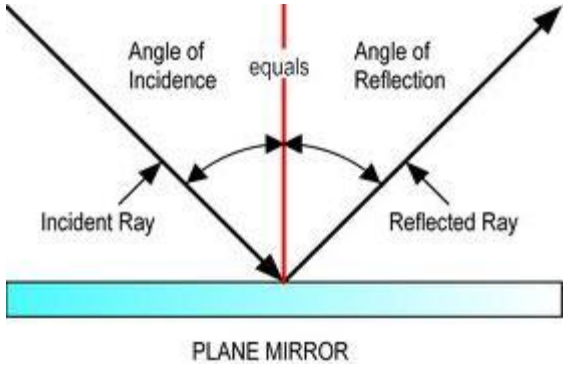
Ray Optics and Optical Instruments

- Electromagnetic radiation belonging to this region of thespectrum (wavelength of about 400 nm to 750 nm) is called light.
- A light wave can beconsidered to travel from one point to another, along a straight line joiningthem. The path is called a *ray* of light, and a bundle of such raysconstitutes a *beam* of light.
- Speed of light $c = 3 \times 10^8 ms^{-1}$

  Laws of Reflection

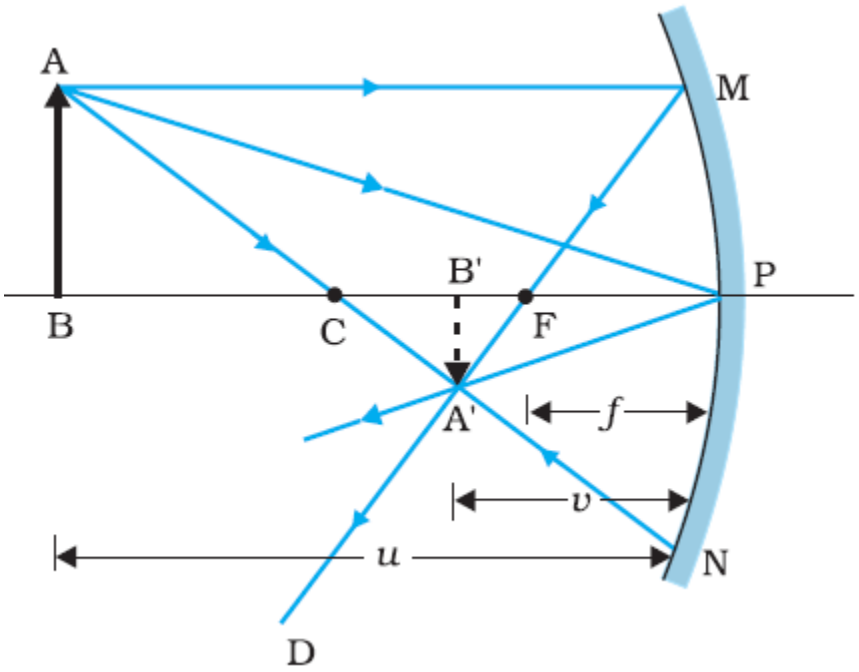
  - The angle of reflection (i.e., the angle between reflected ray and the normal to the reflecting surface or the mirror) equals the angle of incidence (angle between incident ray and the normal).
  - Also that the incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

The geometriccentre of a spherical mirror is called its pole whilethat of a spherical lens is called its optical centre.The line joining the pole and the centre of curvatureof the spherical mirror is known as the principalaxis. In the case of spherical lenses, the principalaxis is the line joining the optical centre with itsprincipal focus.



Sign convention

- All distances are measuredfrom the pole of the mirror or the opticalcentre of the lens.
- The distances measured in the same direction as theincident light are taken as positive andthose measured in the direction opposite to the direction of incidentlight are taken as negative.
- The heights measured upwards with respect to *x*-axis and normal to theprincipal axis (*x*-axis) of the mirror/lens are taken as positive.
- Theheights measured downwards aretaken as negative.



- The distance between the focus F and the pole P of the mirror is calledthe *focal length* of the mirror, denoted by *f*.
- $f = R/2$,where *R* is the radius of curvature of the mirror.

Mirror Equation

(1/v) + (1/u) = (1/f) (See diagram for u, v and f)

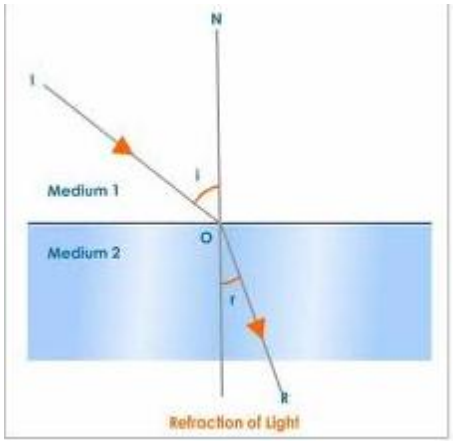
Linear magnification (m) as the ratio of the height of the image (h′) to the height of the object (h):

$m = (h'/h) = -(v/u)$

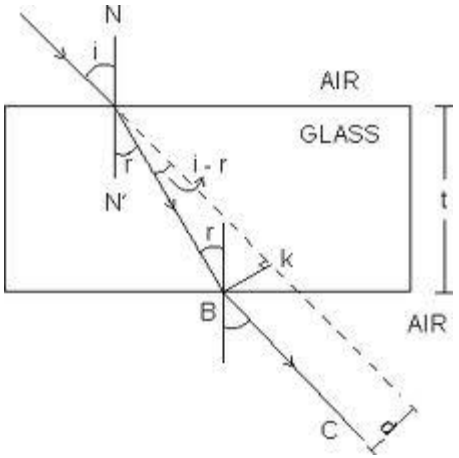
h and h′ will be taken positive or negative in accordance with the acceptedsign convention.

Laws of Refraction (Snell's laws)

- The incident ray, the refracted ray and the normal to the interface at the point of incidence, all lie in the same plane.
- The ratio of the sine of the angle of incidence to the sine of angle of refraction is constant.
  $(\sin i/\sin r) = n_{21,}$ where *n*21 is a constant, called the *refractive index* of the second mediumwith respect to the first medium.
- If $n_{21} > 1$, r <i, the refracted ray bends towards the normal. In such a case medium 2 is said to be optically denser (or denser, in short) than medium 1. On the other hand, if $n_{21} < 1$, r >i, the refracted ray bends away from the normal. This is the case when incident ray in a denser medium refracts into a rarer medium.



Lateral shift of a ray refracted through a parallel-sided slab

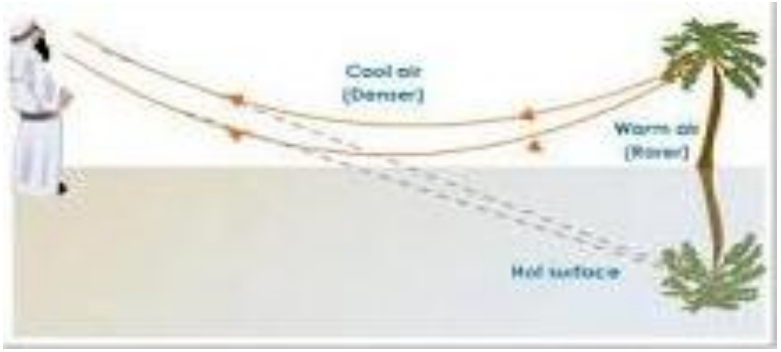


The refraction of light through the atmosphere is responsible for many interesting phenomena. For example, the sun is visible a little before the actual sunrise and until a little after the actual sunset due to refraction of light through the atmosphere.

Total Internal Reflection

- When light travels from an optically denser medium to a rarer medium at the interface, it is partly reflected back into the same medium and partly refracted to the second medium. This reflection is called the internalreflection.
- Critical angle (optics) the angle of incidence above which total internal reflection occurs.
- $\sin i_c = n_{21}$
- **Mirage**

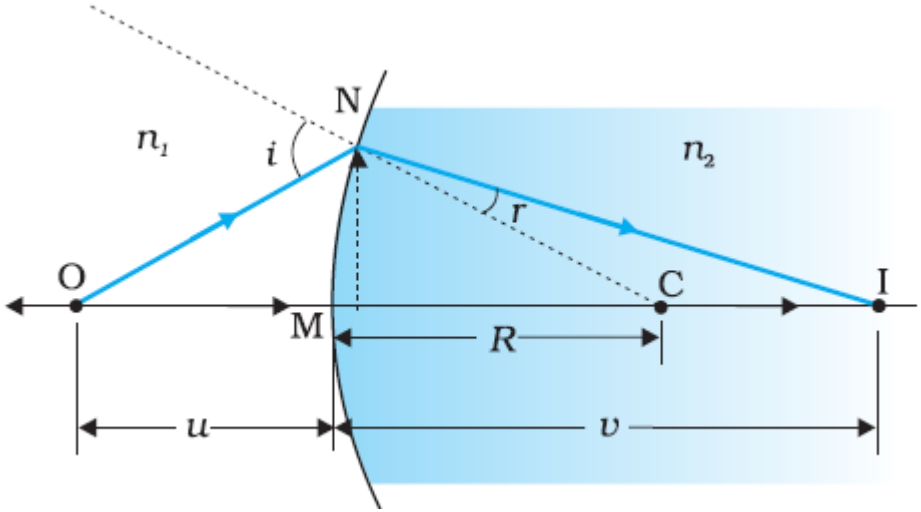
  The illusion results from the way in which light is refracted (bent) through air at different temperatures. Cold air is denser than warm air, and therefore has a greater refractive index. This means that as light passes down from cool to hot air, it gets bent upwards towards the denser air and away from the ground. To your eyes, these distorted rays seem to be coming from the ground, so you perceive a refracted image of the sky on the ground. This looks just like a reflection on the surface of a pool of water, which can easily cause confusion.



- Diamonds are known for their spectacular brilliance. Their brilliance is mainly due to the total internal reflection of light inside them.
- Prisms designed to bend light by90º or by 180º make use of total internalreflection.

Refraction at a spherical surface

$(n_2/v)-(n_1/u) = (n_2-n_1)/R$, gives us a relation between object and image distance in terms of refractive index of the medium and the radius of curvature of the curved spherical surface. It holds for any curved spherical surface.



Lens Maker's formula

$(1/f) = (n_{21} - 1)\{(1/R_1) - (1/R_2)\}$

Thin lens formula

$(1/v) - (1/u) = 1/f$

Magnification(m) = (h'/h) = (v/u)

- The power P of a lens is defined as thetangent of the angle by which it converges or diverges abeam of light falling at unit distant from the optical centre. P = (1/f).The SI unit for power of a lens is dioptre.

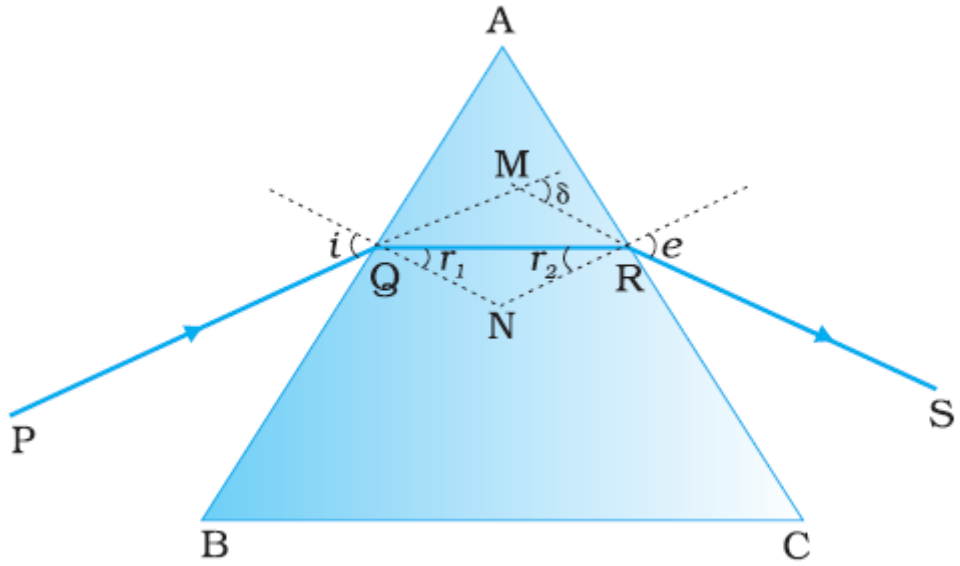
Combination of lenses

Effective focal length $(1/f) = (1/f_1) + (1/f_2)$=…

Effective Power(P) = $P_1 + P_2$ +….

Magnification(m) = $m_1m_2m_3$….

Prism



- $\delta = i + e - A$. Thus, the angle of deviation depends on the angle of incidence.
- $D_m = (n_{21}-1)A$ (Minimum deviation)

Microscope

A simple microscope is a short focal length convex lens. The magnifying power of a simple microscope is

$M = 1 + (D/f)$

The magnifying power, M of a compound microscope is

$M = (v/u)(1 + (D/f_e)) = M_o * M_e$

Where, M_o and M_e denote the linear magnifying of the objective and eye lens.

Telescope

- The magnifying power, M of refracting telescope is

  $M = (f_o/f_e)$
- For the final image is formed at the least distance of distant vision, the magnifying power is given as

  $M = (f_o/f_e)\ \{ 1 + (F_e/D)\}$
- The resolving power of a telescope$\theta = (1.22\lambda)/d$

  where, λ = wavelength of light d = diameter of the objective of the telescope θ = angle subtended by the point object a the objective

Sample Examples