2

HUMAN EYE AND COLOURFUL WORLD

THE HUMAN EYE

The human eye is the organ which gives us the sense of sight, allowing us to learn more about the surrounding world than we do with any of the other four senses. We use our eyes in almost every activity we perform, whether reading, working, watching television, writing a letter, driving a car, and in countless other ways. Most people probably would agree that sight is the sense they value more than all the rest.

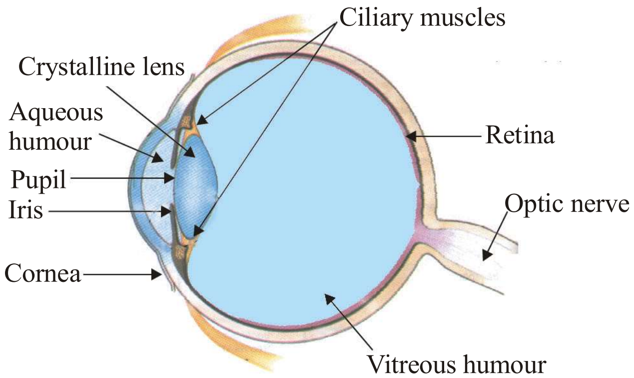


Figure : The human eye

The eye allows us to see and interpret the shapes, colors, and dimensions of objects in the world by processing the light they reflect or emit. The eye is able to see in bright light or in dim light, but it cannot see objects when light is absent.

Eye structures : The ability to see is dependent on the actions of several structures in and around the eyeball. The essential components of the eye's optical system:

Iris : The colored part of the eye is called the iris. It controls light levels inside the eye similar to the aperture on a camera. The round opening in the center of the iris is called the pupil. The iris is embedded with tiny muscles that dilate (widen) and constrict (narrow) the pupil size.

The iris reflex : The eye needs to be able to control the amount of light entering it. In dim conditions, more light is allowed to enter so that a clear image can be formed on the retina. In bright conditions less light is allowed to enter so that the retina is not damaged.

This adjustment is done by two sets of muscles in the iris: its circular muscles contract to close up the iris, making the pupil smaller - while its radial muscles contract to open up the iris, making the pupil larger. Automatic adjustment provided by iris provides a "focal-ratio" for the eye in the range f/3 to f/8 (approximately). The largest aperture size, under very dark conditions, is about 5-7mm.

Pupil : The pupil is the black, circular opening in the center of the iris. It opens and closes in order to regulate the amount of light entering the eyeball.

Sclera : The sclera, commonly known as "the white of the eye," is the tough, opaque tissue that serves as the eye's protective outer coat.

The Cornea : The cornea is the transparent, dome-shaped window covering the front of the eye. It is a powerful refracting surface, providing 2/3 of the eye's focusing power. Like the crystal on a watch, it gives us a clear window to look through.

The purpose of the lens is to focus light onto the back of the eye. The nucleus, the innermost part of the lens is surrounded by softer material called the cortex. The lens is encased in a capsular-like bag and suspended within the eye by tiny guy wires called zonules. The refractive lens is filled with fluid, and its shape can be adjusted by the surrounding muscles so that a sharp ("in focus") image is produced on the retina over a range of distances to objects being viewed.

Vitreous : The vitreous is a thick, transparent substance that fills the center of the eye. It is composed mainly of water and comprises about 2/3 of the eye's volume, giving it form and shape.

Optic Nerve : The optic nerve transmits electrical impulses from the retina to the brain. It connects to the back of the eye near the macula. The visible portion of the optic nerve is called the optic disc.

The Retina : The retina is a very thin layer of tissue that lines the inner part of the eye. It is responsible for capturing the light rays that enter the eye. Much like the film's role in photography. These light impulses are then sent to the brain for processing, via the optic nerve. The retina is not simply a sheet of photocells, but a tiny brain center that carries out complex information processing before sending signals back along the optic nerve. In fact, the retina really is part of the brain and grows out from it during embryonic development.

Four kinds of light-sensitive receptors are found in the retina:

* rods
* three kinds of cones, each "tuned" to absorb light from a portion of the spectrum of visible light
* cones that absorb long-wavelength light (red)
* cones that absorb middle-wavelength light (green)
* cones that absorb short-wavelength light (blue)

Rods do not provide a sharp image, However, rods are extremely sensitive to light rods provide us with a relatively grainy, colorless image, they permit us to detect light that is over a billion times dimmer than what we see on a bright sunny day.

Process of vision : Light waves from an object enter the eye first through the cornea, which is the clear dome at the front of the eye. The light then progresses through the pupil, the circular opening in the center of the colored iris. Next, the light passes through the crystalline lens, which is located immediately behind the iris and the pupil.

Initially, the light waves are bent or converged first by the cornea, and then further by the crystalline lens, to a nodal point (N) located immediately behind the back surface of the lens. At that point, the image becomes reversed (turned backwards) and inverted (turned upside-down).

The light continues through the vitreous humor, the clear gel that makes up about 80% of the eye's volume, and then, ideally, back to a clear focus on the retina behind the vitreous. The small central area of the retina is the macula, which provides the best vision of any location in the retina. If the eye is considered to be a type of camera, the retina is equivalent to the film inside of the camera, registering the tiny photons of light which interact with it.

Within the layers of the retina, light impulses are changed into electrical signals and then sent through the optic nerve, along the visual pathway, to the cortex at the posterior or back of the brain. Here, the electrical signals are interpreted or “seen” by the brain as a visual image. When the light entering the eyes is bright enough, the pupils will constrict (get smaller), due to the pupillary light response.

Actually, then, we do not “see” with our eyes but, rather, with our brains. Our eyes merely are the beginnings of the visual process.

You might have experienced that you are not able to see objects clearly for some time when you enter from bright light to a room with dim light. After sometime, however, you may be able to see things in the dim-lit room. The pupil of an eye acts like a variable aperture whose size can be varied with the help of the iris.

When the light is very bright, the iris contracts the pupil to allow less light to enter the eye. However, in dim light the iris expands the pupil to allow more light to enter the eye. Thus, the pupil opens completely through the relaxation of the iris.

Dynamic range: in a given scene, the eye can distinguish levels of illumination that have a brightness range of about 100:1, so it is said to have a dynamic range of 100. The maximum range of brightnesses detectable by the eye, after adjustments such as dark adaptation, is a remarkable 1,000,000:1.

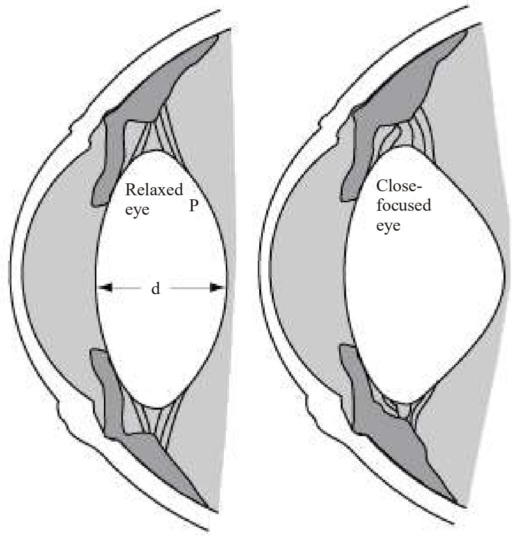
Integration time: the eye automatically adjusts the time interval during which it accumulates light energy before sending an image to the brain. This interval is called the "integration time" and is typically 0.1 sec; it increases to perhaps 0.2 sec for low-light levels. The reason that astronomical photographs show so much more detail than you can see with your eye is mainly due to the fact that cameras can have very long integration times, up to hours if necessary.

Power of Accommodation :

The ability of the lens to change its shape to focus near and distant objects is called accommodation. The table shows how this is done.

Object	Ciliary muscles	Suspensory ligaments	Muscle tension on lens	Lens shape
near	contract	slackened	low	fat
distant	relax	stretched	high	thin

When the eye is relaxed and the interior lens is the least rounded, the lens has its maximum focal length for distant viewing . As the muscle tension around the ring of muscle is increased and the supporting fibers are thereby loosened, the interior lens rounds out to its minimum focal length.



The minimum distance, at which objects can be seen most distinctly without strain, is called the least distance of distinct vision. It is also called the near point(N.P.) of the eye. For a young adult with normal vision, the near point is about 25 cm. The farthest point upto which the eye can see objects clearly is called the far point(F.P.) of the eye.

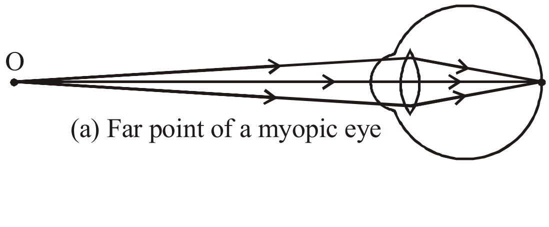
It is infinity for a normal eye. Thus a normal eye can see objects clearly that are between 25 cm and infinity.

If an eye has the ability to assume a focal length of 1.80 cm (56 diopters) to view objects many miles away as well as the ability to assume a 1.68 cm focal length to view an object 0.25 meters away (60 diopters), then its Power of Accommodation would be measured as 4 diopters (60 diopters - 56 diopters). The healthy eye of a young adult has a Power of Accommodation of approximately 4 diopters. As a person grows older, the Power of Accommodation typically decreases as a person becomes less able to view nearby objects. This failure to view nearby objects leads to the need for corrective lenses.

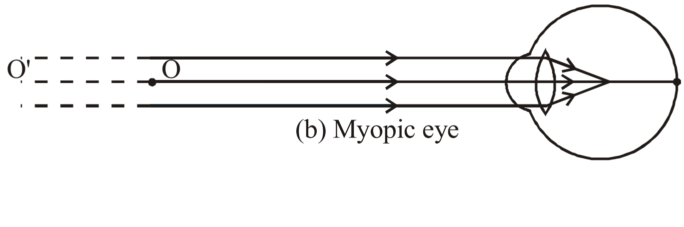
Many animals can see clearly both in water and on land. Some have extraordinary accommodation ranges, and others have developed other strategies. Cormorants and dippers can vary the refractive power of their lenses by 40-50 diopters, compared to about 16 diopters for an average adolescent human. The increased accommodation is due largely to highly developed sphincter muscles which vary the curvature of the front of the lens. Turtles and otters also have very strong sphincter muscles. Variations in lens geometries are used in various species of birds and fish.

DEFECTS OF VISION AND THEIR CORRECTION

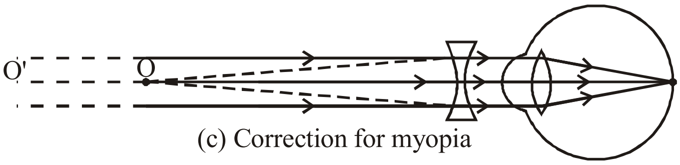
Nearsightedness: If the eyeball is too long or the lens too spherical, the image of distant objects is brought to a focus in front of the retina and is out of focus again before the light strikes the retina. Nearby objects can be seen more easily. Eyeglasses with concave lenses correct this problem by diverging the light rays before they enter the eye. Nearsightedness is called myopia. Myopia most commonly develops in childhood or early teens (between 8 and 14).



(a) Far point of a myopic eye



(b) Myopic eye



(c) Correction for myopia

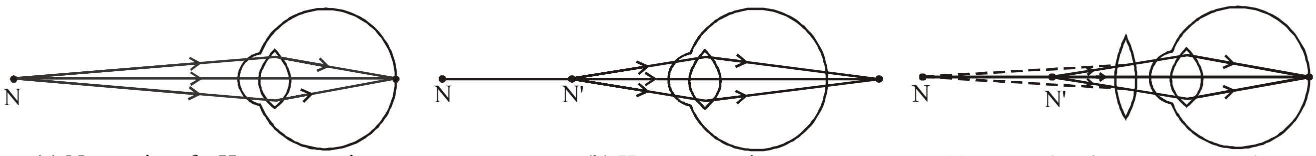
Figure : (a), (b) The myopic eye, and (c) correction for myopia with a concave lens

The risk of developing myopia is increased if there is a family history of it. There may also be a link between myopia and prolonged close-up work, such as reading or sitting close temporary short-sightedness, called pseudomyopia, can be caused by a number of diseases or certain drugs. For example, myopia may be the first sign of type-2 (non insulin-dependent) diabetes. Symptoms of pseudomyopia usually clear up if the underlying cause is treated to the television, although there is little scientific evidence for this.

If deflected far point is at a distance d from eye then focal length of use lens f = – d = – (deflected far point)

A person can see upto distance → x, wants to see distance $\rightarrow y(y > x)$ so $f = \frac{xy}{x - y}$ or power of the lens $P = \frac{x - y}{xy}$.

Farsightedness : If the eyeball is too short or the lens too flat or inflexible, the light rays entering the eye — particularly those from nearby objects — will not be brought to a focus by the time they strike the retina. Eye-glasses with convex lenses can correct the problem. Farsightedness is called hypermetropia or hyperopia.



(a) Near point of a Hypermetropic eye (b) Hypermetropic eye (c) Correction for Hypermetropic eye

Figure : (a), (b) The hypermetropic eye, and (c) correction for hypermetropia

Squinting, eye rubbing, lack of interest in school, and difficulty in reading are often seen in children with hyperopia.

If a person cannot see before distance d but wants to see the object placed at distance D from eye so $f = \frac{dD}{d - D}$

and power of the lens $P = \frac{d - D}{dD}$

Astigmatism: Astigmatism is the most common refractive problem responsible for blurry vision. Most of the eyeball's focusing power occurs along the front surface of the eye, involving the tear film and cornea (the clear 'window' along the front of the eyeball). The ideal cornea has a perfectly round surface.

Anything other than perfectly round contributes to abnormal corneal curvature - this is astigmatism. Here's a good way to demonstrate the effects of astigmatism. Look at your reflection in the curved surface of a round soup spoon and compare it with your reflection in an oval teaspoon.

The cornea is the transparent layer over the colored part of the eye. It bends (refracts) light rays and helps focus the light onto the retina in the back of the eye so people can see. When the cornea is oblong shaped, it causes light rays to focus on two different points on the retina, instead of just one. As a result, people with significant astigmatism may have distorted or blurry vision.

Astigmatism may cause eye strain and also may be combined with nearsightedness or farsightedness. Astigmatism can start in childhood or in adulthood. Cylindrical lens is use to correct astigmatism.

Presbyopia ("after 40" vision) : After age 40, and most noticeably after age 45, the human eye is affected by presbyopia, which results in greater difficulty maintaining a clear focus at a near distance with an eye which sees clearly at a far away distance. This is due to a lessening of flexibility of the crystalline lens, as well as to a weakening

of the ciliary muscles which control lens focusing, both attributable to the aging process.
Person suffering from presbyopia require bifocal lenses. A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision. These days, it is possible to correct the refractive defects with contact lenses or through surgical interventions.

Cataracts :

A cataract is a clouding of the lens in the eye. As people age, cataracts grow progressively darker and more dense, preventing light from easily passing through the lens. This results in vision loss.
Patients with cataracts have difficulty seeing in poorly lit environments. Many people also experience increased sensitivity to light and glare, double vision (or "ghost images"), and fading colors (blue may appear green; white may appear dull beige, etc.).
Most cataracts are highly treatable. Cataract surgery is one of the most common surgeries performed in the world with 95% of patients experiencing improved vision if there are no other eye conditions present. During surgery, the doctor removes the clouded lens, and, in most cases, replaces it with an artificial lens, called an intraocular lens (IOL). An IOL is a clear, plastic lens that requires no care and becomes a permanent part of your eye. Thick eyeglass lenses after surgery might not be needed because of the implanted lens.
Complicated cataracts cannot be extracted like normal cataracts because of potential complications such as other eye conditions, lack of vision in the other eye, or health concerns such as diabetes.

Possible Signs of Cataracts:

- Blurriness throughout your field of vision
- Poor color/contrast sensitivity
- Sensitivity to light

Visual Acuity:

Visual acuity (VA) is acuteness or clearness of vision. VA is a quantitative measure of the ability to identify black symbols on a white background at a standardized distance as the size of the symbols is varied.
A standard eye chart is necessary to make comparisons and to record people's visual acuity. The most common chart used in most doctors' offices is the Snellen eye chart.
The Snellen eye chart has a series of letters or letters and numbers, with the largest at the top. As the person being tested reads down the chart, the letters gradually become smaller. Many other versions of this chart are used for people who cannot read the alphabet. The Tumbling E chart has the capital letter "E" facing in different directions and the person being tested must determine which direction the "E" is pointing, up, down, left, or right.
The Snellen fractions, 20/20, 20/30, etc., are measures of sharpness of sight. They relate to the ability to identify small letters with high contrast at a specified distance. They give no information about seeing larger objects and objects with poor contrast (such as steps and curbs); it also does not inform us as to whether or not meaning is obtained from visual input, how much effort is needed to see clearly or singly, and whether or not vision is less efficient when using both eyes as opposed to each eye individually. In short, visual acuity measures only the smallest detail we can see; it does not represent the quality of vision in general.
August Colenbrander, offers a good explanation of acuity measurement. He says: "If a subject needs letters (or symbols) that are twice as large or twice as close as those that can just be seen by a standard eye, visual acuity is said to be 1/2 (or an equivalent fractional value, such as 20/40, 6/12, etc.). If the magnification need is 5x, visual acuity is 1/5 (20/100, 6/30, etc.), and so on."
Dr. Colenbrander also emphasizes that, contrary to popular belief, 20/20 is not actually normal or average, let alone perfect, acuity. Snellen, he says, established it is a reference standard. Normal acuity in healthy adults is one or two lines better. Average acuity in a population sample does not drop to the 20/20 level until age 60 or 70. This explains the existence of the two lines smaller than 20/20, 20/15 and 20/10.
When checking visual acuity, one eye is covered at a time and the vision of each eye is recorded separately, as well as both eyes together. In the Snellen fraction 20/20, the first number represents the test distance, 20 feet. The

second number represents the distance that the average eye can see the letters on a certain line of the eye chart. So, 20/20 means that the eye being tested can read a certain size letter when it is 20 feet away. If a person sees 20/40, at 20 feet from the chart that person can read letters that a person with 20/20 vision could read from 40 feet away. The 20/40 letters are twice the size of 20/20 letters; however, it does not mean 50% vision since 20/20 sounds like it is one half of 20/40. If 20/20 is considered 100% visual effiency, 20/40 visual acuity is 85% efficient.
If a patient sees 20/200, the smallest letter that they can see at 20 feet could be seen by a normal eye at 200 feet. This is the Snellen Acuity (English). In Metric Acuity, 20/20 equals 6/6. The conversion is that 20 feet equals approximately 6 meters (actually 6.096). Legal Blindness is when a person's best-corrected vision is 20/200 or worse.

Example 1 :

A man who wears glasses of power 3 dioptre must hold a newspaper at least 25 cm. away to see the print clearly. How far away would the newspaper have to be if he took off the glasses and still wanted clear vision ?

Sol. As here u = – 0.25 and f = 1 / P = (1/3) m, from lens formula

$$P = \frac{1}{f} = \frac{1}{v} - \frac{1}{u}\text{, we have } 3 = \frac{1}{v} - \frac{1}{-0.25} \quad \text{or} \quad \frac{1}{v} = 3 - 4 = -1\text{ m} \quad \text{i.e.} \quad v = -1\text{ m}$$

i.e., the lens shifts the object from 25 cm. to 1 m for clear vision, i.e., his near point is 1m. So in absence of glasses, he must hold the newspaper at a distance of 1m away from his eyes for clear vision.

Example 2 :

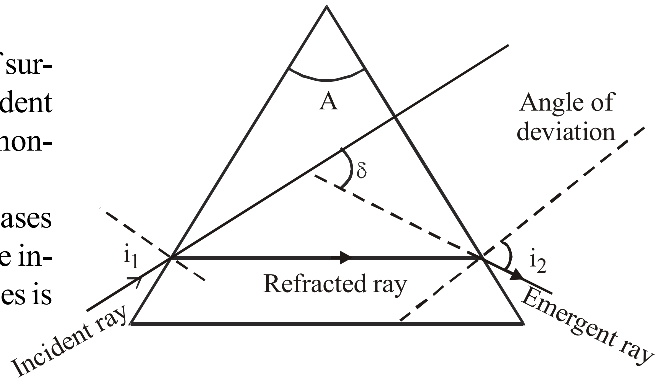
A farsighted person cannot focus clearly an objects that are less than 145cm. from his eyes. To correct this problem, the person wear eyeglasses that are located 2.0 cm. in front of his eyes. Determine the focal length that will permit this person to read a newspaper at a distance of 32.0 cm. from his eyes.

Sol. The near point is 145 cm. and eyeglasses are 2.0 cm. in front of the eyes. Therefore, v = – 143 cm. The object is placed 32.0cm. from the eyes so u = +30.0 cm. The focal length is obtained from equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{(30.0\text{cm})} + \frac{1}{-143\text{cm}} = 0.026\text{ cm}^{-1}\text{. Hence, f} = 38\text{ cm.}$$

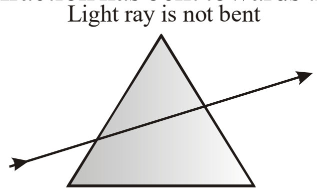
REFRACTION OF LIGHT THROUGH A PRISM

Prism is a transparent medium bounded by any number of surfaces in such a way that the surface on which light is incident and the surface from which light emerges are plane and non-parallel.
Consider a triangular glass prism. It has two triangular bases and three rectangular lateral surfaces. These surfaces are inclined to each other. The angle between its two lateral faces is called the angle of the prism.



In figure you can see the incident ray, the refracted ray inside the prism and the emergent ray. You may note that a ray of light is entering from air to glass at the first surface The light ray on refraction has bent towards the normal. At the second surface, the light ray has entered from glass to air.
Hence it has bent away from normal.
The peculiar shape of the prism makes the emergent ray bend at an angle to the direction of the incident ray. This angle is called the angle of deviation. It's not only the shape that matters but importantly difference of refractive index of prism material

Light ray is not bent



Glass is in fluid of the same index of refraction from surrounding makes ray to deviate, if glass prism is placed in a fluid with same refractive index as that of glass ray will pass without deviation.

Activity :

- Fix a sheet of white paper on a drawing board using drawing pins.
- Place a glass prism on it in such a way that it rests on its triangular base. Trace the outline of the prism using a pencil.
- Draw a straight line PE inclined to one of the refracting surfaces, say AB, of the prism.
- Fix two pins, say at points P and Q, on the line PE as shown in Figure.
- Look for the images of the pins, fixed at P and Q, through the other face AC.
- Fix two more pins, at points R and S, such that the pins at R and S and the images of the pins at P and Q lie on the same straight line.
- Remove the pins and the glass prism.
- The line PE meets the boundary of the prism at point E (see Fig.). Similarly, join and produce the points R and S. Let these lines meet the boundary of the prism at E and F, respectively. Join E and F.
- Draw perpendiculars to the refracting surfaces AB and AC of the prism at points E and F, respectively.
- Mark the angle of incidence ($\angle$ i), the angle of refraction ($\angle$ r) and the angle of emergence ($\angle$ e) as shown in Fig.

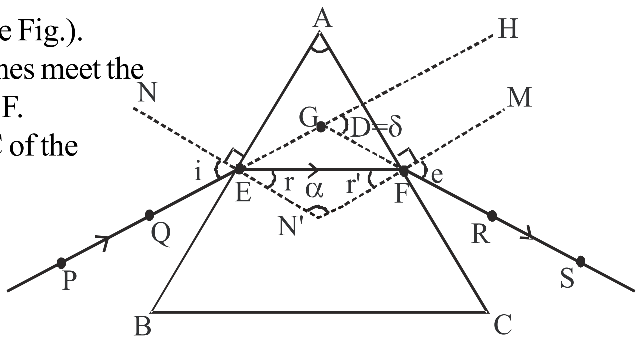


Figure : Refraction of light through a triangular glass prism

PE – Incident ray, $\angle$ i – Angle of incidence, EF – Refracted ray, $\angle$ r – Angle of refraction, FS – Emergent ray, $\angle$ e – Angle of emergence, $\angle$ A – Angle of the prism, $\angle$ D – Angle of deviation

Angle of deviation (δ), in terms of angle of prism (A), $\angle$ i and $\angle$ i′

The angle between the emergent ray and incident ray is called angle of deviation (δ).

In quadrilateral, (see above acitivity) the sum of its four angles should be 360°

$\therefore \angle AEN' + \angle AFM' + \angle A + \angle \alpha = 360°$

$\therefore 180 + \angle A + \angle \alpha = 360°$ or $\angle A + \angle \alpha = 180°$ .... (1)

In a $\Delta E'N'F$, $\angle r + \angle r' + \angle \alpha = 180°$ .... (2)

From (1) & (2) $\angle A = \angle r + \angle r'$ .... (3)

In a Δ GEF $\angle \delta$ = exterior angle

$\therefore \angle \delta = (\angle i - \angle r) + (\angle i' - \angle r')$

$\angle \delta = (\angle i + \angle i') - (\angle r + \angle r')$ or $\delta = (i + i') - A$ .... (A)

Angle of minimum deviation (δ_{min}) : For each angle of incidence i, there is a corresponding angle of deviation δ. As we increase the angle of incidence from zero onwards, the corresponding angle of deviation first decreases, then takes a minimum value whereafter it starts increasing. Let us find out the magnitude of this minimum angle of deviation (δ_{min}).

Condition when δ will be minimum : $\angle i = \angle i' = \theta$ (say) i.e., angle of incidences should be equal to angle of emergence. $\delta_{min} = 2\,i - A$ or $i = \frac{1}{2}(A + \delta_{min})$

Now, we know $\angle$ A. If determine δ_{min} experimentally, we can determine the refractive index, μ of the prism material easily by the relationship $\mu = \dfrac{\sin i}{\sin r}$ [Here $i = \dfrac{1}{2}(A + \delta_{min})$ & $r = \dfrac{A}{2}$]

[because when i = i', r = r' and also when i = i', it becomes a case of symmetry.

$\therefore$ A = 2r or r = A/2 $\quad\therefore\quad \mu = \dfrac{\sin\left(\dfrac{A + \delta_{min}}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

For a small angled prism :

If A is small and measured in radians, then $\sin\left(\dfrac{A + \delta_{min}}{2}\right) \approx \dfrac{A + \delta_{min}}{2}$ and $\sin\left(\dfrac{A}{2}\right) \approx \dfrac{A}{2}$

Putting these values in above-derived formula, we get

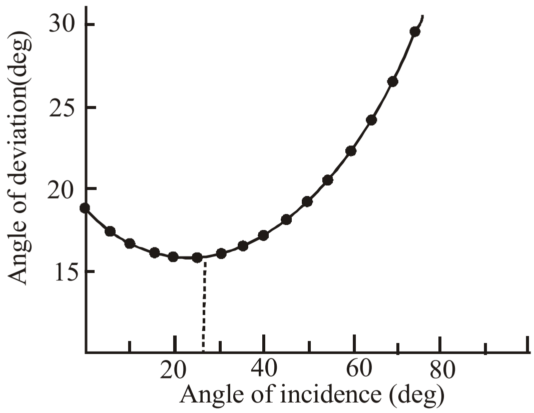
$$\mu = \frac{\dfrac{A + \delta_{min}}{2}}{\dfrac{A}{2}}, \ \mu = \frac{A + \delta_{min}}{A} \ ; \ \mu A = A + \delta_{min} \quad \therefore \delta_{min} = (\mu - 1)\,A$$

It is generally written as below because when $\angle A$ is small, all the δs are $\approx \delta_{min}$; $\delta = (\mu - 1)\,A$

How to determine δ_{min} :

We first determine the values of δ for various values of i. Then we draw a graph for these values. This turns out to be like shown in figure.

From this graph, we can easily find out δ_{min}.



Dispersion of white light by a glass prism :

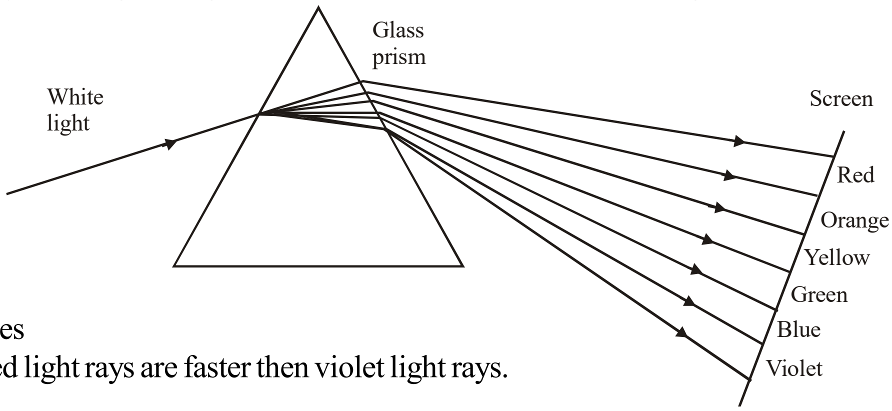
The refraction law underlies the phenomenon of the dispersion of light, that is the decomposition of the white light into the component colors when passing through a prism or through a transparent object delimited by non parallel surfaces A beam of light containing all the visible spectrum of the light is white, because the sum of all the colors generates the white color. Normally the light we use is white. It's light containing all the colors mixed together. We can realize this fact when the beam of light passes through a glass prism: the light is decomposed in all the component colors, Violet, Indigo, Blue, Green, Yellow, Orange and Red,

called as VIBGYOR. The band of the coloured components of a light beam is called its spectrum.

The phenomenon can be explained by thinking that light of different color (different wavelength) has different velocity while travelling in a medium:

$v_m = f\lambda_m$

Hence, the change in velocity of light observed when the light passes from the air to the glass, depends on the wavelength.



By passing the interface air-glass, lower is the wavelength lower becomes the velocity of the light, so , for ex., red light rays are faster then violet light rays.

This change in velocity coupled with the direction of the light beam to the air-glass interface explains the decomposition of a white light ray in the component colours while it is passing through a prism.
This phenomenon is known as "dispersion of the light through a prism" and it's also responsible for rainbows during storms: as a matter of fact, each raindrop can be regarded as a little prism; when a light ray strikes a raindrop it is refracted and decomposed, spreading out all the visible colors ranging from red to violet.

Combination of Prisms :

As the dispersive powers of the different materials are different, two or more prisms of different materials can be combined such that the rays of composite light on passing through the combination may suffer either dispersion without deviation or deviation without dispersion.

(i) Achromatic combination (or deviation without dispersion) Figure (i)

(ii) Dispersion without deviation (Direct vision combination) Figure (ii): This combination is used for dispersion without deviation

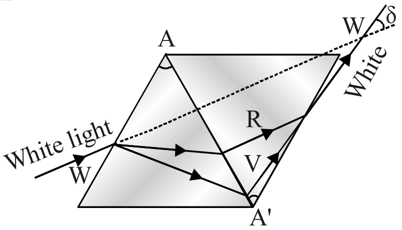


Figure (i)

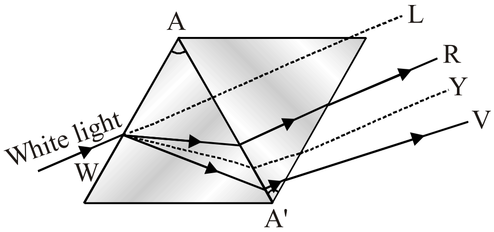


Figure (ii)

RAINBOW

You must have observed most spectacular light shows on earth i.e. rainbow. Indeed the traditional rainbow is sunlight spread out into its spectrum of colors and diverted to the eye of the observer by water droplets. The "bow" part of the word describes the fact that the rainbow is a group of nearly circular arcs of color all having a common center. Rainbows are generated through refraction and reflection of light in small rain drops. The sun is always behind you when you face a rainbow, and that the center of the circular arc of the rainbow is in the direction opposite to that of the sun. The rain, of course, is in the direction of the rainbow i.e. rain drops must be ahead of you and the angle between your line-of-sight and the sunlight will be 40°-42°.

After rain, there are still some tiny water droplets remained in the air. If there is sunshine a white sunbeam will be reflected and refracted by these tiny droplets. Different colors of light have different refractivity. They will be reflected in slightly different directions inside a water droplet. Since water is more dense than air, light is refracted as it enters the drop- red is bent less, blue more.

Some of the light will reflect off the back of the drop if the angle is larger than the critical angle (48° for water)
The light is then refracted again as it leaves the drop(act like a small prism), the colors of white light have been dispersed.

• violet light will leave the drop at an angle of 40° from the beam of sunlight.
• red light will leave the drop at an angle of 42° from the beam of sunlight.

However, you can not see the blue light and red light refracted from the same drop.
So, many drops are involved in producing the rainbow you can only see one wavelength of light refracted from one drop so, to see a rainbow, you need to see light refracted from many drops.
Hence red will be on the top and blue will be on the bottom of the rainbow.

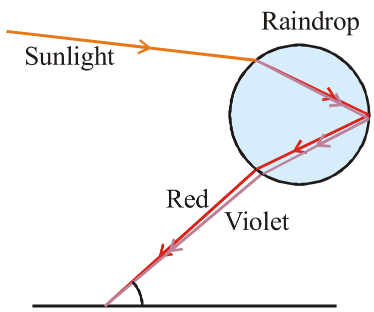
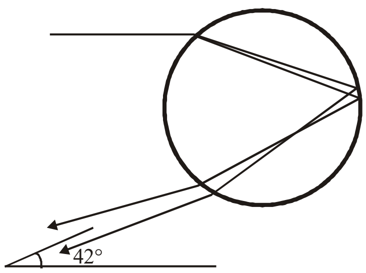


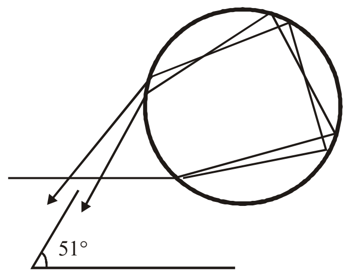
Figure : Rainbow formation

Both the primary and secondary rainbows are phenomena that formed by the reflection and refraction of sunlight in tiny water droplets. When a sunbeam is being refracted twice and reflected once by the droplet, a primary rainbow will form. If the beam is being refracted twice and reflected twice, a secondary rainbow will form .

As the secondary rainbow is formed by one more reflection than the primary rainbow, it is much fainter and rare to see. On the other hand, since the paths of sunbeams in a primary rainbow and a secondary rainbow are different, the colors of the secondary rainbow are arranged in just the reverse order of the primary one.



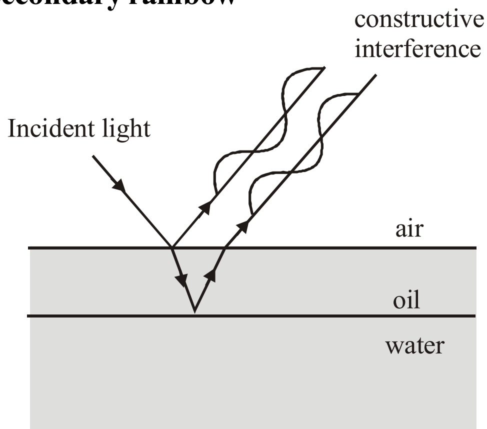
Formation of primary rainbow



Formation of secondary rainbow

Interesting:

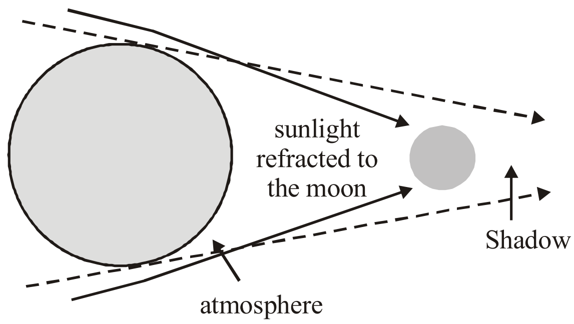
Rainbow-like colors appear on the surface of oil



When petrol is dropped on the road during a rainy day, a thin layer of oil will appear on the water surface. Both the top and bottom surfaces of this oil film can reflect light. If the path difference between two light rays is an integral times of the wavelength, there will be constructive interference. A light ray will pass through different thickness of oil when the angle of reflection varies.

The wavelength corresponding to the constructive interference also differs and this causes the reflected light to have various colours. As a result, a rainbow-like colour pattern is shown on the oil surface and this phenomenon is called thin-film interference.

Moon is seen red during total lunar eclipse :



As we all know, total eclipse of the moon happens when the moon orbits into the shadow of the earth. Since the moon is inside the shadow of the earth, how can the moon reflect light and why is the light red in colour? As a matter of fact, this phenomenon is related to refraction. Solar radiation will be refracted when passing through the earth's atmosphere.

Therefore part of the sunlight can still reach the shadow of the earth. Besides, the earth atmosphere scatters most of the blue light , so there will be more red light reaches the moon. The red light will be reflected back to earth. That is the reason why you can see a red moon rather than total darkness. It is hoped that you can see the red moon in the next total lunar eclipse.

Green sun : If somebody tells you that he saw the sun emitting green light, you must wonder if he was colourblind or insane. However, quite a lot of people really saw the green sun, and this phenomenon has even aroused years of debates. Is it just an illusion or is it real? We know that the green sun really exists after camera was invented.

At sunrise and sunset, when only a small part of the sun appears above the horizon, and provided that the air is clear, the green sun will appear, lasting only for a few seconds. We know that sunlight is refracted when it passes through the atmosphere. As if there is a triangular prism, the white sunlight will be refracted into the colours of the rainbow. Light with a shorter wavelength will be refracted to a higher degree. Therefore, at sunrise (sunset), we should see blue light at first (at last). But blue light is easily scattered in air and it is not easily seen, so what we usually see is green light as it has a slightly larger wavelength than blue light. This is how the green sun is formed. But if it is too dusty, even green light will be scattered, then the green sun cannot be seen. If you have a chance to see the sunrise by the seashore, don't get too shocked by the green sun.

ATMOSPHERIC REFRACTION

Twinkling of stars : The scientific name for the twinkling of stars is stellar scintillation (or astronomical scintillation). Stars twinkle when we see them from the Earth's surface because we are viewing them through thick layers of turbulent (moving) air in the Earth's atmosphere.

Stars (except for the Sun) appear as tiny dots in the sky; as their light travels through the many layers of the Earth's atmosphere, the light of the star is bent (refracted) many times and in random directions (light is bent when it hits a change in density - like a pocket of cold air or hot air). This random refraction results in the star winking out (it looks as though the star moves a bit, and our eye interprets this as twinkling).

Stars closer to the horizon appear to twinkle more than stars that are overhead - this is because the light of stars near the horizon has to travel through more air than the light of stars overhead and so is subject to more refraction.

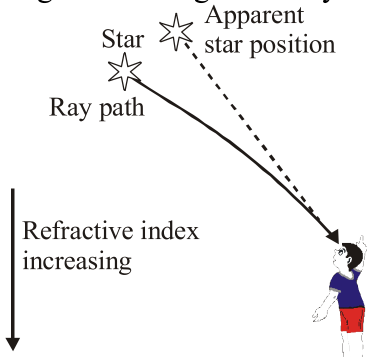


Figure : Apparent star position due to atmospheric refraction

Also, planets do not usually twinkle, because they are so close to us; they appear big enough that the twinkling is not noticeable (except when the air is extremely turbulent).

Stars would not appear to twinkle if we viewed them from outer space (or from a planet/moon that didn't have an atmosphere. Since the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. The star appears slightly higher (above) than its actual position when viewed near the horizon. Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary.

SCATTERING OF LIGHT

The interplay of light with objects around us gives rise to several spectacular phenomena in nature. The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with all this is because of scattering of light.

When sunlight enters the earth atmosphere, air and water vapour molecules will absorb part of the light and reradiate it to all directions. This is called scattering. Generally two types of scattering are consider mie and rayleigh.

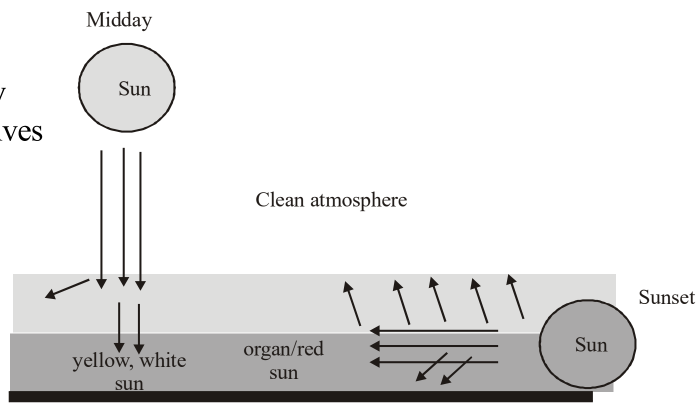
Mie Scattering

- large particles in the atmosphere are able to scatter all wavelengths of white light equally
- when all wavelengths of white light are scattered equally, then Mie scattering is occurring
- this is why clouds appear white.

Rayleigh scattering - the selective scattering of the shorter wavelengths of visible light (violet and blue) by atmospheric gases. Note that Rayleigh scattering involves much smaller scattering particles than Mie scattering

Orange/red sunsets in a clean atmosphere :

Created by rayleigh scattering At mid day, only a bit of the short wavelengths of visible light are scattered since the radiation is passing through a small distance in the atmosphere.



At sunset, however, the radiation must pass through a much thicker layer of the atmosphere. When the sun is at an angle of 4° from horizontal, the atmosphere appears to be 12 times thicker than at midday. Hence, much more blue light, and some green light are scattered. Therefore, the sun appears to look orange/red.

Orange/red sunsets in a dirty atmosphere :

- When pollution is present, the atmosphere contains more particles such as aerosols having larger diameters than the atmospheric gases. Hence, more of the intermediate wavelengths of visible light such as yellow and green are scattered in addition to the blue light what largely remains is red light, hence the sun appears red.

TYNDALL EFFECT

The scattering of light by colloidal particles is called the Tyndall effect. It makes it possible to see the light beam of an automobile on a dusty weather or the sunlight coming through a forest canopy. Not all wavelengths are scattered to the same extent. As a result, brilliant red sunsets are seen when the sun is near the horizon and the air contains dust, smoke, or other particles of colloidal size. If you dilute milk to where it is almost clear, or if you have any type of sol, such as colloidal silver, then the beam of the laser can be easily seen as it travels through the liquid. Tyndall effect can also be observed when a fine beam of light enters a room through a small hole. This happens due to the scattering of light by the particles of dust and smoke in the air.

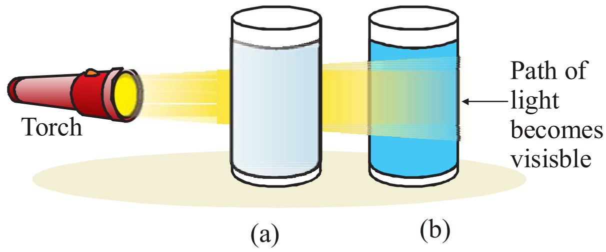


Figure : (a) Solution of copper sulphate does not show Tyndall effect, (b) mixture of water and milk shows Tyndall effect.

Raman effect : Appearance of additional lines in the spectrum of monochromatic light that has been scattered by a transparent material medium. The effect was discovered by Indian N C. V. Raman in 1928. The energy and thus the frequency and wavelength of the scattered light is changed as the light either imparts rotational or vibrational energy to the scattering molecules or takes energy away. The line spectrum of the scattered light will have one prominent line corresponding to the original wavelength of the incident radiation, plus additional lines to each side of it corresponding to the shorter or longer wavelengths of the altered portion of the light. This Raman spectrum is characteristic of the transmitting substance. Raman spectrometry is a useful technique in physical and chemical research, particularly for the characterization of materials, now a days it is used in preparation of nanomaterials.

Why does the sky appear blue when it is sunny? Why does it appear red during sunset?

This is a consequence of the scattering of sunlight. White sunlight is composed of light waves of different colors, whereas blue light has the shortest wavelength and red light has the longest. The short-wavelength blue light is easier to be scattered. The sun is very close to the horizon during sunset. Sunlight must pass through a thicker atmosphere in order to reach the ground

Most of the blue light has been scattered away and red light remains. Therefore the sun appears red during sunset. On the other hand, sunlight just has to pass through a thinner atmosphere during daytime, blue light is scattered less. Therefore the sun appears white. At the same time the sky is full of scattered blue light, that is why the whole sky appears blue.

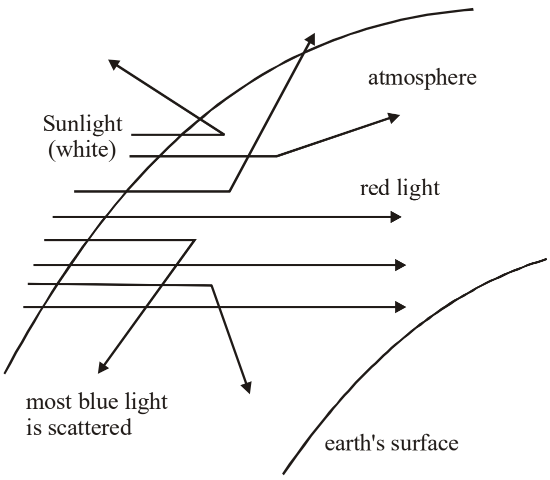


Figure : During sunset, sunlight passes through a thicker atmosphere in order to reach the ground, most blue light is scattered, leaving red light to reach the ground.

A simple experiment of scattering

Equipment: 1 hand torch, a transparent glass fully filled with water, a little amount of milk.

1. Add a few drops of milk into the fully filled glass of water. Stir the mixture very thoroughly.

2. Isolate the setup from other light sources, use the torch to illuminate the glass.

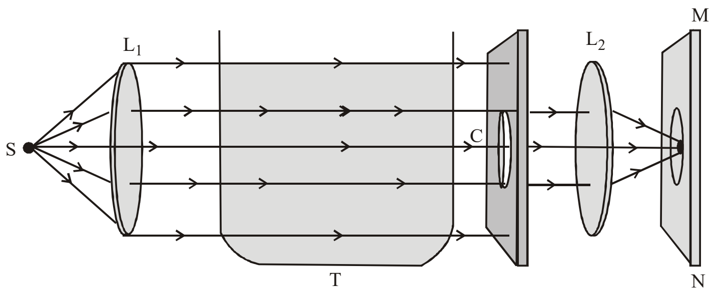
3. Observe the scattered light from different directions of the glass.

4. Pay attention to the region near the light source, the milk suspension appears a little bit blue there, while it appears a little bit red in the regions far away from the light source. This shows that blue light is easier to be scattered.

ACTIVITY

- Place a strong source (S) of white light at the focus of a converging lens (L_1). This lens provides a parallel beam of light.
- Allow the light beam to pass through a transparent glass tank (T) containing clear water.
- Allow the beam of light to pass through a circular hole (c) made in a cardboard. Obtain a sharp image of the circular hole on a screen (MN) using a second converging lens (L_2), as shown in Figure.
- Dissolve about 200 g of sodium thiosulphate (hypo) in about 2 L of clean water taken in the tank. Add about 1 to 2 mL of concentrated sulphuric acid to the water. What do you observe?

  You will find fine microscopic sulphur particles precipitating in about 2 to 3 minutes. As the sulphur particles begin to form, you can observe the blue light from the three sides of the glass tank.



This is due to scattering of short wavelengths by minute colloidal sulphur particles. Observe the colour of the transmitted light from the fourth side of the glass tank facing the circular hole. It is interesting to observe at first the orange red colour and then bright crimson red colour on the screen.

OPTICAL INSTRUMENTS

The size of the image on the retina determines how large an object appears to be. However, the size of the image on the retina is difficult to measure. Alternatively, the angle θ subtended by the image can be used as an indication of the image size. Figure shows this alternative, which has the advantage that θ is also the angle subtended by the object and, hence, can be measured easily. The angle θ is called the angular size of both the image and the object. The larger the angular size, the larger the image on the retina, and the larger the object appears to be.

Angular magnification (X) = Visual angle with instrument/visual angle when object is placed at least distance of distinct vision

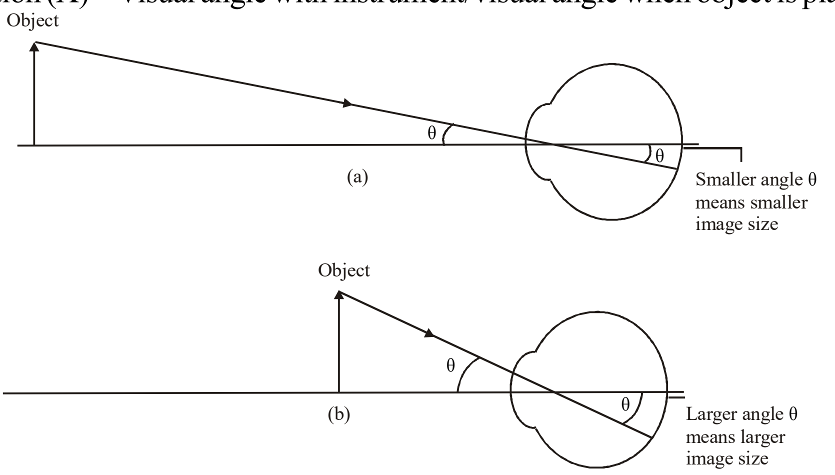


Fig. : In both (a) and (b) the object is the same size, but in (b) the image on the retina is larger because the object is closer to the eye. The angle θ is the angular size of both the image and the object.

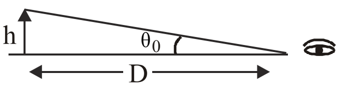
Simple microscope (Magnifying glass or reading lens) : A sign convex lens of lesser focal length.

Magnification by a simple microscope

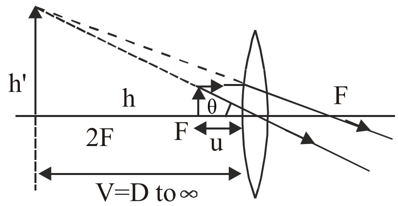
Case 1 : Eye focussed at near point i.e. the image is formed at a distance D from the lens/eye

In this case v = D

$$M = \frac{v}{u} = v \times \frac{1}{u} = v \times \left(-\frac{1}{f} + \frac{1}{v}\right)$$



unadded-eye
(A)



eye with instrument
(B)

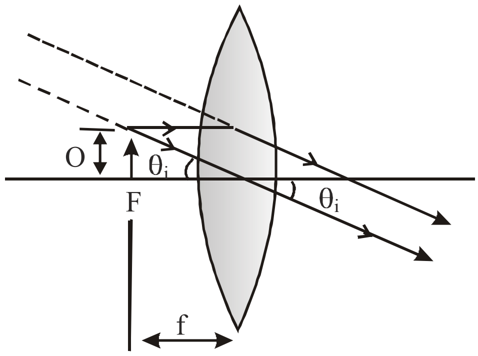
Now, according to our sign convention v is equal to (–D) here.

$$\therefore\ M = (-D) \times \left(-\frac{1}{f} + \frac{1}{-D}\right) \quad \text{or} \quad M = 1 + \frac{D}{f} \quad .... (A)$$

Case 2 : Eye focussed at infinity (Normal adjustment)

In this case we find out angular magnification. If the object is viewed directly by the eye, keeping the object at the near point, then

$$\therefore\ \theta_0 = \frac{O}{D} \ .... (1)$$



Now let us find the angle subtended by its image, if the image is formed to ∞. In this case, the object will have to be kept at the focus of the lens.

In this case, $\theta_i = \dfrac{O}{f}\ \therefore\ M = \dfrac{\theta_i}{\theta_0} = \dfrac{O/f}{O/D}$ or $M = \dfrac{D}{f}$ .... (B)

This is one less than the magnification when the image is formed at the near point, but, naturally, viewing is more comfortable and the difference in magnification usually small.

For example, if we want a magnification of six, f required will be 5 cm. in the first case (taking D = 25 cm) and (D/6 = 25/6) ≈ 4cm is the second case.

For all practical purposes, it is not possible to have magnification > 10 through a simple microscope.

Uses : The watch makers use of convex lens to have a magnified view of the small parts of the watch.

The magnified glass is also used to see slides. It is also used in laboratories to note vernier readings.

Compound Microscope : Two lenses are used hear, one compounding the effect of the other. The one nearer to the object is called objective. The other nearer to the eye is called eyepiece or ocular.

Magnification of a compound microscope : M_0, linear magnification due to the objective

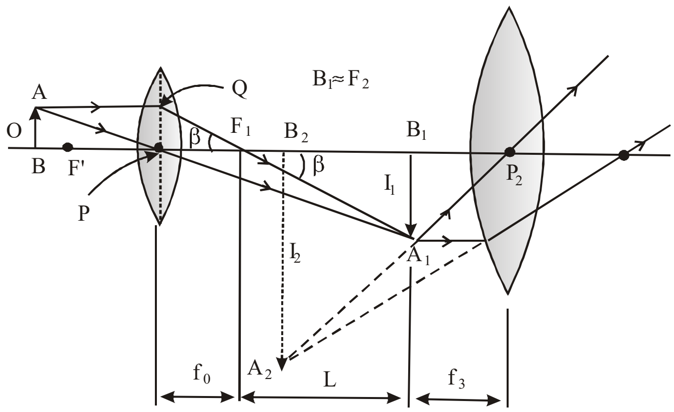
$$= \frac{I_1}{O} = \frac{A_1B_1}{AB} \quad \text{or} \quad \frac{A_1B_1}{PQ} \quad .... (1)$$

Now Δs PQF_1 and $B_1A_1F_1$ are similar,

$$\therefore\ \frac{A_1B_1}{B_1F_1} = \frac{PQ}{PF_1}$$

$$\text{or}\ \frac{A_1B_1}{PQ} = \frac{B_1F_1}{PF_1} = \frac{L}{f_0} \quad .... (2)$$

Put (2) in (1) to get $M_0 = \dfrac{L}{f_0}$ .... (3)



Compound microscope

Now, let the eye is focussed at ∞. This means A_1B_1 (the image by objective) is made at the focus of the eyepiece. Angular magnification by eyepiece (i.e., a simple microscope, as already dealt with), M_e will thus be

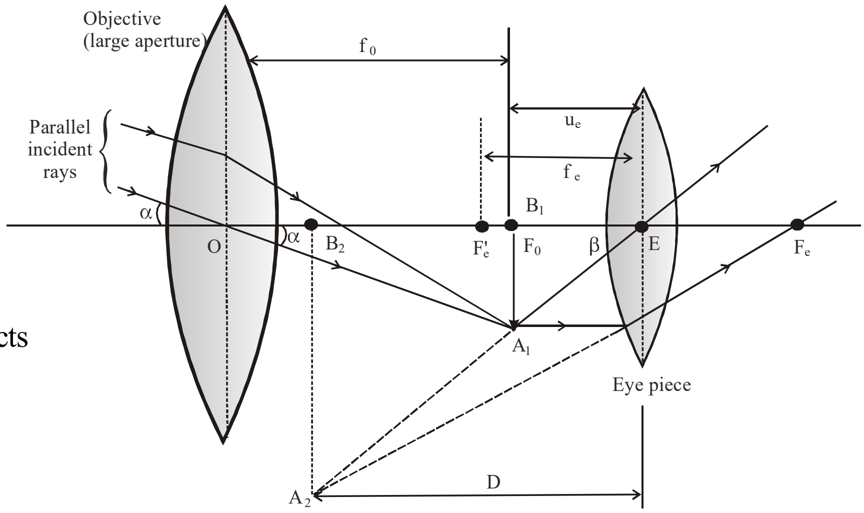
$$M_e = \frac{D}{f_e} \quad \text{........... (4)} \qquad \therefore \text{ Total magnification, } \quad M = M_0 \times M_e \quad \text{or} \quad M = \frac{L}{f_0} \times \frac{D}{f_e}$$

where, for all practical purposes L is approximately equal to the length of the compound microscope, and D = 25 cm, and f_0 & f_e are the focal lengths of the objective and eyepiece respectively.
If the eye is focussed at near point, M_e will be (as already derived in case of a simple microscope) = $(1 + D/f_e)$.

Therefore the total magnification will become, $M = \frac{L}{f_0} \times \left(1 + \frac{D}{f_e}\right)$

TELESCOPE

Telescope is used to provide angular magnification of distant objects.
It is of many types, general categories are :
(i) Refracting type (lenses are used)
(ii) Reflecting type (mirrors are used)
(iii) Astronomical, to view celestial objects
(iv) Terrestial, to view objects on earth.
Thus prism binoculars are also terrestial telescopes.



Magnifying power (M) : Magnifying power (M), also called angular magnification of a telescope is defined as the ratio of the visual angle subtended by the final image at the eye and the visual angle subtended by the object when the object lies in the actual position. (In contrast to the definition of magnifying power of a microscope, the object is not placed at the near point in case of telescope. Why ?)

$$M = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} \ (\because \alpha, \beta \text{ are small}) \ ; \quad M = \frac{A_1B_1 / EB_1}{A_1B_1 / OB_1} \ (\text{in } \Delta AB_1O \ \& \ \Delta \ AB_1E) \Rightarrow \quad M = \frac{OB_1}{EB_1}$$

Using sign convention and taking u_e as object distance for eyepiece, we get

$$M = \frac{+f_0}{-u_e} = -\frac{f_0}{u_e} \qquad \text{............ (1)}$$

This is the general formula for magnifying power of a telescope. M, if eye is focussed at near point
For the eyepiece, $v = -D$, $v = -u_e$, $f = +f_e$, where , D = minimum distance of distinct vision

Using lens formula, we get $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$; $\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$

$$\therefore \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{f_e}\left(1 + \frac{f_e}{D}\right) \qquad \text{............ (2)}$$

Put (2) in (1). We get $\quad M = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right) \qquad$ .... (3)

In this case, the length of the telescope is $= f_0 + u_e$.
M when eye is focussed at ∞ (normal adjustment)

In this case, as already explained, we have $u_e = -f_e$ .... (4)

Put (4) in (1) to get $M = \dfrac{f_0}{f_e}$ .... (5)

In this case, the length of the telescope = $f_0 + f_e$.
This is the reason why the focal length of objective is taken large and of eyepiece small in case of a telescope. This also increases the resolving power of the telescope.
Further, linear or lateral magnification does not convey much meaning in case of a telescope because the size of final images too is negligible compared to actual size of the objects which are generally planets or stars.

Difference between Compound Microscope and Astronomical Telescope

Compound Microscope	Astronomical Telescope
1. It is used to increase visual angle of near tiny object.	1. It is used to increase visual angle of distant large objects.
2. In it field and eye lens both are convergent, of short focal length and aperture.	2. In it objective lens is of large focal length and aperture while eye lens of short focal length and aperture and both are convergent.
3. Final image is inverted. virtual and enlarged and at a distance D to ∞ from the eye.	3. Final image is inverted, virtual and enlarged at a distance D to ∞ from the eye.
4. MP does not change appreciably if field and eye lens are interchanged [MP $\sim$ $(LD / f_0 f_e)$]	4. MP becomes $(1/m^2)$ times of its initial value if objective and eye-lenses are interchanged as MP ~ $[f_0 / f_e]$
5. MP is increased by decreasing the focal length of both the lenses.	5. MP is increased by increasing the focal length of objective lens (and by decreasing the focal length of eye-piece.
6. RP is increased by decreasing the wavelength of light used.	6. RP is increased by increasing the aperture of objective.

CONCEPT MAP

1. White light

↓

(Dispersion)

Red
(Velocity is maximum and deviation is minimum in glass)

Orange

Yellow

Green

Blue

Indigo

Violet
(Velocity is minimum and deviation is maximum in glass.)

2. Defects of Vision

Near sightedness (Myopia)
* Eyelens remains thick.
* Distant object cannot be seen clearly.
* It can be corrected by using concave lens.

Far sightedness (Hypermetropia)
* Eyelens remains thin.
* Nearby object cannot be seen clearly.
* It can be corrected by using convex lens.

ADDITIONAL EXAMPLES

Example 1 :

A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected ?

Sol. Short-sightedness. It can be corrected using short sightedness concave lens.

Example 2 :

A football team 'X' is wearing white shirts and black shorts. A team 'Y' is wearing yellow shirts and blue shorts. The teams are made to play in a flood lit yellow light. It is found that both teams appear to have same dress. Explain.

Sol. The white shirts of team X will appear yellow, because white colour cannot absorb any light and black shorts will appear black because it absorbs yellow colour.

The yellow shirt of team will appear yellow, because yellow pigment will reflect yellow light. The blue shorts will appear black, because blue pigment absorbs yellow colour.

Thus, the dresses of both the teams appear as yellow shirts and black shorts.

Example 3 :

A person needs a lens of power –5.5 dioptres for correcting his distant vision. For correcting his near vision he needs a lens of power +1.5 dioptre. What is the focal length of the lens required for correcting (i) distant vision, and (ii) near vision?

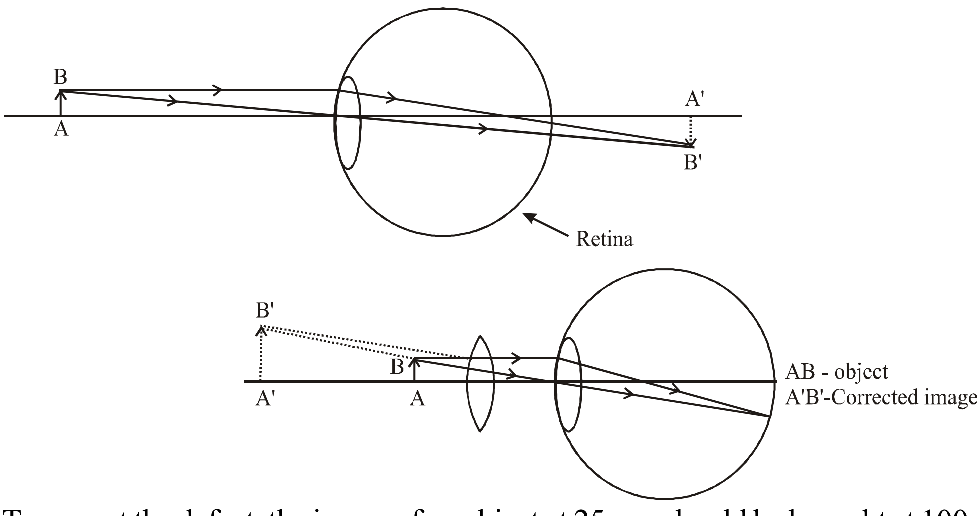
Sol. (i) Focal length of distance viewing $= \frac{1}{\text{Power}} = \frac{-100}{5.5}\text{cm} = -18\text{cm}.$

(ii) Focal length in near vision = 100/1.5 cm = 66.6 cm.

Example 4 :

Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.

Sol.



To correct the defect, the image of an object at 25 cm. should be brought at 100 cm.

$$\therefore \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-100} - \frac{1}{-25} \quad \text{i.e.,} \quad \frac{1}{f} = \frac{-1}{100} + \frac{1}{25} = \frac{-1+4}{100} = \frac{3}{100} \quad \therefore \quad f = +\frac{100}{3} = +33.3 \text{ cm.}$$

So a convex lens of focal length 33.3 cm. is required. Power, $P = \frac{100}{33.3} = 3.0 \text{ D}$

Example 5 :

What happens to the image distance in the eye when we increase the distance of an object from the eye?

Sol. Remains same with the change in focal length of lens done with ciliary muscles.

Example 6 :

Why do stars twinkle?

Sol. The twinkling of a star is due to atmospheric refraction of starlight. The atmospheric refraction occurs in a medium of gradually changing refractive index.

Since, the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. This apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary. Since the stars are very distant, they approximate point-sized sources of light. As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers-the star sometimes appear brighter, and at some other time, fainter, which is the twinkling effect.

Example 7 :

What is meant by power of accommodation of the eye ?

Sol. The ability of the eye lens to adjust its focal length to bring clear vision of distant objects is called accomodation.

Example 8 :

Explain why the planets do not twinkle.

Sol. Planets are nearer and are extended objects. The average of the light from all points in a planet is zero. So they do not twinkle.

Example 9 :

Why does the Sun appear reddish early in the morning?

Sol. In the early morning (at the time of sunrise), when the sun is near the horizon, the sunlight has to travel the greatest distance through the atmosphere to reach us. During this long journey of sunlight, most of the blue colour and shorter wavelength present in it is scattered out and away from our line of sight. So, the light reaching us directly from the rising sun consists mainly of longer wavelength red colour due to which the sun appears reddish early in the morning.

Example 10 :

Why does the sky appear dark instead of blue to an astronaut?

Sol. At very high altitudes, scattering is not prominent due to the absence of atmosphere, so sky appears dark instead of blue to an astronaut.

Example 11 :

A lady uses +1.5D glasses to have normal vision from 25 cm. onwards. She uses a 20D lens as a simple microscope to see an object. Calculate the maximum magnifying power if she uses the microscope (a) together with her glass (b) without the glass.

Sol. (a) $M = 1 + \frac{D}{f} = 1 + PD = 1 + 20 \times \frac{1}{4} = 6$ (b) focal length of glasses $= \frac{100}{1.5} = \frac{1000}{15} = \frac{200}{3}$

$\frac{1}{v} - \frac{1}{-25} = \frac{3}{200}$ or $\frac{1}{v} = \frac{3}{200} - \frac{1}{25} = \frac{3-8}{200} = -\frac{5}{200} = -\frac{1}{40}$; $v = -40$ cm.

Now, $M = 1 + Pv = 1 + 20\ (40/100) = 1 + 8 = 9$

Example 12 :

The refracting angle of the prism is 60°. What is the angle of incidence for minimum deviation ? The refractive index of material of prism is $\sqrt{2}$.

Sol. For minimum deviation, $r = A/2 = 60/2 = 30^o$

From snell's law $\frac{\sin i}{\sin r} = \mu$ or $\sqrt{2} = \frac{\sin i}{\sin 30°}$ $\therefore$ $\sin i = \frac{1}{2} \times \sqrt{2} = \frac{1}{\sqrt{2}} = \sin 45^o$ or $i = 45^o$

Example 13 :

Why is a normal eye not able to see clearly the objects placed closer than 25 cm?

Sol. The maximum accommodation of a normal eye is reached when the object is at a distance of 25 cm. from the eye. The focal length of the eye lens cannot be decreased below this minimum limit. Thus, an object placed closer than 25 cm. cannot be seen clearly by a normal eye because all the power of accommodation has already been exhausted.

Example 14 :

A certain eye has a near point of 11.0cm. and a far point of 15.0 cm. (a) What is the refractive power of the lens that is required to place the far point at infinity ? (b) What is the near point distance when the person uses the lens fount in part (a) ? (c) What is the refractive power of the lens required to yield a near-point distance of 25cm.

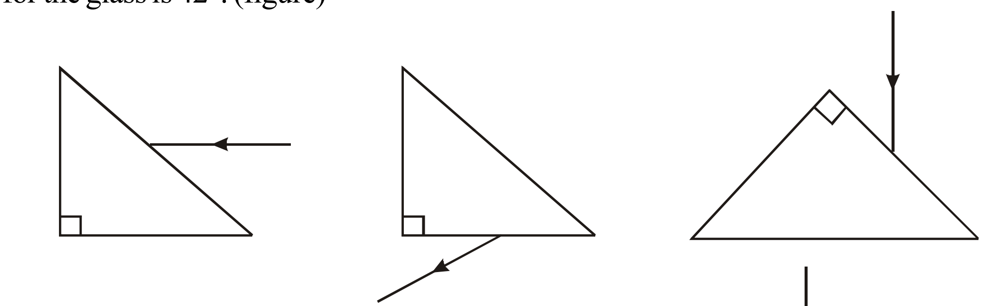
Sol. (a) We want to move the far point to infinity, so $\frac{1}{f} = \frac{1}{\infty} + \frac{1}{(-0.15m)} = -6.7$ diopters

(b) We have, $\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = -6.7m^{-1} - \frac{1}{-0.11m} = 2.4\ m^{-1}$. So that u = 42 cm.

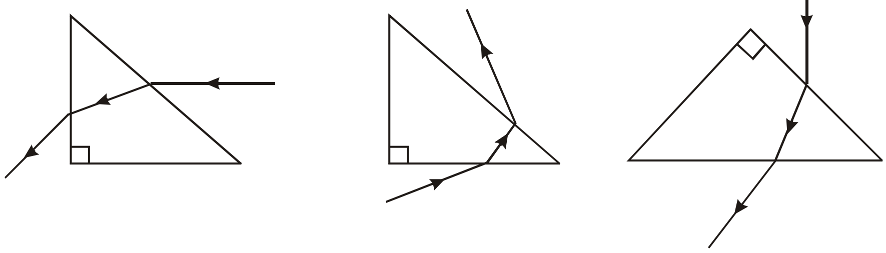
(c) For the near point at 25 cm : $\frac{1}{f} = \frac{1}{0.25m} + \frac{1}{-0.11m} = -5.1$ diopters

Example 15 :

Complete the path of the monochromatic ray of light in each of the right angled isosceles triangle. Critical angle for the glass is 42°. (figure)



Sol.



QUESTION BANK

EXERCISE - 1

Q.1 When a monochromatic light passes through a prism, will it show dispersion ?

Q.2 Will a star appear to twinkle if seen from free space (say moon) ?

Q.3 Can a beam of white light when passed through a hollow prism give spectrum ? Explain.

Q.4 What do you mean by a pure spectrum ?

Q.5 What is the common name for short sightedness ?

Q.6 Name the defect which is corrected by using an astigmatic lens.

Q.7 A person with a myopic eye cannot see objects beyond 1.2m distinctly. What should be the type of the corrective lens used to restore proper vision ?

Q.8 The far point of a myopic person is 80 cm. in front of the eye. What is the nature and power of lens required to correct the problem ?

Q.9 A person cannot see objects nearer than 75 cm. from his eyes while a person with normal vision can see objects upto 25 cm. from his eyes. Find the nature, the focal length and the power of the correcting lens used for the defective vision.

Q.10 A person can see clearly only up to 3 metres. Prescribe a lens for spectacles so that he can see clearly up to 12 metres. Defect is myopia.

Q.11 What is Cataract ?

Q.12 Name a natural spectrum.

Q.13 What is colour blindness ?

Q.14 How do we see colours ?

Q.15 The far point of a myopic person is 80 cm. in front of the eye. What is the power of the lens required to enable him to see the distant objects clearly ?

Q.16 Why does it take some time to see objects in a dim room when you enter the room from bright sunlight outside?

Q.17 A person with a defective eye-division is unable to see the objects nearer than 1.5m. He wants to read books at a distance of 30m. Find the nature, focal length and power of the lens he needs in his spectacles.

Q.18 A ray of light is travelling in water medium falls on the water-air interface at an angle of 45° with the vertical. Will it be possible by the ray of light to come out of the water surface ?

Q.19 A person having a myopic eye uses a concave lens of focal length 50 cm. What is the power of the lens ?

Q.20 What are fibre cables ?

Q.21 Why do different coloured rays deviate differently in the prism ?

Q.22 Why does a diamond sparkle ?

Q.23 Who do stars twinkle on a clear night ?

Passage based questions (Q.24-Q.28)

The ciliary muscles of eye control the curvature of the lens in the eye and hence can alter the effective focal length of the system. When the muscles are fully relaxed, the focal length is maximum. When the muscles are strained the curvature of lens increases (that means radius of curvature decreases) and focal length decreases. For a clear vision the image must be on retina. The image distance is therefore fixed for clear vision and it equals the distance of retina from eye-lens. It is about 2.5 cm for a grown-up person.

A person can theoretically have clear vision of objects situated at any large distance from the eye. The smallest distance at which a person can clearly see is related to minimum possible focal length. The ciliary muscles are most strained in this position. For an average grown-up person minimum distance of object should be around 25 cm.

A person suffering for eye defects uses spectacles (Eye glass). The function of lens of spectacles is to form the image of the objects within the range in which person can see clearly. The image of the spectacle-lens becomes object for eye-lens and whose image is formed on retina.

The number of spectacle-lens used for the remedy of eye defect is decided by the power of the lens required and the number of spectacle-lens is equal to the numerical value of the power of lens with sign. For example power of lens required is +3D (converging lens of focal length 100/3 cm) then number of lens will be +3.
For all the calculations required you can use the lens formula and lens maker's formula. Assume that the eye lens is equiconvex lens. Neglect the distance between eye lens and the spectacle lens.

Q.24 Minimum focal length of eye lens of a normal person is –
(A) 25 cm. (B) 2.5 cm. (C) 25/9 cm. (D) 25/11 cm.

Q.25 Maximum focal length of eye lens of normal person is –
(A) 25 cm (B) 2.5 cm. (C) 25/9 cm. (D) 25/11 cm.

Q.26 A nearsighted man can clearly see object only upto a distance of 100 cm and not beyond this. The number of the spectacles lens necessary for the remedy of this defect will be.
(A) +1 (B) – 1 (C) + 3 (D) – 3

Q.27 A farsighted man cannot see object clearly unless they are at least 100 cm from his eyes. The number of the spectacles lens that will make his range of clear vision equal to an average grown up person
(A) + 1 (B) – 1 (C) + 3 (D) – 3

Q.28 A person who can see objects clearly from distance 10 cm to ∞, then we can say that the person is –
(A) Normal sighted person (B) Near-sighted person
(C) Far-sighted person (D) A person with exceptional eyes having no eye defect

PASSAGE (QUESTIONS 29 - 34)

In the normal human eye, light from an object is refracted by the cornea-lens system at the front of the eye and produces a real image on the retina at the rear of the eye. For a given eye, its lensto-retina distance is fixed at about 2.5 cm. Most of the focusing of an image is done by the cornea, which has a fixed curvature that is convex with respect to incoming light. The importance of the lens is that its radius of curvature can be changed, allowing the lens to fine-tune the focus.
The lens is surrounded by the ciliary muscle. Contraction of the muscle decreases tension on the lens. This allows the natural elasticity of the lens to produce an increase in the radius of curvature. When the muscle relaxes, the lens flattens out, decreasing its radius of curvature. Unfortunately, the lens loses elasticity with age and the ability to alter curvature decreases.
The range over which clear vision is possible is bounded by the far point and the near point. In normal vision the far point is infinity and the near point depends on the radius of curvature of the lens. For normal eyes the average near point for reading is 25 cm.

AGE, years	NEAR POINT, cm
10	7
20	10
30	14
40	22
50	40
60	200

In the myopic (nearsighted) eye, the lens-to-retina length, is too long and/or the radius of curvature of the cornea is too great. This causes rays from an object at infinity to focus at a point in front of the retina. The far point is closer than normal. A corrective, lens will put a virtual image of a distant object at the position of the actual far point of the eye.
In the hyperopic (farsighted) eye, the lens-to-retina length is too short and/or the radius of the curvature of the cornea is not great enough. This causes rays from an object at infinity to focus at
a point behind the retina. The near point is farther away than normal. A corrective lens will put a virtual image of the close object at the position of the actual near point.

The relation among the object (o) and image (i) distances from the eye and the focal length (f') of the lens is given by the lens-distance rule : $\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$

When using this equation, all distances are given in centimeters.

The power of corrective lenses is usually given in units called diopters. Power, in diopters, is the reciprocal of the focal length in meters : $P_{diopter}=\frac{1}{f_{meter}}$

By convention:

I. Converging lenses have positive focal lengths, and diverging lenses have negative focal lengths.

II. Real images have positive distances from the lens, and virtual images have negative distances from the lens.

Q.29 The lens system of the myopic eye is best described as :
(A) producing too much convergence (B) producing too little convergence
(C) producing too much divergence (D) producing too little divergence

Q.30 An optometrist examined John's eyes. The farthest object he can clearly focus on with his right eye is 50cm away. What is the power of the contact lens required to correct the vision in his right eye?
(A) –0.50 diopters (B) –2.0 diopters (C) +2.0 diopters (D) +5.0 diopters

Q.31 In a mildly hyperopic eye, the focal length of the eye's natural lens can be corrected by:
(A) contracting the ciliary muscle and increasing the radius of curvature
(B) contracting the ciliary muscle and decreasing the radius of curvature
(C) relaxing the ciliary muscle and increasing the radius of curvature
(D) relaxing the ciliary muscle and decreasing the radius of curvature

Q.32 Jane must wear a contact lens with a power of +3.00 diopters in one eye to be able to clearly focus on an object 25 cm in front of the eye. Based on the vision in this eye, which of the following is the most likely age range for Jane ?
(A) Less than 40 years old (B) From 40 to 49 years old
(C) From 50 to 59 years old (D) 60 years or older

Q.33 George wears eyeglasses that sit 2.0 cm in front of his eyes. His uncorrected far point is 50 cm. What is the focal length of his eyeglasses –
(A) –50 cm (B) +50 cm (C) – 48 cm (D) + 48 cm

Q.34 In a surgical procedure called Radial Keratotomy, (RK), a laser is used to flatten the cornea by placing a series of hairline cuts around the perimeter of the cornea. Which statement is most accurate –
(A) RK corrects myopia by decreasing the focal length of the eye
(B) RK corrects myopia by increasing the focal length of the eye
(C) RK corrects hyperopia by decreasing the focal length of the eye
(D) RK corrects hyperopia by increasing the focal length of the eye

EXERCISE - 2

Fill in the Blanks :

Q.1 Lens which is used for correcting the presbyopia defect of the eye is ....

Q.2 The colour that deviates maximum while passing through a glass prism is ....

Q.3 Water droplets act as tiny prism in the formation of ....

Q.4 The transparent spherical membrane covering the front of the eye is known as ....

Q.5 The coloured diaphragm between the cornea and the lens is ....

Q.6 The middle point of the iris has a hole, which is called ....

Q.7 The screen on which the image is formed by the lens system of the human eye is called ....

Q.8 .... responds to the intensity of light.

Q.9 .... respond to colour by generating electrical nerve pulses.

Q.10 For young adult with normal vision LDDV = ...
Q.11 The closest distance at which the eye can focus clearly is called the ....
Q.12 For a normal eye, the range of vision is from ....
Q.13 The eye which suffers from myopia as well as from hypermetropia is said to suffer from ....
Q.14 The eye which cannot simultaneously see with the same distinctness all objects or lines making different inclinations is said to suffer from ....
Q.15 The defect of the eye due to which a person is unable to distinguish between certain colours, known as ....
Q.16 Newton demonstrated that white light is made up of .... constituent colours.
Q.17 The phenomenon of splitting of white light into its constituent colours is called ....
Q.18 The band of colours produced on the screen is called ....
Q.19 The ability of the eye to focus both near and distant objects, by adjusting its focal length, is called the ....
Q.20 The smallest distance, at which the eye can see objects clearly without strain, is called the .... of the eye.
Q.21 The common refractive defects of vision include ...., ... and ....
Q.22 The splitting of white light into its component colours is called ....
Q.23 .... causes the blue colour of sky and the reddening of the Sun at sunrise and sunset.
Q.24 Sunlight comprises .... colours.
Q.25 The wavelength of violet colour is ....
Q.26 The wavelength of red colour is ....
Q.27 In the minimum deviation position, the path of ray of light entering a prism is such that the angle of .... is .... to the angle of emergence; also the refracted ray in the prism is .... to the base of the prism.

True-False statements.

Q.28 The eye which can see near object clearly is said to suffer from hypermetropia.
Q.29 The eye which cannot see distant objects clearly is said to suffer from myopia.
Q.30 Colour blindness is a genetic disorder which occurs by inheritance.
Q.31 The ciliary muscles can modify the curvature of the lens.
Q.32 In Myopia the image of distant objects is focussed before the retina.
Q.33 Hypermetropia is corrected by using a convex lens of suitable power.
Q.34 The refractive index of diamond is 2.4. Its critical angle is 24° 38'. (twenty four degree, and thirty eight minutes)
Q.35 For total internal reflection to take place, the angle of incidence in the given (denser) medium must be less than the critical angle for that medium.

EXERCISE - 3

Q.1 The human eye can focus objects at different distances by adjusting the focal length of the eye lens. This is due to
(A) presbyopia (B) accommodation (C) near-sightedness (D) far-sightedness

Q.2 The human eye forms the image of an object at its –
(A) cornea (B) iris (C) pupil (D) retina

Q.3 The least distance of distinct vision for a young adult with normal vision is about –
(A) 25 m (B) 2.5 cm (C) 25 cm (D) 2.5 m

Q.4 The change in focal length of an eye lens is caused by the action of the –
(A) pupil (B) retina (C) ciliary muscles (D) iris

Q.5 Prism angle of a prism is 10^{o}. Their refractive index for red & violet colour is 1.51 & 1.52 respectively. Then dispersive power will be
(A) 0.5 (B) 0.15 (C) 0.019 (D) 0.032

Q.6 Prism angle & refractive index for a prism for a 60^{o} & 1.414. Angle of minimum deviation will be -
(A) 15^{o} (B) 30^{o} (C) 45^{o} (D) 60^{o}

Q.7 Diameter of the moon is 3.5×10^3 km and its distance from earth is 3.8×10^5 km. It is seen by a telescope whose objective and eyepiece have focal lengths 4m and 10cm respectively. The angular diameter of the image of the moon will be nearly –

(A) 5° (B) 10° (C) 20° (D) 25°

Q.8 A telescope consisting of an objective of focal length 60 cm and a single–lens eyepiece of focal length 5 cm is focussed at a distant object in such a way that parallel rays emerge from the eye piece. If the object subtends an angle of 2° at the objective, then the angular width of the image will be –

(A) 10° (B) 24° (C) 50° (D) 1/6°

Q.9 A near sighted person cannot see distinctly beyond 50cm. from his eye. The power in diopter of spectacle lenses which will enable him to see distant objects clearly is –

(A) +50 (B) –50 (C) +2 (D) –2

Q.10 The following one is not a primary colour –

(A) Yellow (B) Red (C) Green (D) Blue

Q.11 Fraunhofer lines in the Sun's spectrum are present because –

(A) Vapours of certain elements present in the atmosphere absorb certain colours

(B) The temperature of the sun is very high (C) The sun does emit certain light

(D) Certain elements present in the sun interfere

Q.12 When a mirror is rotated an angle the reflected ray moves through double that angle, the instrument based on the above principle is –

(A) Periscope (B) Odometer (C) Refractometer (D) Sextant

Q.13 Rainbow is caused due to –

(A) Reflection of sun light air (B) Dispersion of sun light from water drops

(C) Refraction of sun light from water drops (D) Diffraction of sun rays from water drops

Q.14 In the visible spectrum the colour having the shortest wavelength is –

(A) Green (B) Red (C) Violet (D) Blue

Q.15 At the moment dew formation starts on a cool night, the air

(A) Must loose all water vapour (B) Must remain unsaturated

(C) Must get mixed up with some other vapour (D) Must become saturated

Q.16 At sun rise or at sun set the sun appears to be reddish while at mid day it looks white. This is because –

(A) Scattering due to dust particles and air molecules causes this phenomenon

(B) The sun is cooler at sun rise or at sunset

(C) Refraction causes this phenomenon

(D) Diffraction sends red rays to the earth at these times.

Q.17 Sometimes blurred and less sharply defined images are formed. This defect is called –

(A) Chromatic aberration (B) Spherical aberration

(C) Blurred lens (D) None of the above

Q.18 A person cannot see objects clearly which are nearer than 75cms from his eyes, the disease he is suffering from is –

(A) Astigmatism (B) Myopia (C) Hypermetropia (D) Presbyopia

Q.19 On entering a glass prism, sun rays are –

(A) Deviated but not dispersed (B) Deviated and dispersed

(C) Dispersed but not deviated (D) Neither deviated nor dispersed.

Q.20 A piece of cloth looks red in sun light. It is held in the blue portion of a solar spectrum, it will appear –

(A) red (B) black (C) blue (D) white

Q.21 The angle of minimum deviation of a ray of light of glass prism is greatest for the light of colour –

(A) violet (B) orange (C) yellow (D) red

Q.22 To get line spectrum, the substances are excited in their –
(A) solid state (B) molecular state (C) gaseous state (D) atomic state

Q.23 The frequency of light whose wavelength is 5000 Å is –
(A) 15×10^{13} cycles per second (B) 5000 cycles per second
(C) 6×10^{14} cycles per second (D) 15×10^{16} cycles per second

Q.24 The pupil of the eye changes in size to adjust for –
(A) objects at different distances (B) objects of different sizes
(C) different colors (D) different amounts of light

Q.25 To use a magnifying glass, the object should be placed –
(A) as close to the lens as possible (B) just within the lens' focal point
(C) just beyond the focal point (D) some distance beyond the focal point

Q.26 A camera employs a .... lens to form .... images –
(A) diverging .... real (B) diverging .... virtual
(C) converging ... real (D) converging ... virtual

Q.27 In the eye, the position of the image on the retina is adjusted by changing the
(A) position of the lens (B) focal length of the lens
(C) diameter of the pupil (D) length of the eyeball

Q.28 What power lens is needed to correct for nearsightedness where the uncorrected far point is 250 cm?
(A) +2.5 diopters (B) –2.5 diopters (C) + 0.4 diopters (D) –0.4 diopters

Q.29 What power lens is needed to correct for farsightedness where the uncorrected near point is 250 cm?
(A) + 3.6 diopters (B) – 3.6 diopters (C) + 0.28 diopters (D) – 0.28 diopters

Q.30 In a room, artificial rain is produced at one end and a strong source of white light is switched on at the other end. To observe the rainbow an observer must –
(A) Look anywhere in the room (B) Look towards the source (C) Look towards the raindrops
(D) Look in a direction equally inclined to the source of raindrops

Q.31 For which of the following pairs the critical angle is smallest–
(A) Water to air (B) Glass to water (C) Glass to air (D) Glass to glass

Q.32 For which colour the critical angle is maximum in water-air system –
(A) Red (B) Violet (C) Yellow (D) It is same for all colours

Q.33 A direct vision spectrometer uses the phenomenon of –
(A) Diffraction (B) Interference without deviation
(C) Dispersion without deviation (D) Deviation without dispersion

Q.34 A combination is made of two lenses of focal length f and f' in contact, the dispersive powers of the material of the lenses are ω and ω'. The combination is achromatic when–
(A) $\omega = \omega_0, \omega' = 2\omega_0, f' = 2f$ (B) $\omega = \omega_0, \omega' = 2\omega_0, f' = f/2$
(C) $\omega = \omega_0, \omega' = 2\omega_0, f' = -f/2$ (D) $\omega = \omega_0, \omega' = 2\omega_0, f' = -2f$

Q.35 In case of hypermetropia –
(A) The image of near objects is formed in front of retina
(B) The image of near objects is formed behind the retina
(C) A concave lens should be used for correction
(D) A convex lens cannot be used for correction

Q.36 Astigmatism can be corrected by –
(A) Bifocal lenses (B) Cylindrical lenses (C) Concave lenses (D) Planoconvex lenses

Q.37 For seeing a cricket match, we prefer binoculars to the terrestrial telescope, because –
(A) Binoculars give three-dimensional view (B) Terrestrial telescope gives inverted image
(C) To avoid chromatic aberration (D) To have larger magnification

Q.38 The electromagnetic radiation of frequency n, wavelength λ, travelling with velocity v in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of the radiation in the glass slab will be, respectively–

(A) $n, \frac{\lambda}{\mu}, v$ (B) $\frac{n}{\mu}, \lambda, \frac{v}{\mu}$ (C) $n, \frac{\lambda}{\mu}, \frac{v}{\mu}$ (D) $\frac{n}{\mu}, \frac{\lambda}{\mu}, \frac{v}{\mu}$

Q.39 The convex lens is not used –
(A) in camera (B) as glasses to correct for short sight
(C) as glasses to correct for light sight (D) all of the above

Q.40 The defect that may occur in a lens are –
(A) spherical aberration and chromatic aberration
(B) coma and astigmation (C) distortion (D) all of the above

Q.41 When blue light is used in a thin convex lens then the focal length is found to be f. If instead red light is used, then the focal length will be –
(A) equal to f (B) less than f (C) greater than f (D) nothing can be predicted

Q.42 One of the refracting surfaces of a prism is silvered, and the angle of prism is A. It is found that a ray of light incident at an angle of incidence 2A after suffering refraction return back through the same path due to reflection from the second silvered refracting surface. Then the refractive index of the material of the prism is –
(A) 2 sin A (B) 2 cos A (C) tan A (D) ½ cos A

Q.43 Out of the following, which statements are correct –
(A) Sunlight filtering through a tree often makes circular patches on the ground because sun is round
(B) A beam of white light passing through a hollow prism gives no spectrum
(C) The number of images observable between two parallel plane mirrors is infinite
(D) A virtual object placed between the pole and the principal focus of a convex mirror produces an image which is virtual, diminished and upright.

Q.44 Due to refraction of light in atmosphere –
(A) Stars appear to twinkle (B) The sun appears to be oval in morning and evening
(C) The period of visibility of the sun is increased
(D) The phenomena of mirage and looming take place

Q.45 White light is incident on an equilateral prism. In the position of minimum deviation –
(A) Angle of incidence is equal to angle of emergence
(B) The ray inside the prism is parallel to its base
(C) The angle of refraction inside the prism is equal to the angle of prism
(D) The dispersion of all colours is same

Q.46 Out of the following, select the correct statements –
(A) Refractive index varies inversely as the fourth power of the wavelength of light.
(B) When the moon is near the horizon, it appears bigger. This is due to optical illusion.
(C) The colour of light which travels with the maximum speed in glass is red.
(D) If sun is shining brightly in one part of the sky after rain, two rainbows are usually observed.

Q.47 A diver at a depth of 12m in water (μ = 4/3) sees the sky in a cone of semi-vertical angle –
(A) $\sin^{-1}$ (4/3) (B) $\tan^{-1}$ (4/3) (C) $\sin^{-1}$ (3/4) (D) 90°

Q.48 The refractive index of water is 4/3 and that of glass is 5/3. What will be the critical angle for the ray of light entering water from the glass –
(A) $\sin^{-1}$ (4/5) (B) $\sin^{-1}$ (5/4) (C) $\sin^{-1}$ (1/2) (D) $\sin^{-1}$ (2/1)

Q.49 Relation between critical angles of water and glass is –
(A) $C_w > C_g$ (B) $C_w < C_g$ (C) $C_w = C_g$ (D) $C_w = C_g = 0$

Q.50 Critical angle for light going from medium (i) to (ii) is θ. The speed of light in medium (i) is v then speed in medium (ii) is –
(A) $v(1 - \cos\theta)$ (B) $v / \sin\theta$ (C) $v / \cos\theta$ (D) $v(1 - \sin\theta)$

Q.51 If light travels a distance x in t_1 sec. in air and 10x distance in t_2 sec. in a medium, the critical angle of the medium will be –
(A) $\tan^{-1}(t_1/t_2)$ (B) $\sin^{-1}(t_1/t_2)$ (C) $\sin^{-1}(10t_1/t_2)$ (D) $\tan^{-1}(10t_1/t_2)$

Q.52 Dispersion is the term used to describe –
(A) the propagation of light in straight lines
(B) The splitting of a beam of light into component colours
(C) The bending of a beam of light when it strikes a mirror
(D) The change that takes place in white light after passage through red glass.

Q.53 In a glass prism –
(A) Blue light is dispersed more than red light (B) Red light is dispersed more than blue light
(C) Both red light and blue light are equally dispersed (D) None of these

Q.54 Deviation δ produced by a prism of refractive index μ and small angle A is given by –
(A) $\delta = (\mu - 1)$ A (B) $\delta = (\mu + 1)$ A (C) $\delta = (A - 1)\mu$ (D) $\delta = (A + 1)\mu$

Q.55 If for a given prism the angle of incidence is changed from 0° to 90°, the angle of deviation –
(A) Increases (B) Decreases
(C) First decreases and then increases (D) First increases and then decreases

Q.56 The refracting angle of a prism is A and the refractive index of the prism is cot A/2. The angle of minimum deviation is–
(A) 180° – 3A (B) 180° + 2A (C) 90° – A (D) 180° – 2A

Q.57 A ray is incident at an angle of incidence i on one face of a prism of small angle A and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, the angle of incidence i is nearly equal to –
(A) A/μ (B) $A/2\mu$ (C) μA (D) $\mu A/2$

Q.58 An optician while testing the eyes finds the vision of a patient to be 6/12. By this he means that –
(A) The person can read the letters of 6 inches from a distance of 12 m
(B) The person can read the letters of 12 inches from 6 m
(C) The person can read the letters of 6 m which the normal eye can read from 12 m
(D) The focal length of eye lens had become half that of the normal eye

Q.59 A person cannot see objects clearly beyond 50 cm. The power of the lens to correct the vision is –
(A) +5 D (B) –0.5 D (C) –2 D (D) +2 D

Q.60 A long sighted person has a minimum distance of distinct vision of 50 cm. He wants to reduce it to 25 cm. He should use a –
(A) Concave lens of focal length 50 cm. (B) Convex lens of focal length 25 cm.
(C) Convex lens of focal length 50 cm. (D) Concave lens of focal length 25 cm.

Q.61 A long-sighted person cannot see objects clearly at a distance less than 40 cm. from his eye. The power of the lens needed to read an object at 25 cm. is –
(A) – 2.5 D (B) + 2.5 D (C) – 6.25 D (D) + 1.5 D

Q.62 In which of the following cases, is total internal reflection not possible –
(A) A ray incident from water to glass (B) A ray incident from glass to water
(C) A ray incident from glass to air (D) A ray incident from water to air

Q.63 Critical angle of light passing from glass to air is maximum for –
(A) violet (B) blue (C) yellow (D) red

Q.64 A mirage occurs because –
(A) The refractive index of atmosphere increases with height
(B) The refractive index of atmosphere decreases with height
(C) The hot ground acts like a mirror
(D) Refractive index remains constant with height

Q.65 A well cut diamond appears bright because –

(A) Of reflection of light (B) Of dispersion of light

(C) The total internal reflection (D) Of refraction of light

Q.66 Twinkling of stars is on account of –

(A) Large distance of stars and storms in air (B) Small size of stars

(C) Large size of stars (D) Large distance of stars and fluctuations in the density of air.

Q.67 You are under the water in a clear lake looking at the surface and see the image of a fish due to total internal reflection. What is the minimum angle that the light leaving the fish makes with the normal to the surface of the lake?

(A) 42° (B) 53° (C) 49° (D) 37°

Q.68 White light is incident at an angle to the surface of a triangular piece of glass. Which color of light deviates most from its original path after leaving the glass?

(A) red (B) orange (C) green (D) blue

EXERCISE - 4

Match the column–

Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **column I** have to be matched with statements (p, q, r, s) in **column II**.

Q.1 Match the following :

Column I	**Column II**
(A) Inverted crown-flint glass prism	(p) Deviation $\propto \dfrac{1}{\text{dispersive power}}$
(B) Achromatism	(q) Deviation without dispersion
(C) Hollow prism	(r) Absence of chromatic aberration
(D) Glass slab	(s) Dispersion without deviation

Q.2 Column II gives lens that can be use to correct the defect of vision given in column I, match them correctly.

Column I	**Column II**
(A) Myopia	(p) convex lens
(B) Hyperopia	(q) concave lens
(C) Astigmatism	(r) cylindrical lens
(D) Presbyopia	(s) bi-focal lens

ASSERTION & REASON TYPE

Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.

(C) Statement -1 is True, Statement-2 is False.

(D) Statement -1 is False, Statement-2 is True. (E) Statement -1 is False, Statement-2 is False.

Q.3 **Statement 1 :** Refractive index of material of a prism depends on angle of prism A and angle of minimum deviation δ_m.

Statement 2 : Because $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin(A/2)}$

Q.4 **Statement 1 :** Optical fibres are used to transmit light without any appreciable loss in its intensity over distance of several kilometers.

Statement 2 : Optical fibres are very thick and all the light is passed through it without any loss.

Q.5 **Statement 1 :** When we seen an object, the image formed on the retina is real and inverted.
Statement 2 : If the magnification of a system is less than one, then the image formed in inverted.

Q.6 **Statement 1 :** A man wearing glasses of focal length + 1m cannot see beyond 1m.
Statement 2 : A convex lens forms a real image of a point object placed on its principal axis. If the upper half of the lens is painted black, the intensity of the image will decrease but the image will not be shifted upward or downward.

Q.7 **Statement 1:** Rainbow is an example of the dispersion of sunlight by the water droplets.
Statement 2 : Light of shorter wavelength is scattered much more than light of larger wavelength.

Q.8 **Statement 1 :** The focal length of a lens is dependent on the wavelength of light.
Statement 2 : The velocity of light changes with the medium.

Q.9 **Statement 1 :** The number of wavelengths in the visible region of the spectrum are infinite.
Statement 2 : Ray optics is valid, when characteristic dimensions are much larger than the wavelength of light.

Q.10 **Statement 1 :** Bird flying high up in air does not shadow on the earth ground.
Statement 2 : The size of bird is smaller than sun.

Q.11 **Statement 1 :** A star will appear to twinkle if seen from free space (say moon)
Statement 2 : An air bubble inside water behave like a convergent lens.

Q.12 **Statement 1 :**The twinkling of stars is due to the fact that refractive index of the earth's atmosphere fluctuates.
Statement 2 : In cold countries, the phenomenon of looming (i.e. ship appears in the sky) takes place, because refractive index of air decreases with height.

Q.13 **Statement 1 :** Critical angle is maximum for red colour in water-air system for visible light.
Statement 2 : Because $\sin \theta_C = 1/\mu$ and μ_r (refractive index of red colour) is minimum for visible light.

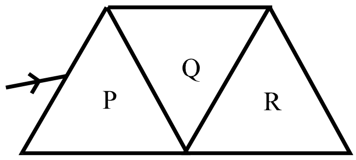
Q.14 **Statement 1 :** Deviation δ produced by a prism of refractive index μ and small angle A is given by $\delta = (\mu - 1)\, A$

Statement 2 : Because for a prism of refractive index μ and refraction angle A, $\mu = \dfrac{\sin\left(\dfrac{A+\delta}{2}\right)}{\sin(A/2)}$

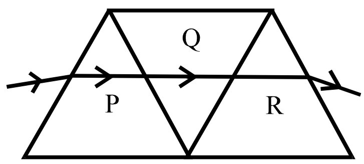
and for small θ, $\sin\theta \approx \theta$

Q.15 **Statement 1 :** Telescope is an optical instrument used to increase the visual angle of distance large objects.
Statement 2: Power of a lens is the capacity or ability of the lens to deviate the path of rays passing through it.

Q.16 **Statement 1 :** A given ray of light sufferes minimum deviation in an equilateral prism P. Additional prisms Q and R of identical shape and of same material as P are now added as shown in figure. The ray will now suffer same deviation as before.



Statement 2 : When a ray suffers minimum deviation, it becomes parallel to the base of prism. In above system the ray continues to be parallel to the base of prism Q and R (See figure)



EXERCISE - 5

PREVIOUS YEARS COMPETITION PROBLEMS

Q.1 Angle of deviation (δ) by a prism (refractive index = μ, and supposing the angle of prism A to be small) can be given by –

(A) $\delta = (\mu - 1)A$ (B) $\delta = (\mu + 1)A$ (C) $\delta = \frac{\sin(A+\delta)/2}{\sin(A/2)}$ (D) $\delta = \frac{\mu - 1}{\mu + 1}A$

Q.2 Light waves projected on oil surface show seven colours due to –

(A) Polarisation (B) Diffraction (C) Refraction (D) Interference

Q.3 If the refractive index of a material of equilateral prism is $\sqrt{3}$, then angle of minimum deviation of the prism is

(A) 30° (B) 45° (C) 60° (D) 75°

Q.4 The splitting of white light into several colours on passing through a glass prism is due to –

(A) refraction (B) reflection (C) interference (D) diffraction

Q.5 Rainbow is formed due to a combination of –

(A) Refraction and absorption (B) Dispersion and focussing
(C) Refraction and scattering (D) Dispersion and total internal reflection

Q.6 The image formed by an objective of a compound microscope is

(A) virtual and diminished (B) real and diminished (C) real and enlarged (D) virtual and enlarged

Q.7 A person using a lens as a simple microscope sees an –

(A) inverted virtual image (B) inverted real magnified image
(C) upright virtual image (D) upright real magnified image

Q.8 The astronomical telescope consists of objective and eye-piece. The focal length of the objective is –

(A) equal to that of the eye piece (B) greater than that of eye piece
(C) shorter than that of eye piece (D) five times shorter than that of the eye piece

Q.9 A doctor advises a patient to use spectacles with a convex lens of focal length 40 cm. in contact with a concave lens of focal length 25 cm. What is the power of the resultant combination –

(A) –6.5 D (B) –1.5 D (C) 6.5 D (D) 1.5 D

Q.10 An endoscope is employed by a physician to view the internal parts of a body organ. It is based on the principle of –

(A) refraction (B) reflection (C) total internal reflection (D) dispersion

Q.11 Myopia is due to –

(A) elongation of eye ball (B) irregular change in focal length
(C) shortening of eye ball (D) older age

Q.12 Blue colour of sky is due to phenomenon of –

(A) Reflection (B) Refraction (C) Scattering (D) Dispersion

Q.13 When light is passed through a prism, the colour which deviates least is –

(A) Red (B) Violet (C) Blue (D) Green

Q.14 The formation of rainbow is due to the phenomenon of –

(A) reflection (B) dispersion (C) refraction (D) interference

Q.15 A violet ray entering from medium 1 to medium 2 at certain angle just escapes from total internal reflection. Which of the following coloured radiation will be able to come to medium 2 under same condition to incidence–

(1) VIB (2) YOR (3) all except green (4) all

Q.16 Ability of the eye to see objects at all distances is called –

(A) Binocular vision (B) Myopia (C) Hypermetropia (D) Accommodation

Q.17 A person having the nearest distance of distinct vision of 32 cm. uses a reading lens of 8 cm. focal length. The magnification of his reading lens is –

(A) 5 (B) 4 (C) 3 (D) 2

Q.18 Rainbow is formed due to-
(A) Scattering & Refraction
(B) Total internal reflection & dispersion
(C) Reflection only
(D) Diffraction and dispersion

Q.19 A ray of light passing through a prism having $\mu = \sqrt{2}$ suffers minimum deviation. If angle of incident is double the angle of refraction within prism, than angle of prism is –
(A) 30°
(B) 45°
(C) 60°
(D) 90°

Q.20 Which of the prism is used to see infrared spectrum of light –
(A) Rock salt
(B) Nicol
(C) Flint
(D) Crown

Q.21 The far point of a myopic eye is 1.5 m. To correct this defect of the eye, the power of lens is –
(A) 0.66 D
(B) – 0.66 D
(C) + 1.5 D
(D) – 1.5 D

Q.22 Which of the following statements is correct about rainbow ?
(A) In primary rainbow, red colour is on the outside and violet colour is on the inside.
(B) In primary rainbow, violet colour is on the outside and red colour is on the inside.
(C) Secondary rainbow is brighter than primary rainbow.
(D) In secondary rainbow, light wave suffers one total internal reflection before coming out.

Q.23 Sky appears to be red colour at the time of sunset. The reason is-
(1) Blue colour out sun rays is scattered away by the atmosphere
(2) As sun emits out only red colour in the morning
(3) White light is made to appear red by atmosphere
(4) None of the above

EXERCISE - 6

PREVIOUS YEARS BOARD QUESTIONS

Q.1 What kind of lens is used in the spectacles of a person suffering from myopia (near-sightedness) ?

Q.2 State the reason for the following observations recorded from the surface of moon.
(i) Sky appears dark (ii) Rainbow is never formed.

Q.3 A 14-year old student is not able to see clearly the questions written on the blackboard placed at a distance of 5 m from him.
(a) Name the defect of vision he is suffering from.
(b) name the type of lens used to correct this defect.

Q.4 Explain the following terms used in relation to defects in vision and correction provided by them :
(a) myopia
(b) Astigmatism
(c) Bifocal lenses
(d) Far sightedness.

Q.5 A ray of light incident on an equilateral glass prism shows minimum deviation of 30º. Calculate the speed of light through the glass prism.

ANSWER KEY

EXERCISE - 1

(1)	No	**(5)**	Myopia.	**(6)**	Spherical aberration.	**(7)**	focal length 1.2m &power –0.83 D		
(8)	– 1.25 D	**(9)**	+2.67D	**(10)**	4m	**(15)**	–1.25D (Dioptres)		
(17)	2.67D	**(19)**	–2 dioptres	**(24)**	(D)	**(25)**	(B)	**(26)**	(A)
(27)	(C)	**(28)**	(D)	**(29)**	(A)	**(30)**	(B)	**(31)**	(C)
(32)	(C)	**(33)**	(C)	**(34)**	(B)				

EXERCISE - 2

(1) convex **(2)** Violet **(3)** rainbow **(4)** cornea **(5)** iris **(6)** pupil
(7) retina **(8)** Rods **(9)** Cones **(10)** 25 cm. **(11)** near point **(12)** 25 cm to infinity
(13) presbyopia. **(14)** astigmatism. **(15)** colour blindness **(16)** seven
(17) dispersion **(18)** spectrum **(19)** accommodation of the eye. **(20)** near point
(21) myopia, hypermetropia , presbyopia. **(22)** dispersion.
(23) Scattering of light **(24)** 7 **(25)** 4×10^{-7} m **(26)** 7×10^{-7} m
(27) incidence, equal, parallel **(28)** False **(29)** True **(30)** True
(31) True **(32)** True **(33)** True **(34)** True **(35)** False

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11
A	B	D	C	C	C	B	C	B	D	A	D
Q	12	13	14	15	16	17	18	19	20	21	22
A	D	B	C	D	A	B	C	B	B	A	D
Q	23	24	25	26	27	28	29	30	31	32	33
A	C	D	B	C	B	D	A	C	C	A	C
Q	34	35	36	37	38	39	40	41	42	43	44
A	D	B	B	A	C	B	D	C	B	B,C	all
Q	45	46	47	48	49	50	51	52	53	54	55
A	A,B	B,C,D	C	A	A	B	C	B	A	A	C
Q	56	57	58	59	60	61	62	63	64	65	66
A	D	D	C	C	C	D	A	D	A	C	D
Q	67	68									
A	C	D									

EXERCISE - 4

(1) (A) → s, (B) → r, p, (C) → q, (D) → q **(2) (A) → q, (B) → p, (C) → r (D) → s**
(3) (E) **(4)** (C) **(5)** (C) **(6)** (B) **(7)** (B) **(8)** (A)
(9) (B) **(10)** (A) **(11)** (E) **(12)** (B) **(13)** (A) **(14)** (A)
(15) (B) **(16)** (A)

EXERCISE - 5

Q	1	2	3	4	5	6	7	8	9	10	11
A	A	D	C	A	D	C	C	B	B	C	A
Q	12	13	14	15	16	17	18	19	20	21	22
A	C	A	B	D	D	A	B	D	A	B	A
Q	23										
A	A										

EXERCISE - 6

(1) Concave lens. **(3)** (a) Short-sightedness (Myopia). (b) Concave lens. **(5)** $\dfrac{3 \times 10^8}{\sqrt{2}}$ ms^{-1}.