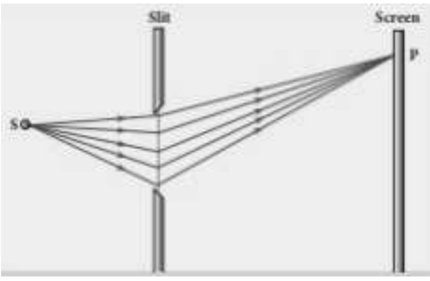
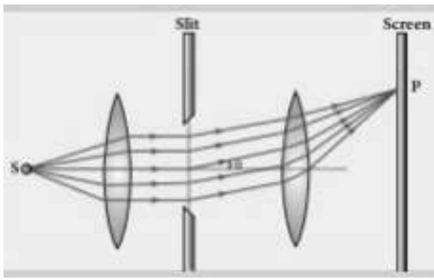
DIFFRACTION OF LIGHT

- Diffraction the bending of light around the edges or an obstacle. Or it is the encroachment of light within the geometrical shadow of an object.
- For observing diffraction, the size of the object causing the diffraction must be comparable to wavelength.

Fresnel & Fraunhofer Diffraction

Fresnel Diffraction	Fraunhofer Diffraction
Source and sceen are at finite distance from object causing diffraction.	Source and sceen are at infinite distance from object causing diffraction.
Incident wavefront is cylindrical or spherical.	Incident wavefront is plane.
No lens required to observe diffraction.	To observe diffraction in laboratory, lenses are required





Theory of Diffraction

- ✓ Huygens' wave theory states that every point on the wave front acts as the source of secondary wavelets.
- ✓ Fresnel defined diffraction as the interference of secondary wavelets originating from various points of the wave front which are not obstructed by the obstacle.

Plane Transmission Grating

A diffraction grating consists of a very large number of extremely narrow parallel slits separated by equal opaque spaces. Grating is made by ruling fine lines at equal distances on an optically plane glass plate with a diamond point. Gratings used in laboratories are replicas of original ruled grating. Such gratings are made as follows. A thin layer of gelatin solution is poured over the ruled surface of the grating and is allowed to harden. When stripped from the grating, gelatin retains an impression of the ruling of the original grating. The gelatin film is then mounted between two glass plates to form a transmission grating

Grating Equation

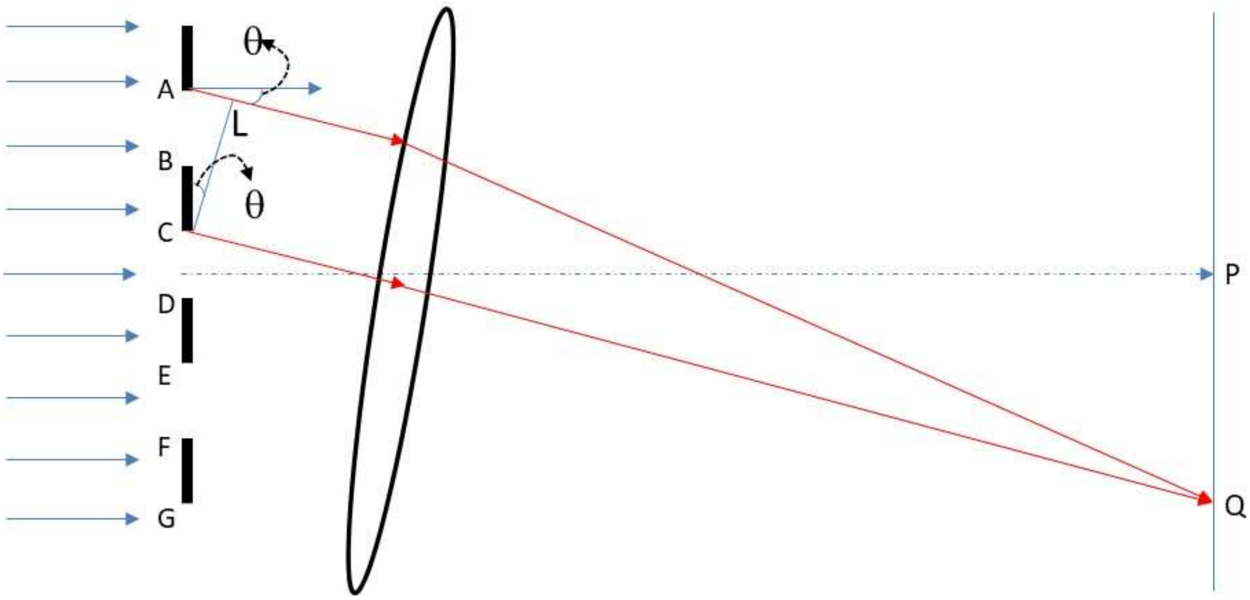
Consider a diffraction grating with its parallel slits, placed perpendicular to the plane of the paper. AB is a transparent portion(slit) and BC is the opaque portion. Let the width of the transparent portion is ‘a’ and width of opaque portion is ‘b’. Then the number of lines (slits) per unit length is

$$N = \frac{1}{(a+b)} \quad \text{-----------------------------------}(1)$$

The distance ‘a+b’ is called grating element or grating constant. Points separated by distance equal to an integral multiple of ‘a+b’ are called corresponding points.

Consider the case when a plane wavefront is incident normally on the grating. Each point in the slits will send secondary wavelets in all directions. Most of these secondary wavelets will travel in the same direction as that of the wavefront. When focussed by a convex lens, these wavelets will get focussed at the focal plane of the lens (P). This is called central maximum.

But there are other secondary wavelets travelling in different directions. Consider secondary wavelets from two consecutive corresponding points like A and C, travelling at an angle θ with respect to the incident wavefront and reaching the point Q.



Path difference between wavelets originating from A and C reaching Q is

$$AL = AC \sin\theta = (a+b)\sin\theta$$

If $(a+b)\sin\theta = n\lambda$, where n=1,2,3,….

wavelets will reinforce. In this case wavelets originating from various corresponding points at an angle θ will reinforce to give a principal maximum at Q.

By putting values n=1,2,3 etc, different directions on either side of central maximum can be obtained where principal maxima can be observed.

$$(a+b)\sin\theta = n\lambda,$$

$$\sin\theta = \frac{n\lambda}{(a+b)}$$

Substituting from eqn (1)

$\mathbf{\sin\theta = Nn\lambda}$ This is known as Grating Equation

where

n represents the order of diffraction. n=1 is first order, n =2 is second order etc.

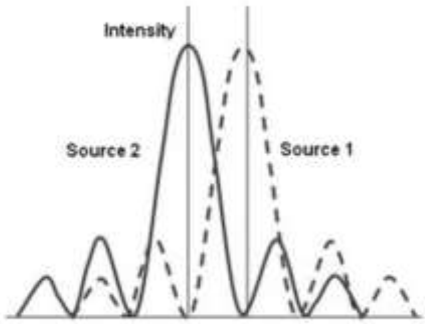
N is the number of lines per unit length of grating

θ is the angle of diffraction

Resolving Power

The ability of an optical instrument to produce separate images of two objects that are close together is called its resolving power.

The diffraction phenomenon sets a limit to resolving power of an optical instrument. The image of a point source of light focused by a lens is not a point image, but is of a definite size disc shape surrounded by diffraction pattern. When the image of two point sources are created, their diffraction pattern may overlap, making it difficult to distinguish the images.



Rayleigh Criterion for Resolving Power

Two sources can be regarded as resolved when the maximum of one source coincides with first diffraction minimum of other

Resolving Power of Grating

- ✓ Resolving Power of grating is its ability to separate two very close spectral lines.

Consider that two wavelengths λ and λ+dλ are just resolved by the grating. In accordance t=with Rayleigh Criteria, this means the maximum of λ+dλ and first diffraction minimum of λ are coinciding.

Condition for n^{th} maximum of λ+dλ

$$(a+b)\sin\theta = n(\lambda+d\lambda)$$

Condition for secondary minimum of λ

$$(a+b)\sin\theta = n\lambda + \frac{\lambda}{N'}$$

N' is the total number of lines in the grating

$$n(\lambda+d\lambda) = n\lambda + \frac{\lambda}{N'}$$

$$nd\lambda = \frac{\lambda}{N'}$$

$$\mathbf{R} = \frac{\lambda}{d\lambda} = \mathbf{nN'}$$

Resolving power of the grating depends on the order of spectrum and the total number of lines on the grating surface.

Dispersive Power of Grating

Dispersive Power of grating is defined as the change in angle of diffraction for unit change in wavelength.

From Grating equation

$\sin\theta = Nn\lambda$

Differentiating above eqn
$\cos\theta\, d\theta = Nn\, d\lambda$

$$D = \frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta}$$

Dispersive power of the grating depends on the number of lines per unit length and the order of spectrum.