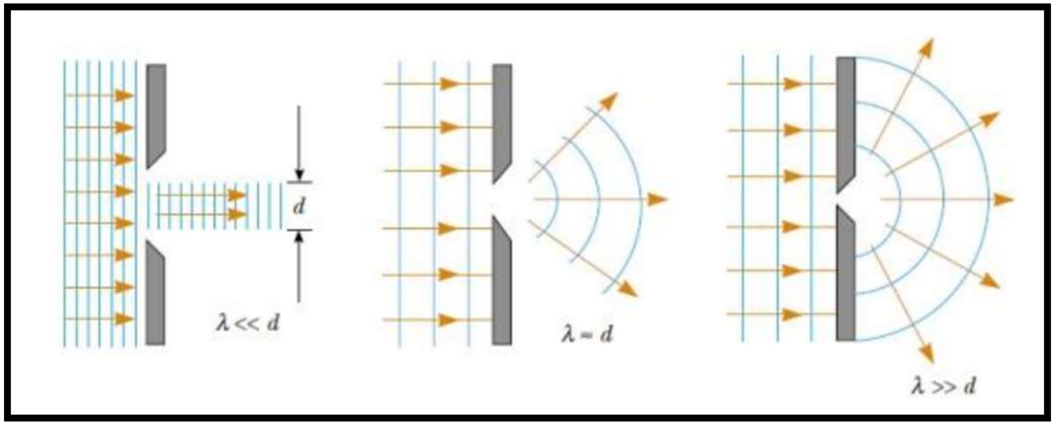
INTRODUCTION

Module 1
Unit 1.2: Diffraction

DIFFRACTION

- Diffraction of light: The phenomenon of bending of light waves around the corners of the obstacle and entering into the region of geometrical shadow of the obstacle is called diffraction.
- It was first observed by Scientist Grimaldi.
- Diffraction of light depends on following two factors:
- (I) Size of the slit or aperture (a) (2) Wavelength of the light wave incident (λ)
- For maximum diffraction : a= λ.

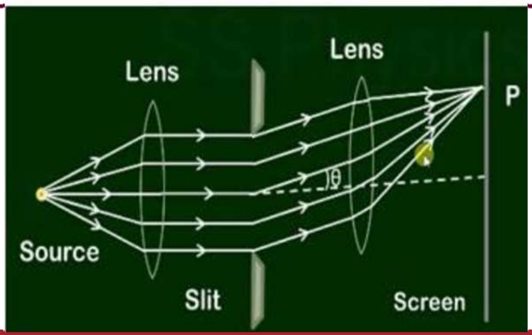


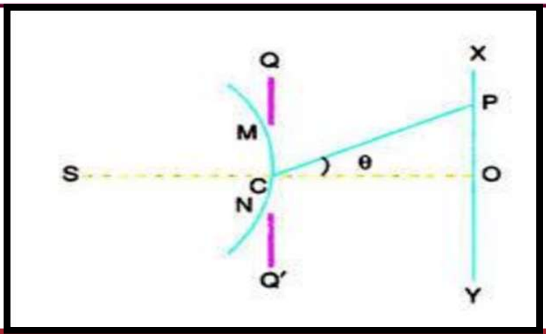
INTERFERENCE & DIFFRACTION

S. No.	Properties	Diffraction	Interference
1	Origin	Superposition between infinite coherent waves.	Superposition between two coherent waves.
2	Maxima	Never of equal intensity.	Always of equal intensity
3	Width of fringes	Never of equal width.	May or may not be of equal width.
4	Minima	Minima intensity may increase with order.	All minima have the same Intensity.
5	Number of fringes observed.	Always small	Generally large.

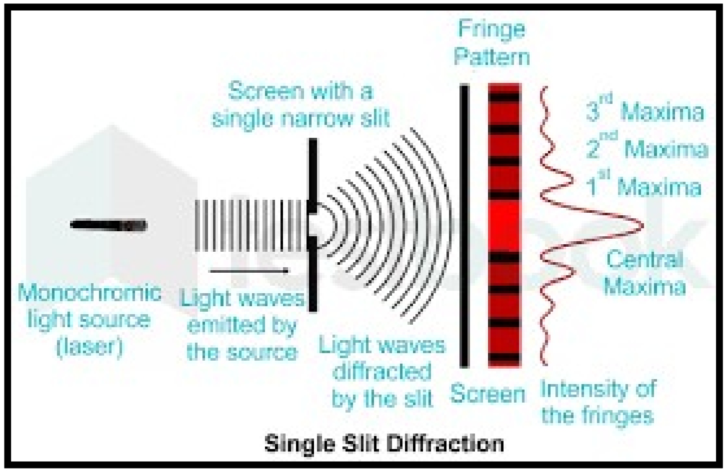
TYPES OF DIFFRACTION

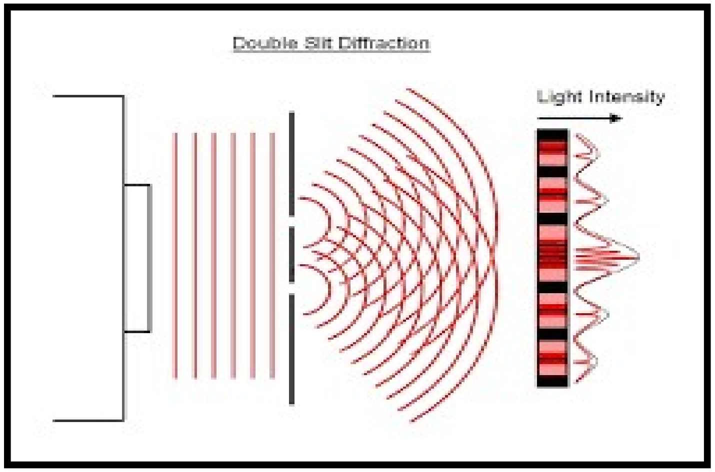
Fraunhaufer's diffraction	Fresnel's diffraction
Source and screen are at infinite distances from slit.	Source and screen are at finite distances from slit.
Incident wavefront on the aperture is plane.	Incident wavefront on the aperture is either spherical or cylindrical.
The diffracted wavefront is plane.	The diffracted wavefront is either spherical or cylindrical.
Two biconvex lenses are needed to study diffraction in lab.	No lenses are needed to study diffraction in the lab.

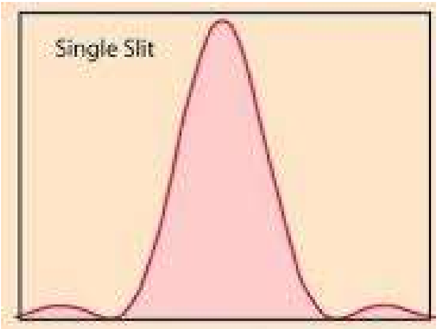


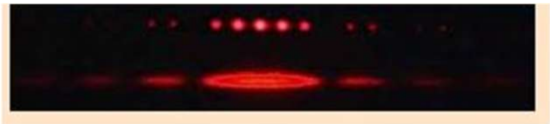


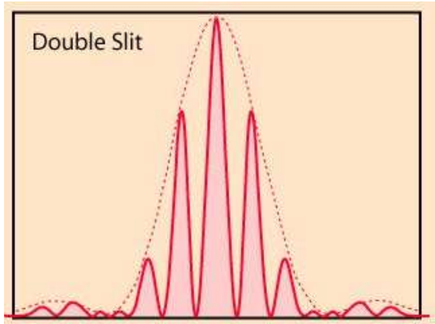
SINGLE SLIT & DOUBLE SLIT DIFFRACTION











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DIFFRACTION GRATING

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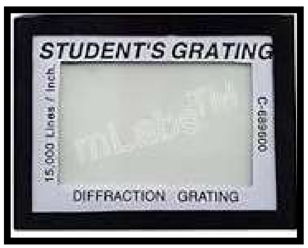
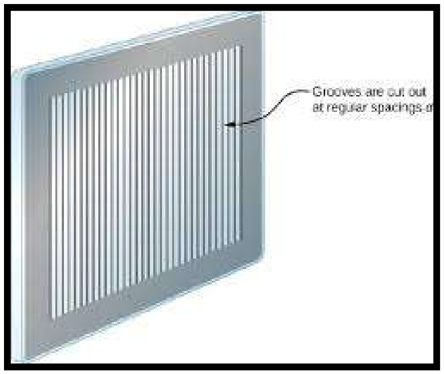
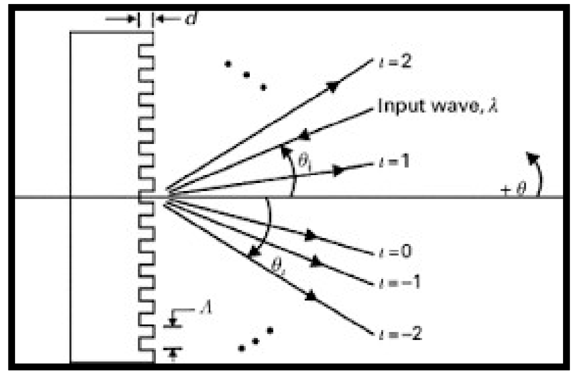
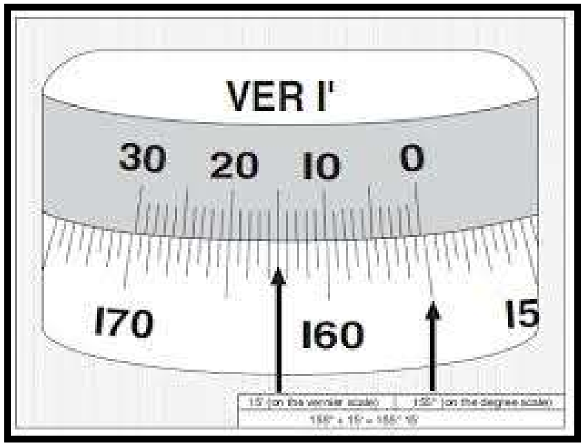
- Diffraction grating: an optical component with a large number of closely spaced, parallel slits. Many fine transparent vertical stripes (approx. 1,000 lines/mm), or slits that are not visible to the naked eye. It consists of a very large number of equally spaced parallel lines scratched on a transparent surface.
- These slits are typically very narrow and are separated by opaque regions.
- When light passes through these slits, it diffracts and interferes, creating a pattern of bright and dark fringes (maxima and minima)

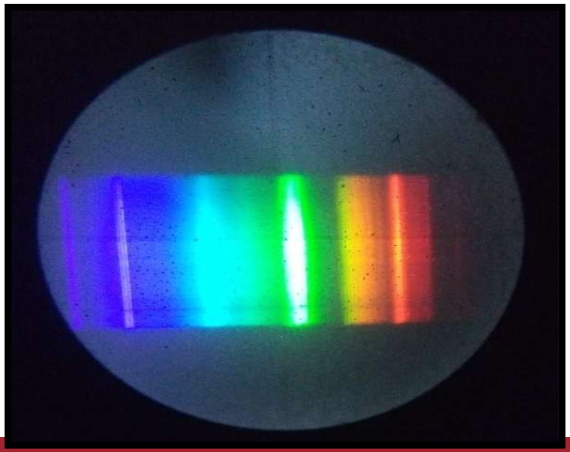




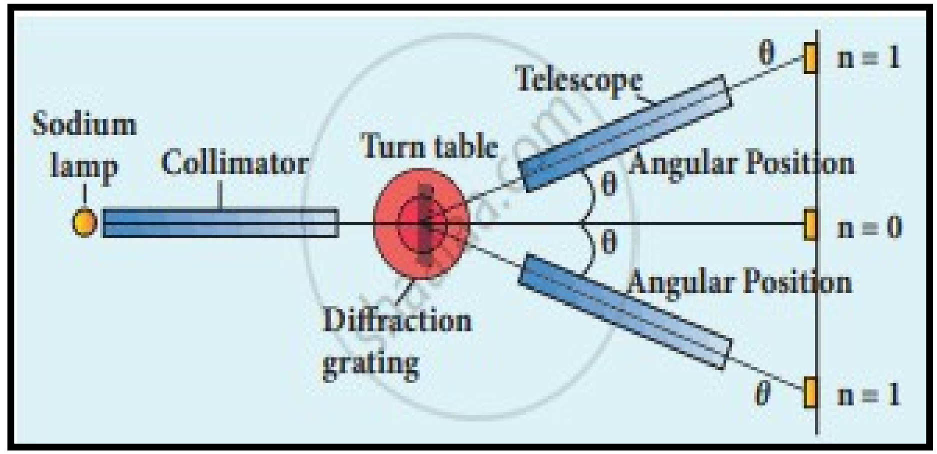


SPECTROMETER





EXPERIMENTS BASED ON DIFFRACTION GRATING

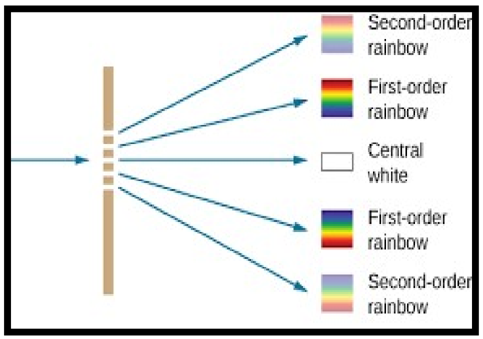


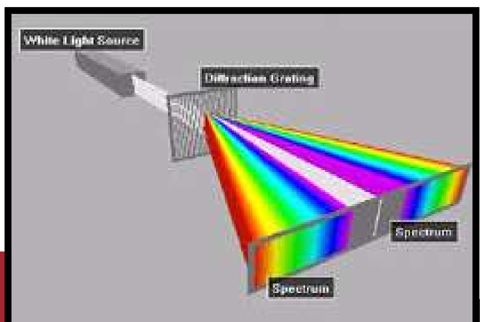
- To measure the wavelength of light using a diffraction grating, a laser source, a diffraction grating, a screen and a ruler is needed.
- The setup involves shining the laser light through the grating and onto the screen, then measuring the distance between the central bright spot and the first-order bright spot, along with the distance from the grating to the screen.
- This allows you to calculate the angle of diffraction and subsequently, the wavelength of the light/ No. of lines on the grating.

APPLICATION OF A GRATING

- To measure wavelengths, we need a device that can split a beam of light up into different wavelengths a diffraction grating is used.

- An incandescent lamp gives off a continuous spectrum containing all wavelengths in the visible part of it, from red to violet. A laser emits light of a single wavelength.





Higher order maxima may be observed at angles given by the general formula

$$n\lambda = 2d\sin\theta$$

with n = 1, 2, 3, ...

No. of lines N (lines/cm) on the grating is calculated as: $(\boldsymbol{a}+\boldsymbol{b})\boldsymbol{\sin\theta} = \boldsymbol{n\lambda}$

where a is the slit width and b is the opaque width.

$\boldsymbol{N} = \frac{\mathbf{1}}{(\boldsymbol{a}+\boldsymbol{b})}$ and (a+b) is known as grating element or grating constant.

$\therefore N = \frac{\sin\theta}{n\lambda}$

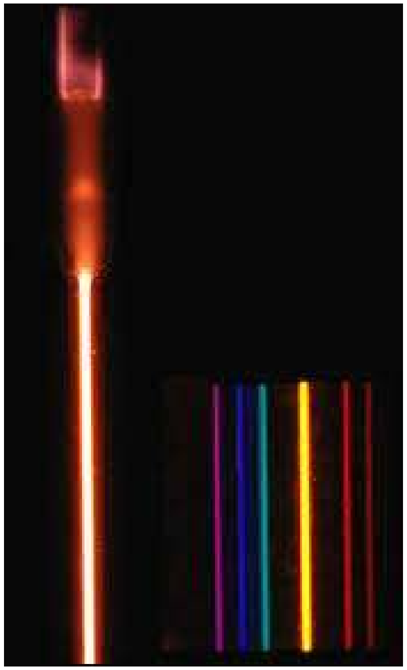
RESOLUTION

To see two close objects just separate is called Resolution.

Types of Resolutions:-

(1) Geometrical Resolution:- When the geometrical position of the two nearby point object are to be resolved then it is called geometrical resolution. For example Microscope, Telescope.

(2) Spectral Resolution:- When spectral lines corresponding to wavelength having small distances are to be just resolved then it is called spectral resolution. For example Diffraction Grating.



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RESOLVING POWER

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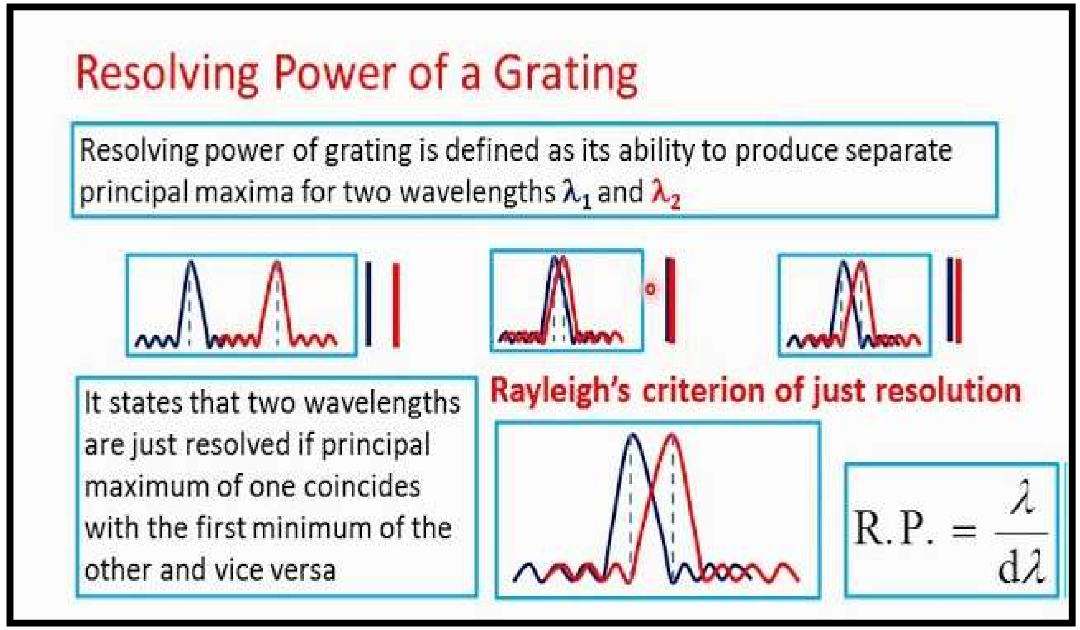
<u>Resolution Limit</u>:- The smallest distance between the two close objects whose images can be seen just as separate is called resolution limit.

<u>Resolving Power</u>:- The ability or the power of an optical instruments to see to close objects just as separate is called resolving power.

<u>Relation between resolving power and resolution limit:-</u>

Resolution limit α 1/ Resolving power



The resolving power of diffraction grating is the ability of grating to resolve two nearby spectral lines that is, to see these two spectra lines just as separate.

APPLICATION OF DIFFRACTION

1. Spectroscopy

- Used in spectrometers to separate light into its constituent wavelengths, allowing scientists to identify the composition of substances by analyzing their spectral signatures
- Used in astronomy to study the composition of stars and galaxies, and in chemistry for analyzing the elements and compounds in samples.

2. Holography

- Holograms are essentially diffraction gratings that, when illuminated with light, reconstruct a three-dimensional image of the original object. This is used in security features (like on credit cards), data storage, and artistic displays.

3. X-ray Diffraction

- X-rays diffract when passing through materials, and the resulting diffraction patterns can be used to determine the atomic and molecular structure of solids.
- Used to assess bone content and potentially diagnose conditions Like osteomalacia without invasive biopsies in the medicine field.

4. Laser Technology

- Used in lasers to select specific wavelengths of light, allowing for tunable lasers with applications in telecommunications, medicine, and scientific research.
- Diffraction patterns also play a role in laser beam focusing and optical storage devices like CDs and DVDs.

NUMERICALS

1. In a Plane transmission grating the angle of diffraction for second order principal maximum for the wavelength 5 x 10^{-5} cm is 30^0 . Calculate the number of lines/cm on the grating surface.

2. Calculate the highest order spectrum that can be obtained by monochromatic light of wavelength 6000 Å by a grating with 6000 lines/cm.

3. A diffraction grating used at normal incidence gives a line 5400 Å in a certain order superimposed on another line 4050 Å of the nest higher order. If the angle of diffraction is 30^0, how many lines/cm are there on grating?

4. In an experiment with grating, third order wavelength coincides with the four order spectral line of wavelength 4992 Å. Calculate the value of the wavelength.

5. A grating has 620 rulings/mm and is 0.5mm wide. What is the smallest wavelength interval that can resolved in the third order at 1 = 481 nm?

6. Find the maximum resolving power of a grating 2 cm with 6000 lines/cm illuminated by a light of wavelength 5890 Å.