano-convex lens is polished, the formula is $F = -\frac{R}{2\mu_{ga}}$; where $\mu_{ga} = \frac{\mu_g}{\mu_a} = \mu_g = \mu\ (say) = ?$

- $10 = -\frac{R}{2\mu}$; R = - 20μ ------------------------(2)

Comparing (1) and (2), we get 60(μ-1) = 20μ → 60μ- 60 = 20μ → 40μ = 60 → $\mu = \frac{60}{40} = \frac{3}{2} = 1.5$

A plano-convex lens fits exactly into the plano-concave lens. Their plane surfaces are parallel to each other. The two lenses are made of different materials of refractive indices μ1 & μ2 and the R is the radius of curvature of the curved surfaces of the two lenses. What is the focal length of the system?

Without going into ray diagrams, let us use the Lens maker's formula $\frac{1}{f} = \left[\frac{\mu_{glass}}{\mu_{air}} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$; since $(\mu_{air} = 1) \rightarrow \frac{1}{f} = [\mu - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

For plano-convex lens, $R_1 = +R$ & $R_2 = \infty$; $\frac{1}{f_1} = \frac{[\mu_1-1]}{R}$; For plano-concave lens, $R_1 = \infty$ & $R_2 = R$; $\frac{1}{f_2} = -\frac{[\mu_2-1]}{R}$

The focal length of the combination is $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \rightarrow \frac{1}{F} = \frac{[\mu_1-1]}{R} - \frac{[\mu_2-1]}{R} = \frac{[\mu_1-\mu_2]}{R}$

Therefore, focal length of the system of combination of these two lenses = $F = \frac{R}{[\mu_1-\mu_2]}$

When two lenses of focal lengths f_1 and f_2 are placed co-axially at a distance x from each other, then the equivalent focal length is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \quad \text{and} \quad P = P_1 + P_2 - x P_1 P_2$$

When two thin lenses of equal and opposite focal lengths (i.e. one convex and other concave lens) are placed in contact, then the equivalent focal length is given by

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{-f} = \frac{1}{f} - \frac{1}{f} = 0 \quad \text{or} \quad F = \frac{1}{0} = \infty$$

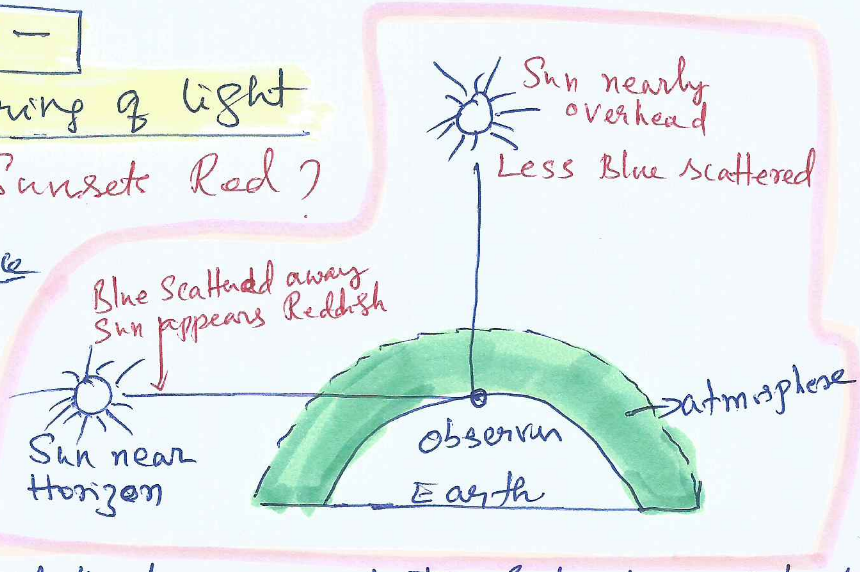
and power, $P = P - P = 0$

Such combination of lenses behaves as a plane glass plate.

—81 D—

Dispersion and Scattering of light

① Why are Sunrises and Sunsets Red ?



Ans:- Sunlight travels <u>more distance</u> through the atmosphere during ~~the~~ sunsets and sunrises. So, there is enough time for all the shorter wavelength colours (green, blue etc.....) to get scattered away ($I \propto \frac{1}{\lambda^4}$) and the longer wavelength Red colour is least scattered and is transmitted through the atmosphere and reaches our eyes. This gives rise to the reddish appearance of the Sun.

② Why is Sun overhead appears white ?

Ans:- See above figure.

Light from the Sun overhead would travel relatively shorter distance as compared to the Sun near the horizon. So, at noon, only a little of the blue and violet colours are scattered. All the colours reach our ~~ey~~ eyes and hence the Sun appears white.

③ Why is colour of the clear sky Blue ?

According to Rayleigh's law, the intensity of scattered light $I \propto 1/\lambda^4$ and the scattering is due to tiny atmospheric particles. We know that $\lambda_{red} > \lambda_{blue}$, thus the blue and violet colours are scattered the most and the red colour is scattered the least. Since our eyes are more sensitive to blue colour than the violet colour, we perceive sky as blue.

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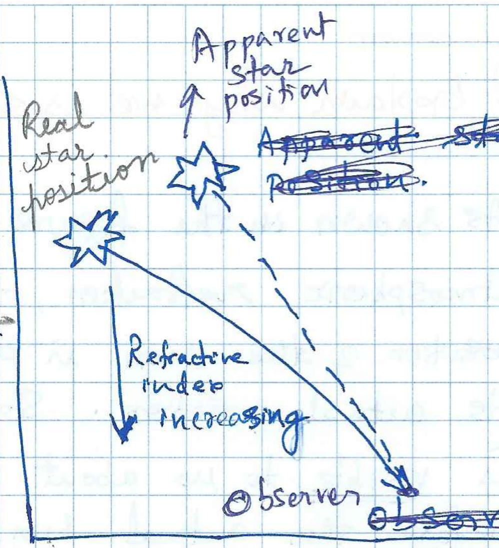
Onderwerp :

④ Why do stars twinkle ?



The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth, due to ~~gradual~~ changes in refractive index. Since the atmosphere bends the starlight towards normal (rarer → denser medium), the apparent position of the star is slightly different from it's actual position. Since the stars are very ~~very~~ distant from earth, they approximate point-sized sources of light. The apparent position of this distant ~~stars~~ star keeps ~~keep~~ on changing ~~due~~ slightly due to the physical conditions ~~of~~ of the earth's atmosphere are not stationary. Therefore the star ~~star~~ sometimes appears brighter, and at some other time, ~~at~~ fainter, the starlight entering the eye flickers, which is the ~~twinklone~~ twinkling effect.

⑤ Explain why the planets do not twinkle ?

The planets are much closer to the earth ~~than stars~~ as ~~compa~~ compared to stars and are hence seen as extended sources. If We ~~we consid~~ consider a planet as a collection of a large number of point-sized sources ~~source~~ of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullifying the twinkling effect. So ~~planets~~ planets do not twinkle.

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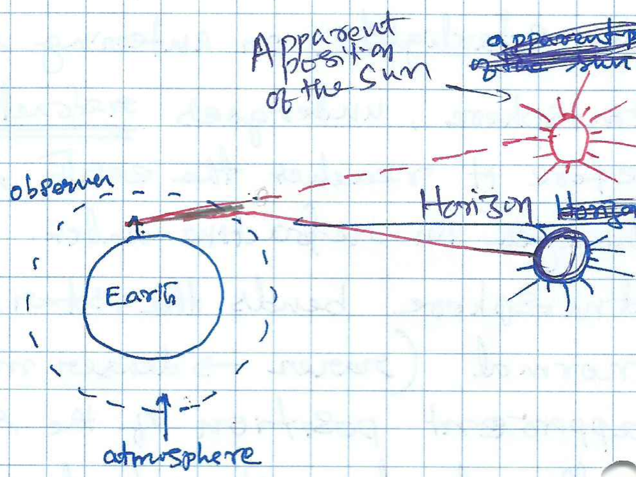
Datum .... 20......

Onderwerp :

(6) Explain why we see advance sunrise and delayed sunset.

As shown in the figure, due to atmospheric refraction, the apparent position of the sun is different from its actual position. So the sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset.



(7) Why ~~some~~ clouds are white?

Clouds are made up of clusters of water droplets in a ~~variety~~ variety of sizes. The different size clusters scatter different ~~colours~~ colours. ~~The~~ For example, the tiniest ~~clusers~~ clusters tend to scatter ~~blue~~ blue light, slightly larger cluster → green light and still ~~larger~~ larger cluster → Red light. So the overall result is a ~~white cloud~~ white cloud.

(8) Why some clouds are dark?

Such clouds predominantly consist of larger clusters of droplets, which absorb much of the light incident ~~upon the~~ upon them so the scattered intensity is less. So such clouds composed of larger clusters are darker.

(Further increase in the size of the clusters causes them ~~to~~ to fall as raindrops, and we have rain).

(9) Why does the sky appear dark instead of blue to an ~~astronaut~~ astronaut?

There is no atmosphere above that height, so there is ~~no~~ no scattering of light. Hence the sky appears dark to an ~~astronaut~~ astronaut.

- 81G -

H-18

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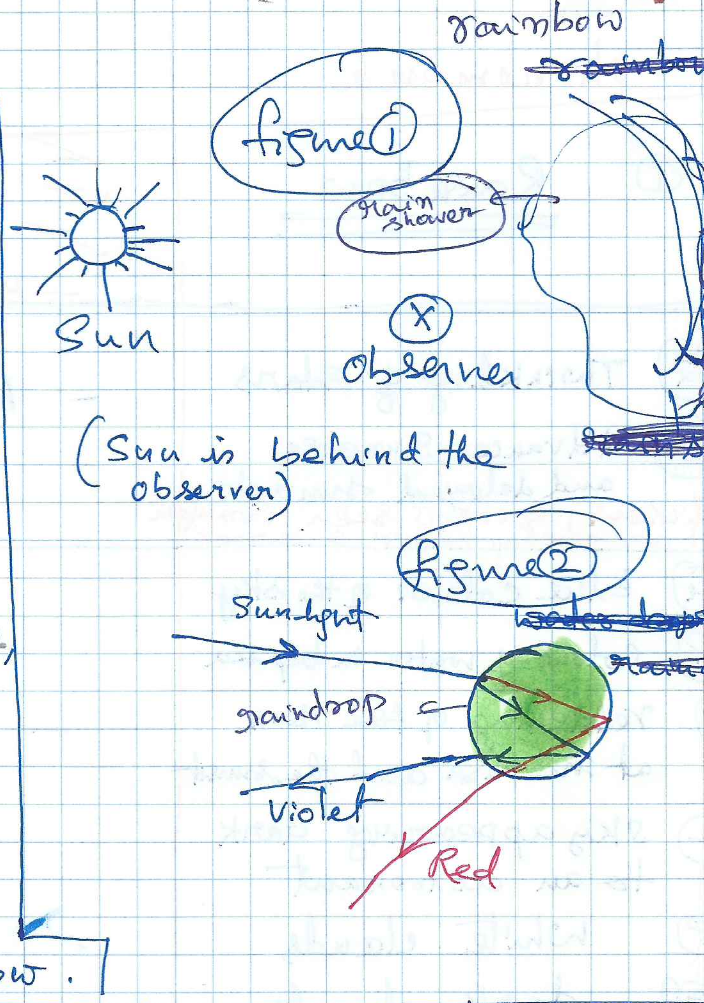
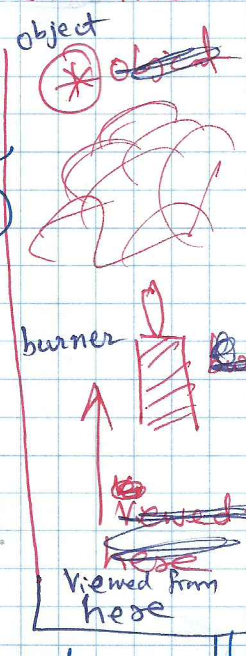
Onderwerp :

(10) How is rainbow formed ?



Rainbow is formed due to dispersion of sunlight by tiny water droplets, present in the atmosphere. As shown in the figure (2), tiny water droplets act like prism, so they refract and disperse the incident ~~light~~ sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop. So due to dispersion and internal reflection, different colours reach the observer's eye, forming rainbow.

(11) Objects viewed through hot air rising above a burner appear to shake, why ?



The light from the object undergoes atmospheric refraction which is due to ~~gradual~~ change in refractive index (μ) of the medium. The μ is changing because the air just above the burner is hotter than the air further up, so $\mu_{hot\ air} < \mu_{cool\ air}$. Since the ~~medium is not stationary~~ refracting medium is not stationary, the apparent position of the object, as ~~seen~~ viewed through hot air, fluctuates. Hence the objects appear to shake.

Important

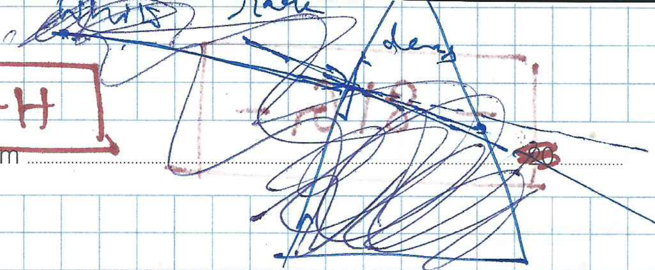
81-H

81-H

(Chroma means colour)

Onderwerp :

Datum



phenomena	Cause
① Rainbow	– Refraction. – Dispersion (Since Sunlight is white ~~white~~) – ~~inter~~ ~~total~~ internal reflection – ~~Refraction~~ total (~~total internal refl~~
② Twinkling of stars ③ Advance Sunrise and delayed sunset 4 – Flickering of objects seen through hot air rising above a burner.	– Atmospheric Refraction.
④ blue colour of the sky ⑤ Colour of water in deep sea ⑥ reddening of the sun at sunrise and the sunset ⑦ sky appearing dark to an astronaut ⑧ White clouds ⑨ dark clouds	– Scattering of light

Secret behind colours of dusk, dawn

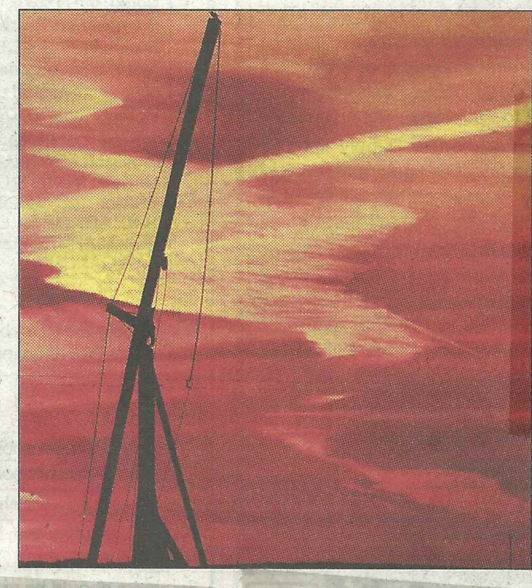
New York: Ever wondered why the sky turns a deep and blazing red or orange at sunset? It's due to a phenomenon called scattering, explains a new study.

Scattering happens when light collides against molecules in the atmosphere, causing it to scatter. The study, by researchers at the University of Wisconsin at Madison, shows how scattering determines the colours you see in the sky at sunset or sunrise.

According to Steven Ackerman, who led the study, the colour blue, being of shorter wavelength, is scattered more than other colours by the molecules. This, he says, is why blue light reaches our eyes from all directions on a clear day and the sky appears blue.

At sunrise or sunset, explains Ackerman, as the Sun is low on the horizon, sunlight passes through more of the atmosphere — and hence encounters more molecules.

"When the path is long enough, all of the blue and violet light scatters out of your line of sight. The other colours continue to your eyes. This is why sunsets are often yellow, orange, and red." As red has the longest wavelength of any visible light, the sun seems red when it's on the horizon, where its extremely long path through the atmosphere scatters all other colours away. AGENCIES



PAINTING THE SKY RED