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LIGHT-REFLECTION AND REFRACTION

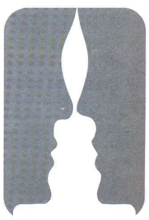
INTRODUCTION

Light is that form of energy which enables people to 'see' things. For a person to see any object, light energy must enter the eye. This energy is converted into a 'picture' in a very complex process, but a simplified version is as follows :

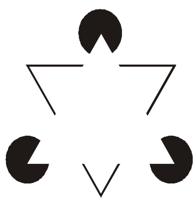
(a) light enters the eye through a 'hole' in the iris, called the pupil,
(b) the crystalline lens focussed the light to form a real, inverted image on the retina,
(c) energy is collected by the rods and cones making up the retina.
(d) this energy is transmitted as electrical impulses via the optic nerve to the brain,
(e) the brain re-inverts the image and produces a 'picture'.

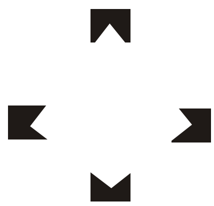
To show that our eyes deceive (mislead purposely) us

Look at fig. Which line do you think is the longer ? Measure the two lines to prove that they are, in fact, equal in length. Why do you think the lower line 'looks' longer than the upper line ?



Illusions : What do you see ? A candle or two faces ?





See Pyramid (not drawn) in two figures

WHAT IS LIGHT ?

Light is a thing, and it travels from one point to another. Another issue that few people have considered is whether a candle's flame simply affects your eye directly, or whether it sends out light which then gets into your eye. Again, the rapidity of the effect makes it difficult to tell what's happening. If someone throws a rock at you, can see the rock on its way to your body, and you can tell that the person affected you by sending a material substance your way, rather than just harming you directly with an arm motion, which would be known as "action at a distance." It is not easy to do a similar observation to see whether there is some "stuff" that travels from the candle to your eye, or whether it is a case of action at a distance.

Newtonian physics includes both action at a distance (e.g. the earth's gravitational force on a falling object) and contact forces such as the normal force, which only allow distant objects to exert forces on each other by shooting some substance across the space between them (e.g. a garden hose spraying out water that exerts a force on a bush).

One piece of evidence that the candle sends out stuff that travels to your eye is that intervening transparent substances can make the candle appear to be in the wrong location, suggesting that light is a thing that can be bumped off course. Many people would dismiss this kind of observation as an optical illusion, however. (Some optical illusions are purely neurological or psychological effects, although some others, including this one, turn out to be caused by the behavior of light itself.)

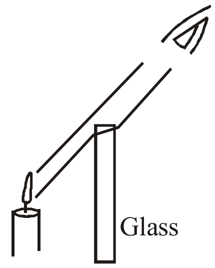
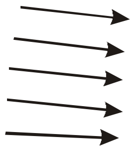
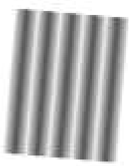


Figure : Light from a candle is bumped off course by a piece of glass. Inserting the glass causes the apparent location of the candle to shift. The same effect can be produced by taking off your eyeglasses and looking at what you see in the lens, but a flat piece of glass works just as well as a lens for this purpose.

A more convincing way to decide in which category light belongs is to find out if it takes time to get from the candle to your eye; in Newtonian physics, action at a distance is supposed to be instantaneous. The fact that we speak casually today of "the speed of light" implies that at some point in history, somebody succeeded in showing that light did not travel infinitely fast. Galileo tried, and failed, to detect a finite speed for light, by arranging with a person in a distant tower to signal back and forth with lanterns. Galileo uncovered his lantern, and when the other person saw the light, he uncovered his lantern. Galileo was unable to measure any time lag that was significant compared to the limitations of human reflexes.

Models of light : The ray model of light seems natural once we convince ourselves that light travels through space, and observe phenomena like sunbeams coming through holes in clouds the ray model is not the ultimate truth about light, but the ray model is simpler, and in any case science always deals with models of reality, not the ultimate nature of reality. The ray model is successful in explaining the image formation due to reflection and refraction. The following table summarizes three models of light.

Ray model :  Advantage : Simplicity

Wave model :  Advantage : Colour is described naturally in terms of wavelength. Required in order to explain the interaction of light with material objects with sizes comparable to a wavelength of light or smaller.

Particle model :  Required in order to explain the interaction of light with individual atoms. At the atomic level, it becomes apparent that a beam of light has a certain graininess to it.

NATURE OF LIGHT

(a) Light waves are electromagnetic waves which do not require material medium for propagation. They are non-mechanical waes.

(b) The speed of the light in vacuum is 3×10^8 m/s

(c) The speed of the light is reduced when passing through a medium. The amount of reduction in speed depends on the type of the medium.

(d) Wavelength of visible light ranges from 4×10^{-7}m to 8×10^{-7}m (i.e., 4000 Å to 8000 Å).

(e) Wavelength of light is very small compared to the normal size of the object. In this situation, a light wave can be considered to travel from one point to another in straight line path joining them. A straight line path joining one point to another in the direction of propagation of light is known as a ray.

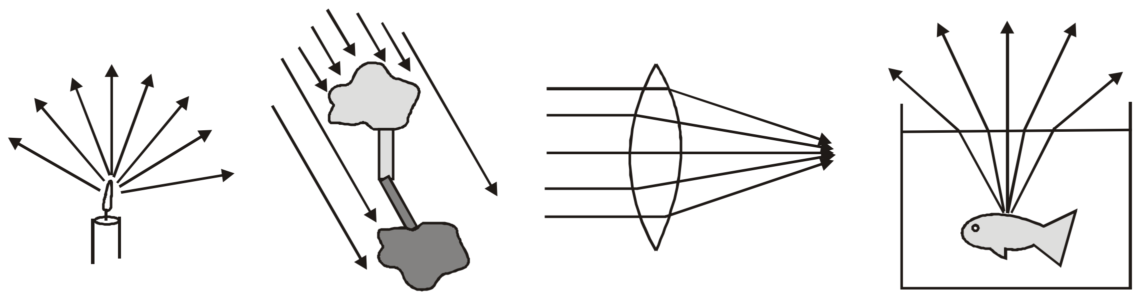
(f) A bundle of such rays of light is called beam of light.

(g) When light is incident on a surface separating two media, part of the incident light is reflected, a part is transmitted and a part is absorbed.

(h) Light ways can be focused by lens and sperical mirror.

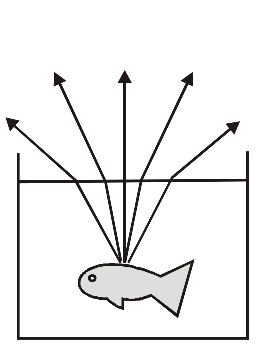
RAY DIAGRAMS

Without even knowing how to use the ray model to calculate anything numerically, we can learn a great deal by drawing ray diagrams. For instance, if you want to understand how eyeglasses help you to see in focus, a ray diagram is the right place to start. Many students under utilize ray diagrams in optics and instead rely on rote memorization or plugging into formulas. The trouble with memorization and plug-ins is that they can obscure what's really going on, and it is easy to get them wrong. Often the best plan is to do a ray diagram first, then do a numerical calculation, then check that your numerical results are in reasonable agreement with what you expected from the ray diagram.

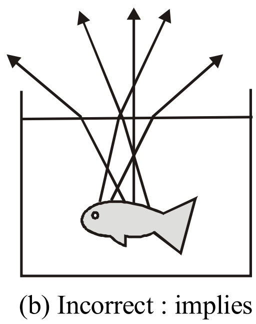


Examples of ray diagrams.

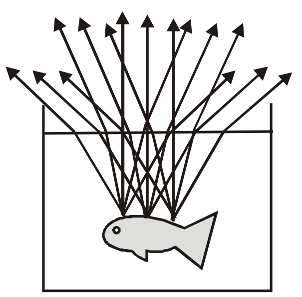
Examples (a) through (c) show some guidelines for using ray diagrams effectively. The light rays bend when then pass out through the surface of the water (a phenomenon that we'll discuss in more detail later). The rays appear to have come from a point above the goldfish's actual location, an effect that is familiar to people who have tried spear fishing.



(a) Correct



(b) Incorrect : implies that diffuse reflection only gives one ray from each reflecting point



(c) Correct, but unnecessarily complicated

- A stream of light is not really confined to a finite number of narrow lines. We just draw it that way. In (a), it has been necessary to choose a finite number of rays to draw (five), rather than the theoretically infinite number of rays that will diverge from that point.
- There is a tendency to conceptualize rays incorrectly as objects. In his Optics, Newton goes out of his way to caution the reader against this, saying that some people "consider ... the refraction of ... rays to be the bending or breaking of them in their passing out of one medium into another." But a ray is a record of the path traveled by light, not a physical thing that can be bent or broken.
- In theory, rays may continue infinitely far into the past and future, but we need to draw lines of finite length. In (a), a judicious choice has been made as to where to begin and end the rays. There is no point in continuing the rays any farther than shown, because nothing new and exciting is going to happen to them. There is also no good reason to start them earlier, before being reflected by the fish, because the direction of the diffusely reflected rays is random anyway, and unrelated to the direction of the original, incoming ray.
- When representing diffuse reflection in a ray diagram, many students have a mental block against drawing many rays fanning out from the same point. Often, as in example (b), the problem is the misconception that light can only be reflected in one direction from one point.
- Another difficulty associated with diffuse reflection, example (c), is the tendency to think that in addition to drawing many rays coming out of one point, we should also be drawing many rays coming from many points. In (a), drawing many rays coming out of one point gives useful information, telling us, for instance, that the fish can be seen from any angle. Drawing many sets of rays, as in (c), does not give us any more useful information, and just clutters up the picture in this example. The only reason to draw sets of rays fanning out from more than one point would be if different things were happening to the different sets.

GEOMETRY OF SPECULAR REFLECTION

To change the motion of a material object, we use a force. Is there any way to exert a force on a beam of light? Experiments show that electric and magnetic fields do not deflect light beams, so apparently light has no electric charge. Light also has no mass, so until the twentieth century it was believed to be immune to gravity as well. Einstein predicted that light beams would be very slightly deflected by strong gravitational fields, and he was proven correct by observations of rays of starlight that came close to the sun, but obviously that's not what makes mirrors and lenses work!

If we investigate how light is reflected by a mirror, we will find that the process is horrifically complex, but the final result is surprisingly simple.

What actually happens is that the light is made of electric and magnetic fields, and these fields accelerate the electrons in the mirror. Energy from the light beam is momentarily transformed into extra kinetic energy of the electrons, but because the electrons are accelerating they reradiate more light, converting their kinetic energy back into light energy. We might expect this to result in a very chaotic situation, but amazingly enough, the electrons move together to produce a new, reflected beam of light, which obeys two simple rules:

- The angle of the reflected ray is the same as that of the incident ray.

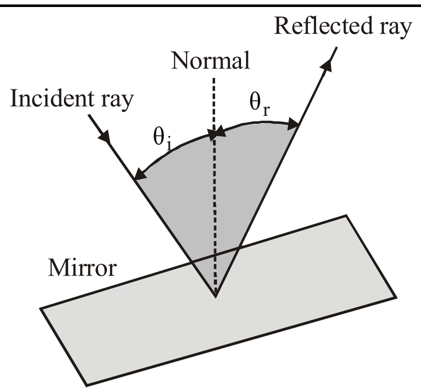
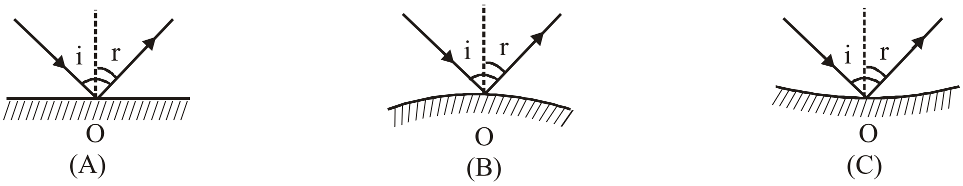


Figure : The angle of reflection θ_r equals the angle of incidence θ_i.
These angles are measured with respect to the normal, which is a line drawn perpendicular to the surface of the mirror at the point of incidence.

- The reflected ray lies in the plane containing the incident ray and the normal (perpendicular) line. This plane is known as the plane of incidence.

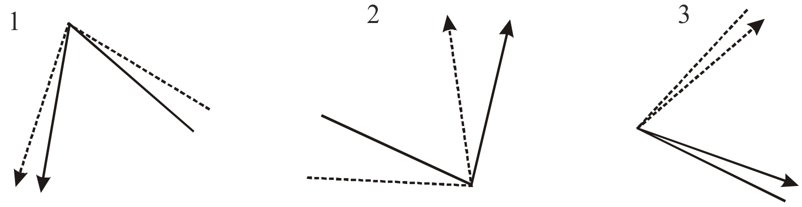
  Rules are applicable for plane surfaces as well as curved surfaces.



Most people are surprised by the fact that light can be reflected back from a less dense medium. For instance, if you are diving and you look up at the surface of the water, you will see a reflection of yourself.

Example 1 :

Each of these diagrams is supposed to show two different rays being reflected from the same point on the same mirror. Which are correct, and which are incorrect ?



Sol. Only 1 is correct. Draw the normal that bisects the solid ray, it also bisects the dashed ray.

REVERSIBILITY OF LIGHT RAYS

The fact that specular reflection displays equal angles of incidence and reflection means that there is a symmetry: if the ray had come in from the right instead of the left in the figure above, the angles would have looked exactly the same. This is not just a pointless detail about specular reflection.

It's a manifestation of a very deep and important fact about nature, which is that the laws of physics do not distinguish between past and future. Cannonballs and planets have trajectories that are equally natural in reverse, and so do light rays. This type of symmetry is called time-reversal symmetry. Typically, time-reversal symmetry is a characteristic of any process that does not involve heat. For instance, the planets do not experience any friction as they travel through empty space, so there is no frictional heating.

We should thus expect the time-reversed versions of their orbits to obey the laws of physics, which they do. In contrast, a book sliding across a table does generate heat from friction as it slows down, and it is therefore not surprising that this type of motion does not appear to obey time-reversal symmetry. A book lying still on a flat table is never observed to spontaneously start sliding, sucking up heat energy and transforming it into kinetic energy.

Similarly, the only situation we've observed so far where light does not obey time-reversal symmetry is absorption, which involves heat. Your skin absorbs visible light from the sun and heats up, but we never observe people's skin to glow, converting heat energy into visible light. People's skin does glow in infrared light, but that doesn't mean the situation is symmetric. Even if you absorb infrared, you don't emit visible light, because your skin isn't hot enough to glow in the visible spectrum.

THE PRINCIPLE OF LEAST TIME FOR REFLECTION

We had to choose between an unwieldy explanation of reflection at the atomic level and a simpler geometric description that was not as fundamental. There is a third approach to describing the interaction of light and matter which is very deep and beautiful. Emphasized by the twentieth century physicist Richard Feynman, it is called the principle of least time, or Fermat's principle.

Let's start with the motion of light that is not interacting with matter at all. In a vacuum, a light ray moves in a straight line. This can be rephrased as follows: of all the conceivable paths light could follow, the only one that is physically possible is the path that takes the least time. What about reflection? If light is going to go from one point to another, being reflected on the way, the quickest path is indeed the one with equal angles of incidence and reflection. If the starting and ending points are equally far from the reflecting surface, (a), it's not hard to convince yourself that this is true, just based on symmetry.

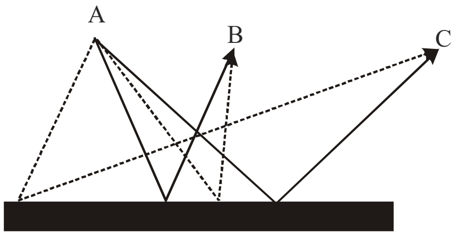
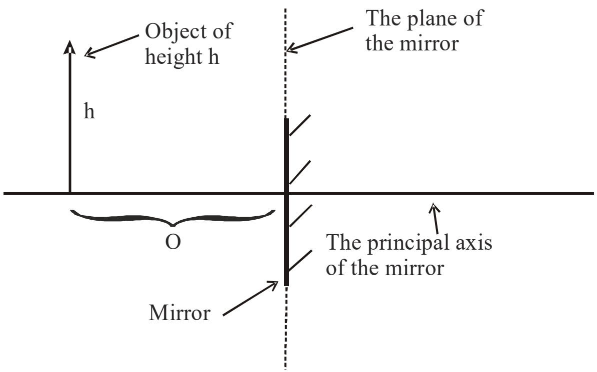


Figure : The solid lines are physically possible paths for light rays traveling from A to B and from A to C. They obey the principle of least time. The dashed lines do not obey the principle of least time, and are not physically possible.

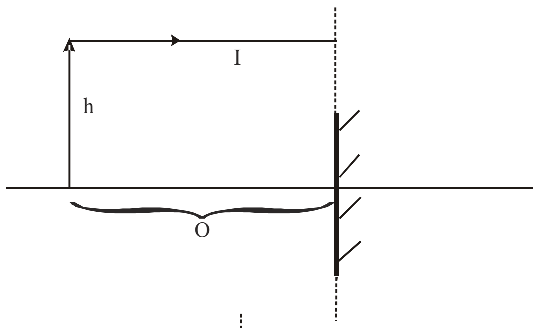
Not only does the principle of least time work for light in a vacuum and light undergoing reflection, it works for the bending of light when it passes from one medium into another.
Although it is beautiful that the entire ray model of light can be reduced to one simple rule, the principle of least time, it may seem a little spooky to speak as if the ray of light is intelligent, and has carefully planned ahead to find the shortest route to its destination.

RAY OPTICS APPLIED TO A PLANE MIRROR

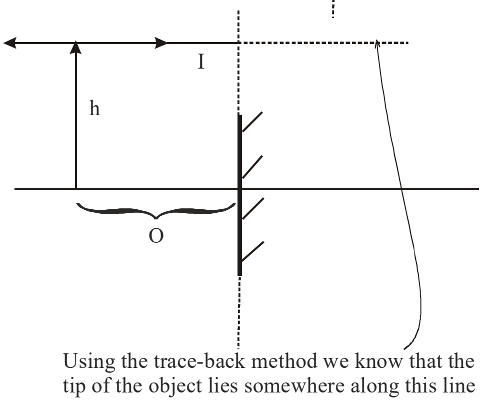
Let's apply ray-diagram methods to the case of an object in front of a plane mirror in order to determine the position of the image of that object. Here's the configuration.



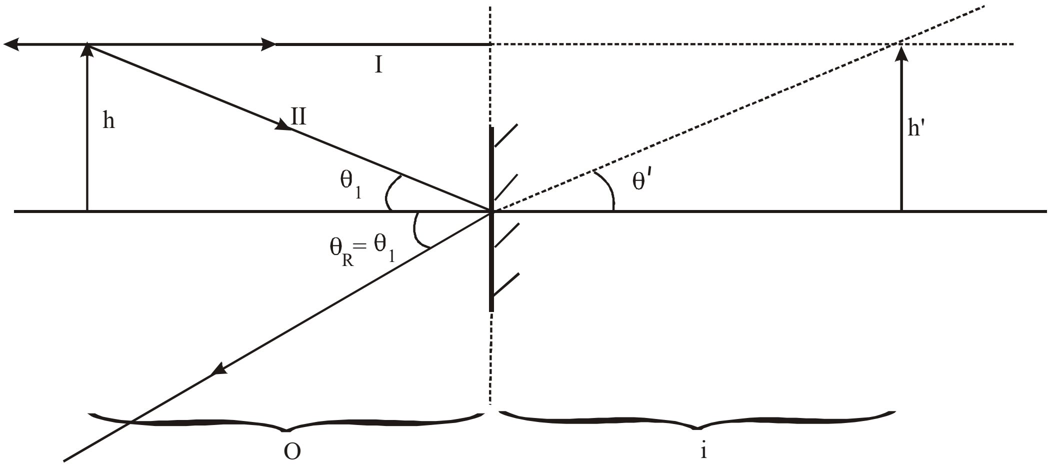
We have an object of height h a distance o from the plane of the mirror. Our object is represented by an arrow. The tail of the arrow is on a reference line that is perpendicular to the plane of the mirror. I am calling the reference line "the principal axis of the mirror."
The plane of the mirror is the infinite plane that contains the surface of the mirror.
We use the method of principal rays to determine the position of the image of the object. In the method of principal rays, we consider only a few incident rays for which the reflected rays are particularly easy to determine. Experimentally, we find that the position of the image is independent of the size of the mirror, so we consider the mirror to be as large as it needs to be for the principal rays to hit it. In particular, if a principal ray appears to miss the mirror in our diagram, we show the ray as reflecting off the plane of the mirror nevertheless.



Our Principal Ray I for the case at hand is one that approaches the plane of the mirror along a line that is parallel to the principal axis of the mirror.
According to the law of reflection, Principal Ray I is reflected straight back on itself as depicted in the following diagram:



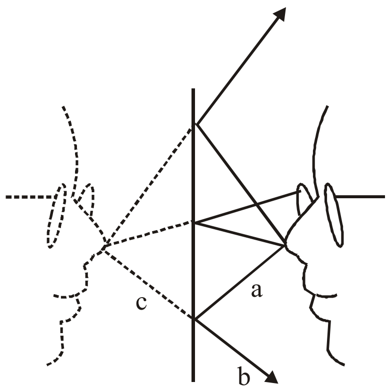
Principal Ray II hits the mirror right where the principal axis of the mirror intersects the mirror. In accord with the Law of Reflection, with, for the ray in question, the principal axis of the mirror being the normal, the reflected ray makes the same angle with the principal axis of the mirror as the incident ray does.



Tracing back the second reflected ray, to the point where it intersects the first reflected ray traceback line, yields the position of the image of the tip of the arrow. The image height h' is the distance between the same two parallel lines that the object height h is the distance between. So, h' = h. Since vertical angles are equal, we have θ' in the diagram above being equal to θ_R which we know to be equal to θ_I from the law of reflection.
Thus the right triangle of side h' and angle θ' is congruent to the triangle of height h and angle θ_1.
Hence, since corresponding sides of congruent triangles are equal, we have i = O. That is to say that the image distance, from the plane of the mirror, is equal to the object distance.

Example 2 :

Imagine that the person in figure moves his face down quite a bit a couple of feet in real life, or a few inches on this scale drawing. Draw a new ray diagram. Will there still be an image? If so, where is it visible from?

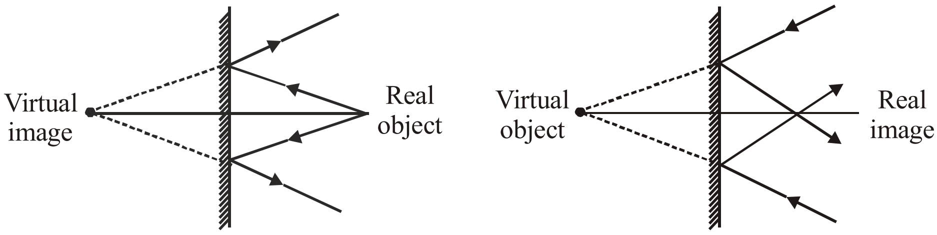


Sol. From ray diagram you will find that an image is still formed, and it has simply moved down the same distance as the real face. However, this new image would only be visible from high up, and the person can no longer see his own image.

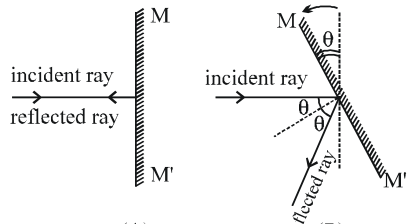
If you couldn't draw a ray diagram that seemed to result in an image, the problem was probably that you didn't choose any rays that happened to go away from the face in the right direction to hit the mirror.

Note :

1. Distance of object from mirror = Distance of image from mirror.
2. The image is laterally inverted (better word perversion).
3. The line joining the object point with its image is normal to the reflecting surface.
4. The size of the image is the same as that of the object.
5. For a real object the image is virtual and for a virtual object the image is real.



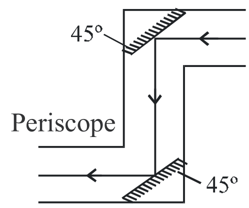
6. If keeping the incident ray fixed, the mirror is rotated by an angle θ, about an axis in the plane of mirror, the reflected ray is rotated through an angle 2θ.



(A) (B)

7. As every part of a mirror forms a complete image of an extended object and due to superposition of images brightness will depend on its light reflecting area, a large mirror gives more bright image than a small one. This in turn also implies that if a portion of a mirror is obstructed, complete image will be formed but of reduced brightness.

8. Plane mirrors are used in, Optical lever, Sextant, Kalcidoscope, Periscope, Seeing round corners, Dental mirror, telescope flat.



Example 3 :

Find the minimum height of a mirror where one can see his full image.

Sol. Let HL is the height of the person and E is the position of his eyes.

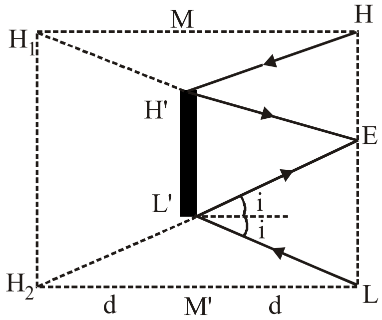
Now applying laws of reflection,

we have, $M'L' = \frac{1}{2}$ EL and $MH' = \frac{1}{2}$ HE

Now, $H'L' = MM' - MH' - L'M'$

$= HL - \frac{1}{2} HE - \frac{1}{2} EL = HL - \frac{1}{2} HL = \frac{1}{2} HL$

So the required height of the mirror be half of the height of the person



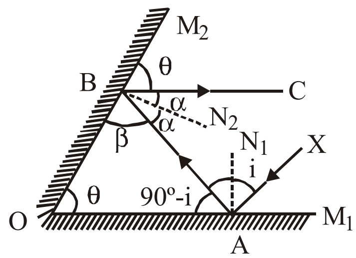
Example 4 :

Two plane mirrors are inclined at an angle θ . A ray of light is incident on one mirror at an angle of incidence i. The ray is reflected from this mirror, falls on the second mirror from where it is reflected parallel to the first mirror. What is the value of i, the angle of incidence in term of θ ?

Sol. The situation is illustrated in figure. XA is the incident ray. BC is the final reflected ray. It is given that BC is parallel to mirror M_1. Look at the assignment of the angles carefully. Now N_2 is normal to mirror M_2. Therefore $\beta = \theta$

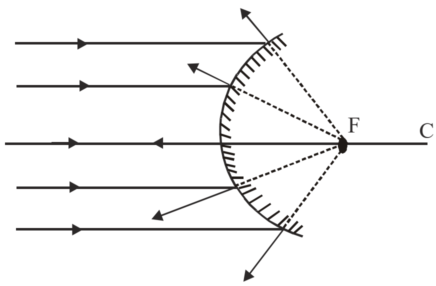
Then from Δ OAB, $\theta + \beta + 90^o - i = 180^o$ or $\theta + \theta + 90^o - i = 180^o$ or $i = 2\theta - 90^o$

Thus if the angle of incidence is $i = 2\theta - 90^o$, then the final reflected ray will be parallel to the first mirror.

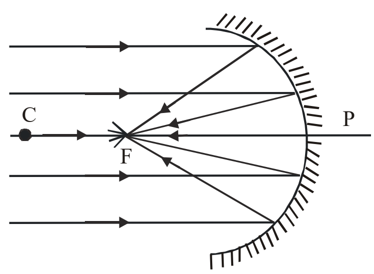


REFLECTION AT CURVED SURFACES

Types of curved mirror : A curved mirror is a smooth reflecting part (in any shape) of a symmetrical curved surface such as paraboloidal, ellipsoidal, cylindrical of spherical. Here we will discuss only on spherical mirrors.



Convex mirror



Concave mirror

Concave Mirror : If the reflection takes place from the inner surface of a spherical mirror, then the mirror is called concave mirror.

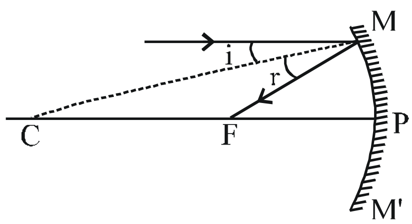
Convex Mirror : If the outer surface of the spherical mirror acts as a reflector then the mirror is called convex mirror.

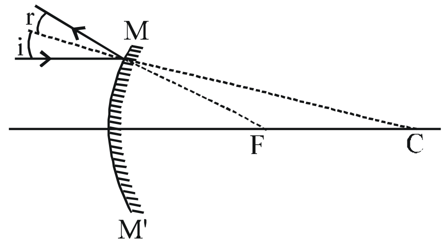
TERMS RELATED TO SPHERICAL MIRROR

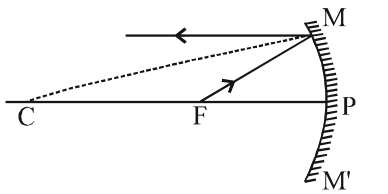
Centre of Curvature (C) : It is the centre of sphere of which the mirror is a part.
Radius of Curvature (R) : It is the radius of the sphere of which the mirror is a part.
Pole (P) : It is the geometrical centre of the spherical reflecting surface.
Principal Axis : It is the straight line joining the curvature to the pole.
Focus (F) : When a narrow beam of rays of light, parallel to the principal axis and close to it (know as paraxial rays), is incident on the surface of a mirror, the reflected beam is found to converge (concave mirror) or appear to diverge (convex mirror) from a point principal axis. This point is called focus.
Focal Length (F) : It is the distance the pole and the principal focus. For spherical mirrors, f = R/2.

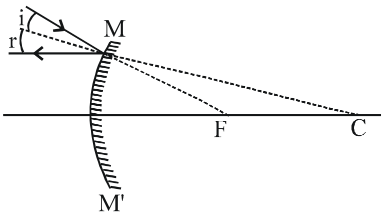
RULES FOR RAY DIAGRAMS

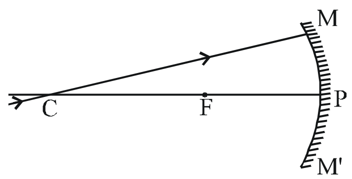
When a ray falls in the direction of centre of curvature of mirror then it reflects back along the same path. A ray, parallel to the principal axis will after reflection, pass through the focus. A ray, passing through the focus is reflected parallel to the principal axis.
Observe the following diagrams to draw ray diagrams.

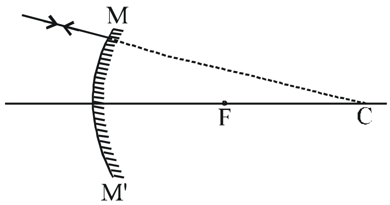


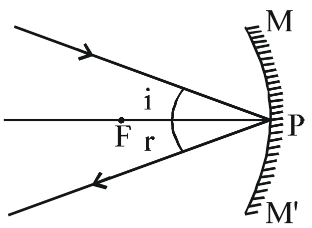


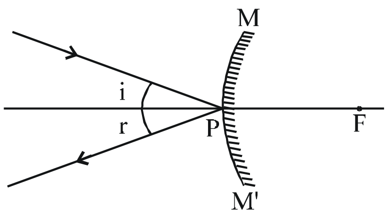






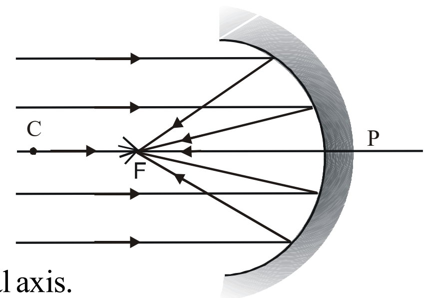






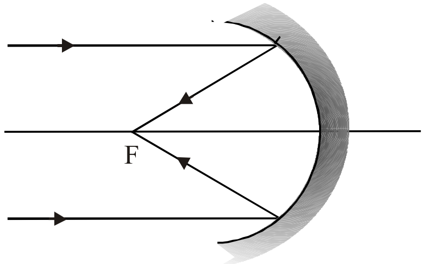
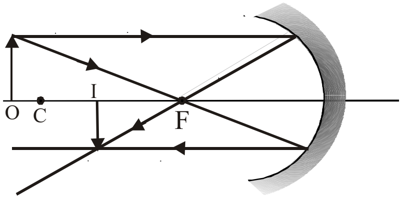
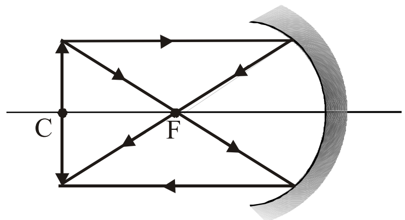
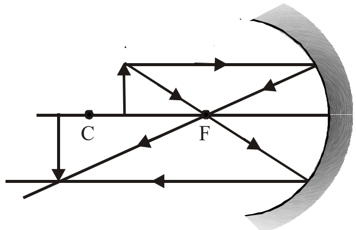
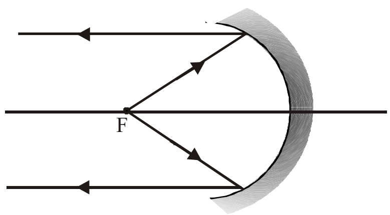
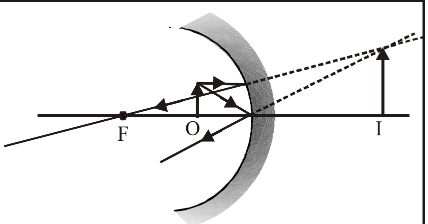
REFLECTION THROUGH CONCAVE MIRROR

F → Principal focus
P → Pole of mirror
C → Centre of curvature.
PC = Radius of curvature.
PF = Focal length.
When a narrow beam of light travelling parallel to the principal axis is incident on the reflecting surface of the concave mirror, the beam after reflection converge at a point on the principal axis.



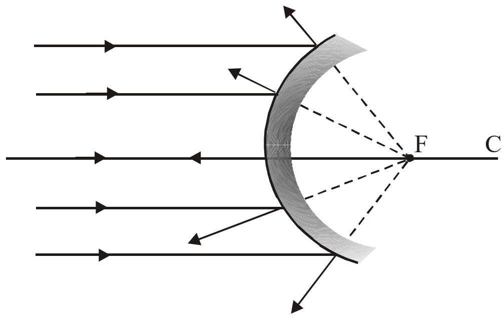
Concave mirror

Image formed by the concave mirror :

Position of object	Position of image	Nature	Figure
At infinity	At the focus	Real, inverted & diminished	
Between infinity & Centre of Curvature	Between focus & centre of curvature	Real inverted small in size	
At centre of curvature	At centre of curvature	Real, inverted and of the same size	
Between Focus & centre of curvature	Beyond centre of curvature	Real, inverted and enlarged	
At Focus	At infinity	Real, inverted and very large	
Between Focus & Pole	Behind the mirror	Erect virtual & enlarged	

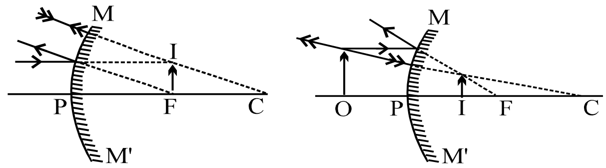
Makeup and shaving mirrors are concave mirrors. When you place your face between the mirror and its focal point, you see an enlarged virtual image of yourself. Concave mirrors are also used in a new method for displaying the speed of a car.

Reflection through convex mirror : When a narrow beam of light travelling parallel to the principal axis is incident on the reflecting surface of the mirror, the beam after reflection appear to diverge from a point on the principal axis.
When a ray incident on convex mirror in the direction of centre of curvature after reflection comes back along the same path.
When a ray incident on convex mirror parallel to the principal axis, after reflection, appears to come from the focus.
A ray appearing to pass through the focus is reflected parallel to the principal axis.



Convex mirror

Image formed by convex mirror : A convex mirror forms only virtual images for all positions of the real object. The image is always virtual, erect, smaller than the object and is located between the pole & the focus.



The image becomes smaller and moves closer to the focus as the object is moved away from the mirror.

The virtual image is diminished in size and upright, relative to the object. A convex mirror form a virtual image of the object, no matter where in front of the mirror the object is placed. Because of the shape of convex mirrors, they give a wider field of view than do other types of mirrors. Therefore, they are often used for security purposes. A mirror with a wide field of view is also needed to give a driver a good rear view. Thus, the outside mirror on the passenger side is often a convex mirror. Printed on such a mirror is usually the warning *"vehicles in mirror are closer than they appear."*


Figure : Rear view mirror

The reason for the warning is that the virtual image in figure is reduced in size and therefore looks smaller, just as a distant object would appear in a plane mirror. An unwary driver, thinking that the side-view mirror is a plane mirror, might incorrectly deduce from the small size of the image that the car behind is far enough away to ignore.

Comparing the fields of view of a Plane Mirror & a Convex Mirror
For a fair comparison to be made the two mirrors must be the same size and the eye must be placed at the same distance from each of them. The maximum angle of view is obtained when the angle of reflection at the mirror is a maximum, i.e., when the normal to the mirror are drawn at the extreme edges of the mirror.
The normals to the convex mirror are lines which are continuations of the radii at the edges of the mirror. Once the angles of reflection have been drawn, equal angles must be drawn on the other side of the normals to give the position of the incident rays. The angle of incidence for the convex mirror is much greater than the angle of incidence for the plane mirror, hence the convex mirror has a greater field of view that the plane mirror.

SIGN CONVENTION

(1) All distances are measured from the pole.
(2) The distance measured along the direction of propagation of light are taken as positive and the direction opposite to the propagation of light is taken as negative.
(3) The distance(heights) measured above the principal axis i.e. along positive Y axis, are taken as positive while distances below the principal axis i.e. along negative Y axis are taken as negative.

MIRROR FORMULAE

If an object is placed at a distance u from the pole of a mirror and its images is formed at a distance v (from the pole) then $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R}$

In this formula to calculate unknown, known quantities are substituted with proper sign.

If a thin object linear size O situated vertically on the axis of a mirror at a distance u from the pole and its image of size I is formed at a distance v (from the pole). magnification (transverse) is defined as

$$m=\left[\frac{I}{O}\right]=-\left[\frac{v}{u}\right]$$

- (+ve Erect image)
- (–ve inverted image)
- ($|m|>1$ large image)
- ($|m|<1$ Small image)

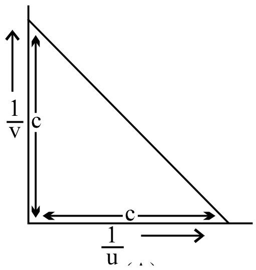
Here-ve magnification implies that image is inverted with respect to object while +ive magnification means that image is erect with respect to object.

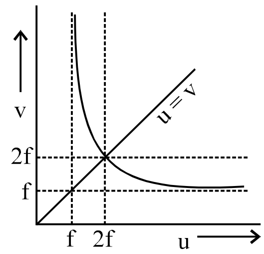
Other formulae of magnification $m=\frac{f}{f-u}$, $m=\frac{f-v}{f}$

The power of a mirror is defined as its capacity to converge or diverge. Mathematically it is defined as inverse of focal length. For concave mirror power is positive as it is a converging mirror and for convex it is negative as it is a diverging mirror.

$P=-\frac{1}{f(\text{in m})}=-\frac{100}{f(\text{in cm})}$. The unit of power is diopter.

In sign convention, f (or R) is negative for concave or converging mirror and positive for convex or diverging mirror.





Graph :

f = x-coordinate of focus, v = x-coordinate of image,
u = x-coordinate of object

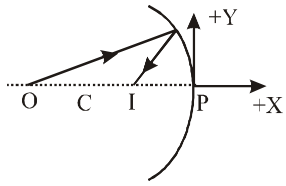
Newton's formula : $XY=f^2$

X and Y are the distance along the principal axis of the object and image respectively from the principal focus.

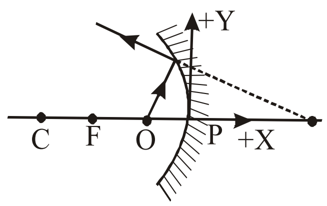
(You can obtain the relation using $\frac{1}{v+X}+\frac{1}{u+Y}=\frac{1}{f}$)

Note : Many Students get confused in applying sign convention and a small error in sign of one variable will throw all your calculation. Please study 3 points carefully (put known quantities with proper sign unknown quantity will come automatically with proper sign).

(i) Consider the mirror shown in figure. Here, the object is on the left and image is also on the left. The mirror is a concave mirror. The incident ray is directed from left to right and so the positive X-axis is also from left to right. Here, Object distance u = – PO, Image distance v = – PI, Radius of curvature R = –PC, Focal length f = – ve.

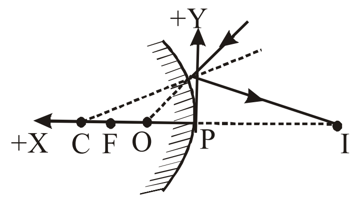


(ii) Consider the mirror shown in figure. Here, the object is on the left and image is on the right and the mirror concave. The incident ray is once again from left to right and so the positive X-axis.



Here, Object distance u = – PO, Image distance v = + PI,
Radius of curvature R = –PC, Focal length f = – ve.

(iii) Consider the mirror shown in figure. Here, the object is virtual and on the left, image is also on the right and the mirror is a convex. The incident ray is from the right and the positive X-axis is from right to left.



Here, Object distance u = + PO, Image distance v = – PI,
Radius of curvature R = + PC,
Focal length f = + ve.

Example 5 :

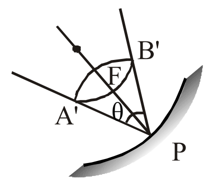
A concave mirror of focal length f produces a real image n time the size of the object. What is the distance of the object from the mirror.

Sol. $m = -n$; $m = \frac{f}{f-u}$; $-n = \frac{-f}{-f-u}$ $\Rightarrow$ $nf + nu = -f$; $nu = -f - nf \Rightarrow u = \frac{-(n+1)}{n}f$

Example 6 :

The sun (diameter D) subtends an angle θ radian at the pole of a concave mirror of focal length f. What is the diameter of the image of the sun formed by the mirror.

Sol. Since the sun is very distant, u is very large and so 1/u is practically zero



$\frac{1}{u} \approx 0$; $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$; $\frac{1}{v} = -\frac{1}{f}$; $v = -f$

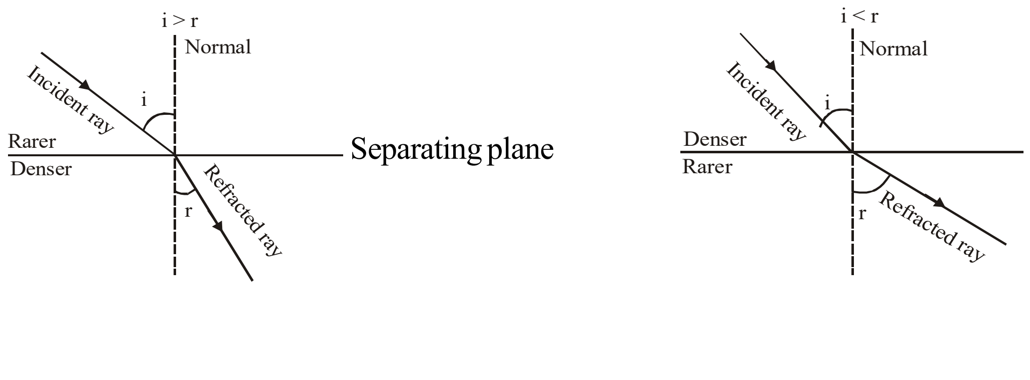
The image of sun will be formed at the focus and will be real, inverted and diminished

A'B' = height of image

$$\theta = \frac{\text{Arc}}{\text{Radius}} = \frac{A'B'}{FP} \Rightarrow \theta = \frac{d}{f} \Rightarrow d = f\,\theta$$

REFRACTION AT PLANE SURFACES

The bending of the light ray from its path in passing from one medium to the other medium is called refraction of light. If the refracted ray bends towards the normal relative to the incident ray, then the second medium is said to be denser than the first medium. But if the refracted ray bends away from the normal, then the second medium is said to be rarer than the first medium.



You must have seen bending of pencil in water beaker due to refraction.

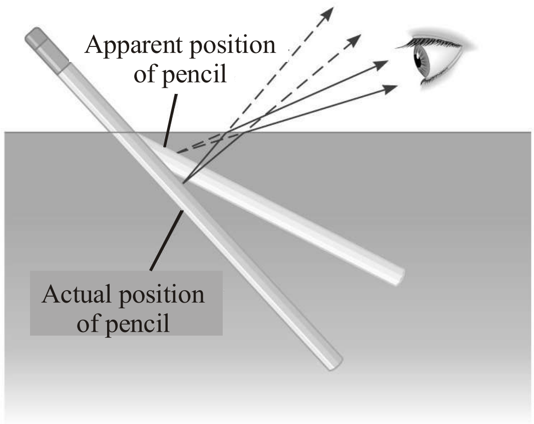


Figure : A pencil in a glass of water looks bent due to the light refraction

Refractive Index : Light travels through a vacuum at a speed $c = 3.00 \times 10^8$ m/s. It can also travel through many materials, such as air, water and glass. Atoms in the material absorb, reemit and scatter the light, however. Therefore, light travels through the material at a speed that is less than c, the actual speed depending on the nature of the material.

To describe the extent to which the speed of light in a material medium differs from that in a vacuum, we use a parameter called the index of refraction (or refractive index).

Absolute refractive index : It is defined as the ratio of speed of light in free space c to that in a given medium v,

i.e. μ or $n = \frac{c}{v}$ .... (1) It is a scalar and has no units and dimensions.

As in vacuum or free space, speed of light of all wavelengths is maximum and equal to c so for all wavelengths the refractive index of free space is minimum and is $\mu = \frac{c}{v} = \frac{c}{c} = 1$

For a given light, denser is the medium, lesser will be the speed of light and so greater will be the refractive index, e.g. as $v_{glass} < v_{water}$, $\mu_G > \mu_w$

i.e. for a given light refractive index depends on nature of medium [i.e., $\mu \propto (1/v)$]s

For a given medium (other than free-space), the speed of light of different wavelengths is different,i.e., $v \propto \lambda$ and $\mu = (c/v)$, $\mu \propto (/\lambda)$, i.e. greater the wavelength of light lesser will be the refractive index e.g. $\lambda_R > \lambda_B$, so in water or glass $\mu_R < \mu_B$, i.e., for a given medium (other than free space) refractive index depends on wavelength of light.

As for light in free space $c = f\lambda_0$ and in a medium $v = f\lambda$,

$\mu = \frac{c}{v} = \frac{\lambda_0}{\lambda}$ .... (3) i.e., for a given light and medium refractive index is equal to the ratio of wavelength of light in free space to that in the medium. Refractive index decreases with the increase in temperature.

Relative Refractive index : When light passes from one medium to the other, the refractive index of medium 2 relative to 1 is written as ${}_1\mu_2$ and is defined as $${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{(c/v_2)}{(c/v_1)} = \frac{v_1}{v_2} \quad .... (4)$$

while using the concept of relative μ, is must be kept in mind that :

$${}_2\mu_1 = \frac{\mu_1}{\mu_2} = \frac{v_2}{v_1} \quad \text{So that, } ({}_1\mu_2)({}_2\mu_1) = \frac{v_1}{v_2} \times \frac{v_2}{v_1} = 1 \quad \text{i.e., } {}_1\mu_2 = \frac{1}{{}_2\mu_1} \quad .... (5)$$

Usually 'μ' is used for relative refractive index and it implies the refractive index of denser medium relative to rarer one, i.e., $\mu = \frac{\mu_D}{\mu_R} = \frac{v_R}{v_D} > 1$

In lens theory μ is used for the refractive index of material of lens relative to the medium, i.e.,

$\mu = \frac{(\mu)_{Lens}}{(\mu)_{Medium}}$ and can be greater than, less than or equal to unity.

LAW OF REFRACTION

Snell's Law : For any two media and for light of a given wave length, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. $\frac{\text{Sin } i}{\text{Sin } r}$ =constant, where, i = incidence angle, r = refraction angle.

The incident ray, the refracted ray and the normal at the incident point all lie in the same plane.

Frequency (and hence colour) and phase do not change (while wavelength and velocity changes)

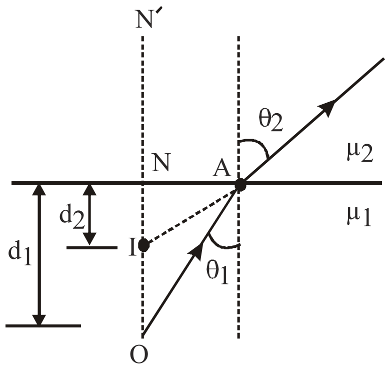
APPLICATION OF REFRACTION ON PLANE SURFACE

Basic Concept : Take two incident ray from object on interface of two medium one normal and other at some angle, normal ray will pass without any deviation & other ray will deviate according to medium. Find intersection point (use backward tracing if needed) of refracted ray to locate image. Use Snell rule & basic maths (approximation) to calculate relevant distances.

Apparent depth and Normal shift

We can easily determine the relationship between the object distance and image distance. Consider the object in fig.

From triangles ONA and INA we have



$$\frac{NA}{IN} = \tan\theta_2, \quad \frac{NA}{ON} = \tan\theta_1$$

Dividing the equations we have $\frac{ON}{IN} = \frac{\tan\theta_2}{\tan\theta_1}$

ON = actual depth, IN = apparent depth

Paraxial Approximation : Assuming that the rays are all contained in a cone with a very small half angle, the value of θ is very small (Normal view), we can say that $\sin\theta = \tan\theta$, Therefore, $\frac{ON}{IN} = \frac{\sin\theta_2}{\sin\theta_1}$

From Snell rule, $\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2$ or $\frac{\sin\theta_2}{\sin\theta_1} = \frac{\mu_1}{\mu_2}$,Substituting we get, $\frac{ON}{IN} = \frac{\mu_1}{\mu_2}$ or $\frac{\mu_1}{ON} = \frac{\mu_2}{IN}$

Apparent depth = $\frac{\mu_2}{\mu_1}$ actual depth. This gives us the position of the image.

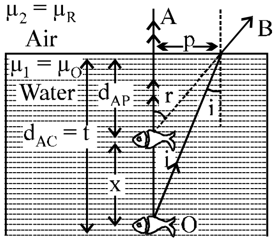
There are two possibilities :

(1) If $\mu_1 > \mu_2$ i.e., object in a denser medium is seen from a rarer medium

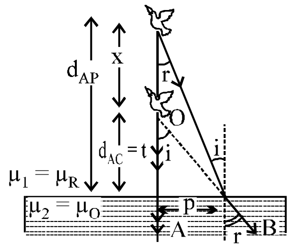
$$\frac{\mu_1}{\mu_2} = \frac{\mu_D}{\mu_R} = \mu(>1) \text{ So, } \quad d_{Ap} = (d_{Ac}/\mu), \text{ i.e., } d_{Ap} < d_{Ac}$$

i.e., the image of object will appear at a lesser distance. This is why an under water object (like stone or fish) appears to be at lesser depth than in reality. The distance between object and its image, called normal shift and with $d_{Ac} = t$, will be

$$x = d_{Ac} - d_{Ap} = t - (t/\mu) = t\,[1-(1/\mu)]$$



(A)



(B)

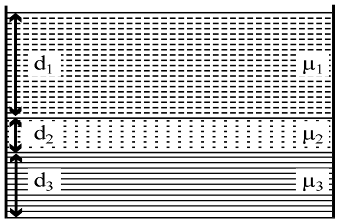
(2) If $\mu_1 < \mu_2$ i.e., object in a rarer medium is seen from a rarer medium

$$\frac{\mu_1}{\mu_2} = \frac{\mu_D}{\mu_R} = \mu\ (<1)\text{. So, } d_{Ap} = \mu d_{Ac}\text{, i.e., } d_{Ap} > d_{Ac}$$

i.e., the image of the object will appear to be at a greater distance. This is why a high flying object (like bird or aeroplane) appears to be higher than in reality. Normal shift in this situation will be

$$x = d_{Ac} - d_{Ap} = [(\mu - 1)]\,t \quad \text{with } d_{Ac} = t$$

Note : If there are number of liquids of different depths, one over the other



$$d_{Ac} = d_1 + d_2 + d_3 ...... \text{ and } d_{Ac} = \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3} + ...$$

So $$\mu = \frac{d_{Ac}}{d_{Ap}} = \frac{d_1 + d_2 + d_3 ....}{\frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3} + ...} = \frac{\Sigma d_i}{\Sigma\,(d_i/\mu_i)}$$

In case of two liquids if $d_1 = d_2$, $\mu = \left[\frac{2\mu_1 + \mu_2}{\mu_1 + \mu_2}\right]$ = Harmonic mean

Refraction across slab

Normal shift : Two cases are possible –

Refer figure (a) : An object is placed at O. Plane surface CD forms its image (virtual) at I_1. This image acts as object for EF which finally forms the image (virtual) at I. Distance OI is called the normal shift and its value is,

$$OI = \left(1 - \frac{1}{\mu}\right) t$$

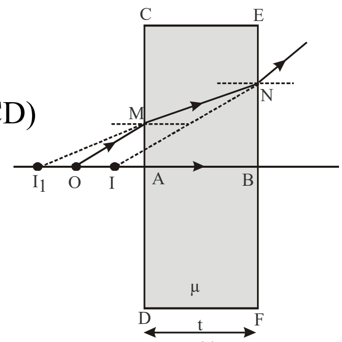
Let $OA = x$ then $AI_1 = \mu x$ (Refraction from CD)

$BI_1 = \mu x + t$

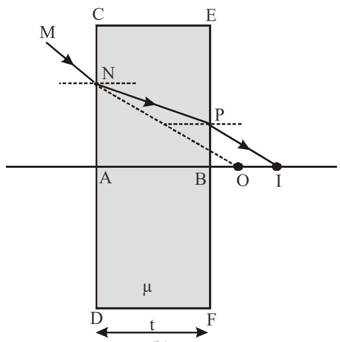
$BI = \frac{BI_1}{\mu} = x + \frac{t}{\mu}$ (Refraction from EF)

$\therefore$ OI = (AB + OA) – BI

$$OI = (t + x) - \left(x + \frac{t}{\mu}\right) = \left(1 - \frac{1}{\mu}\right) t$$



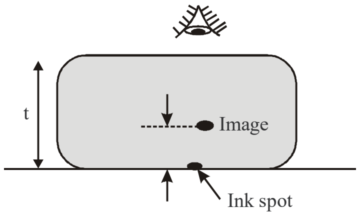
(a)



(b)

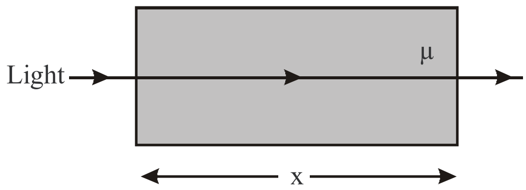
Refer figure (b) : The ray of light which would had met line AB at O will now meet this line at I after two times refraction from the slab. Here $OI = \left(1 - \frac{1}{\mu}\right) t$

If there is an ink spot at the bottom of a glass slab, it appears to be raised by a distance $x = t - a$ or $x = t\left(1 - \frac{1}{\mu}\right)$



Optical Path

It is defined as distance travelled by light in vacuum in the same time in which it travels a given path length in a medium.

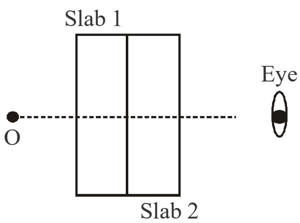


Time taken by light ray to pass through the medium = $\frac{\mu x}{c}$,

where x = geometrical path and μx = optical path

Refraction across multiple slabs

A light ray emerging from O refracts at three surfaces. Net shift in the position of the image is simply the sum of the individuals shifts at each of the slabs if they were independently placed in air.



Relation between object and image Velocities :

(i) If an object O moves toward the plane boundary of a denser medium then the image appears to be farther but moves faster to an observer in denser medium. If $v_0 = v$ then $v_1 = \mu v$ Where , v_0 & v_1 represents object and image velocities respectively.

(ii) If an object O moves toward the plane boundary of a rarer medium then the image appears to be closer but moves slower to an observer in rarer medium. If $v_0 = v$ then $v_1 = v/\mu$

Example 7 :

Light waves of 5895 Å wavelength travels from vacuum to a medium of refractive index of 1.5. Find the velocity of light and wavelength in medium.

Sol. If velocity of light in vacuum is c then velocity of light in medium is $v = \frac{c}{n} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8$ m/sec

wavelength of light in medium is $\lambda_w = \frac{\lambda}{n} = \frac{5895}{1.5} = 3930$ Å.

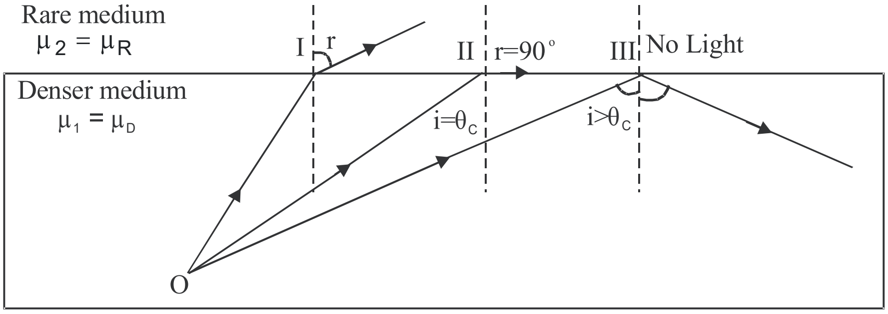
Example 8 :

When a glass slab is placed on a dot on a paper. It appears displaced by 4 cm, viewed normally. What is the thickness of slab if the refractive index 1.5.

Sol. We know that Displacement $= t\left(1 - \frac{1}{\mu}\right)$. So $4 = t\left(1 - \frac{1}{\mu}\right)$; $t = \frac{\mu \times 4}{\mu - 1} = \frac{1.5 \times 4}{1.5 - 1} = 12$ cm

TOTAL INTERNAL REFLECTION (TIR)

When light passes from a medium of larger refractive index into one of smaller refractive index - for example, from water to air-the refracted ray bends away from the normal. As the angle of incidence increases, the angle of refraction also increases. When the angle of incidence reaches a certain value, called the critical angle θ_c, the angle of refraction is 90°. Then the refracted ray points along the surface. When the angle of incidence exceeds the critical angle, there is no refracted light. All the incident light is reflected back into the medium from which it comes, a phenomenon called total internal reflection. Total internal reflection occurs only when light travels from a higher-index medium toward a lower-index medium. It does not occur when light propagates in the reverse direction-for example, from air to water.



An expression for the critical angle θ_c can be obtained from Snell's law by setting $\theta_1 = \theta_c$ and $\theta_2 = 90°$:

Critical angle $\sin\theta_c = \frac{\mu_2 \sin 90°}{\mu_1} = \frac{\mu_2}{\mu_1} \quad (\mu_1 > \mu_2)$

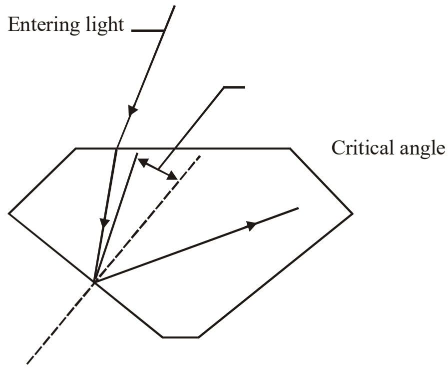
For instance, the critical angle for light traveling from water ($\mu_1 = 1.33$) to air ($\mu_2 = 1.00$) is

$\theta_c = \sin^{-1}(1.00/1.33) = 48.8°$. For incident angles greater than 48.8°, Snell's law predicts that $\sin\theta_2$ is greater than unity, a value that is not possible. Thus, light rays with incident angles exceeding 48.8° yield no refracted light, and the light is totally reflected back into the water.

In case of total internal reflection, as all (i.e., 100%) incident light is reflected back into the same medium, there is no loss of intensity while in case of reflection from mirrors or refraction from lenses there is some loss of intensity as all light can never be reflected or refracted. This is why images formed by TIR are much brighter than formed by mirrors or lenses.

Application of TIR

1. **Sparking of diamond :** A diamond sparkles because, when it is held a certain way, the intensity of the light coming from it is greatly enchanced. A ray of light striking a bottom facet of the diamond at an angle of incidence exceed the critical angle, are totally reflected back into the diamond, eventually exiting the top surface to give the diamond its sparkle. Many of the small critical angle in air, the critical angle is 24.4°. The value is so small, because the index of refraction of diamond is large compared to that of air.

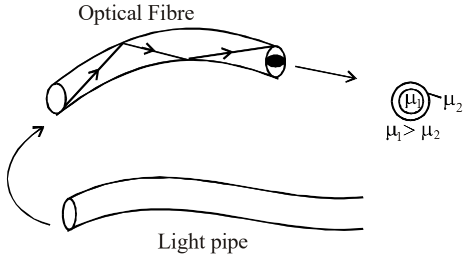


Now consider what happens to the same ray of light within the diamond when the diamond is placed in water. Because water has a larger index of refraction than air, the critical angle increases to 33.3°. Therefore, this only some of the light is reflected back into the diamond, and the remainder escapes into the water. Consequently, less light exits from the top of the diamond, causing it to lose much of its brilliance.

2. **Optical fibre :** Take a thin solid wire (called strand) made up of glass or quartz, etc. Coat it from outside with some material whose μ is less than that of glass or quartz, etc. Now, because it is thin, hence whichever ray of light enters it from one of its end, will strike the inside surface at some angle which will definitely be greater than the critical angle. Hence, it will suffer total internal reflection again and again until it comes out from the other end. This is the principle on which optical fibres work.

Hence, in effect, light can travel axially within an optical fibre, although the axis of fibre may be flexible having bent or wavy profile.

A bundle of optical fibres is called a light pipe and is able to send image of an extended object from one end to another by picking up images of small-small parts of the object and sending them likewise to the other end.

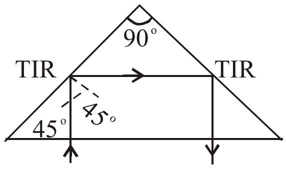


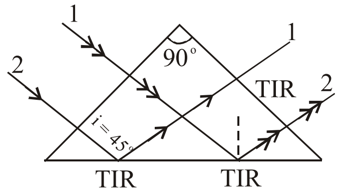
Use of Optical fibres

(a) For medical examination inside the stomach, intensities etc., called endoscopy.

(b) The recent trend is to send even electrical signals through optical fibres, by converting them into electromagnetic radiations/light waves.

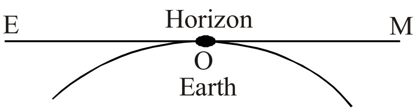
3. Many optical instruments, such as binoculars, periscopes, and telescopes, use glass prisms and total internal reflection to turn a beam of light through 90° or 180°.

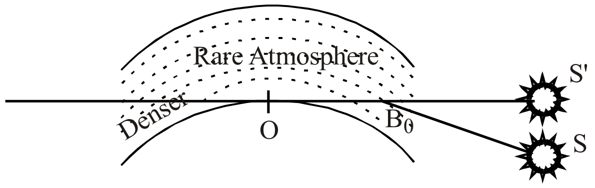




4. Duration of Sun's Visibility:

In absence of atmosphere the sun will be visible for its position from M to E as shown in fig. However, in presence of atmosphere (in which μ decreases with height) due to the phenomenon of TIR, the sun will become visible even when it is below the horizon (when $i > \theta_C$) and will remain visible for some time even when it goes below the horizon as shown in fig. This results in increase in duration for which the sun is visible. It is estimated that due to this effect the period of visibility of the sun increases by 2 minutes in the morning and 2 minutes in the evening.





5. Mirrage

Mirrage is an optical illusion of water observed in deserts (or in a region of high temperature) when the inverted image of an object such as a tree is observed along with the object itself on a hot day.

If atmospheric conditions are reversed i.e., the lower strata of air are cooler than the upper strata, then another sort of image called 'looming' occurs. This generally takes place over a snow field or a body of cold water. The rays of light from a distant object are deviated downwards. We may see an image of a ship above the ship itself. It is also possible that the curvature of the light rays may bring into view objects normally below the horizon.

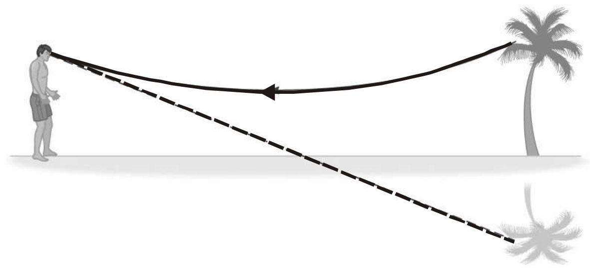


Figure : A mirage is created due to the bending of light. The index of refraction of the hot air near the ground is lower than the colder air on the top.

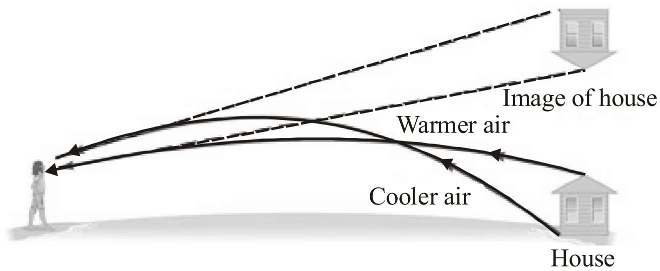
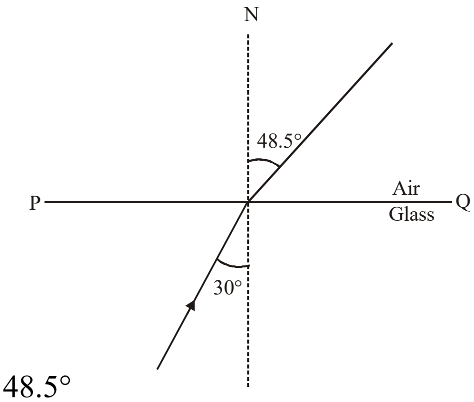


Figure : Looming

Problem based on TIR are very simple, to solve them remember condition for TIR + apply Snell rule + Basic Mathematics and common sense.

Example 9 :

Crtical angle for glass air interface is 42°. A light ray moves from glass to air at angle of incidence i = 30°, 42° and 50°. What should be the value of angle of refraction r in each case ?



Sol. Since critical angle $i_c = 42°$, refractive index

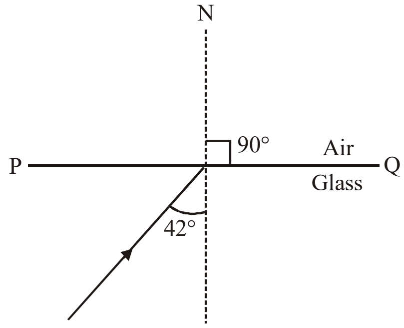
$${}_a\mu_g = \frac{1}{\sin 42} = \frac{1}{0.67} = 1.5$$

Case I : When i = 30°, i.e., $i < i_c$

$${}_g\mu_a = \frac{\sin 30}{\sin r} \;;\; \sin r = \frac{\sin 30}{{}_g\mu_a} = {}_a\mu_g \times \sin 30 = 1.5 \times \frac{1}{2} = 0.75 \;;\; r = 48.5°$$

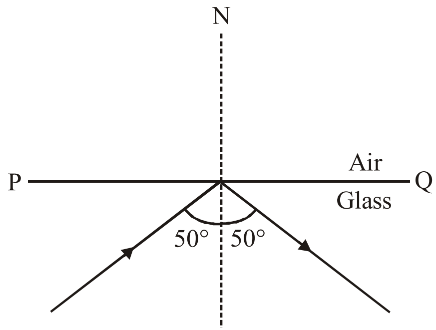
Case II : When i = 42° = i_c

At critical angle of incidence angle of refraction r = 90° and the light after refraction goes along the surface. (figure)



Case III : When i = 50° > i_c

Since angle of incidence is more than critical angle total internal reflection of the light takes place and the ray reflects back to glass at angle of reflection 50°. (figure)

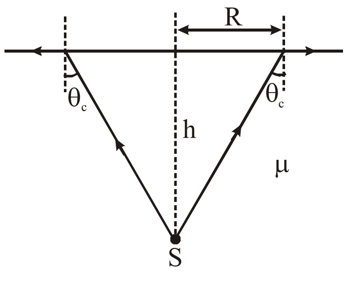


Example 10 :

A point source of light is placed at the bottom of a tank containing a liquid (refractive index = μ) upto a depth h. A bright circular spot is seen on the surface of the liquid. Find the radius of this bright spot.

Sol. Rays coming out of the source and incident at an angle greater than θ_c will be reflected back into the liquid therefore, the corresponding region on the surface will appear dark.

As is obvious from the figure, the radius of the bright spot is given by



$$R = h\tan\theta_c = \frac{h\sin\theta_c}{\cos\theta_c} \quad \text{or} \quad R = \frac{h\sin\theta}{\sqrt{1-\sin^2\theta_c}}$$

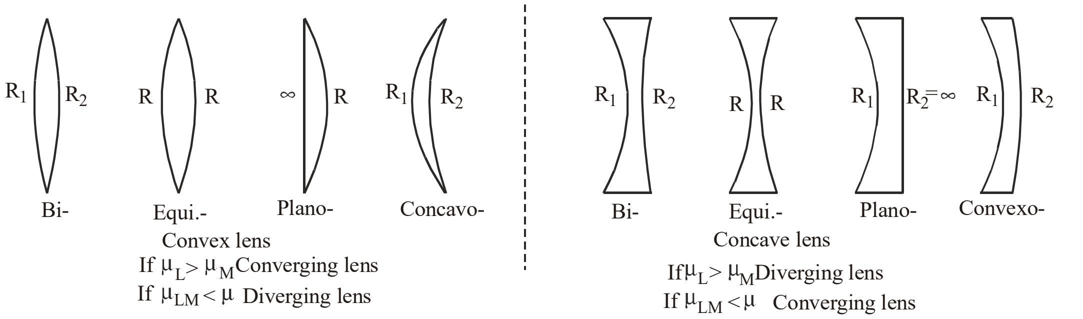
Since $\sin\theta_c = \frac{1}{\mu}$ $\quad\therefore\quad$ $R = \frac{h}{\sqrt{\mu^2 - 1}}$

LENS

A lens is a piece of transparent material with two refracting surface such that least one is curved and refractive index of use material is different from that of the surroundings.

A thin spherical lens with refractive index greater than that of surrounding behaves a convergent or convex lens i.e. converges parallel rays its central (i.e. paraxial) portion is thicker than marginal one.

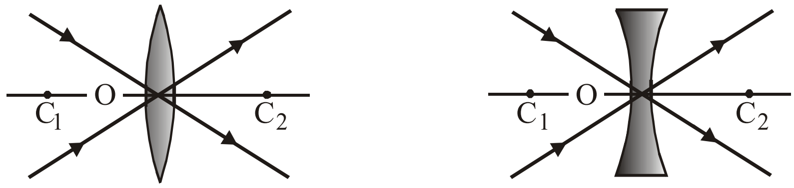
However if the central portion of a lens (with $\mu_L > \mu_M$) is thinner than marginal, it diverges parallel rays and behaves as divergent or concave lens. This is how we classify and identify convergent and divergent lenses.



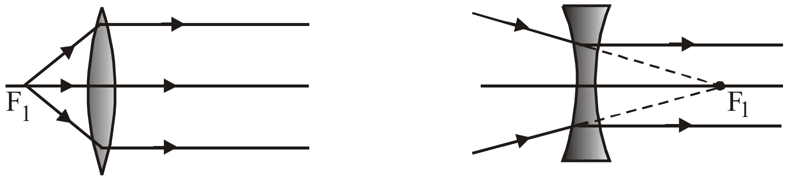
Terms related to thin spherical lens

Optical - O is a point for given lens through which any ray passes undeviated.

Principal - Axis - C_1 C_2 is a line passing through optical and perpendicular to the lens. The centre of curvature of curved surface always lie on the principal axis (as in a sphere is always perpendicular to surface)



Principle - Focus - A lens has two surface and hence two focal points first focal point is an object on the principal axis for which image is at infinite while



Second focal point is an image point on the principle axis for which object is at infinity.

Focal - Length f - is defined as the distance between optical centre of a lens and the point where the parallel beam of light converges or appear to converge.

Aperture - In reference to lens aperture means to effective diameter of its light transmitting area so that brightness i.e. intensity of image formed by a lens which depends on the light passing through the lens will depends on the square of aperture i.e. $I \propto (\text{Aperture})^2$

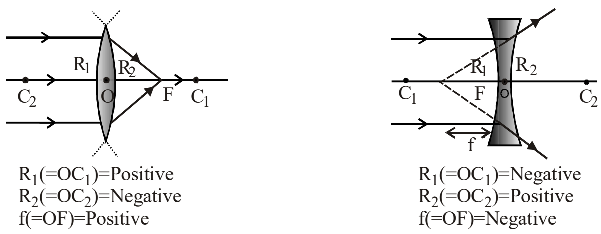
Sign - Convention

1. Whenever and where possible, rays of light are taken to travel from left to right.
2. Transverse distance measured from optical centre and are taken to be positive while those below it negative.
3. Longitudinal distances are measured from optical centre and are taken to be positive if in the direction of light propagation and negative if opposite to it (according to our sign convention)

While using the sign convention it must be kept in mind that -

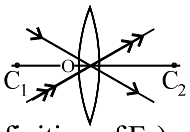
(i) To calculate an unknown quantity the known quantities are substituted with sign in a given formula.

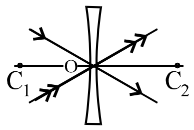
(ii) In the result sign must be interpreted as there are number of sign conventions and same sign has different meaning in different conventions.



Rules for image formation : In order locate the image formed by a lens graphically following rules are adopted

1. A ray passing through optical centre proceeds undeviated through the lens. (by definition of optical centre).



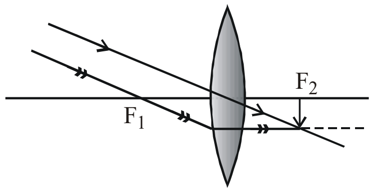
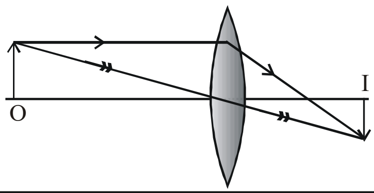
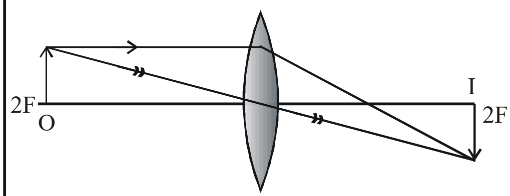
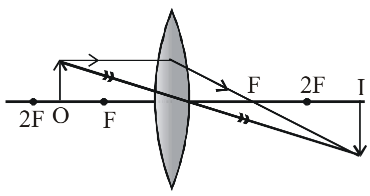
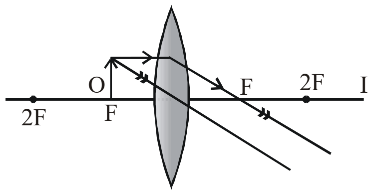
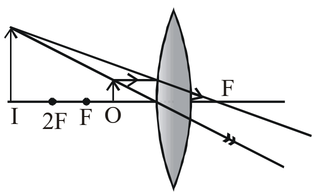


2. A ray passing through first focus or directed towards it, after refraction from the lens becomes parallel to the principal axis. (by definition of F_1)

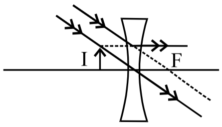
3. A ray passing parallel to the principal axis after refraction through the lens passes or appear to pass through F_2 (by definition of F_2).

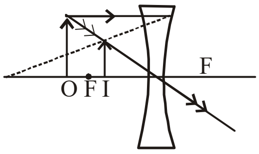
4. Only two rays from the same point of an object are needed for image formation and the point where the rays after refraction through the lens intersect or appear to intersect is the image of the object. If they actually intersect each other the image is real and if they appear to intersect the image is said to be virtual.

Image formation by a lens : (a) For convergent or Convex Lens

Position of object	Details of image	Figure
At infinity	Real, inverted diminished (m<<–1) At F	
Between∞and 2F	Real, inverted diminished (m<–1) Between F and 2F	
At 2F	Real, inverted equal m = –1 at 2F	
Between 2F and F	Real, inverted enlarged (m>–1) Between 2F and ∞	
At F	Real, inverted enlarged (m>>–1) At infinity	
Between focus and pole	Virtual, erect enlarged (m > +1) Between ∞ and object on same side	

(b) For Divergent or Concave lens

If object at infinity  image will be formed at focus

In front of lens  Virtual, erect

REFRACTION THROUGH A THIN LENS

If an object is placed at a distance u from the optical centre of a lens and its images is formed at a distance v (from the optical centre) and focal length of this length is f then $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

The power of a lens is defined as $P=\frac{1}{f(\text{in m})}=\frac{100}{f(\text{in cm})}$

The unit of power is diopter.

If a thin object linear size O situated vertically on the axis of a lens at a distance u from the optical centre and its image of size I is formed at a distance v (from the optical centre). magnification (transverse) is defined as

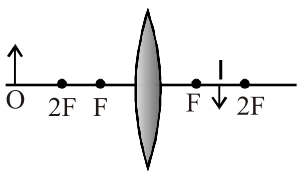
$m=\left[\frac{I}{O}\right]=\left[\frac{v}{u}\right]$ →
- (+ve Erect image)
- (–ve inverted image)
- (|m| >1 large image)
- (|m| < 1 Small image)

Here-ve magnification implies that image is inverted with respect to object while+ive magnification means that image is erect with respect to object.

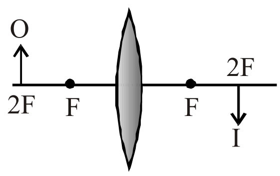
Other formulae of magnification $m=\frac{f}{f+u}$, $m=\frac{f-v}{f}$

For real extended object, if the image formed by a single lens in inverted (i.e., m is negative) it is always real and the lens is convergent i.e., convex. In this situation if the size of image is -

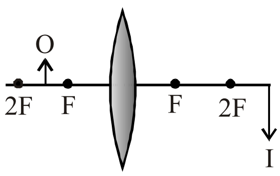
Smaller than object	Equal to object	Larger than object
Object between ∞ and 2F	Object is at 2F	Object is between 2F and F
Image is between F and 2F	Image is at 2F	Image is between 2F and ∞



A



B



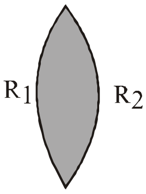
C

Focal length of lens (lens maker formula) $\frac{1}{f}=({}_m\mu_{\ell}-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$

where ${}_m\mu_{\ell}$ refractive index of lens with respect to medium.

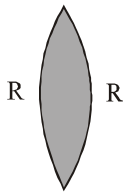
R_1 = radius of curvature of first surface of lens, R_2 = radius of curvature of second surface of lens

Observe the sign convention for R_1 and R_2 in following figures



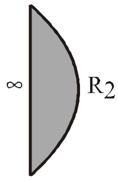
$r_1 = +R_1, r_2 = -R_2$

$\therefore \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$



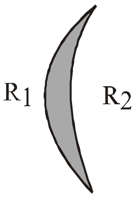
$r_1 = R, r_2 = -R$

$\frac{1}{f} = (\mu - 1)\frac{2}{R}$



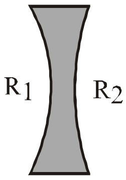
$r_1 = \infty, r_2 = -R$

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{\infty} + \frac{1}{R}\right) = \left(\frac{\mu - 1}{R}\right)$



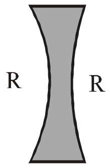
$r_1 = +R_1, r_2 = +R_2$

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



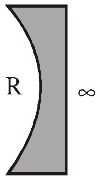
$r_1 = -R_1, r_2 = +R_2$

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



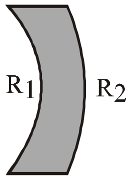
$r_1 = -R, r_2 = +R$

$\frac{1}{f} = -(\mu - 1)\frac{2}{r}$



$r_1 = \infty, r_2 = +R.$

$\frac{1}{f} = -(\mu - 1)\frac{1}{R}$



$r_1 = +R_1, r_2 = +R_2$

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

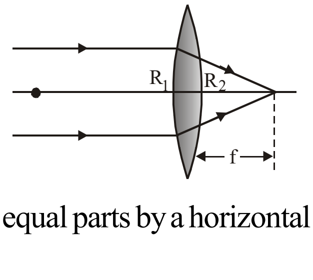
Note :

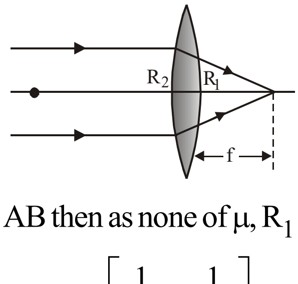
(i) In case of sun - goggles, the radii of curvature of two surface are equal with centre on same side i.e., $R_1 = R_2 = R$

So $\frac{1}{f} = (\mu - 1)\left[\frac{1}{+R} - \frac{1}{+R}\right] = 0$ i.e., $f = \infty$ and $P = (1/f) = 0$

This is why sun - goggles have no power or infinite focal length. Same is true for a transparent sheet with the difference that here $R_1 = R_2 = \infty$

(ii) If the two radii of curvatures of a thin lens are not equal, the focal length remains unchanged whether the light is incident on first face or the other. This is because if we substitute R_1 and R_2 with proper sign in lens - makers formula, we always have $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$

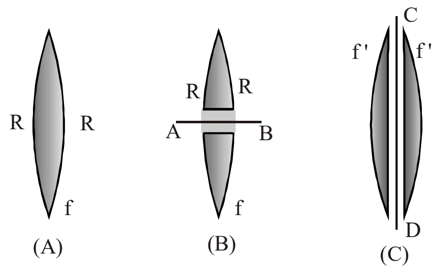




(iii) If an equiconcave lens of focal length f is cut into equal parts by a horizontal plane AB then as none of μ, R_1 and R_2 will change the focal length of each part will be equal to that of initial lens i.e. $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$

If $R_1 = R_2 = R \Rightarrow \frac{1}{f} = \frac{2(\mu-1)}{R}$

However in this situation as light transmitting area of each part becomes half of initial so intensity will reduce to half and aperture to 1/4 time of its initial value (as $\propto$ (Aperture)^2)



However if the same lens in cut into equal parts by a vertical plane CD the focal length of each part will become

$$\frac{1}{f'} = (\mu-1)\left[\frac{1}{R} - \frac{1}{\infty}\right] = \frac{\mu-1}{R} = \frac{1}{2f} \Rightarrow f' = 2f$$

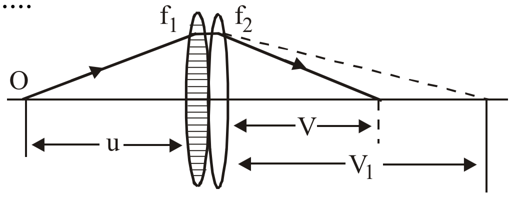
i.e., focal length of each part will be double of initial value. In this situation as the light transmitting area of each part of lens of remains equal to initial intensity and aperture will not change.

COMBINATION OF LENSES

When several lenses are used co-axially, the image formation is considered one after another in steps. The image formed by the lens facing the object serves as object for next lens the image formed by the second lens acts as object for the third and so on. The total magnification is such situations will be given by

$$m = \frac{I}{o} = \frac{I_1}{o} \times \frac{I_2}{I_1} \times .... \quad \text{i.e. } m = m_1 \times m_2 \times ....$$

In case of two thin lens in contact if the first lens of focal length f_1 forms the image I_1 (of an object)at a distance v_1 from it.



$$\frac{I}{v_1} - \frac{1}{u} = \frac{1}{f_1}$$

now the image I_1 will act as object for second lens and if the second lens forms image. I at a distance v from it

$\frac{I}{v} - \frac{1}{v_1} = \frac{1}{f_2}$. Adding above equations $\frac{I}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$ or $\frac{I}{v} - \frac{1}{u} = \frac{1}{f}$ with $\frac{I}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

i.e. the combination behave as a single lens of equivalent focal length f given by –

$$\frac{I}{F} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{or} \quad P = P_1 + P_2$$

Note : If the two thin lens are separated by a distance d apart F is given by

$$\frac{I}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \quad \text{so} \quad P = P_1 + P_2 - P_1 P_2 d.$$

If two thin lens of equal focal length but of opposite nature (i.e. one convergent and other divergent) are put in contact, the resultant focal length of the combination be

$\frac{I}{F} = \frac{1}{+f} + \frac{1}{-f} = 0$ i.e. $F = \infty$ and $P = 0$ i.e. the system will behave as a plane. glass plate.

If two thin lens of same nature are put in contact then as

$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$; $\frac{1}{F} > \frac{1}{f_1}$ and $\frac{1}{F} > \frac{1}{f_2}$ i.e. $F < f_1$ and $F < f_2$

i.e. the resultant focal length will be lesser than smallest individual.

ACTIVITY : AIR LENS

Purpose : To apply your knowledge of light behavior and glass lenses to a different type of lens system.

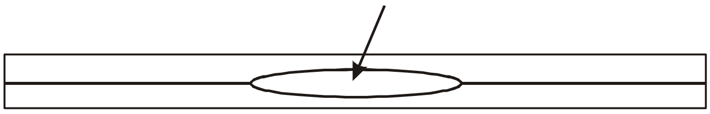
Required Equipment/Supplies : 2 depression microscope slides, light source, screen

Discussion : Ordinary lenses are made of glass. A glass lens that is thicker at the center than at the edge is convex in shape, converges light, and is called a converging lens. A glass lens that is thinner at the middle than at the edge is concave in shape, diverges light, and is called a diverging lens.

Suppose you had an air space that was thicker at the center than at the edges and was surrounded by glass. This would comprise a sort of "convex air lens." What would it do to light? This activity will let you find out.

Procedure :

Step 1: A convex air lens encased in glass can be produced by placing two depression microscope slides together, as shown in Figure.



1. Predict whether this arrangement makes a diverging or converging lens. Explain your prediction.

Step 2: Use your lens with a light source and screen to check your prediction.

2. What do you discover ?

Analysis :

3. Why is the statement "The shape of a lens determines whether it is a converging or diverging lens" not always true?

4. Draw ray diagrams for both a convex and a concave air lens encased in glass to show what these lenses do to light rays passing through them.

CONCEPT MAP

1.

Reflection
(Angle of reflection equals the angle of incidence)

- **Plane mirror**
  Image : Virtual, erect and behind the mirror
  Image distance = object distance
  Image size = object size (m = 1)
- **Spherical mirrors, Concave and convex**
  Focal length f = R/2
  Mirror formula : $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$
  Magnification : $m=\frac{h'}{h_0}=-\frac{v}{u}$
  - Concave mirror
    - Real and inverted images, formed in front of mirror, m is negative. (f, R, u, v, h' are negative; h is positive)
    - Virtual and erect image, formed behind the mirror, m is positive. (f, R, u are negative; v, h and h' is positive)
  - Convex mirror
    - Only virtual and erect image, formed behind the mirror m is positive. (f, R, u, v, h, h' are positive; u is negative)

2. **Refraction**

(Bending of a ray of light when it is oblique incident at a boundary separating two media)

- Rarer to denser medium
  - Ray bends towards the normal
  - Speed of the ray decreases
- Denser to rarer medium
  - Ray bends away from the normal
  - Speed of the ray increases

3. **Refraction**

- Absolute refractive index of medium : $n = \frac{c}{v}$
- Refractive index of medium (2) relative to (1) : $n_{21} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$
- Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- Spherical lenses : convex and concave lens
  Lens formula : $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
  Power of a lens : $P = \frac{1}{f}$
  - Convex lens
    - Images : Real and inverted and other side of lens. (when $u \geq f$) (f, h v are positive; u, h' are negative)
    - Image : Virtual and erect on the same side of the lens as the object. (when $u < f$) (f, h, h' are positive; u, v are negative)
  - Concave lens
    - Only virtual and erect image, on the same side of lens as the object.

ADDITIONAL EXAMPLES

Example 1 :

An object is situated at a distance of f/2 from a convex lens of focal length f. Find the distance of image.

Sol. For a spherical lens, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

For convex lens, $u = -f/2$ and f is + ve $\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = +\frac{1}{f} - \frac{2}{f} = -\frac{1}{f}$ $\therefore$ $v = -f$

Example 2 :

Name the type of mirror used in the following situations.

(a) Headlights of a car. (b) Side/rear-view mirror of a vehicle. (c) Solar furnace.

Support your answer with reason.

Sol. (a) Concave mirror is used in car headlights, to get powerful beams of light. When a small but powerful light source is placed at the focus of the concave mirror, then the concave mirror produces a powerful beam of parallel light rays. This helps us to see things up to a considerable distance in the darkness of light.
(b) Convex mirror is used as side/rear-view mirror of a vehicles.
(c) Concave mirror is used in the field of the solar energy to focus sun's rays for heating solar furnaces. The solar furnace is placed at the focus of a large concave mirror.
The concave mirror focuses the sun's infra-red (heat rays) on the furnace due to which the solar furnace gets very hot.

Example 3 :
An object of length 1 cm is placed at a distance of 15 cm from a concave mirror of focal length 10 cm. Find the nature and size of the image.

Sol. Given u = – 15 cm, f = – 10 cm, O = 1 cm

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f},\ \frac{1}{v}=\frac{1}{f}-\frac{1}{u} = \frac{1}{-10}-\frac{1}{-15} \ \therefore v = -30 \text{ cm};\ \frac{I}{O}=\frac{v}{u}=-\frac{-30}{-15}=-2 \ ;\ I = -2\times 1 = -2 \text{ cm}$$

Image is inverted and on the same side (real) of size 2 cm.

Example 4 :
Name a mirror that can give an erect and enlarged image of on object.

Sol. Concave mirror can give an erect and enlarged image of an object, when object is placed between pole and focus of the mirror.

Example 5 :
Why do we prefer a convex mirror as a rear-vies mirror in the vehicles ?

Sol. Convex mirror are uses a rear-view mirrors in vehicles to see the traffic rear side. Convex mirrors are preferred because (i) they always given an erect, though diminished image.
(ii) they have a wider field of view as they are curved outwards.
Thus, convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

Example 6 :
A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

Sol. Radius of curvature, R = + 3.00 m; Object-distance, u = – 5.00 m;
Image-distance, v = ? Height of the image, h'= ?

Focal length, $f = R/2 = +\frac{3.00\text{m}}{2} = +1.50\text{m}$

Since $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=+\frac{1}{1.50}-\frac{1}{(-5.00)}=\frac{1}{1.50}+\frac{1}{5.00}=\frac{5.00+1.50}{7.50}$

$$v=\frac{+7.50}{6.50}=+1.15\text{m}$$

The image is 1.15m at the back of the mirror.

Magnification, $m=\frac{h'}{h}=-\frac{v}{u}=-\frac{1.15\text{m}}{-5.00\text{m}}=+0.23$

The image is virtual, erect and smaller in size by a factor of 0.23.

Example 7 :

An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and the size of the image.

Sol. Object-size, h = + 4.0 cm; Object-distance, u = – 25.0 cm; Focal length, f = –15.0 cm;
Image-distance, v = ? Image-size, h' = ?

From $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-15.0}-\frac{1}{-25.0}=-\frac{1}{15.0}+\frac{1}{25.0}$ or $\frac{1}{v}=\frac{-5.0+3.0}{75.0}=\frac{-2.0}{75.0}$

or v = – 37.5 cm.

The screen should be placed at 37.5 cm. from the mirror. The image is real.

Also, magnification, $m=\frac{h'}{h}=-\frac{v}{u}$ or $h'=-\frac{vh}{u}=\frac{(-37.5cm)\,(+4.0cm)}{(-25.0cm)}$

Height of the image, h' = –6.0 cm. The image is inverted and enlarged.

Example 8 :

Two converging lenses with focal lengths 15 cm. and 25cm. are placed 18cm. apart. An object is located 8.0 cm. to the left of the 15cm. focal length lens. Where is the final image formed ?

Sol. Find the image location for the first lens using the thin lens equation.

$\frac{1}{v_1}=\frac{1}{f_1}-\frac{1}{u_1}=\frac{1}{15cm}-\frac{1}{8.0cm}$ which gives $v_1 = -17cm$

This image forms the object of the second lens located 17 cm + 18 cm = 35 cm away. The thin lens equation gives for the second lens

$\frac{1}{v_2}=\frac{1}{f_2}-\frac{1}{u_2}=\frac{1}{25cm}-\frac{1}{35m}$ which gives $v_2 = 87.5$ cm

The final image lies 87.5 cm to the right of the second lens (25 cm) lens.

Example 9 :

Find out, from Table, the medium having highest optical density. Also find the medium with lowest optical density.

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31		
Water	1.33	Rock salt	1.54
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

Sol. A substance having higher refractive index is optically denser than another substance having lower refractive index. So the medium having highest optical density is diamond. The medium with lowest optical density in air.

Example 10 :

The radius of curvature of a spherical mirror is 20 cm. What is its focal length ?

Sol. f = R/2 = 10cm.

Example 11 :

You are given kerosene, turpentine and water. In which of these does the light travel fastest? Use the information given in Table.

Sol. Refractive index = $\dfrac{\text{speed of light in air}}{\text{speed of light in medium}}$ or $1.50 = \dfrac{3\times10^8}{\text{speed of light in medium}}$

or Speed of light in glass = $\dfrac{3\times10^8}{1.50}\,\text{ms}^{-1} = 2\times10^8\,\text{ms}^{-1}$. The speed of light in glass in 2×10^8 m/s.

Example 12 :

A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification produced by the lens.

Sol. A concave lens always forms a virtual, erect image on the same side of the object.
Image-distance v = –10 cm; Focal length f = –15 cm; Object-distance u = ?

Since $\dfrac{1}{v}-\dfrac{1}{u}=\dfrac{1}{f}$ or $\dfrac{1}{u}=\dfrac{1}{v}-\dfrac{1}{f}$; $\dfrac{1}{u}=\dfrac{1}{-10}-\dfrac{1}{(-15)}=-\dfrac{1}{10}+\dfrac{1}{15}$; $\dfrac{1}{u}=\dfrac{-3+2}{30}=\dfrac{1}{-30}$ or $u = -30$ cm.

Thus, the object-distance is 30 cm.

Magnification m = v/u ; $m=\dfrac{-10\text{cm.}}{-30\text{cm.}}=\dfrac{1}{3}=+0.33$

The positive sign shows that the image is erect and virtual. The image is one-third of the size of the object.

Example 13 :

A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal? Why?

Sol. It bends towards the normal as water in denser than air.

Example 14 :

A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

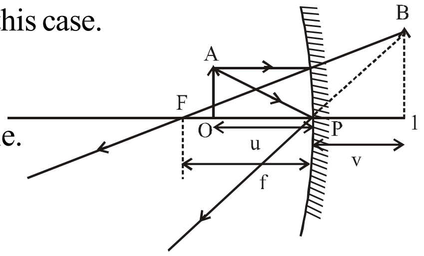
Sol. Height of the object h = + 2.0 cm; Focal length f = + 10 cm; object-distance u = –15 cm; Image-distance v = ?
Height of the image h' = ?

Since $\dfrac{1}{v}-\dfrac{1}{u}=\dfrac{1}{f}$ or $\dfrac{1}{v}=\dfrac{1}{u}+\dfrac{1}{f}$ or $\dfrac{1}{v}=\dfrac{1}{(-15)}+\dfrac{1}{10}=-\dfrac{1}{15}+\dfrac{1}{10}$; $\dfrac{1}{v}=\dfrac{-2+3}{30}=\dfrac{1}{30}$ or $v = +30$ cm.

Example 15 :

We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror ? What is the nature of the image? Is the image larger or smaller than the object? Draw a ray diagram to show the image formation in this case.

Sol. f = – 15 cm.
For getting an erect image using a concave mirror the object should be placed at a distance less than the focal length (i.e.) 15cm. from pole. Image will be virtual, enlarged are erect.



Example 16 :

One-half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object? Verify your answer experimentally. Explain your observations.

Sol. Yes, even when one half of the lens is covered with a black paper, complete image will be formed.
Take a convex lens and focus the light from a distant object on to a screen. As expected an image (sharp) is formed at a distance equal to the focal length. Cover the lower or the upper half of the lens and focus the light from the same object on to the same screen. You will be able to get a sharp image, however the brightness of the image will be less in the second case. The same effect will be seen even if the covering is with intermittent black strips.

Example 17 :

An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and nature of the image.

Sol. Given u = – 10 cm, f = + 15 cm, v = ?

Using the mirror formula $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$, we have $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{15}-\frac{1}{(-10)}$ or $\frac{1}{v}=\frac{1}{15}+\frac{1}{10}=\frac{2+3}{30}=\frac{5}{30}$

or v = 30/5 = 6cm. Hence, the image is formed at a distance of 6 cm. behind the mirror.
The image is virtual and erect.

Example 18 :

The magnification produced by a plane mirror is +1. What does this mean?

Sol. The positive (+) sign of magnification (m) indicates that the image is virtual and erect. The magnification, m = 1 indicates that the image is of the same size as the object. Thus, the magnification of +1 produced by a plane mirror means – the image formed in a plane mirror is virtual, erect and of the same size as the object.

Example 19 :

An object of size 7.0 cm is placed at 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed, so that a sharp focussed image can be obtained? Find the size and the nature of the image.

Sol. h_0 = 7.0 cm., u = – 27 cm., f = – 18 cm.

Using, $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$, we get $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-18}-\frac{1}{(-27)}=\frac{-1}{18}+\frac{1}{27}=\frac{-3+2}{54}=\frac{-1}{54}$ or v = – 54 cm.

Using $m=\frac{h_1}{h_0}=\frac{v}{u}$ we get, $h_1=h_0\frac{v}{u}=7\times\frac{-54}{-27}=14\text{cm}.$

Since $h_1 > h_0$, the image is enlarged. Since v is –ve, the image is real and inverted.

Example 20 :

A doctor has prescribed a corrective lens of power +1.5 D. Find the focal length of the lens. Is the prescribed lens diverging or converging ?

Sol. P = + 1.5 D; $f=\frac{100}{P}\text{cm}=\frac{100}{1.5}=\frac{1000}{15}=+66.67\text{ cm}=+0.67\text{m}$

So the focal length is +ve, it is convex lens. Hence it is a converging lens.

Example 21 :

A lens placed at a distance of 20 cm from an object produces a virtual image 2/3 the size of the object. Find the position of the image, kind of lens and its focal length.

Sol. Virtual image means, I is positive and it is given that I = (2/3)O. Thus, m = + 2/3

Further because u = –20 cm (given), using $m = f/(f+u)$

we get, $\frac{2}{3} = \frac{f}{f+(-20)}$ or f = – 40 cm. The f is negative, thus the lens is a concave lens. Again using $m = \frac{v}{u}$

We get $\frac{2}{3} = \frac{v}{-20}$ or $v = -\frac{2}{3} = -1.33$ cm. The virtual image is on the same side of the object.

Example 22 :

An object is placed at a distant of 1.50 m from a screen and a convex lens placed in between produces an image magnified 4 times on the screen. What is the focal length and the position of the lens.

Sol. The information given in the question ray diagram. It is given that m = I/O = – 4

Let lens is placed at a distance of x from the object. Then

u = – x, and v = (1.5 – x)

using $m = \frac{v}{u}$, we get $-4 = \frac{1.5-x}{-x}$ or 4x = 1.5 – x or 5x = 1.5. Thus, x = 0.3 metre

The lens is placed at a distance of 0.3m from the object (or 1.20m from the screen)

For focal length, we may use $m = \frac{f}{f+u}$ or $-4 = \frac{f}{f+(-0.3)}$ or – 4f + 1.2 = f or 5f = 1.2

Thus, f = 1.5/5 = 0.24. The focal length is 0.24m (or 24 cm)

Example 23 :

A convex lens of focal length 10.0 cm is placed in contact with a convex lens of 15.0 cm focal length. What is the focal length of the combination.

Sol. For combination of lenses $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{10} + \frac{1}{15} = \frac{25}{150} = \frac{1}{6}$. Therefore, f = 6 cm

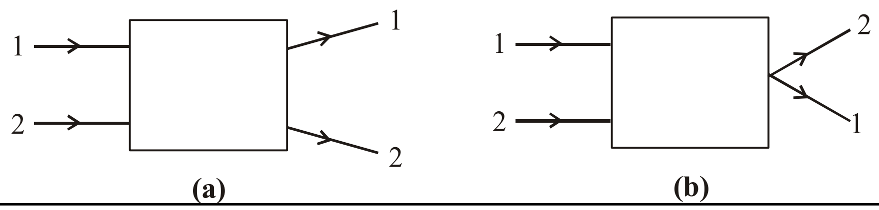
Example 24 :

Ten identical converging thin lenses, each of focal length 10 cm, are in contact. What is the power of the combined lens.

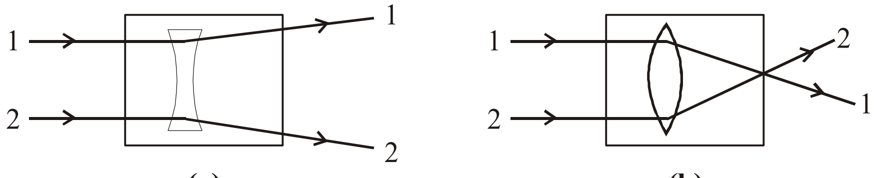
Sol. For thin lenses in contact $P = P_1 + P_2 + ... = 10\,P_1 = \frac{10 \times 100}{10} = 100$ D

Example 25 :

Figure (a) and (b) show the incident and the refracted rays through a lens kept in the box. In each case, draw the lens and complete the path of rays.



Sol. The compound ray diagrams are shown in figure (a) and (b). The incident and the refracted rays have been produced to find the point of intersection which gives the position of the lens.

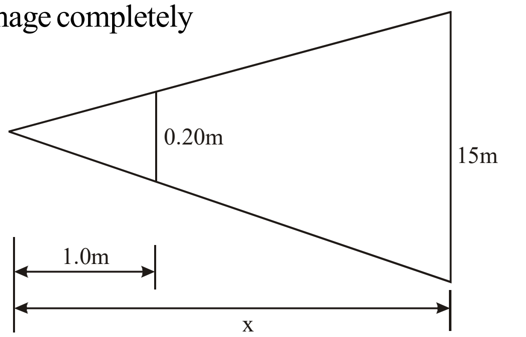


In figure (a), the incident rays 1 and 2 have diverged after refraction, so the lens is concave.
In figure (b), the incident rays 1 and 2 have converged after refraction, so the lens is convex.

Example 26 :

You hold a plane mirror 1.0m in front of your eyes and are able to see a 15m high tree behind your. If the mirror is 20.0cm. high, and the tree image completely fills the mirror, how far are you standing from the tree ?

Sol. The ray diagram can be drawn in the following way :
To find the distance x, use the two similar triangles to obtain the following ratio :



$$\frac{x}{1.0m} = \frac{15m}{0.20m} \Rightarrow x = \frac{(15m)\,(1.0m)}{0.20m} = 75m$$

Therefore, the tree is 75 – 1.0m = 74m behind you.

Example 27 :

The image of an object viewed in a concave mirror of focal length 25.0 cm appears 75.0 cm. in front of the mirror. Find the location of the object and the magnification .

Sol. We have, $\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{25.0} - \frac{1}{75.0} = 0.0267\ cm^{-1} \Rightarrow u = 37.5\ cm.$; $m = -\frac{v}{u} = \frac{-(75.0\ cm)}{37.5\ cm} = -2.00$

Example 28 :

An object is placed 35cm. in front of a convex mirror of focal length -25 cm. Find the location and magnification of the image.

Sol. We have $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-25cm} - \frac{1}{-35cm} = -0.069\ cm^{-1} \Rightarrow d_i = -15cm$

The magnification is, $m = -\frac{v}{u} = -\frac{(-15cm)}{35cm} = +0.43$

Example 29 :

A concave makeup mirror is designed so the virtual image is twice the size of the object, when the distance between the object and mirror is 15cm. (a) Determine the radius of curvature of the mirror. (b) Draw a ray diagram to scale, showing this situation.

Sol. The magnification is, $m = -\frac{v}{u} = +2$ where u is 15 cm. Therefore, $v = -2u = -3.0 \times 10^1$ cm.

Therefore, the focal length is found from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ which yields f = + 30 cm. Therefore, R = 2f = 60 cm.

QUESTION BANK

EXERCISE - 1

Q.1 A person is in a room whose ceiling and two adjacent walls are mirrors. (a) How many images are formed? (b) How many images of himself can he see ? (c) Are all the images virtual and erect ?

Q.2 A high flying bird does not cast shadow on the ground. Why?

Q.3 What is the difference between the images formed by a large and a small mirror ?

Q.4 What will happen to the image formed by a mirror if half of it is covered with a black paper ?

Q.5 Can a virtual image be photographed by a camera or projected on a screen ?

Q.6 For a plane mirror what is the focal length and the magnification ?

Q.7 The level of clear water in a clear colourless glass can be seen easily, but that of liquid helium cannot be. Why?

Q.8 Why is convex mirror preferred as rear - view mirror in cars?

Q.9 Prove the mirror formula for reflection of light from a concave mirror.

Q.10 Will the reflected rays converge at a point when a parallel beam of light lis incident on a concave mirror of large aperture ?

Q.11 If you want to see an enlarged image of your face, state whether you will use a concave mirror or a convex mirror.

Q.12 What do you mean by a normal to the reflecting surface ?

Q.13 In case of a spherical mirror, do both the sides act as reflecting surfaces ?

Q.14 For driving a car, what type of mirror would you prefer to see the traffic at your back ?

Q.15 A ray of light passes through the optical centre of a lens. Does it suffer any deviation ?

Q.16 What do you mean by a focal plane ?

Q.17 Will the focal length of the lens change when it is put in water?

Q.18 Define the principal focus of a concave mirror.

Q.19 A concave mirror produces three times magnified (enlarged) real image of an object placed at 10cm in front of it. Where is the image located ?

Q.20 Light enters from air to glass having refractive index 1.50. What is the speed of light in the glass ? The speed of light in vacuum is 3×10^8 ms^{-1}.

Q.21 The refractive index of diamond is 2.42. What is the meaning of this statement.

Q.22 Find the power of a concave lens of focal length 2m.

Q.23 An object 5.0 cm in length is placed at a distance of 20 cm. in front of a convex mirror of radius of curvature 30cm. Find the position of the image, its nature and size.

Q.24 Find the focal length of a lens of power –2.0 D. What type of lens is this ?

Q.25 What is a ray ?

Q.26 What is the radius of a plane mirror ?

Q.27 In what way is the word AMBULANCE printed infront of the hospital vans ? Why is it printed this way ?

Q.28 Why does a convex mirror has a virtual principal focus ?

Q.29 A truck uses a convex mirror as view finder whose radius of curvature is 2.0 m. A maruti car is coming behind the truck at a distance of 10m. What will be the position of the image of the car and size of the image of the car when observed by the driver of the truck through the convex mirror ?

Q.30 An object is placed 90 cm away from a concave mirror of focal length 30 cm. Find the position and the nature of the image formed.

Q.31 An object is placed at a distance of 15 cm. from a convex mirror of focal length 30 cm. Find the position and the nature of the image.

Q.32 A monochromatic ray of light strikes the surface of a transparent medium at an angle of incidence 60° and gets refracted into the medium at an angle of refraction 45°. What is the refractive index of the medium ?
[sin 60° = 0.866, sin 45° = 0.707]

Q.33 An object 3 cm in height is placed 20cm from convex lens of focal length 12 cm. Find the nature, position and height of the image.

Q.34 A real image, 4/5 size of the object is formed 18 cm from a lens. Calculate the focal length of the lens.

Q.35 A convex lens is of focal length 10 cm. what is its power ?

Q.36 A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens ? Also, find the magnification produced by the lens.

Q.37 What is the nature of light ?

Q.38 What is spherical mirror ?

Q.39 For what position of an object, a concave mirror forms a virtual and magnified image ?

Q.40 A man standing in front of a spherical mirror, finds his image having a very small head, a fat body and legs of normal size. What types of mirrors are used in the small parts ?

Q.41 What type of mirror is formed when a mercury drop falls on the earth ?

Q.42 Define refraction.

Q.43 What is a rarer medium ?

Q.44 What is a lens ?

Q.45 Define one dioptre.

Q.46 Write down the magnification formula for a lens in terms of object distance and image distance. How does it differ from the corresponding formula for a mirror ?

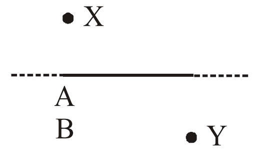
Q.47 Differentiate between virtual image of a concave mirror and of a convex mirror.

Q.48 A glass block 3.0m thick is placed over a stamp. Calculate the height through which image of stamp is raised. Refractive index of glass is 1.54.

Q.49 A postage stamp placed under a glass, appears raised by 8mm. If refractive index of glass is 1.5, calculate the actual thickness of glass slab.

Q.50 A 5 cm. tall object is placed on the principal axis of diverging lens of focal length 15 cm. and at a distance of 10 cm. from it. Find the nature, position and size of image.

Q.51 An image Y is formed of a point object X by a lens whose optic axis is AB as shown in figure. Draw a ray diagram to locate the lens and its focus. If the image Y of the object X is formed by a concave mirror (having the same optic axis AB) instead of lens, draw another ray diagram to locate the mirror and its focus . Write down the steps of construction of the ray diagrams.



Q.52 You read a newspaper because of the light that it reflects. Then why do you not see even a faint image of yourself in the newspaper ?

Q.53 The wall of a room is covered with a perfect plane mirror. Two movie films are made, one recording the movement of a man and the other of his image. From viewing the films later, can an outsider tell which is which?

Q.54 Under what condition will a concave mirror produce an erect image ? A virtual image ? An image smaller than the object ? An image larger than the object ?

Q.55 A concave spherical mirror has a radius of curvature of 40 cm. Draw ray diagrams to locate the image (if one is formed) for an object at a distance of (a) 100 cm, (b) 40cm, (c) 20 cm and (d) 10 cm. from the mirror. For each case, state whether the image is real or virtual, erect or inverted, and enlarged, reduced, or the same size as the object.

Q.56 In previous question instead of concave if convex mirror (same radius of curvature) is used what will be the answer.

Q.57 A beam of light converges to a point P. A lens is placed in the path of the convergent beam 12 cm. from P. At what point does the beam converge if the lens is (a) a convex lens of focal length 20 cm, and
(b) a concave lens of focal length 16 cm. ?

Q.58 (a) Determine the 'effective focal length' of the combination of a convex lens of focal length 30 cm. and a concave lens of focal length 20 cm. if they are placed 8 cm. apart with their principal axes coincident. Does the answer depend on which side a beam of parallel light is incident ? Is the notion of the effective focal length of this system useful at all ?

(b) An object 1.5 cm. in size is placed on the side of the convex lens in the above arrangement. The distance between the object and the convex lens is 40 cm. Determine the magnification produced by the two-lens system, and the size of the image.

Q.59 Two thin converging lenses of focal lengths 0.15m and 0.30m are held in contact with each other. Calculate power and focal length of combination.

Q.60 What is the focal length of a convex lens of focal length 30 cm. in contact with a concave lens of focal length 20 cm ? Is the system a converging or diverging lens ? Ignore thickness of the lenses.

Q.61 Two thin lenses of focal lengths + 10 cm. and – 5cm. are kept in contact. What is the focal length and power of the combination?

PASSAGE BASED QUESTIONS

Inside a substance such as glass or water, light travels more slowly than it does in a vacuum. If c denotes the speed of light in a vacuum and v denotes its speed through some other substance, then $v = c/n$
where n is a constant called the index of refraction.

To good approximation, a substance's index of refraction does not depend on the wavelength of light. For instance, when red and blue light waves enter water, they both slow down by about the same amount. More precise measurements, however, reveal that n varies with wavelength. Table presents some indices of refraction of Custon glass, for different wavelengths of visible light. A nanometer (nm) is 10^{-9} meters. In a vacuum, light travels as $c = 3.0 \times 10^8$ m/s

Table : Indices of refraction of Custon glass

Approximately colour	Wavelength in vacuum (nm)	n
yellow	580	1.500
yellow orange	600	1.498
orange	620	1.496
orange red	640	1.494

Q.62 Inside Custon glass –
(A) Orange light travels faster than yellow light (B) Yellow light travels faster than orange light
(C) Orange and Yellow light travels equally fast (D) We cannot determine which color of light travels faster

Q.63 For blue-green of wavelength 520 nm, the index of refraction of Custon glass is probably closest to –
(A) 1.49 (B) 1.50 (C) 1.51 (D) 1.52

Q.64 Which of the following phenomena happens because n varies with wavelength –
(A) A lens focuses light (B) A prism breaks sunlight into different colors
(C) Total internal reflections ensures that light travels down a fiber optic cable
(D) Light rays entering a pond change direction at the pond's surface

EXERCISE - 2

Fill in the Blanks :

Q.1 The power of a convex lens is .... and that of a concave lens is ....

Q.2 Light seems to travel in ....

Q.3 A light ray travelling obliquely from a denser medium to a rarer medium bends .... the normal. A light ray bends .... the normal when it travels obliquely from a rarer to a denser medium.

Q.4 In case of a rectangular glass slab, the refraction takes place at both .... interface and .... interface. The emergent ray is .... to the direction of incident ray.

Q.5 Power of a lens is the reciprocal of its ....

Q.6 The SI unit of power of a lens is ....

Q.7 The angle of incidence is .... to the angle of reflection.

Q.8 The reflecting surface of a spherical mirror may be curved .... or ....

Q.9 the surface of the spoon can be approximated to a .... mirror.

Q.10 The centre of the reflecting surface of a spherical mirror is a point called the ....

Q.11 The centre of curvature of a concave mirror lies in .... of it.

Q.12 Line passing through the pole and the centre of curvature of a spherical mirror is called the ....

Q.13 A ray parallel to the principal axis, after reflection, will pass through the ....

Q.14 The dentists use .... mirrors to see large images of the teeth of patients.

Q.15 A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a ....

Q.16 The degree of .... of light rays achieved by a lens is expressed in terms of its power.

Q.17 An object is placed in front of a spherical mirror. The image is found to be virtual for all positions of the object. The spherical mirror is ....

Q.18 Two immiscible transparent liquids A and B have 1.2 and 1.5 as their refractive indices (with respect to air). The refractive index of B with respect to A is ....

True-false Statements –

Q.19 The reflecting surfaces, of all types, obey the laws of reflection.

Q.20 The magnification produced by a spherical mirror is the ratio of the height of the image to the height of the object.

Q.21 Light travels in vacuum with an enormous speed of 3×10^8 ms^{-1}.

Q.22 The speed of light is different in different media.

Q.23 The refractive index of a transparent medium is the ratio of the speed of light in vacuum to that in the medium.

Q.24 The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.

Q.25 Centre of curvature is not a part of the mirror.

Q.26 Image formed by a plane mirror is always virtual and erect.

Q.27 The principal focus of a spherical mirror lies midway between the pole and centre of curvature.

Q.28 convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

Q.29 A concave lens will always give a virtual, erect and diminished image.

Q.30 A ray of light passing through the optical centre of a lens will emerge without any deviation.

Q.31 A plane mirror can form virtual images.

Q.32 An object is placed in front of a mirror and an image of it is formed at the object itself. The mirror mentioned in question is a convex mirror.

Q.33 A concave mirror can produce both real and virtual images.

Q.34 Light travels faster in glass than in air.

EXERCISE - 3

Q.1 Which one of the following materials cannot be used to make a lens?
(A) Water (B) Glass (C) Plastic (D) Clay

Q.2 The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object –
(A) Between the principal focus and the centre of curvature (B) At the centre of curvature
(C) Beyond the centre of curvature (D) Between the pole of the mirror and its principal focus.

Q.3 Where should an object be placed in front of a convex lens to get a real image of the size of the object?
(A) At the principal focus of the lens (B) At twice the focal length (C) At infinity
(D) Between the optical centre of the lens and its principal focus.

Q.4 A spherical mirror and a thin spherical lens have each a focal length of –15 cm. The mirror and the lens are likely to be – (A) both concave. (B) both convex.
(C) the mirror is concave and the lens is convex (D) the mirror is convex, but the lens is concave

Q.5 No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be
(A) plane. (B) concave. (C) convex. (D) either plane or convex.

Q.6 Which of the following lenses would you prefer to use while reading small letters found in a dictionary?
(A) A convex lens of focal length 50 cm. (B) A concave lens of focal length 50 cm.
(C) A convex lens of focal length 5 cm. (D) A concave lens of focal length 5 cm.

Q.7 One light wave is incident upon a plate of refracting index μ. Incident angle i, for which refractive & reflective waves are mutually perpendicular will be
(A) $i = 45^o$ (B) $i = \sin^{-1}(\mu)$ (C) $i = \text{cosec}^{-1}(\mu)$ (D) $i = \tan^{-1}(\mu)$

Q.8 An object is situated at a distance of f/2 from a convex lens of focal length f. Distance of image will be –
(A) + (f/2) (B) + (f/3) (C) + (f/4) (D) – f

Q.9 An object is placed 60 cm in front of a concave mirror. The real image formed by the mirror is located 30 cm in front of the mirror. What is the object's magnification?
(A) + 2 (B) –2 (C) + 0.5 (D) –0.5

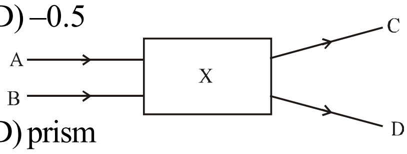
Q.10 Two plane mirrors are set at right angle and a flower is placed in between the mirrors. The number of images of the flower which will be seen is –
(A) One (B) Two (C) Three (D) Four

Q.11 A lens behaves as a converging lens in air and diverging lens in water. The refractive index of the material of the lens is –
(A) 1 (B) between 1 and 1.33 (C) 1.33 (D) greater than 1.33

Q.12 A man is 6.0 ft tall. What is the smallest size plane mirror he can use to see his entire image –
(A) 3.0 ft (B) 6.0 ft (C) 12 ft (D) 24 ft

Q.13 An object is placed 60 cm in front of a convex mirror. The virtual image formed by the mirror is located 30 cm behind the mirror. What is the object's magnification –
(A) + 2 (B) –2 (C) + 0.5 (D) –0.5

Q.14 Light rays A and B fall on optical component X and come out as C and D.
The optical component is a –
(A) concave lens (B) convex lens (C) convex mirror (D) prism



Q.15 An object is placed 20.0 cm in front of a concave mirror whose focal length is 25.0 cm. What is the magnification of the object?
(A) + 5.0 (B) – 5.0 (C) + 0.20 (D) – 0.20

Q.16 On passing through a glass slab , red light suffers a change of –
(A) wavelength (B) frequency (C) amplitude (D) both frequency and wavelength

Q.17 The focal length of a concave mirror depends upon –
(A) The radius of curvature of the mirror (B) The object distance from the mirror
(C) The image distance from the mirror (D) Both image and object distance

Q.18 An object is placed at the radius of curvature of a concave spherical mirror. The image formed by the mirror is
(A) located at the focal point of the mirror.
(B) located between the focal point and the radius of curvature of the mirror.
(C) located at the center of curvature of the mirror. (D) located out beyond the center of curvature of the mirror.

Q.19 The radius of curvature of a plane mirror is -
(A) zero (B) infinite (C) negative (D) finite

Q.20 If the refractive indices for water and diamond relative to air are 1.33 and 2.4 respectively, then the refractive index of diamond relative to water is –
(A) .55 (B) 1.80 (C) 3.19 (D) None of these

Q.21 There is an equiconvex lens of focal length of 20cm. If the lens is cut into two equal parts perpendicular to the principle axis, the focal lengths of each part will be –
(A) 20 cm. (B) 10 cm. (C) 40 cm. (D) 15 cm.

Q.22 Tick out the only wrong statements in the following –
(A) Light travels with a speed greater than that of sound (B) Light cannot travel through vacuum
(C) Light travels in a straight line (D) Light has no weight

Q.23 An object is placed 20.0 cm in front of a concave mirror whose focal length is 25.0 cm. Where is the image located?
(A) 1.0×10^2 cm in front of the mirror (B) 1.0×10^2 cm behind the mirror
(C) 5.0×10^1 cm in front of the mirror (D) 5.0×10^1 cm behind the mirror

Q.24 When viewed vertically a fish appears to be 4 meter below the surface of the lake. If the index of refraction of water is 1.33, then the true depth of the fish is –
(A) 5.32 metres (B) 3.32 metres (C) 4.32 metres (D) 6.32 metres

Q.25 Convex spherical mirrors produce images which –
(A) are always larger than the actual object (B) are always smaller than the actual object
(C) are always the same size as the actual object (D) are sometimes larger, sometimes smaller.

Q.26 Light waves –
(A) Require air or another gas to travel through (B) Require an electric field to travel through
(C) Require a magnetic field to travel through (D) Can travel through perfect vacuum

Q.27 An object is placed 40.0 cm in front of a convex mirror. The image appears 15 cm behind the mirror. What is the focal length of the mirror?
(A) + 24 cm (B) + 11 cm (C) – 11 cm (D) – 24 cm

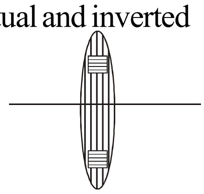
Q.28 Morning sun is not so hot as the mid day sun because –
(A) Sun is cooler in the morning (B) Heat rays travel slowly is the morning
(C) It is God gift
(D) The sun's rays travel a longer distance through atmosphere in the morning

Q.29 The image formed by a convex spherical mirror is –
(A) sometimes real, sometimes virtual (B) sometimes erect, sometimes inverted
(C) always real and inverted (D) always virtual and upright.

Q.30 When light passes from into glass it experiences a change of –
(A) Speed only (B) Wavelength and speed
(C) Frequency only (D) frequency and speed

Q.31 If a real object is placed inside the focal point of a concave mirror, the image is –
(A) real and upright (B) real and inverted (C) virtual and upright (D) virtual and inverted

Q.32 The layered lens shown below is made of two different transparent materials. A point object is placed on its axis. The object will form –



(A) one image (B) infinite images
(C) no image (D) two images

Q.33 An object is placed in front of a concave mirror of focal length 50.0 cm and a real image is formed 75 cm in front of the mirror. How far is the object from the mirror –
(A) 25 cm (B) 30 cm (C) 150 cm (D) –150 cm

Q.34 A person standing infront of a mirror finds his image smaller than himself and erect. This implies the mirror is –
(A) plane (B) concave (C) convex (D) None of the above

Q.35 A number of images of a candle flame can be seen in a thick mirror. The brightest image is –
(A) Fourth (B) Second (C) Last (D) First

Q.36 The term refraction of light is –
(A) The bending of light rays when they enter from one medium to another medium
(B) Splitting of white light into seven colours when it passes through the prism
(C) Bending of light round corners of obstacles and apertures
(D) Coming back of light from a bright smooth surface

Q.37 A ray from air enters water, then through a thick layer of glass placed below water. After passing through glass, it again comes out in air medium. Then final emergent ray will –
(A) Bend towards the normal (B) Bend away from the normal (C) Suffer lateral displacement
(D) Have the same path as if it had not passed through glass and water.

Q.38 A concave spherical mirror has a radius of curvature of 100 cm. What is its focal length –
(A) 50 cm (B) 100 cm (C) 200 cm (D) 300 cm

Q.39 Light is incident on an air-water interface at an angle of 25° to the normal.. What angle does the refracted ray make with the normal –
(A) 19° (B) 34° (C) 25° (D) 90°

Q.40 Light reflected from a boundary between an unknown substance and air is seen to become 100% polarized when the angle of incidence is 62.0°. What is the index of refraction of the unknown substance?
(A) 1.88 (B) 1.13 (C) 2.14 (D) 0.532

Q.41 A converging lens has a focal length of 15 cm. An object is placed 9.0 cm from the lens. Describe the image formed
(A) real, upright, enlarged (B) real, inverted, reduced in size
(C) virtual, inverted, reduced in size (D) virtual, upright, enlarged

Q.42 An object is placed 10.0 cm from a diverging lens which forms an image 6.5 cm from the lens. What is the focal length of the lens? Include the sign.
(A) + 3.9 cm (B) – 16.5 cm (C) – 21.2 cm (D) – 18.6 cm

Q.43 Under what conditions does a diverging lens form a virtual image of a real object –
(A) Only if $u > f$. (B) Only if $u < f$. (C) Only if $u = f$
(D) A diverging lens always forms a virtual image of a real object.

Q.44 A convex lens of focal length 25 cm receives light from the sun. A diverging lens of focal length – 12 cm is placed 37 cm to the right of the converging lens. Where is the final image located relative to the diverging lens?
(A) 6 cm to the left (B) 25 cm to the left (C) At infinity (D) 12 cm to the right

Q.45 A lens produces a enlarged, virtual image. What kind of lens is it?
(A) converging (B) diverging
(C) It could be either diverging or converging. (D) None

Q.46 A camera lens focuses light from a 12.0 m tall building located 35.0 m away on film 50.0 mm behind the lens. How tall is the image of the building on the film?
(A) 17.1 mm (B) 7.00 mm (C) 2.50 cm (D) 1.25 mm

Q.47 Four students reported the following observation tables for the experiment, to trace the path of a ray of light passing through a glass slab for different angles of incidence. The observations, likely to be correct are those of student.

i	r	e
30°	40°	30°
40°	50°	40°
50°	50°	50°

I

i	r	e
30°	20°	30°
40°	30°	40°
50°	40°	50°

II

i	r	e
30°	20°	40°
40°	30°	50°
50°	40°	60°

III

i	r	e
30°	20°	20°
40°	30°	30°
50°	40°	40°

IV

(A) I (B) II (C) III (D) IV

Q.48 In an experiment to determine the focal length of a concave lens, a student obtained the image of a distant window on the screen. To determine the focal length of the lens, she/he should measure the distance between the
(A) lens and the screen only (B) lens and the window only
(C) screen and the window only
(D) screen and the lens and also between the screen and the window

Q.49 On the basis of experiment 'to trace the path of a ray of light passing through a rectangular glass slab' four students arrived at the following interpretations :

I. Angle of incidence is greater than the angle of emergence.

II. Angle of emergence is less than the angle of refraction.

III. Emergent ray is parallel to the incident ray. IV. Emergent ray is parallel to the refracted ray.

The correct interpretation is that of the student.

(A) I (B) II (C) III (D) IV

Q.50 Light waves

(A) are mechanical waves (B) are electromagnetic waves

(C) travel with the same velocity in all media (D) requires a material medium for their propagation

Q.51 Virtual images of object of the same size are formed by –

(A) a concave mirror (B) a convex mirror (C) a plane mirror (D) all the above

Q.52 Two plane inclined mirrors form 5 images by multiple reflection. The angle of inclination is –

(A) 90° (B) 60° (C) 45° (D) 30°

Q.53 A bright × (cross) mark is made on a sheet of white paper. Over the white paper a rectangular glass-slab of thickness 3 cm is placed. On looking through, the image of the mark appears above the mark. It is below the upper surface of the slab by –

(A) 2.5 cm (B) 1.5 cm (C) 2 cm (D) 1.75 cm.

Q.54 The critical angle of a transparent medium denser than air

(A) increases with its refractive index (B) decreases with its refractive index

(C) is independent of its refractive index (D) None of these

Q.55 Orange, blue and yellow are 3 of the colours formed by a prism. Their order according to increasing deviation is–

(A) blue, orange, yellow (B) yellow, blue, orange

(C) blue, yellow, orange (D) orange, yellow, blue

Q.56 Images formed by an object placed between two plane mirrors whose reflecting surfaces make an angle of 90° with one another lie on a –

(A) Straight line (B) Zig-zag curve (C) Circle (D) Ellipse

Q.57 A diver in a swimming pool wants to signal his distress to a person lying on the edge of the pool by flashing his water-proof torch –

(A) He must direct the beam of light vertically upwards

(B) He must direct the beam horizontally

(C) He must direct the beam at an angle to the vertical which is slightly lesser than the critical angle

(D) He must direct the beam at an angle to the vertical which is slightly greater than the critical angle

Q.58 The absolute refractive index of a medium depends on –

(A) nature of the medium only (B) wavelength of light only

(C) temperature of the medium only (D) all of the above

Q.59 Mark the wrong statement –

(A) Refractive index decreases with increase in temperature

(B) Refractive index depends on the angle of incidence

(C) Foucault demonstrated experimentally that the speed of light in air is more than that in water

(D) Polarization of light was discovered by Malus

Q.60 Two plane mirrors are inclined at an angle θ. A ray of light is incident on one mirror and is then reflected from the other mirror. Then the angle between the first ray and the final ray will be –

(A) θ (B) 2θ (C) between θ and 2θ (D) $> 2\theta$

Q.61 In comparison to the case when a ray of light travels from glass to air, the critical angle for total internal reflection of light when a ray of light travels from glass to water is –

(A) greater (B) smaller (C) same (D) nothing can be predicted

Q.62 A glass slab is placed in the path of a beam of convergent light, then the point of convergence of light –
(A) moves towards the glass slab (B) moves away from the glass slab
(C) remains at the same point (D) undergoes a lateral shift

Q.63 Mark the wrong statement about a virtual image –
(A) A virtual image can be photographed (B) A virtual image can be seen
(C) A virtual image can be photographed by exposing a film at the location of the image
(D) A virtual image may be diminished or enlarged in size in comparison to an object.

Q.64 A real image is formed by a convex mirror when the object is placed at –
(A) infinite (B) between center of curvature and focus
(C) between focus and pole (D) none of the above

Q.65 A virtual image is formed by a concave mirror when the object is placed between –
(A) infinity and center of curvature (B) center of curvature and focus
(C) focus and the pole (D) All of the above

Q.66 Which of the following are used in a Kaleidoscope –
(A) Plane mirrors (B) concave (C) convex mirrors (D) all of the above

Q.67 When a spherical convex lens made up of glass is immersed in water, its focal length –
(A) decreases (B) does not change (C) increases (D) none of the above

Q.68 Out of the following –
(a) pole (b) focus (c) radius of curvature (d) principal axis
for a spherical mirror, the quantities that do not depend on whether the rays are paraxial or not, are –
(A) a, b, c and d (B) only a, b and c (C) only a, c and d (D) only a and d

Q.69 A person standing at some distance from a mirror finds his image erect, virtual and of the same size. Then the mirror is possibly–
(A) plane mirror (B) concave mirror
(C) plane or concave mirror (D) plane or concave or convex mirror

Q.70 Concave mirrors are used –
(A) as reflectors in lamps (B) as objectives in reflecting type of astronomical telescope
(C) in Opthalmoscope (D) in all of the above

Q.71 Mark the wrong statement –
(A) A convex mirror produces an erect image
(B) A convex mirror always produces an erect image of an erect object
(C) A convex mirror always produces a diminished in size image
(D) A convex mirror is used as a shaving mirror

Q.72 When a clock is viewed in a mirror, the needles exhibit a time which appears to be 8.20. Then the actual time will be–
(A) 4.40 (B) 3.40 (C) 8.20 (D) 3.20

Q.73 When a light ray enters a refracting medium it is found that the magnitude of the angle of refraction is equal to half the angle of reflection. If μ is the refractive index of the medium, then the angle of incidence is –
(A) $2\sin^{-1}(\mu/2)$ (B) $2\cos^{-1}(\mu/2)$ (C) $\cos^{-1}(\mu/2)$ (D) $\sin^{-1}(\mu/2)$

Q.74 A container of depth H is filled with two immiscible transparent liquids of refractive index μ_1 and μ_2 respectively. The depth of each liquid is H/2. When viewed from above, the apparent depth of the vessel is –
(A) $\frac{H}{2\mu_1}+\frac{H}{2\mu_2}$ (B) $\frac{H}{2\mu_1}-\frac{H}{2\mu_2}$ (C) $\frac{H}{2\mu_1}+\frac{H\mu_1}{2\mu_2}$ (D) $\frac{H}{2\mu_1}-\frac{H\mu_1}{2\mu_2}$

Q.75 A short linear object of length L lies along the axis of a concave mirror of focal length f, at a distance u from the pole of the mirror. Then the size of the image is approximately equal to –
(A) $L\left(\frac{u-f}{f}\right)^{1/2}$ (B) $L\left(\frac{f}{u-f}\right)^{1/2}$ (C) $L\left(\frac{u-f}{f}\right)$ (D) $L\left(\frac{f}{u-f}\right)^{2}$

Q.76 For a concave mirror of focal length 20 cm. if the object is at a distance of 30 cm. from the pole, then the nature of the image and magnification will be –

(A) real and –2 (B) virtual and –2 (C) real and +2 (D) virtual and +2

Q.77 An object is placed xf to the right of the focus of a concave spherical mirror of focal length f. Then the image will be formed at a distance of –

(A) xf to the right of the focus (B) xf to the left of the focus
(C) f/x to the right of the focus (D) f/x to the left of the focus

Q.78 A lens forms a real image of an object on a screen placed at a distance of 100 cm. from the object. If the lens is moved by 20 cm. towards the screen, another image of the object is formed on the screen. Then the focal length of the lens is –

(A) 12 cm. (B) 24 cm. (C) 50/3 cm. (D) 48 cm.

Q.79 A parallel beam of light falls normally on the plane surface of a planoconvex lens of refractive index 1.5. If the radius of the curved surface of the lens is 20 cm, the beam will be focused at a distance from the lens given by –

(A) 10 cm. (B) 15 cm. (C) 25 cm. (D) 40 cm.

Q.80 In order to obtain a real image of magnification 2 using a converging lens of focal length 20 cm, where should an object be placed–

(A) – 30 cm. (B) 30 cm. (C) – 50cm. (D) 50 cm.

Q.81 An object placed 10 cm in front of a lens has an image 20 cm. behind the lens. What is the power of the lens (in dioptre) ?

(A) 1.5 (B) 3.0 (C) –5.0 (D) +15.0

Q.82 In vacuum the speed of light does not depend on –

(A) Wavelength (B) Frequency (C) Intensity (D) Speed of observer

Q.83 When light passes from air to water which of the following changes –

(A) Wavelength (B) Velocity (C) Frequency (D) Colour

Q.84 In case of reflection by a plane-mirror, which of the following statements are not correct –

(A) It can never give real image (B) It can never give inverted image
(C) It changes left into right (D) It changes front into back

Q.85 If two mirrors are inclined to each other at 90°, the image seen may be –

(A) One (B) Two (C) Three (D) Four

Q.86 In case of three plane-mirrors meeting at a point to form a corner of a cube, if incident light suffers one reflection on each mirror–

(A) The emergent ray is antiparallel to incident one
(B) The emergent ray is perpendicular to incident one
(C) The emergent ray is in phase with incident one
(D) The emergent ray is in opposite phase with incident one

Q.87 A plane mirror, reflecting a ray of incident light, is rotated through an angle θ about an axis through the point of incidence in the plane of the mirror perpendicular to the plane of incidence, then –

(A) the reflected ray does not rotate (B) the reflected ray rotates an angle θ
(C) the reflected ray rotates an angle 2θ (D) the incident ray is fixed

Q.88 A beaker containing liquid is placed on the table underneath a microscope which can be moved along a vertical scale. The microscope is focussed, through the liquid onto a mark on the table when the reading on the scale is a. It is next focussed on the upper of liquid and the reading is b. More liquid is added and the observations are repeated. The corresponding readings are c and d. The refractive index of liquid is –

(A) $\frac{d-b}{d-c-b+a}$ (B) $\frac{d-c-b+a}{d-b}$ (C) $\frac{b-d}{d-c-b+a}$ (D) $\frac{d-c-b+a}{b-d}$

Q.89 Five images are formed, if two plane-mirrors are inclined to each other at an angle of –

(A) 60° (B) 70° (C) 72° (D) 90°

Q.90 Out of the following which statements are correct –

(A) Two plane mirrors are inclined to each other at an angle of 60°. If a ray of light incident on the first mirror is parallel to the second mirror, it is reflected from the second mirror parallel to the first mirror.

(B) A bird flying high up in the air does not cast a shadow on the ground because layers of atmosphere are dense.

(C) If a ray reflected successively from two plane mirrors inclined at a certain angle undergoes a deviation of 300°, then the number of images observable is 11.

(D) A clock indicates a time of 3.25. On seeing it in a plane mirror, the time appears as 8.35.

Q.91 When a plane mirror is placed horizontally on level ground at a distance of 60 m from the foot of a tower, the top of the tower and its image in the mirror subtend an angle of 90° at the eye. The height of the tower is –

(A) 30 m (B) 60 m (C) 90 m (D) 120 m

Q.92 Which of the following letters do not suffer lateral inversion

(A) HGA (B) HOX (C) VET (D) YUL

Q.93 N plane mirrors are arranged parallel to one another each moving with a speed v. The linear velocity of the Nth image of a point object placed in front of the first mirror is–

(A) Nv (B) Nv^2 (C) Nv^3 (D) 2Nv

Q.94 In case of concave mirror, the minimum distance between a real object and its real image is –

(A) f (B) 2f (C) 4f (D) zero

Q.95 The image formed by a convex mirror of a real object is larger than the object –

(A) when u < 2f (B) when u > 2f (C) for all values of u (D) for no value of u

Q.96 A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror and C its centre of curvature A point object is placed at C. It has a real image, also located at C. If the mirror is now filled with water, the image will be –

(A) real, and will remain at C (B) real, and located at a point between C and ∞.

(C) virtual, and located at a point between C & O (D) real, and located at a point between C and O

Q.97 In case of a curved mirror if the distance of object (u) and image (v) are measured from the pole and a graph is plotted between (1/u) and (1/v), the graph is a –

(A) Straight and passing through the origin (B) Straight line making an intercept with both u and v axes

(C) Parabola (D) Hyperbola

Q.98 A concave mirror of focal length f produces an image n times the size of the object. If the image is real then the distance of the object from the mirror is –

(A) $(n-1)\,f$ (B) $\frac{(n-1)}{n}f$ (C) $\frac{(n+1)}{n}f$ (D) $(n+1)\,f$

Q.99 In a concave mirror if x_1 and x_2 are the distances of object and its image respectively from the focus, then the focal length of the mirror is –

(A) x_1x_2 (B) $\sqrt{x_1x_2}$ (C) $(x_1+x_2)/2$ (D) $x_1x_2/(x_1+x_2)$

Q.100 The index of refraction of diamond is 2.0, velocity of light in diamond in cm/second is approximately –

(A) 6×10^{10} (B) 3.0×10^{10} (C) 2×10^{10} (D) 1.5×10^{10}

Q.101 Light travels through a glass plate of thickness t and having refractive index n. If c is the velocity of light in vacuum, the time taken by the light to travel this thickness of glass is –

(A) t/nc (B) tnc (C) nt/c (D) tc/n

Q.102 Light takes 8 min 20 sec. to reach from sun on the earth. If the whole atmosphere is filled with water, the light will take the time (${}_a\mu_w = 4/3$)

(A) 8 min 10 sec. (B) 8 min. (C) 6 min. 11 sec. (D) 11 min. 6 sec.

Q.103 The length of the optical path of two media in contact of length d_1 and d_2 of refractive indices μ_1 and μ_2 respectively, is –

(A) $\mu_1 d_1 + \mu_2 d_2$ (B) $\mu_1 d_2 + \mu_2 d_1$ (C) $\frac{d_1 d_2}{\mu_1 \mu_2}$ (D) $\frac{d_1 + d_2}{\mu_1 \mu_2}$

Q.104 An under water swimmer is at a depth of 12 m below the surface of water. A bird is at a height of 18m from the surface of water, directly above his eyes. For the swimmer the bird appears to be at a distance from the surface of water equal to (Refractive index of water is 4/3)

(A) 24m (B) 12m (C) 18m (D) 9m

Q.105 A ray of light is incident on a transparent glass slab of refractive index 1.62. The reflected and the refracted rays are mutually perpendicular. The angle of incidence is –

(A) 58.3° (B) 50° (C) 35° (D) 30°

Q.106 A microscope is focussed on a coin lying at the bottom of a beaker. The microscope is now raised up by 1cm. To what depth sound the water be poured into the beaker so that coin is again in focus ? (Refractive index of water is 4/3)

(A) 1 cm. (B) 4/3 cm. (C) 3 cm. (D) 4 cm.

Q.107 Refractive index of air is 1.0003. The correct thickness of air column which will have one more wavelength of yellow light (6000 Å) than in the same thickness in vacuum is –

(A) 2 mm. (B) 2 cm. (C) 2 m. (D) 2 km.

Q.108 A glass slab of thickness 3cm. and refractive index 3/2 is placed on ink mark on a piece of paper. For a person looking at the mark at a distance 5.0 cm. above it, the distance of the mark will appear to be –

(A) 3.0 cm. (B) 4.0 cm. (C) 4.5 cm. (D) 5.0 cm.

Q.109 A thin lens has focal length f and its aperture has diameter d. It forms an image of intensity I. Now, the central part of the aperture up to diameter (d/2) is blocked by an opaque paper. The focal length and image intensity will change to–

(A) (f/2) and (I/2) (B) f and (I/4) (C) (3f/4) and (I/2) (D) f and (3I/4)

Q.110 For image magnification one needs at least –

(A) two convex lens (B) one concave and one convex lens
(C) one concave lens (D) one convex lens

Q.111 An object is located at 10 cm. in front of a convex lens of focal length 12 cm. The image is located at –

(A) 60 cm. at the back of the lens (B) 60 cm. in front of the lens
(C) 5.45 cm. at the back of the lens (D) 5.45 cm. in front of the lens

Q.112 The sun subtends an angle of (1/2)° at the surface of the earth. A converging lens of focal length 100 cm. is used to obtain an image of the sun on a screen. The diameter of the image formed is about –

(A) 1 mm (B) 9 mm. (C) 18 mm. (D) 50 mm.

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**.

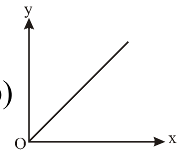
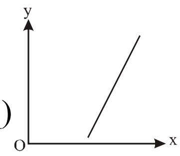
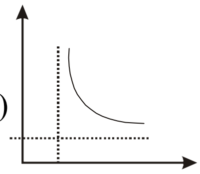
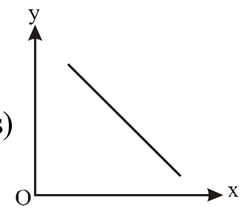
Q.1 Match the following :

Column I	Column II
(A) Power of convex mirror	(p) Positive power
(B) Power of concave mirror	(q) Negative power
(C) Power of plane mirror	(r) Zero power
(D) Power of convex lens	(s) Infinite power

Q.2 A convex lens (f) forms an image on a screen Considering the object to be at the zero mark in a scale, match the following.

Column I	Column II
(A) Image	(p) Moves the image of infinite object further away
(B) Additional lens in contact	(q) Not unique as lens is moved between object and source.
(C) Reduction in refractive index	(r) Virtual for screen position at a distance <4f from the object.
(D) Slicing the lens to have one plane and another convex surface	(s) Object at d forms real image further nearer plano-convex lens.

Q.3 The graphs given apply to convex lens of focal length f, producing a real image at a distance v from the optical centre when self luminous object is at distance u from the optical centre. The magnitude of magnification is m. Identify the following graphs with the first named quantity being plotted along y-axis.

Column I	**Column II**
(A) v against u	(p) 
(B) $\frac{1}{v}$ against $\frac{1}{u}$	(q) 
(C) m against v	(r) 
(D) (m + 1) against $\frac{v}{f}$	(s) 

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.4 **Statement 1 :** A point object is placed at a distance of 26 cm. from a convex mirror of focal length 26cm. The image will form at infinity.
Statement 2 : For above given system the equation $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ gives $v=\infty$.

Q.5 **Statement 1 :** When a concave mirror is held under water, its focal length will increase.
Statement 2 : The focal length of a concave mirror is independent of the medium in which it is placed.

Q.6 **Statement 1 :** A convex mirror is used as a driver's mirror.
Statement 2 : Because convex mirror's field of view is large and images formed are virtual, erect and diminshed.

Q.7 **Statement 1 :** In visible light $\mu_r < \mu_v$
Statement 2 : This follows from cauchy's formula $\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$

Q.8 **Statement 1 :** Keeping a point object fixed, if a plane mirror is moved, the image will also move.
Statement 2 : In case of a plane mirror, distance of object and Its image is equal from any point on the mirror.

Q.9 **Statement 1 :** When the object moves with a velocity $\vec{v}$, its image in the plane mirror moves with a velocity of $-2\vec{v}$.
Statement 2 : The minimum height of the mirror to be required to see the full image of man of height h is h/2.

Q.10 **Statement 1 :** If both plane mirror and object are moved through a distance x, then the image moves through a distance 3x.
Statement 2 : When the object is fixed and plane mirror is moved through a distance x. Then the image is also moves through the distance 2x.

Q.11 **Statement 1 :** As the temperature of a medium increases the refractive index decreases.
Statement 2 : When a ray travels from vacuum to a medium, then μ is known as absolute refractive index of the medium. ($\mu_{vacuum} = 1$)

Q.12 **Statement 1 :** If a spherical mirror is dipped in water, its focal length remains unchanged.
Statement 2 : A laser light is focused by a converging lens. There will be a significant chromatic aberration.

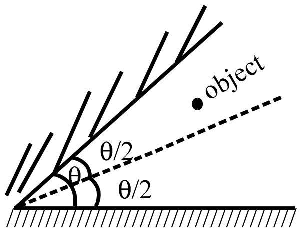
Q.13 **Statement 1 :** A virtual image cannot be photographed.
Statement 2 : Only real objects are photographed

Q.14 **Statement 1 :** The small object, to be seen in a microscope, is kept within the focus of its objective.
Statement 2 : In this case, the image formed by the objective is nearer to the eyepiece.

Q.15 **Statement 1 :** A point source of light is placed at a distance of 2f from a converging lens of focal length f. The intensity of the other side of the lens is maximum at distance 2f.
Statement 2 : In chromatic aberration the rays of different colours fail to converge at a point after going through a converging lens.

Q.16 **Statement 1 :** Light rays retrace their path when their direction is reversed (Law of reversibility of light rays)
Statement 2 : For the refraction light, water is denser than air, but for the refraction of sound, water is rarer than air.

Q.17 **Statement 1 :** If the angle between the two plane mirror is 72° and the object is asymmetrically placed between the two mirrors, then 5 images of the object will be formed.



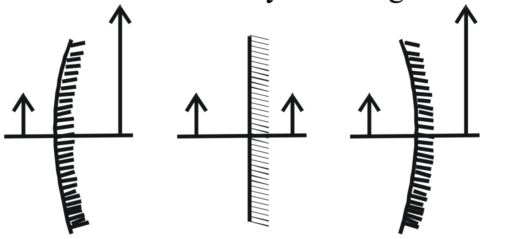
Statement 2 : For given system of mirror the total number of images formed due to successive reflection is equal to either $\frac{360°}{\theta}$ or $\frac{360°}{\theta} - 1$ accordingly as $\frac{360°}{\theta}$ is odd or even respectively.

Q.18 **Statement 1 :** Red light travels faster in glass than green light.
Statement 2 : The refractive index of glass is less for red light than for green light.

Q.19 **Statement 1 :** Speed of light in glass of $\mu = 1.5$ is 2×10^8 m/sec
Statement 2 : According to dual theory, light has particle nature and wave nature simultaneously.

Q.20 **Statement 1 :** As light travels from one medium to another, the frequency of light does not change.
Statement 2 : Because frequency is the characteristic of source.

Q.21 **Statement 1 :** We can decide the nature of a mirror by observing the size of erect image in the mirror (see figure)



Statement 2 : The minimum distance between a real object and its real image in a concave mirror is zero.

EXERCISE - 5

PREVIOUS YEARS COMPETITION PROBLEMS

Q.1 A beam of monochromatic light is refracted from vacuum into a medium of refractive index 1.5. The wavelength of refracted will be–
(A) dependent on intensity of refracted light (B) same
(C) smaller (D) larger

Q.2 Time taken by the sunlight to pass through a window of thickness 4 mm. whose refractive index is 1.5 is
(A) 2×10^{-8} second (B) 2×10^{8} second (C) 2×10^{-11} second (D) 2×10^{11} second

Q.3 Ray optics is valid, when characteristic dimensions are –
(A) of the same order as the wavelength of light (B) much smaller than the wavelength of light
(C) of the order of one millimeter (D) much larger than the wavelength of light

Q.4 The focal length of the convex lens depends upon –
(A) frequency of the light ray (B) wavelength of the light ray
(C) both (A) and (B) (D) None of these

Q.5 Focal length of a convex lens will be maximum for –
(A) blue light (B) yellow light (C) green light (D) red light

Q.6 If a convex lens of focal length 80 cm. and a concave lens of focal length 50 cm. are combined together, what will be their resulting power –
(A) + 6.5 D (B) – 6.55 D (C) + 7.5 D (D) – 0.75 D

Q.7 The refractive index of water is 1.33. What will be the speed of light in water ?
(A) 3×10^{8} m/s (B) 2.25×10^{8} m/s (C) 4×10^{8} m/s (D) 1.33×10^{8} m/s

Q.8 Light travels through a glass plate of thickness t and having a refractive index μ. If c is the velocity of light in vacuum, the time taken by light to travel this thickness of glass is –
(A) $t\mu c$ (B) tc/μ (C) $t/\mu c$ (D) $\mu t/c$

Q.9 Power of a lens is – 4D and for second lens, power is +2D, the total power for the couple is –
(A) –2D (B) 6D (C) –6D (D) –8D

Q.10 A ray of light from air is incident in water then which property of light will not change in water –
(A) velocity (B) frequency (C) amplitude (D) colour

Q.11 When a mirror is rotated through an angle θ, the reflected ray from it turns through an angle of –
(A) θ (B) $\theta/2$ (C) 2θ (D) 0

Q.12 The index of refraction of diamond is 2.0. The velocity of light in diamond in cm/s is –
(A) 6×10^{10} (B) 2×10^{10} (C) 3×10^{10} (D) 1.5×10^{10}

Q.13 Two thin lenses of focal length f_1 and f_2 are placed coaxially in contact. The combination acts as a single lens of focal length is –

(A) $\frac{f_1 f_2}{(f_1 + f_2)}$ (B) $\sqrt{f_1 f_2}$ (C) $\frac{(f_1 + f_2)}{f_1 f_2}$ (D) $\frac{f_1 + f_2}{2}$

Q.14 A convex lens of focal length 0.5 m and concave lens of focal length 1m are combined. The power of resulting lens will be

(A) 1 D (B) –1 D (C) 0.5 D (D) –0.5 D

Q.15 A concave lens and a convex lens have same focal length of 20 cm. and both put in contact this combination is used to view an object 5 cm. long kept at 20 cm. from the lens combination. As compared to object the image will be –

(A) Magnified and inverted (B) Reduced and erect

(C) Of the same size and erect (D) Of the same size and inverted

Q.16 The focal length of convex lens is 30 cm. and the size of image is quarter of the object, then the object distance is –

(A) 150 cm. (B) 60 cm. (C) 30 cm. (D) 40 cm.

Q.17 Radius of curvature of convex mirror is 40 cm. and the size of object is twice as that of image, then the image distance is –

(A) 10 cm. (B) 20 cm. (C) 40 cm. (D) 30 cm.

Q.18 A ray of light is incident on the surface of separation of a medium with the velocity of light at an angle 45° and is refracted in the medium at an angle 30°. What will be the velocity of light in the medium –

(A) 1.96×10^8 m/s (B) 2.12×10^8 m/s (C) 3.18×10^8 m/s (D) 3.33×10^8 m/s

Q.19 The speed of a wave in a medium is 760 m/s. If 3600 waves are passing through a point, in the medium in 2 minutes, then its wavelength is –

(A) 13.8 m (B) 25.3 m (C) 41.5 m (D) 57.2 m

Q.20 The combined power of two lenses is contact is +10D. When they are separated by 20 cm, their power becomes +6.25 D. The powers of these lenses are –

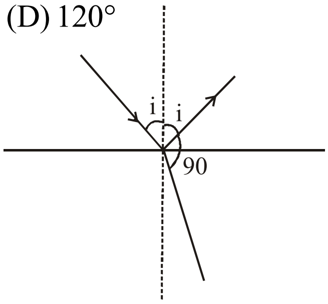
(A) –3.5 D, +6.5 D (B) –7.5 D, +2.5 D (C) +7.5 D, +2.5 D (D) +9.0 D, +1.0 D

Q.21 To get three images of a single object, one should have two plane mirrors at an angle of –

(A) 30° (B) 60° (C) 90° (D) 120°

Q.22 A ray of light strikes a transparent surface from air at an angle θ. If the angle between the reflected and refracted ray is a right angle, the refractive index of the other surface is given by –

(A) $\mu = 1/\tan\theta$ (B) $\mu = \tan^2\theta$ (C) $\mu = \sin\theta$ (D) $\mu = \tan\theta$

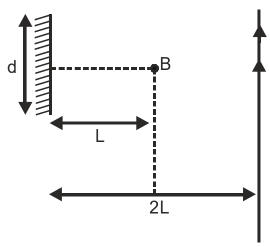


Q.23 A tall man of height 6 feet, want to see his full image. Then required minimum length of the mirror will be-

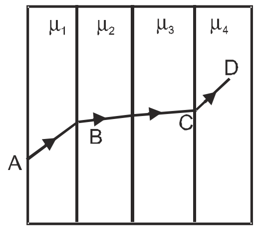
(A) 12 feet (B) 3 feet (C) 16 feet (D) Any length

Q.24 A point source of light B, placed at a distance L in front of the centre of a mirror of width d, hangs vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance 2L from it as shown. The greatest distance over which he can see the image of the light source in the mirror is–

(A) d/2 (B) d (C) 2d (D) 3d



Q.25 A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3, and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have:

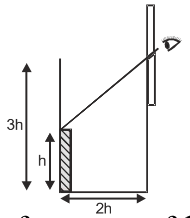


(A) $\mu_1 = \mu_2$ (B) $\mu_2 = \mu_3$ (C) $\mu_3 = \mu_4$ (D) $\mu_4 = \mu_1$

Q.26 In order to obtain image on wall of a bulb at a distance d from the wall a convex lens is placed between bulb and wall. Focal length of lens will be -

(A) d/2 (B) Between d/2 & d/4 (C) More then d/2 (D) Less than d/4

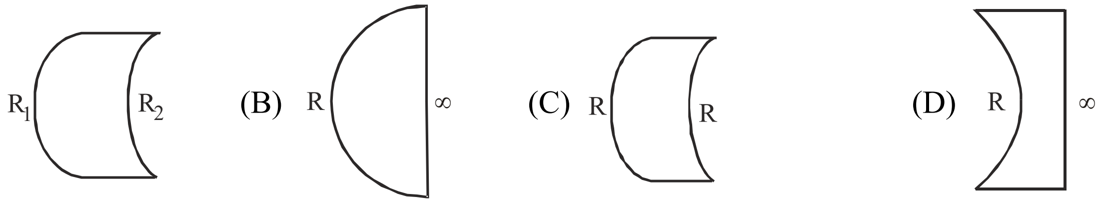
Q.27 An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is–



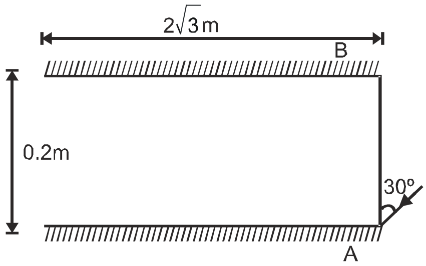
(A) 5/2 (B) $\sqrt{5/2}$ (C) $\sqrt{3/2}$ (D) 3/2

Q.28 Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams.

(A) (B) (C) (D)



Q.29 Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle 30º at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is–



(A) 30 (B) 31 (C) 32 (D) 34

Q.30 An object is placed 12 cm to the left of a converging lens of focal length 8 cm. Another converging lens of 6 cm focal length is placed at a distance of 30 cm to the right of the first lens. The second lens will produce–

(A) a virtual enlarged image (B) no image
(C) a real inverted image (D) a real enlarged image

Q.31 A ray of light is incident at the glass-water interface at an angle i, it emerges finally parallel to the surface of water, then the value of μ_g would be:

(A) (4/3) sin i (B) 1/sin i (C) 4/3 (D) i

Q.32 If two mirrors are kept at 60º to each other, then the number of images formed by them is

(A) 5 (B) 6 (C) 7 (D) 8

Q.33 A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm. below the surface, the radius of this circle in cm. is –

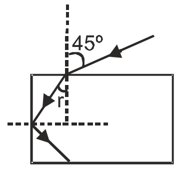
(A) $36\sqrt{5}$ (B) $4\sqrt{5}$ (C) $36\sqrt{7}$ (D) $36/\sqrt{7}$

Q.34 A cut diamond sparkles because of its –

(A) Hardness (B) High refractive index
(C) Emission of light by the diamond (D) Absorption of light by the diamond

Q.35 Consider telecommunication through optical fibres. Which of the following statement is not true –
(A) Optical fibres can be of graded refractive index
(B) Optical fibres have extremely low transmission loss
(C) Optical fibres are subject to electromagnetic interference from outside
(D) Optical fibres may have homogeneous core with a suitable cladding

Q.36 What will be refractive index of glass for total internal reflection –

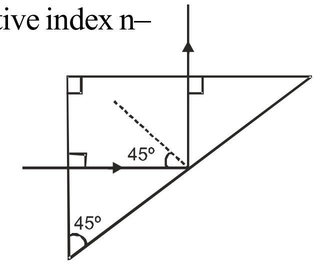


(1) $\frac{\sqrt{3}+1}{2}$ (2) $\frac{\sqrt{5}+1}{2}$

(3) $\frac{\sqrt{2}+1}{2}$ (4) $\sqrt{\frac{3}{2}}$

Q.37 Which of the following is used in optical fibres ?
(1) total internal reflection (2) scattering (3) diffraction (4) refraction

Q.38 A light ray is incident perpendicularly to one face to a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n–



(1) $n < \frac{1}{\sqrt{2}}$ (2) $n > \sqrt{2}$

(3) $n > \frac{1}{\sqrt{2}}$ (4) $n < \sqrt{2}$

EXERCISE - 6

PREVIOUS YEARS BOARD QUESTIONS

Q.1 How does the frequency of a beam of ultra violet light change when it goes from air into glass ?
Q.2 What is the focal length of a plane mirror ?
Q.3 When light undergoes refraction at the surface of separation of two media, what happens to its wavelength ?
Q.4 How does a focal length of convex lens change if monochromatic red light is used instead of monochromatic blue light ?
Q.5 A concave mirror is placed in water. Will there be any change in focal length ? Give reason.
Q.6 The image of an object formed by a lens on the screen is not in sharp focus. Suggest a method to get clear focussing of the image on the screen without disturbing the position of the object, the lens or the screen.
Q.7 Refractive index of glass for light of yellow, green and red colours are μ_y, μ_g and μ_r respectively. Rearrange these symbols in the increasing order of values.
Q.8 Give the ratio of velocities of light rays of wavelengths 4000 Å and 8000 Å.
Q.9 An object is placed at a distance of 12 cm in front of a concave mirror. It forms a real image four times larger than the object. Calculate the distance of the image from the mirror.
Q.10 With respect to air, the refractive index of ice is 1.31 arid that of rock salt is 1.54. Calculate the refractive index of rock salt with respect to ice.
Q.11 Light enters from air into glass plate which has a refractive index of 1.50. Calculate the speed of light in glass. The speed of light in air is 3×10^8 ms^{-1}.
Q.12 A concave mirror and a convex lens are held separately in water. What changes, if any, do you expect in the focal length of either?
Q.13 If the wavelength of incident light on a (i) concave mirror and (ii) convex lens is increased, how will the focal length of each of these change ?
Q.14 Use the mirror formula to show that for an object lying between the pole and focus of a concave mirror, the image formed is always virtual in nature.

Q.15 A concave lens has focal length of 20 cm. At what distance from the lens a 5 cm tall object be placed so that it forms an image at 15 cm from the lens ? Also calculate the size of the image formed.

Q.16 An object 50 cm tall is placed on the principal axis of a convex lens. Its 20 cm tall image is formed on the screen placed at a distance of 10 cm from the lens. Calculate the focal length of the lens.

Q.17 An object 20 cm tall is placed on the principal axis of a convex lens. Its 30 cm tall image is formed on the screen placed at a distance of 10 cm from the lens. Calculate the focal length of the lens.

Q.18 An object 30 cm tall is placed on the principal axis of a convex lens. Its 10 cm tall inverted image is formed on the screen placed at a distance of 15 cm from the lens. Calculate the focal length of the lens.

Q.19 A 5.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from the lens is 30 cm. By calculation determine (i) the position and (ii) the size of the image formed.

Q.20 An object 3.0 cm high is placed perpendicular to the principal axis of a concave lens of focal length 15.0 cm. The image is formed at a distance of 10.0 cm from the lens. Calculate
(i) distance at which the object is placed and (ii) size and nature of the image formed.

Q.21 An object 2.0 cm in size is placed 20.0 cm in front of a concave mirror of focal length 10.0 cm. Find the distance from the mirror at which a screen should be placed in order to obtain sharp image. What will be the size and nature of the image formed ?

Q.22 A convex lens has a focal length of 25 cm. Calculate the distance of the object from the lens if the image is to be formed on the opposite side of the lens at a distance of 75 cm from the lens. What will be the nature of the image ?

Q.23 A convex lens has a focal length of 30 cm. Calculate at what distance should the object be placed from the lens so that in forms an image at 60 cm on the other side of the lens. Find the magnification produced by the lens in this case.

Q.24 An object 3 cm high is placed at a distance of 9 cm in front of a concave mirror of focal length 18 cm. Find the position, nature and size of the image formed.

Q.25 An object 4 cm high is placed at a distance of 20 cm in front of a convex lens of focal length 12 cm. Find the position, nature and size of the image formed.

Q.26 Find the position, nature and size of the image of an object 3 cm high placed at a distance 6 cm from a concave mirror of focal length 12 cm.

Q.27 Where should an object be placed from a converging lens of focal length 20 cm, so as to obtain a real image of magnification 2?

Q.28 Find the position of the object which when placed in front of a convex mirror produces a virtual image, which is half the size of the object.

Q.29 Find the position of an object which when placed in front of a concave mirror of focal length 20 cm produces a virtual image, which is twice the size of the object.

Q.30 An object is kept in front of a concave mirror of focal length 15 cm. The image formed is three times the size of object. Calculate two possible distances of the object from the mirror.

Q.31 Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected (b) refracted light ? (n of water = 1.33)

Q.32 An object 10 cm long is placed at 15 cm away from a convex lens of focal length 10 cm. Find the position and size of image.

Q.33 (a) State the relation between object distance, image distance and focal length of a spherical mirror.
(b) A concave mirror of focal length 15 cm form an image of an object kept at a distance of 10 cm from the mirror. Find the position nature and size of the image formed by it. (c) Draw a ray diagram to show the image formed by a concave mirror when an object is placed between pole and focus of the mirror.

Q.34 What is meant by 'critical angle' for a ray of light going from a denser to a rarer medium ?
What will be the consequence, if the angle of incidence, at the interface is greater than the critical angle ?

ANSWER KEY

EXERCISE - 1

(11) Concave mirror **(19)** – 30 cm. **(20)** 2×10^8 ms^{-1}. **(22)** –0.5D
(23) 2.15cm. **(24)** – 0.50 m **(29)** 1/11 times smaller **(30)** – 45 cm.
(31) v = + 10 cm. **(32)** 1.22.
(33) The image is 30 cm. from the convex lens, located on the other side of the object. It is real inverted and 4.5 cm. high. **(34)** 10 cm. **(35)** P = + 10 dioptre (or + 10 D)
(36) +0.33 **(48)** 1.06 cm. **(49)** 24 mm
(50) 6 cm., Nature : Image is virtual, erect and diminished.
(54) The image will be virtual and erect is s < F, the image will be smaller is s > 2F and larger if s < 2F.
(55) (a) real inverted reduced (b) real, inverted, same size (c) no image is formed (d) virtual, erect, enlarged
(56) (a) virtual, erect, reduced (b) virtual, erect, reduced (c) virtual, erect, reduced (d) virtual, erect, reduced
(57) (a) 7.5 cm. (b) 48 cm. **(58)** (a) (i) +30 cm, –22 cm, (ii) –20 cm, –42 cm, (b) 0.98 cm.
(59) 10D, 0.1 **(60)** 60 cm. **(61)** –10 cm., –10 D **(62)** (A) **(63)** (C) **(64)** (B)

EXERCISE - 2

(1) positive, negative. **(2)** straight lines. **(3)** away from, towards **(4)** air-glass, glass-air, parallel
(5) focal length **(6)** dioptre **(7)** equal **(8)** inwards , outwards. **(9)** concave
(10) pole **(11)** front **(12)** principal axis **(13)** principal focus **(14)** concave
(15) lens. **(16)** convergence or divergence **(17)** convex **(18)** 5/4
(19) True **(20)** True **(21)** True **(22)** True **(23)** True
(24) True **(25)** True **(26)** False. **(27)** True **(28)** True
(29) True **(30)** True **(31)** True **(32)** False **(33)** True **(34)** False

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11
A	D	D	B	A	D	C	D	D	D	C	B
Q	12	13	14	15	16	17	18	19	20	21	22
A	A	C	A	A	A	A	C	B	B	C	B
Q	23	24	25	26	27	28	29	30	31	32	33
A	B	A	B	D	D	D	D	B	C	D	D
Q	34	35	36	37	38	39	40	41	42	43	44
A	C	B	A	C	A	A	A	D	D	D	A
Q	45	46	47	48	49	50	51	52	53	54	55
A	A	A	B	A	C	B	C	B	C	B	D
Q	56	57	58	59	60	61	62	63	64	65	66
A	C	C	D	B	B	A	B	C	D	C	A
Q	67	68	69	70	71	72	73	74	75	76	77
A	C	C	A	D	D	B	B	A	D	A	C
Q	78	79	80	81	82	83	84	85	86	87	88
A	B	D	A	D	A,B,C	A,B	A,B,C	A,B,C	A,D	C,D	A
Q	89	90	91	92	93	94	95	96	97	98	99
A	A,B,C	A,C,D	B	B	D	D	D	D	B	C	B
Q	100	101	102	103	104	105	106	107	108	109	110
A	D	C	D	A	A	A	D	B	B	B	D
Q	111	112									
A	B	B									

EXERCISE - 4

(1) (A) → q, (B) → p, (C) → r, (D) → p **(2)** (A) → q, r (B) → s (C) → p (D) → p, r

(3) (A) → r, (B) → s, (C) → q, (D) → p **(4)** (E) **(5)** (D) **(6)** (A)

(7) (A) **(8)** (D) **(9)** (B) **(10)** (E) **(11)** (B)

(12) (C) **(13) (E).** An image is a plane mirror is virtual and it can be photographed.

(14) (E). Object is placed between F and 2F of objective lens.

(15) (B) **(16)** (B) **(17)** (A) **(18)** (A)

(19) (C) **(20)** (A) **(21)** (B)

EXERCISE - 5											
Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
A	C	C	D	B	D	D	B	D	A	B	C
Q	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
A	D	A	A	C	A	A	B	B	C	C	D
Q	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
A	B	D	D	D	B	C	B	C	B	A	D
Q	**34**	**35**	**36**	**37**	**38**						
A	B	C	D	A	B						

EXERCISE - 6

(7) $\mu_r < \mu_g < \mu_y$. **(8)** 1 : 1 **(9)** 48 cm on the same side of object. **(10)** 1.18.

(11) 2×10^8 ms^{-1}. **(15)** 5/4, Image is enlarged and virtual. **(16)** 7.14 cm.

(17) + 4 cm. **(18)** 11.25 cm.

(19) (i) + 60 cm. Image is real and inverted. (ii) – 10 cm. Size of image is twice the size of object.

(20) (i) u = – 30 cm. (ii) + 1.0. Image is virtual, erect and of same size.

(21) Nature of image : Real, inverted, same size (h' = h). **(22)** – 37.5 cm

(26) 12 cm. Nature : virtual, erect, enlarged, Size of image : Twice the size of object.

(27) – 30 cm. **(28)** Object has to be at a distance equal to focal length. **(29)** u = – 10 cm.

(30) 10 cm and 20 cm in front of concave mirror. **(31)** (a) 5.09×10^{14} Hz (b) 442 nm.

(32) – 20.