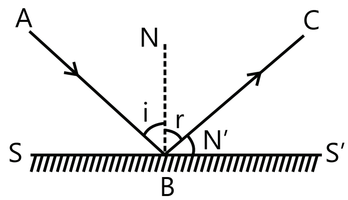
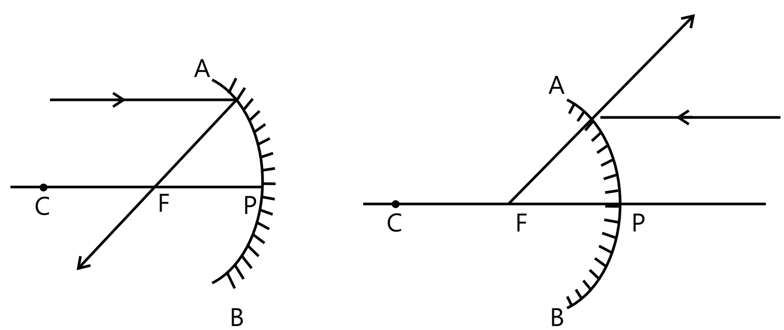
FORMULAE SHEET

S. No	KEY CONCEPTS	DESCRIPTIONS
1	**Law of reflection**	**(i)** The incident ray (AB), the reflected ray (BC) and normal (NN′) to the surface (SS′) of reflection at the point of incidence (B) lie in the same plane. This plane is called the plane of incidence (also the plane of reflection). **(ii)** The angle of incidence (the angle between the normal and the incident ray) and reflection angle (the angle between the reflected ray and the normal) are equal. $\angle i = \angle r$.  **Figure 16.105**
2	**Object**	**(a) Real:** Point from which rays actually diverge. **(b) Virtual:** Point toward which rays appear to converge.
3	**Image**	The image is decided by the reflected or refracted rays only. The point image for a mirror is that point (i) Toward which the rays reflected from the mirror actually converge (real image), OR (ii) From which the reflected rays appear to diverge (virtual image).
4	**Characteristics of reflection by a plane mirror**	(a) The size of the image is the same as that of the object. (b) For a real object, the image is virtual, and for a virtual object, the image is real. (c) For a fixed incident light ray, if the mirror is rotated through an angle θ, the reflected ray turns through an angle of 2θ.
5	**Spherical mirrors**	 Concave Convex **Figure 16.106**
6	**Paraxial rays**	Rays that form very small angle with principal axis are called paraxial rays.

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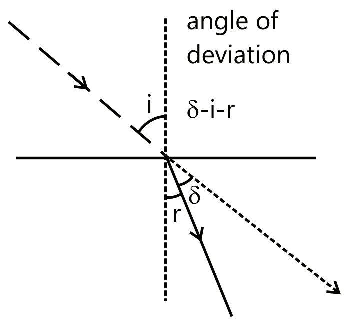
7	**Sign convention**	We follow the Cartesian coordinate system convention according to which (a) The pole of the mirror is the origin. (b) The direction of the incident rays is a positive x-axis. (c) Vertically up is positive y-axis. **Note:** According to this, a convention radius of curvature and focus of concave mirror are negative and of convex mirror are positive.
8	**Mirror formula**	*f*=x-coordinate of focus; $\boxed{\frac{1}{f}=\frac{1}{v}+\frac{1}{u}}$, where *v*=x-coordinate of the image; *u*=x-coordinate of the object. **Note: Valid only for paraxial rays.**
9	**Transverse magnification**	$h_2 = y$ -coordinate of the image $\boxed{m=\frac{h_2}{h_1}=-\frac{v}{u}}$. $h_1 = y$ -coordinate of the object. (both are perpendicular to the principle axis of the mirror)
10	**Optical power**	Optical power of a mirror (in dioptres) = $-\frac{1}{f}$, where *f* is the focal length (in m) with a respective sign.
REFRACTION – PLANE SURFACE		
1	**Laws of refraction (at any refracting surface)**	**(i)** The incident ray (AB), the normal (NN') to the refracting surface (II') at the point of incidence (B) and the refracted ray (BC) all lie in the same plane called the plane of incidence or the plane of refraction. **(ii)** $\boxed{\frac{\sin i}{\sin r}=\text{Constant}:}$ for any two given media and light of a given wavelength. This is the Snell's law. $\boxed{\frac{\sin i}{\sin r}={}_1n_2=\frac{n_2}{n_1}=\frac{v_1}{v_2}=\frac{\lambda_1}{\lambda_2}}$ **Note:** The frequency of light does not change during refraction.
2	**Deviation of a ray due to refraction**	 **Figure 16.107**

<table>
<tr><th>S. No</th><th>KEY CONCEPTS</th><th>DESCRIPTIONS</th></tr>
<tr><td>3</td><td>Refraction through a parallel slab</td><td>

(i) Emerged ray is parallel to the incident ray, if medium is same on both sides.

(ii) Lateral shift $\boxed{x = \dfrac{t\sin(i-r)}{\cos r}}$,

where *t*= thickness of the slab.

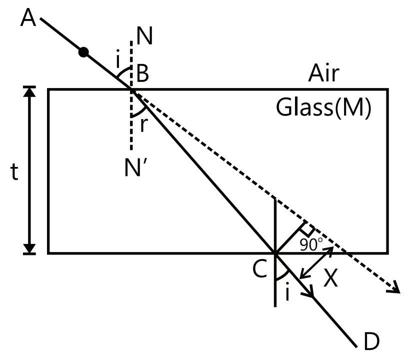


Figure 16.108

Note: Emerged ray is not parallel to the incident ray if the media on both the sides are different.

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<tr><td>4</td><td>Apparent depth of a submerged object</td><td>

At near normal incidence,

$\boxed{h' = \dfrac{\mu_2}{\mu_1}h}$

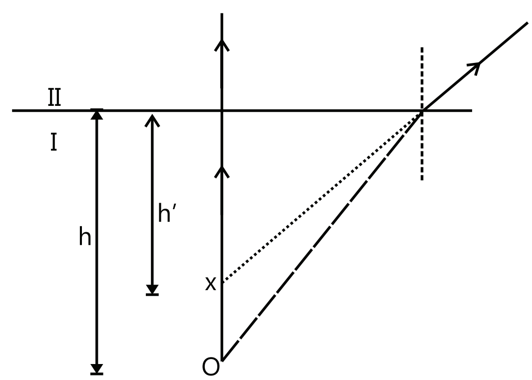

Figure 16.109

Note: *h* and *h*′ are always measured from the surface.

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<tr><td>5</td><td>Critical angle & total internal reflection (TIR.)</td><td>

(i) Ray travels from a denser to a rarer medium.

(ii) The angle of incidence should be greater than the critical angle ($i>c$).

Critical angle $\boxed{C = \sin^{-1}\dfrac{n_r}{n_i}}$

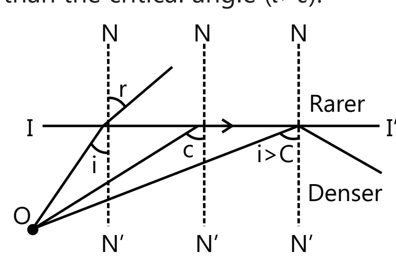

Figure 16.110

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<tr><th>S. No</th><th>KEY CONCEPTS</th><th>DESCRIPTIONS</th></tr>
<tr><td>6</td><td>Refraction through prism</td><td>

1. $\delta = (i + i') - (r + r')$.

2. $r + r' = A$.

3. Variation in δ versus (shown in diagram).

4. There is one and only one angle of incidence, for which the angle of deviation is minimum.

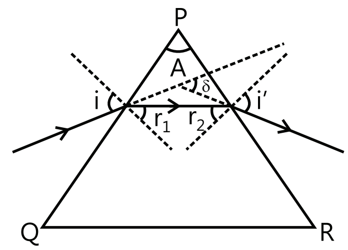

Figure 16.111

When $\delta = \delta_m$ then $i = i'$ & $r = r'$,
the ray passes symmetrically through the prism, and then (where *n*=absolute RI of glass),

$$n \frac{\sin\left[\frac{A + \delta m}{2}\right]}{\sin\left[\frac{A}{2}\right]}$$.

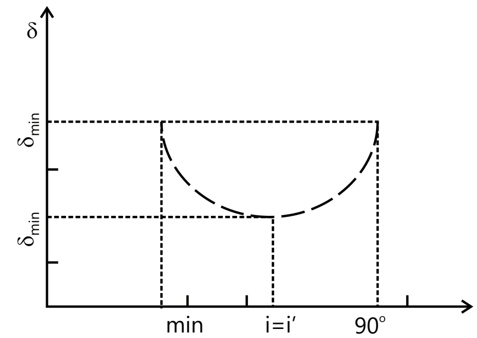

Figure 16.112

Note: When the prism is dipped in a medium, then (where *n*=RI of glass w.r.t. medium).

5. For a thin prism, $\left(A < 10^0\right)$; $\delta = (n-1)A$.

6. Dispersion of light: The angular splitting of a ray of white light into a number of components when it is refracted in a medium other than air is called dispersion of light.

7. Angle of dispersion: An angle between the rays of the extreme colors in the refracted (dispersed) light is called angle of dispersion. $\theta = \delta_v - \delta_r$.

8. Dispersive power (ω) of the medium of the material of prism.

$$(\omega) = \frac{\text{Angular dispersion}}{\text{Derivation of mean ray (yellow)}}$$

For a small-angled prism, (A<10°)

$$\omega = \frac{\delta_v - \delta_R}{\delta_y} = \frac{n_v - n_R}{n-1}; n = \frac{n_v + n_R}{2},$$

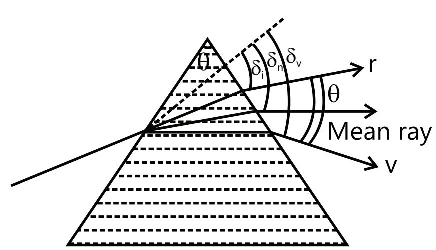

Figure 16.113

where n_v, n_R and *n* are RI of the material for violet, red and yellow colors, respectively.

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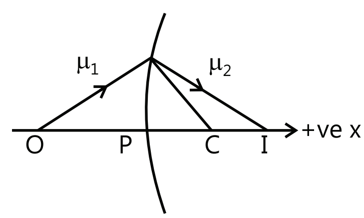
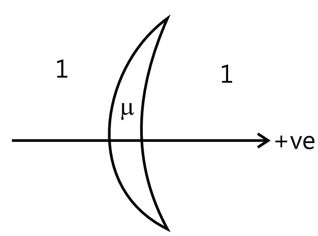
		9. Combination of two prisms: **(i)** Achromatic combination: It is used for deviation without dispersion. Condition for this is $(n_v - n)A = (n'_v - n'_r)A'$. Net mean Deviation $= \left[\frac{n_v + n_R}{2} - 1\right] A - \left[\frac{n'_v + n'_R}{2} - 1\right] A'$. Or $\omega\delta + \omega'\delta' = 0$ where ω, ω' are dispersive powers for the two prisms and δ, δ' are the mean deviations. **(ii)** Direct vision combination: It is used to produce dispersion without deviation; condition for this is $\left[\frac{n_v + n_R}{2} - 1\right] A = \left[\frac{n'_v + n'_R}{2} - 1\right] A'$. Net angle of dispersion $(n_v - n)A - (n'_v - n'_r)A'$.
REFRACTION AT A SPERICAL SURFACE		
1		**(a)** $\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}}$; *v*, *u* a *R* are kept with sign. As *v* = PI *u* = −PO *R* = PC (**Note radius is with sign).** **(b)** $\boxed{m = \frac{\mu_1 v}{\mu_2 u}}$  **Figure 16.114**
2	**Lens formula**	**(a)** $\boxed{\frac{1}{v} - \frac{1}{u} = \frac{1}{f}}$ **(b)** $\boxed{\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$ **(c)** $\boxed{m = \frac{v}{u}}$  **Figure 16.115**