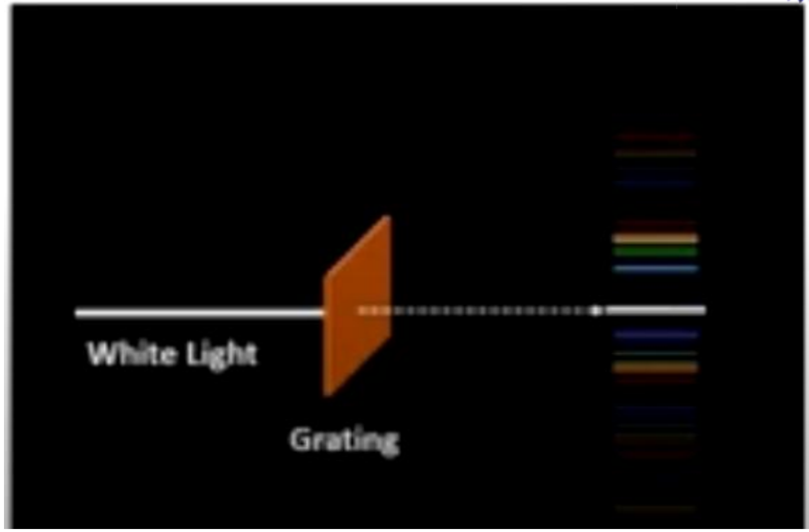
Experiment Title
Spectrometer Grating



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Plan of the talk

Diffraction

Types of diffraction

Grating

Diffraction through grating

Experiment (Aim, Apparatus required, Formula used)

Least count of spectrometer

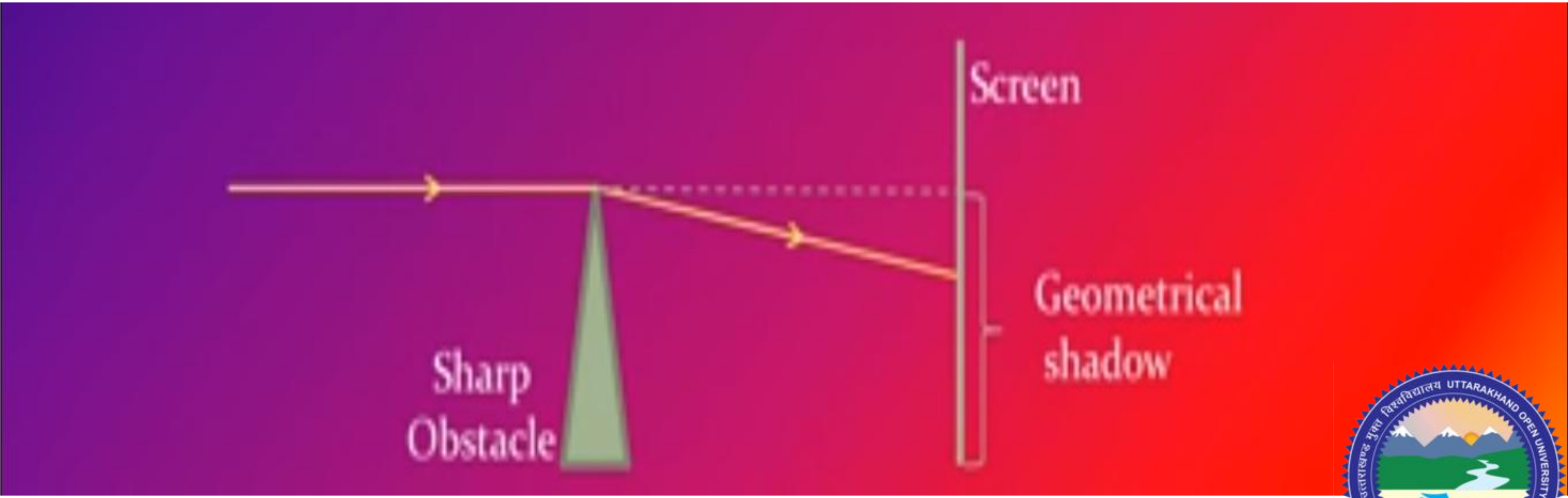
Procedure to perform experiment

Precautions and sources of error

References

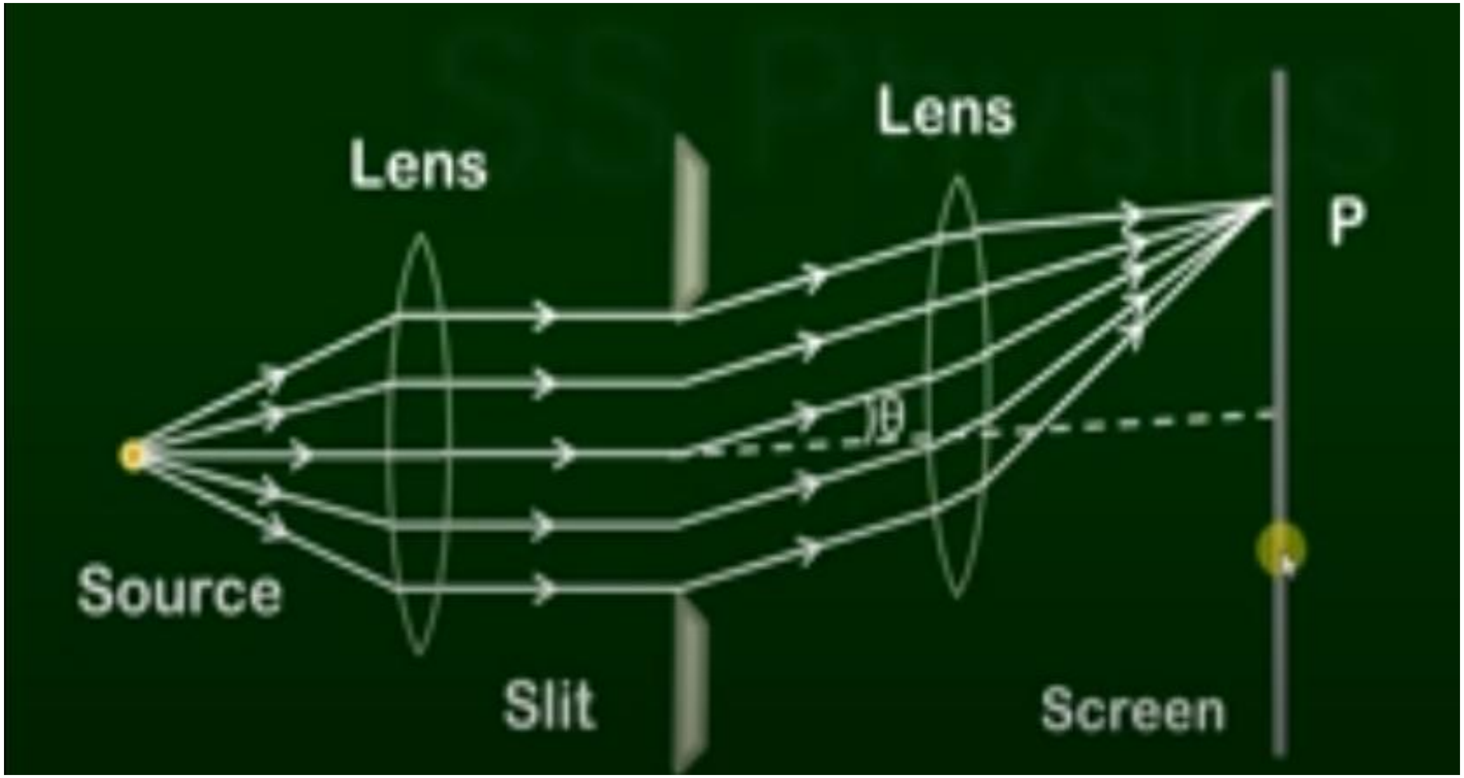
Diffraction of Light

Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of light around the corners of an obstacle or aperture into the region of geometrical shadow of the obstacle.



Fraunhofer diffraction

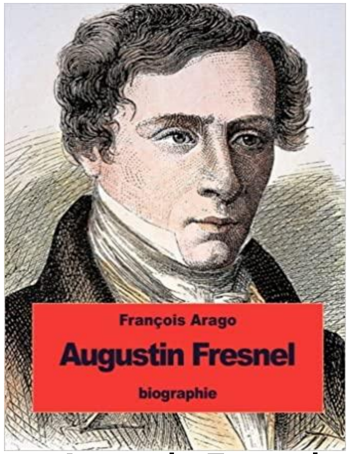
In this type source of light and screen are at infinite distance from the obstacle.



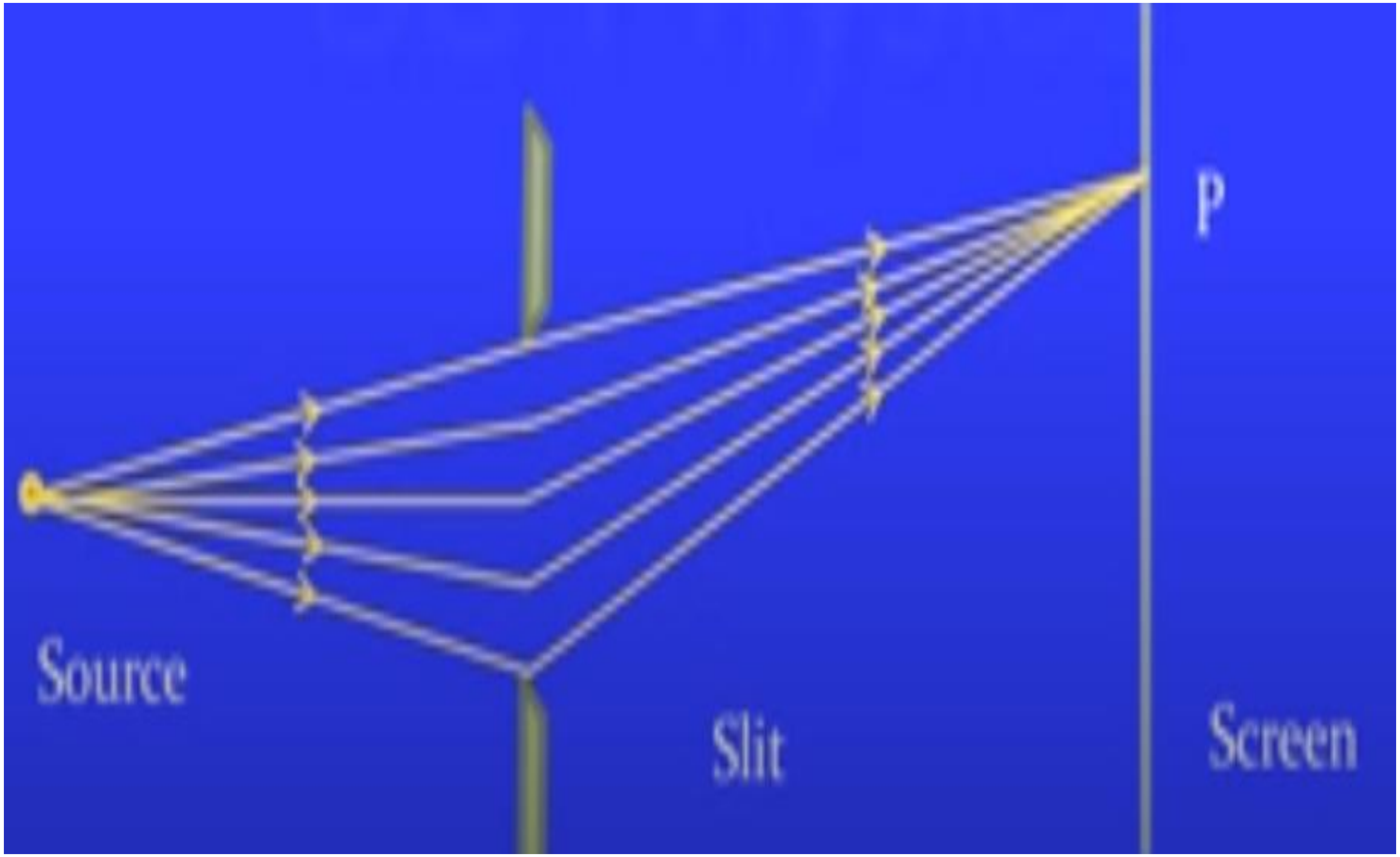
Joseph von Fraunhofer
1787-1826

Fresnel diffraction

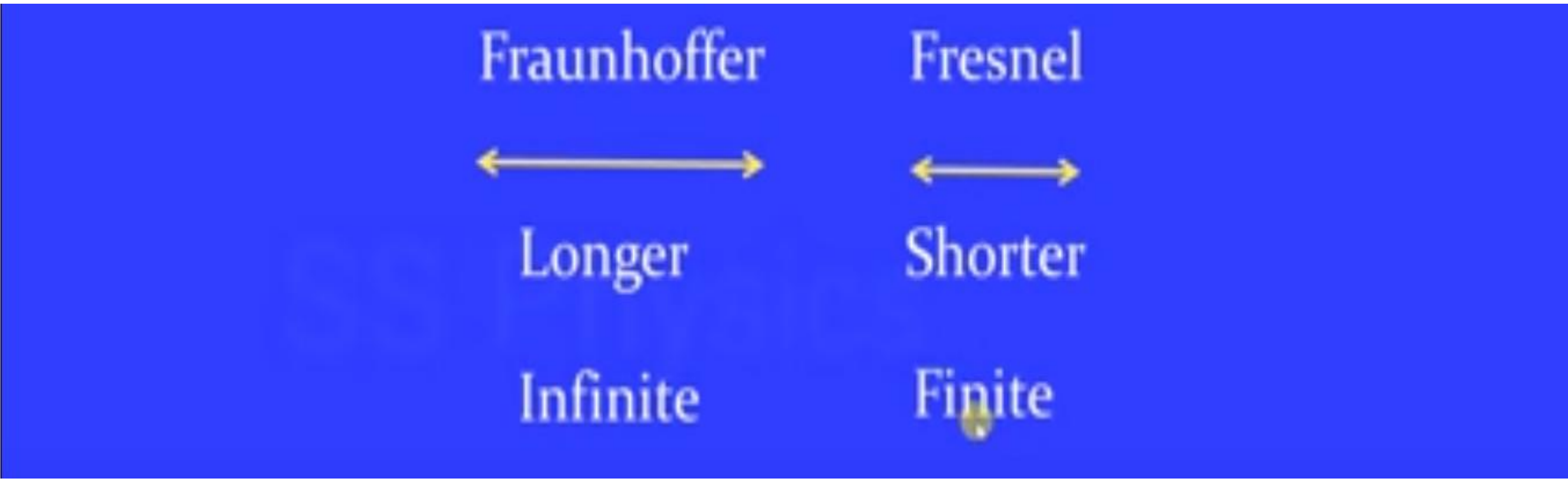
In this type source of light and screen are at finite distance from the obstacle.



Augustin Fresnel



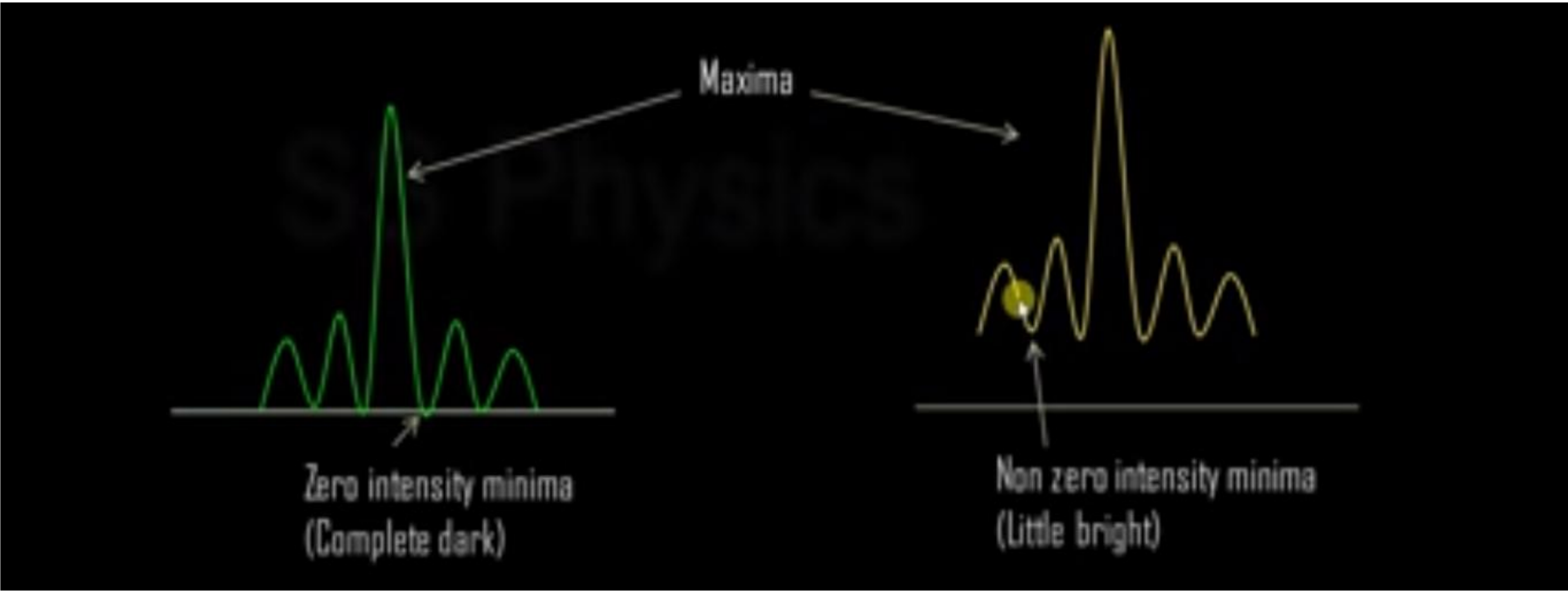
Simple trick to remember



Difference between Fraunhofer and Fresnel diffraction

	Fraunhofer	Fresnel
1	Source and screen are at infinite distance from slit	Source and screen are at finite distance from slit
2	Incident wavefront on the aperture is plane	Incident wavefront on the aperture is either spherical or cylindrical
3	The diffracted wavefront is plane	The diffracted wavefront is either spherical or cylindrical
4	Two biconvex lenses are required to study diffraction in laboratory	No biconvex lenses are required to study diffraction in laboratory
5	Mathematical treatment is easy	Mathematical treatment is complicated
6	It has many applications in designing the optical instruments	It has less applications in designing the optical instruments

Fraunhofer and Fresnel diffraction intensity pattern



The maxima and minima are well defined

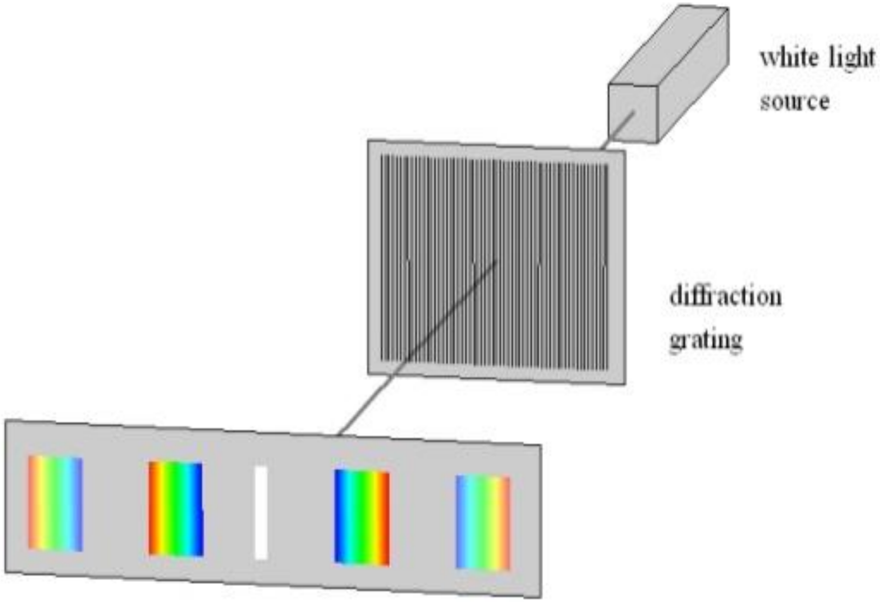
The maxima and minima are not well defined

Diffraction Grating

A diffraction grating is an arrangement equivalent to a large number of parallel slits of equal widths and separated from one another by equal opaque spaces.

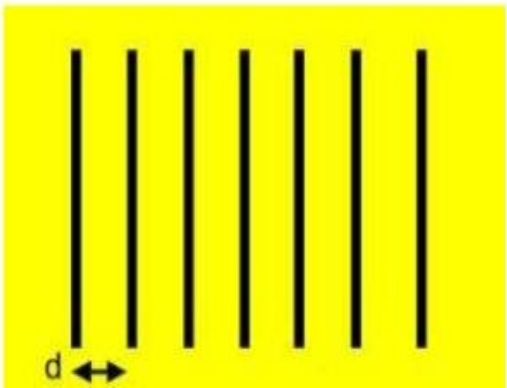
Construction

Diffraction grating can be made by drawing a large number of equidistant and parallel lines on an optically plane glass plate with the help of a sharp diamond point. The rulings scatter the light and are effectively opaque, while the unruled parts transmit light and act as slits. The experimental arrangement of diffraction grating is shown



They are two type refection and transmission gratings

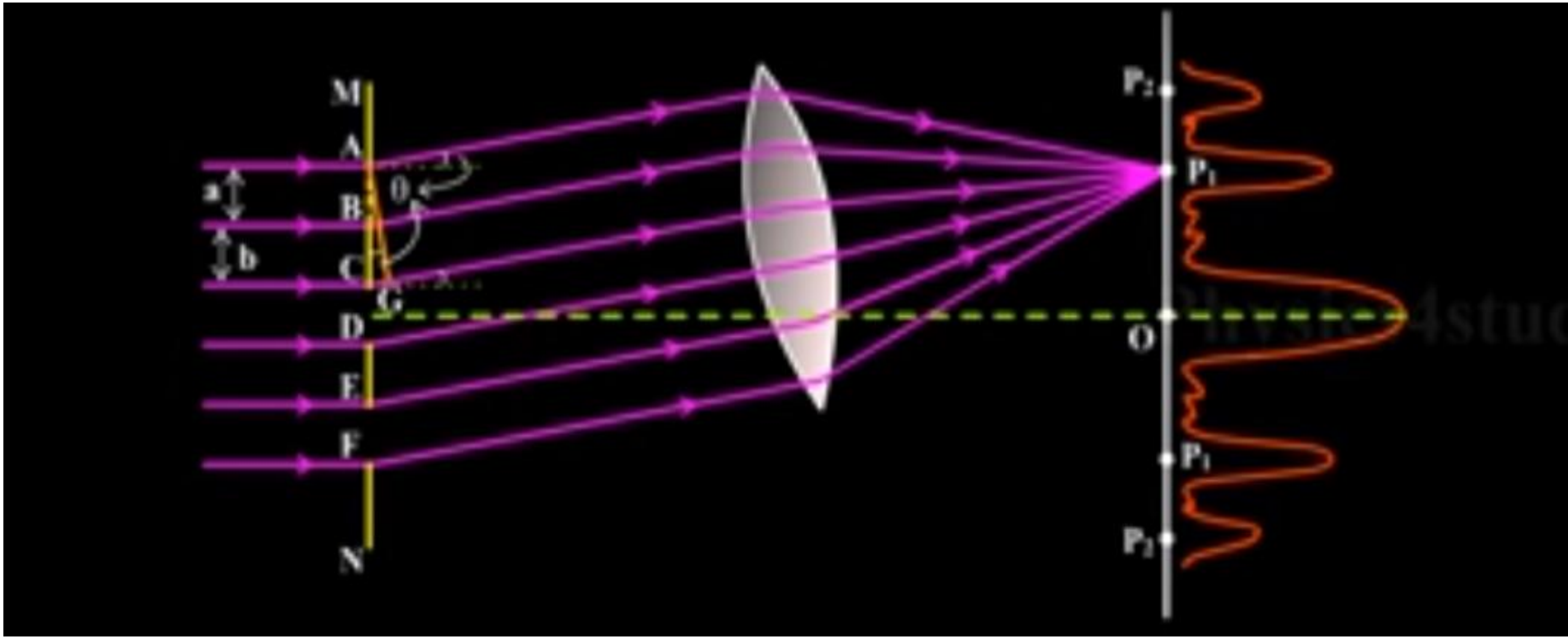
In grating spectrum, red color is deviated (diffracted) most and violet least.



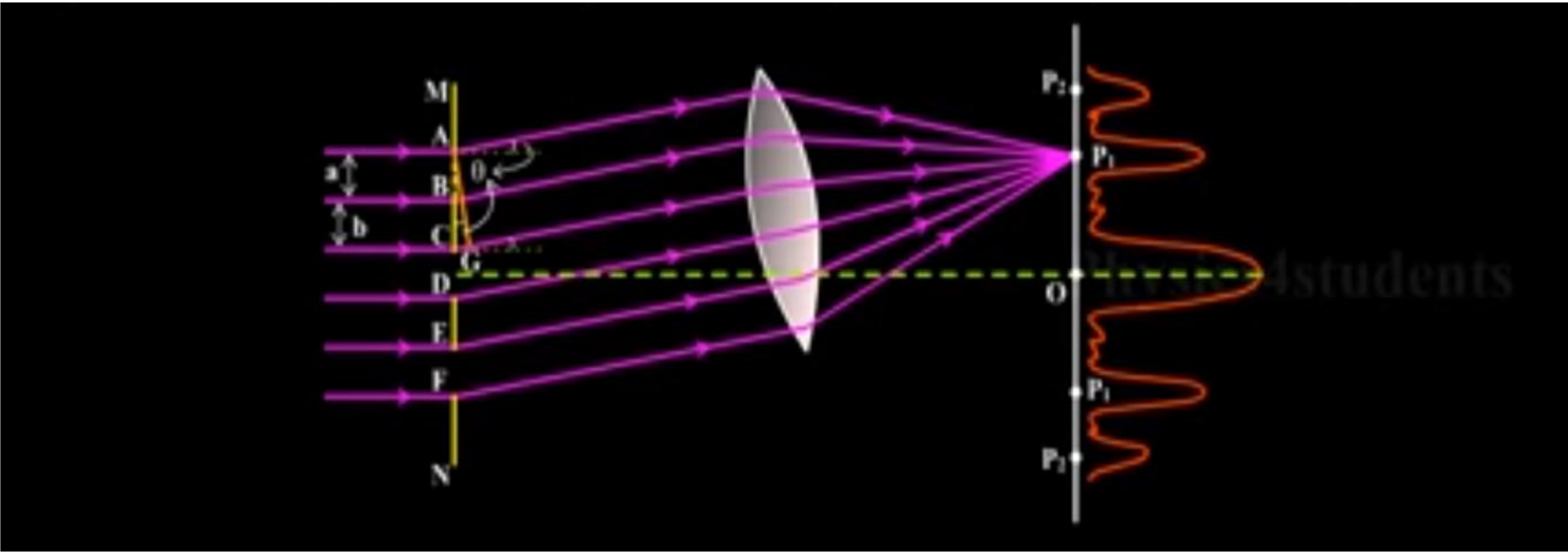
•The principles of diffraction gratings were discovered by James Gregory, about a year after Newton's prism experiments, initially with items such as bird feathers.

•The first man-made diffraction grating was made around 1785 by Philadelphia inventor David Rittenhouse, who strung hairs between two finely threaded screws.

James Gregory

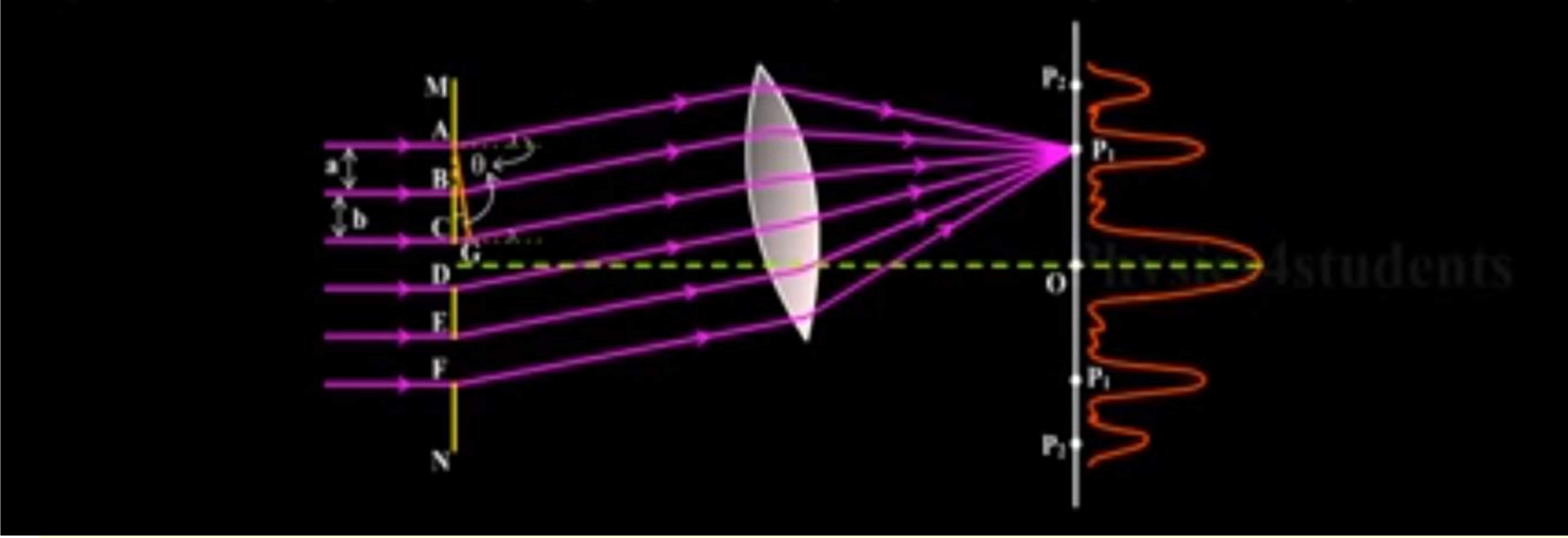


MN represents the section of a plane transmission grating. AB, CD, EF…. are the successive slits of equal width a and BC, DE… be the rulings of equal width b. Let e = a+b.



Let a plane wave front of monochromatic light of wave length λ be incident normally on the grating. According to the Huygen's principle, the points in the slit AB, CD… etc. act as a source of secondary wavelet which spread in all directions on the other side of the grating.

Let us consider the secondary diffracted wavelets, which makes an angle θ with the normal to the grating.

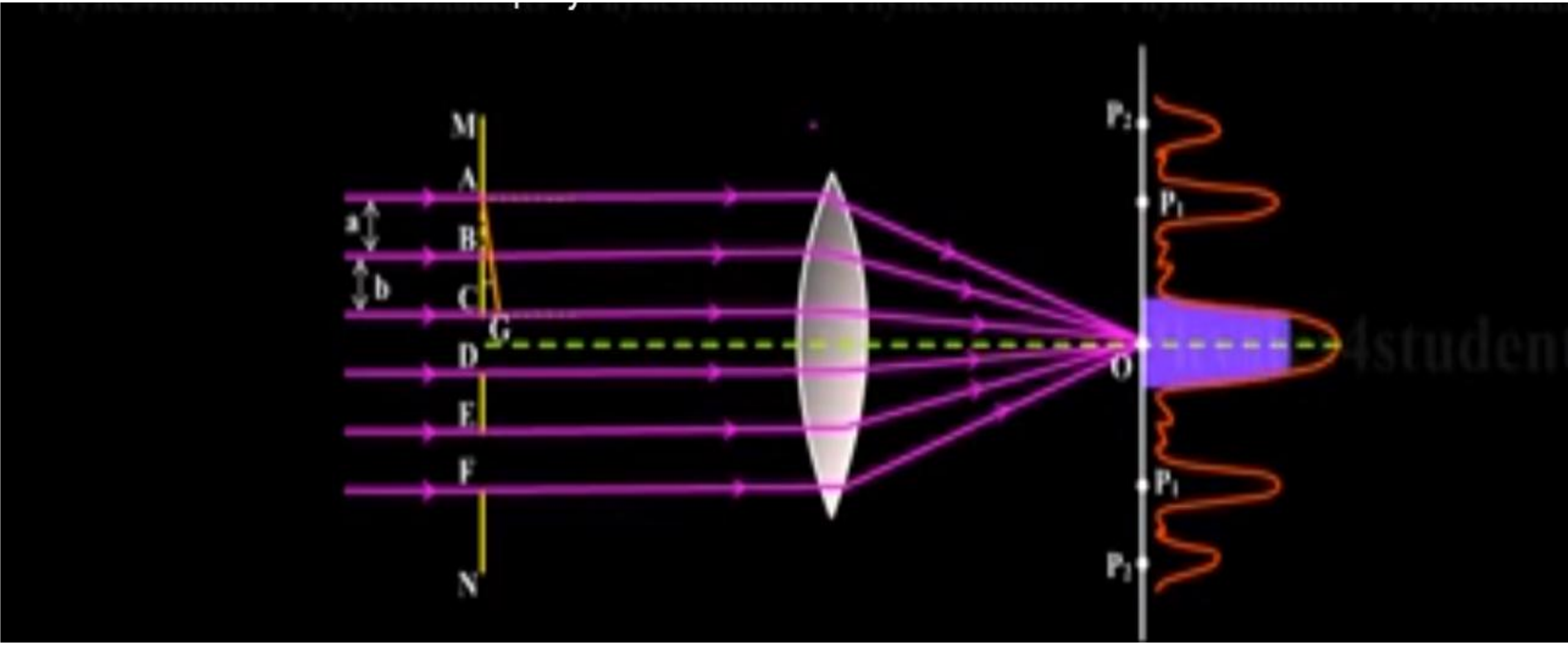


•The path difference between the wavelets from one pair of corresponding points A and C is CG = (a+b) sin θ.

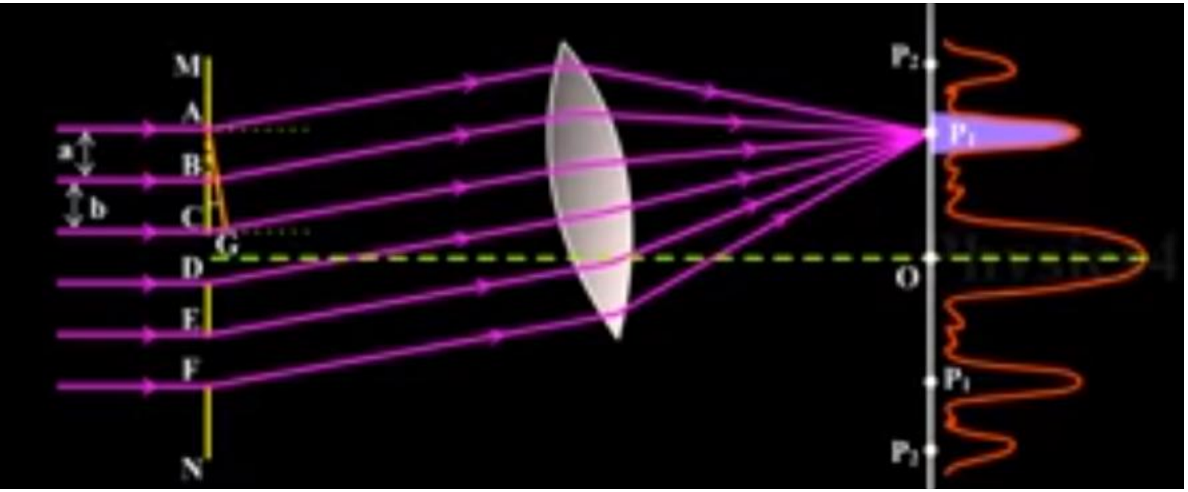
•It will be seen that the path difference between waves from any pair of corresponding points is also (a+b) sin θ.

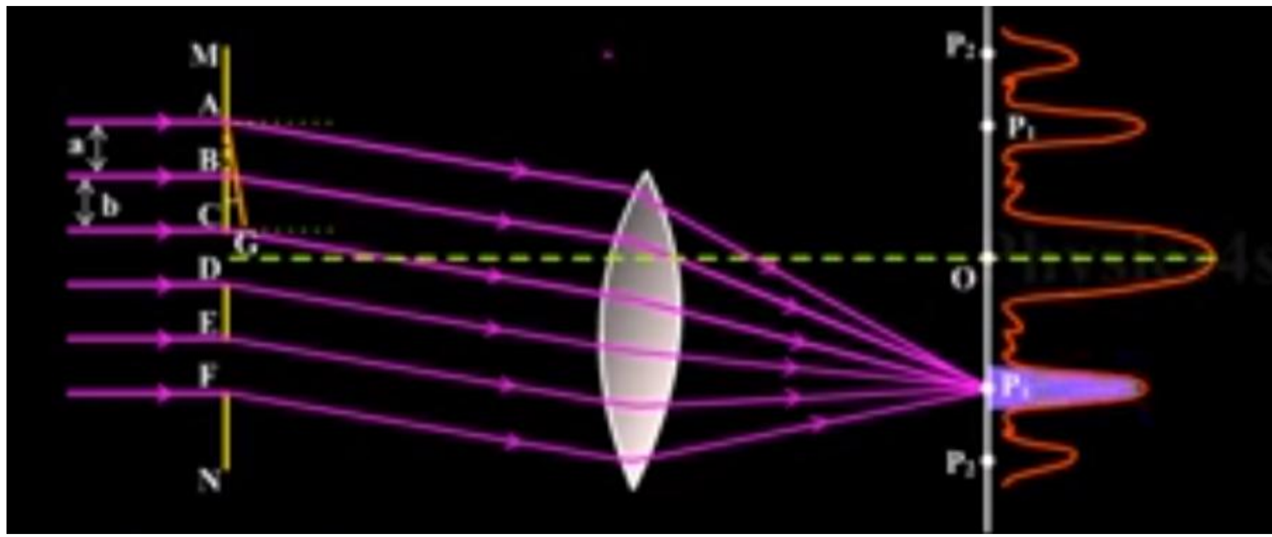
•The point P_1 will be bright, when $(a+b) \sin\theta = m\lambda$ where m=0,1,2,3..

•In the undiffracted position $\theta = 0$ and hence $\sin\theta = 0$.
$(a+b) \sin\theta = 0$, satisfies the condition for brightness for m=0.

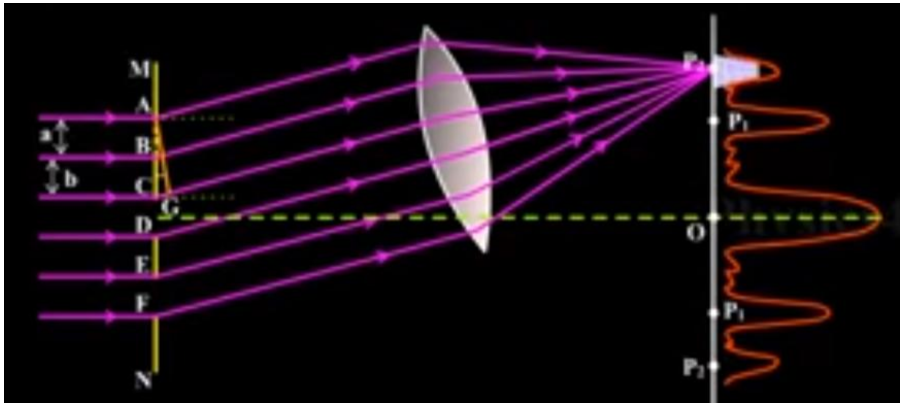


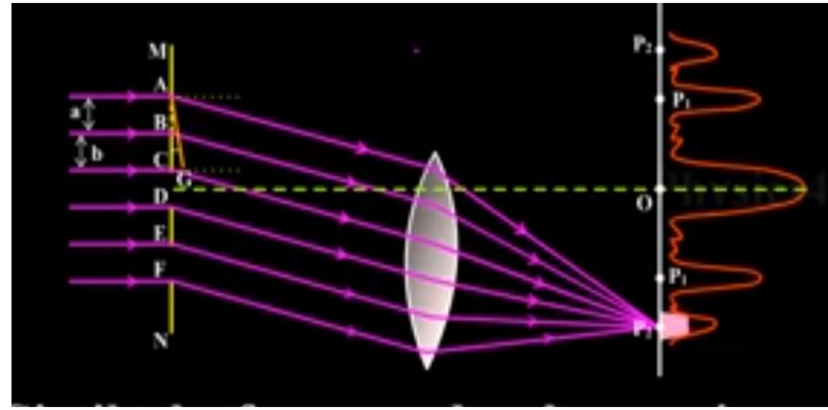
Hence the waveletes proceeding in the direction of the incident rays will produce maximum intensity at the centre o of the screen. This is also called zero order maximum or central maximum

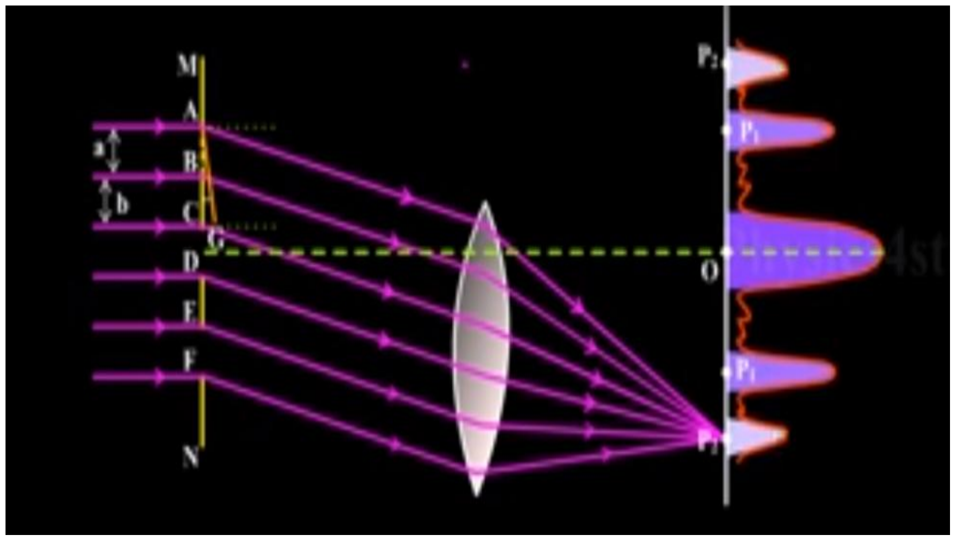




If (a+b) $\sin\theta_1=\lambda$, the diffracted wavelets inclined at an angle θ_1 to the incident direction, reinforce and the first order maximum is obtained.



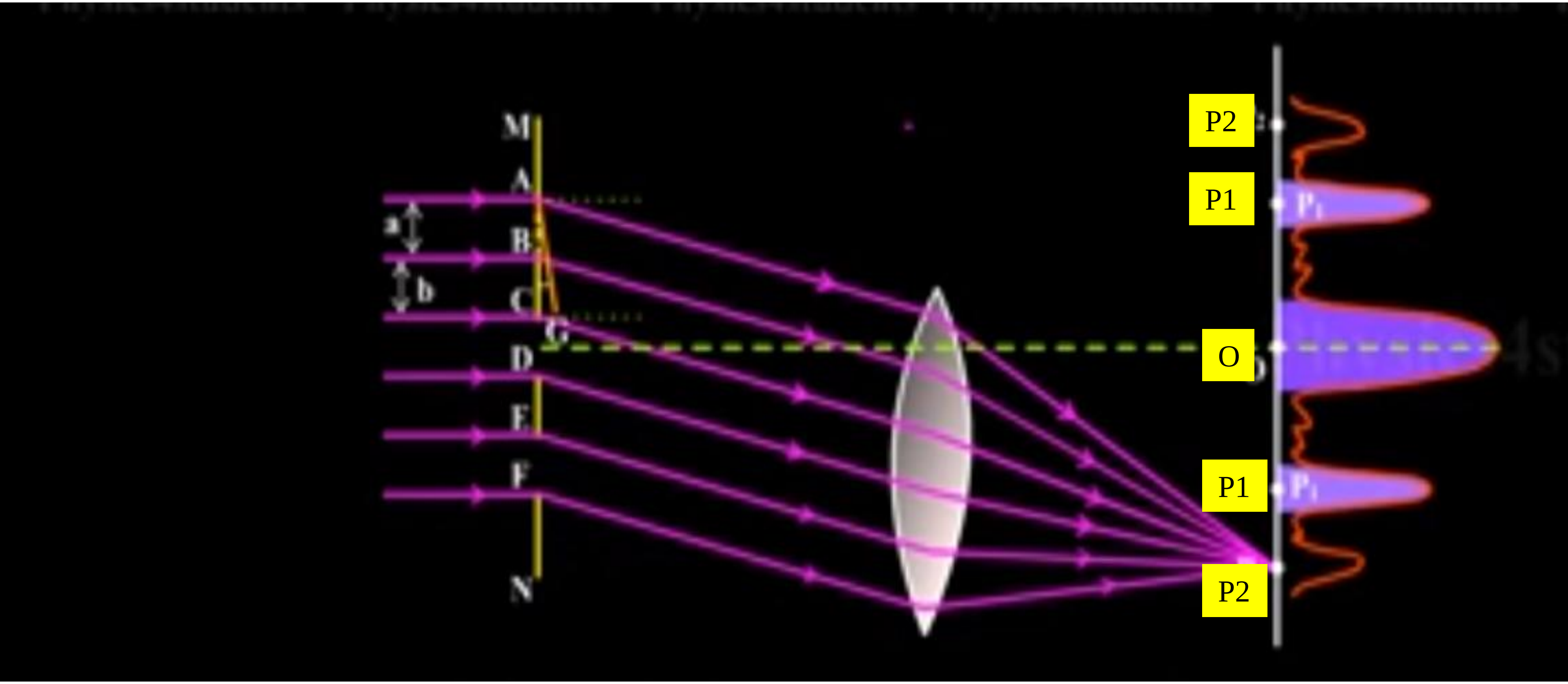




Similarly, for second order maximum,

$$(a+b)\sin\theta_2 = 2\lambda$$

On either side of central maxima different orders of secondary maxima are formed at the point P_1, P_2.

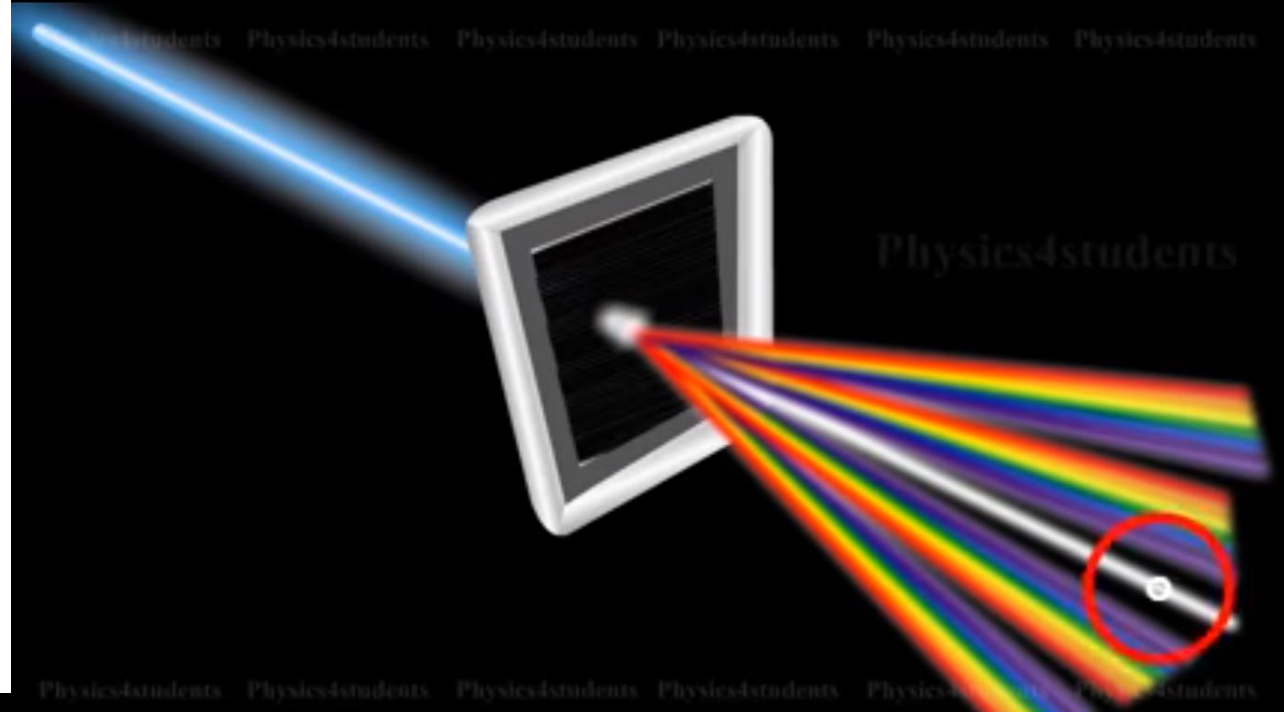


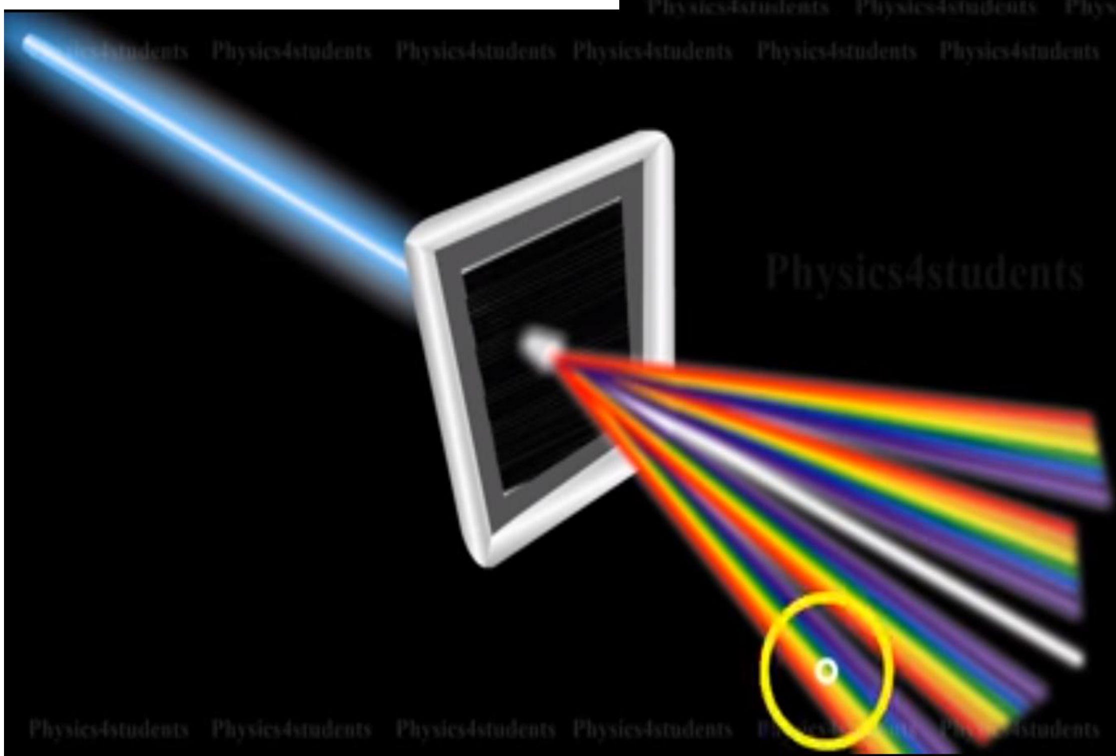
In general, (a+b) sin θ = mλ, is the condition for maximum intensity, where m is an integer, the order of the maximum intensity.

$\sin\theta = (m\lambda)/(a+b)$

Here (a+b) gives the number of grating element or nuber of lines per unit width of the grating

When white light is used, the diffraction pattern consist of a white central maximum and on both side continuous color images are formed.





At centre all the wavelengths reinforce each other producing maximum intensity for all wave lengths. Hence an undispersed white image is observed.

Spectrometer Grating

Spectrometer -Grating

Aim of the Experiment:

To measure the wavelength of spectral lines of mercury (Hg) source using diffraction grating and spectrometer.

Apparatus Required:

1. Diffraction Grating
2. Spectrometer
3. Mercury (Hg) Source
4. Spirit level
7. Reading Lens

Apparatus Required

A **spectrometer** is a instrument used to measure spectral components of a physical phenomenon.

Spectrometer

Spirit level

A sealed glass tube partially filled with alcohol or other liquid, containing an air bubble whose position reveals whether a surface is perfectly level.

Reading lens

Grating

In optics, a diffraction **grating** is an optical component with a periodic structure that splits and diffracts light into several beams travelling in different directions.

Mercury lamp

A **mercury-vapor lamp** is a gas discharge lamp that uses an electric arc through vaporized mercury to produce light.

Grating holder
is used to mount the grating properly

Grating holder

Grating

No of rulings per inch on the grating = 15,000

1 inch = 0.0254 meter

No of rulings per meter on the grating, N= 15,000/ 0.0254

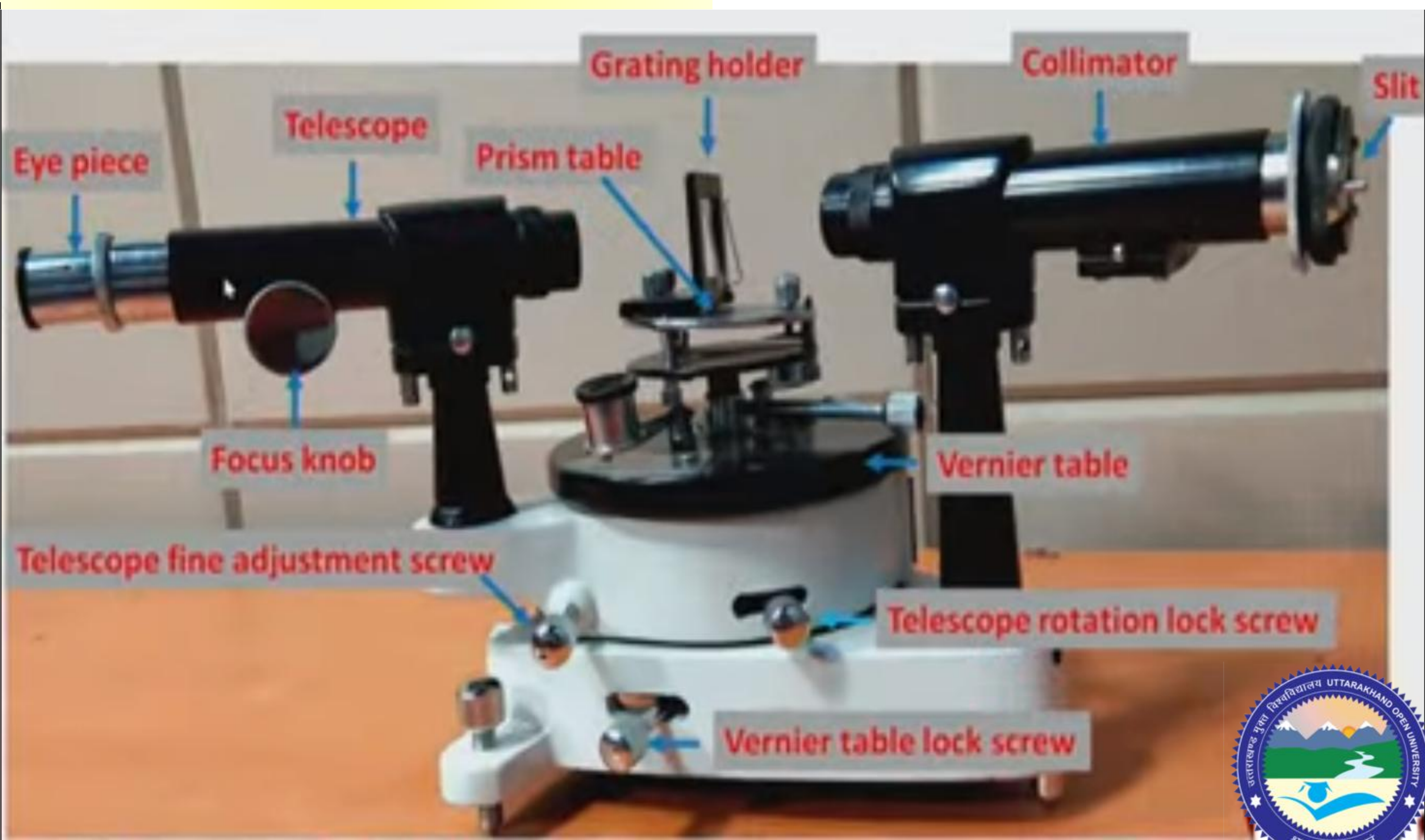
= 590551

= 5.9 X 10^5 lines/metre

Spectrometer

The spectrometer has three components:

- **Collimator**
- **Telescope**
- **Prism Table**



Least count of Spectrometer

Least Count

DEFINITION : Minimum possible measurable value of the instrument.

Calculation of Least count of spectrometer

Least count = 1 M.S.D. – 1 V.S.D.

20 M.S.D. = 10°

Value of 1 M.S.D. = ½° or 30'

If there are 60 divisions in the vernier scale then

60 V.S.D. = 59 M.S.D.

60 V.S.D. = 59 X ½ °

1 V.S.D. = (59/60) X ½ °

Least count = 1 M.S.D. – 1 V.S.D.

20 M.S.D. = 10°

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1 V.S.D. = (59/60) X ½°

Least count = ½° - (59/60) X ½° = (1°/120)

= (½)'

= half minute

Working Formula

Spectrometer Grating

Theory and Working Formula:

The Wavelength of given light can be calculated from Bragg's diffraction equation given by

$$\lambda = \frac{2.54 \sin\theta}{n.N}$$

Where λ = Wavelength of spectral lines of different colors

θ = Diffraction angle

n = Diffraction order

N = Number of parallel lines per inch in grating element

Observation

No of rulings per meter on the grating, N= 5.9 X 10^5 lines/metre

Least count of the spectrum $= (½)'$ = half minute

Order of spectrum m =1

How to take observation by spectrometer

Main scale reading and vernier scale coincidence

Main scale reading

Vernier scale reading

Procedure

Procedure

The whole procedure may be divided into three parts:

1. **Adjustment of the spectrometer**
2. **Adjustment of the grating**
3. **The actual experiment procedure**

Procedure

Procedure

•The preliminary adjustments of the spectrometer are made.

•The grating is set for normal incidence.

•The slit is illuminated by mercury vapour vamp.

•The telescope is brought in a line with the collimator and the direct image of the slit is made to coincide with the vertical cross wire.

•The readings of one vernier are noted. The vernier table is firmly clamped.

•Now, the telescope is rotated exactly through 90° and is fixed in this position. The grating is mounted vertically on the prism table with its ruled surface facing the collimator.

•The vernier table is released and is slowly rotated till the reflected image coincides with the vertical cross wire.

•

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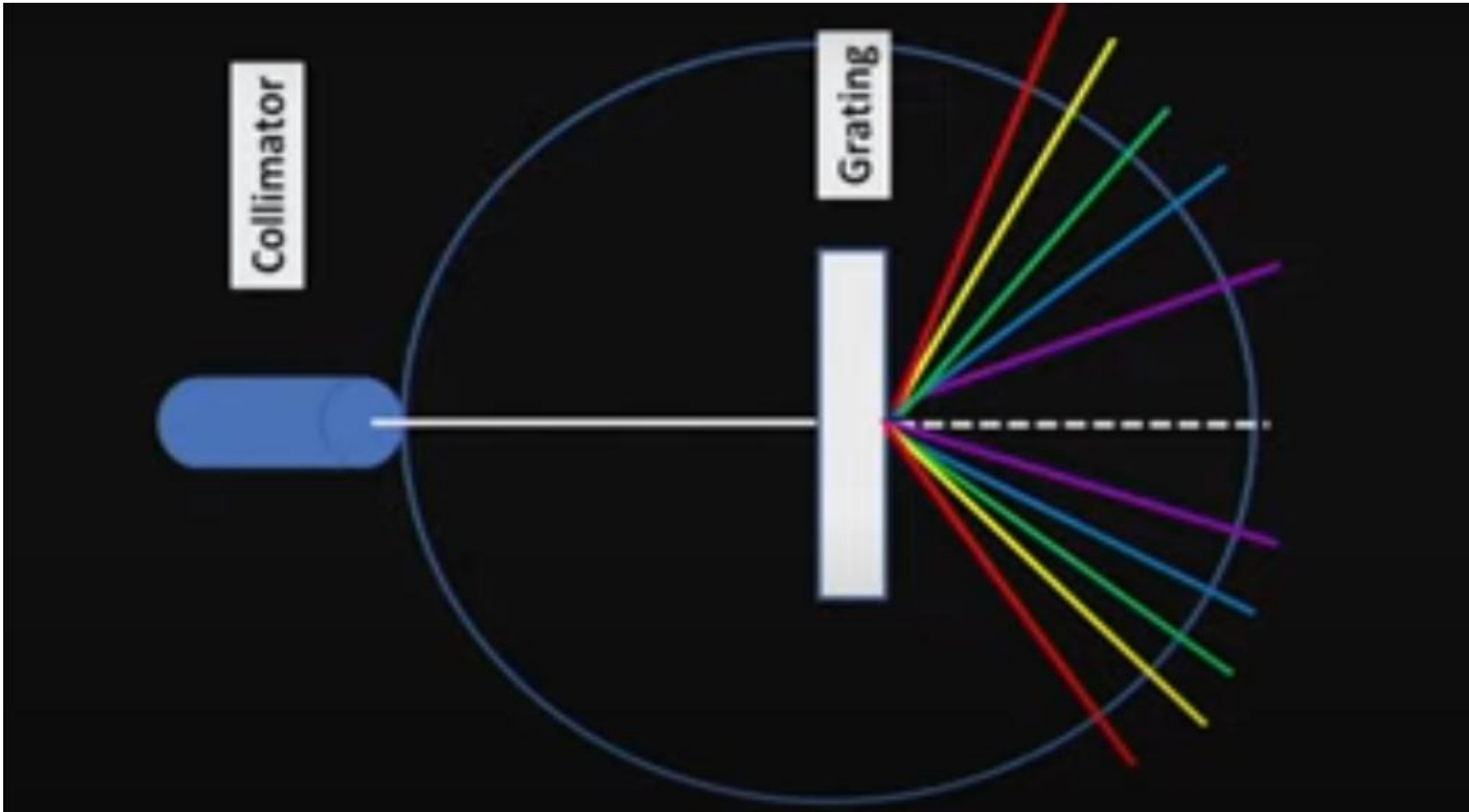
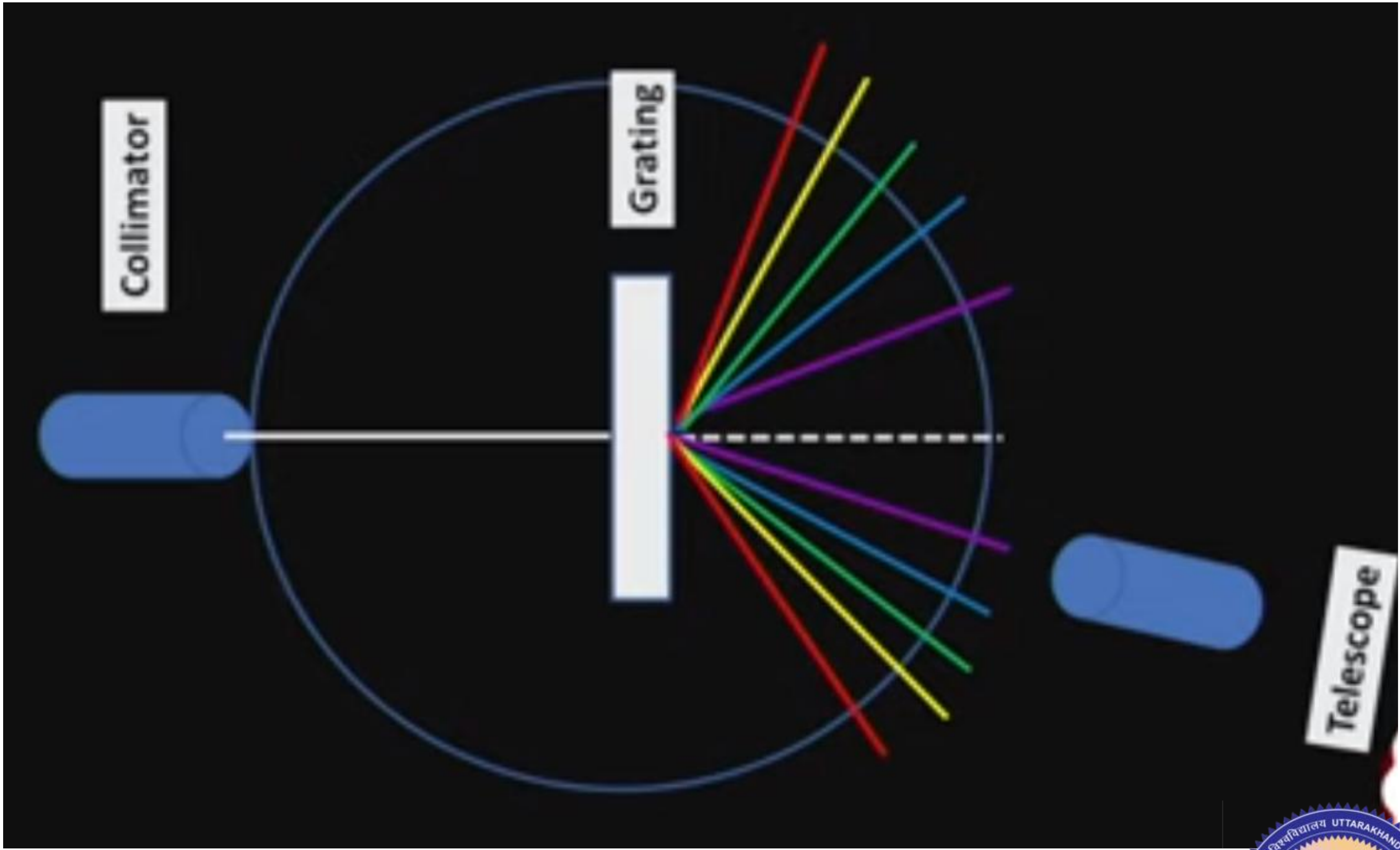
- The leveling screws are adjusted so that the image is at the centre of the field of view of the telescope.
- The prism table is fixed and after making fine adjustments with the tangential screw, the readings of the vernier are noted.
- Now, the angle of incidence is 45°. The vernier table is then released and rotated exactly through 45° in the proper direction so that the surface of the grating becomes normal to the incident light. The vernier table is firmly clamped in this position.
- The telescope is then released and is brought to observe the direct image. On the either side of the direct image, the diffraction spectra are seen.
- The telescope is turned slowly towards the left so that the vertical cross wire coincides with the violet lines of the first order. The readings of the vernier are taken.
- The vertical cross wire is then made to coincide with the other lines on the left and the vernier readings are taken in each case.
- The telescope is then moved to the right and the reading of different lines is simil taken.

- The difference between the readings on the left and right on the same vernier is determined for each line.
- The mean value of this difference gives 2θ-twice the angle of diffraction. Thus the angle of diffraction θ for each spectral line is determined.
- The wavelength of the green line is 546.1×10^{-9} m.
- The number of lines per meter (N) of the grating is calculated. Using this value of N, the wavelengths of the other prominent lines in this spectrum are calculated

Please watch the video

Observation


Collimator
Grating


Collimator
Grating
Telescope

Observation table for angle of diffraction

Order of Spectrum	Color of Spectrum	Reading for the Spectrum on				Value of 2θ			Value of θ (in degrees)
		L.H.S.		R.H.S.		Vernier			
		V_1 (a) (in degrees)	V_2 (b) (in degrees)	V_1(c) (in degrees)	V_2 (d) (in degrees)	1st a-c (deg)	2nd b-d (deg)	Mean (in degrees)	
1st	Green	352.5	172.5	312.06	131.55	40.44	40.95	40.69	20.34
	Yellow	352.21	172.55	312.03	131.03	40.18	41.53	40.85	20.42
	Red	353.17	173.37	311.25	130.40	41.92	42.97	42.44	21.22
2nd (Desirable)	Green								
	Yellow								
	Red								

Calculation

$$\lambda_{blue} = \frac{2.54 \sin(\theta_{blue})}{1 \times 15000}$$

$$\lambda_{green} = \frac{2.54 \sin(\theta_{green})}{1 \times 15000}$$

$$\lambda_{red} = \frac{2.54 \sin(\theta_{red})}{1 \times 15000}$$

Results

1. Number of lines on plane transmission grating = ______________
2. Wavelength of Blue spectral line = ________________ nm
3. Wavelength of Green spectral line = ________________ nm
4. Wavelength of Red spectral line = ________________ nm

Conclusion

After performing the experiment, the wavelength of the spectral lines were calculated and compared with the theoretical values.

Precautions and sources of error

PRECAUTIONS:

1.The grating should not be touched with hand or rubbed. It should always be held by means of fingers kept on the opposite edges of the grating.

2.Grating should be perfectly normal to the axis of the collimator.

3.The turn table must be leveled optically.

4.The slit should be as narrow as possible.

5.All the preliminary adjustments of the spectrometer must be made before starting the experiment.

6.While taking observations the turn table must remain clamped.

7. Reading for both the verniers should be taken.

Sources of error:

1.The spectrometer is not properly adjusted.

2.If the reading is not taken overhead the spectrometer.

3.Reading may not be taken by taking care of precautions.

Reference

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THANKS

VIVA-VOCE QUESTIONS AND ANSWERS

1. What is the main difference between the spectrum obtained by grating and that due to a prism?
Ans: In grating spectrum, red color is deviated (diffracted) most and violet least. The sequence of the colors in grating spectrum is reversed than that of prism spectrum.

2. How many types of gratings are known to you?
Ans: There are two types of gratings:
- Transmission grating
- Reflection grating

3. What is a travelling microscope?

Ans: A travelling microscope is an instrument for measuring length with a resolution typically in the order of 0.01mm. The precision is such that better-quality instruments have measuring scales made from Invar to avoid misreadings due to thermal effects. The instrument comprises a microscope mounted on two rails fixed to, or part of a very rigid bed. The position of the microscope can be varied coarsely by sliding along the rails, or finely by turning a screw. The eyepiece is fitted with fine cross-hairs to fix a precise position, which is then read off the vernier scale.

Difference between Diffraction grating and Prism

Diffraction gratings are based on diffraction while prisms are based on dispersion, two very different principles. Prisms can spread light spectra into many colors for analysis. This is often good enough. A diffraction grating does very much the same thing. However, a diffraction grating is less sensitive to the color of the light and can be made to spread colors over a larger angle than a prism.

Importance of Diffraction and grating

The **diffraction grating** is an important device that makes use of the diffraction of light to produce spectra. Diffraction is also fundamental in other applications such as x-ray diffraction studies of crystals and holography.
Spectra produced by diffraction gratings are extremely useful in applications from studying the structure of **atoms** and molecules to investigating the composition of stars.

Why is the light incident on the side of the grating which has no ruling?

To avoid refraction of diffracted light.

Dispersion?

Splitting of light into its constituents

What is grating element?

Distance between the centers of ant two successive ruled lines or transparent stripe.

Difference between prism and grating spectrum

The **grating** violet colour is least deviated and red colour more deviated but in prism reverse is true.

Formula sin theta = (n lambda/ e+d)

A prism gives more intense spectrum becz in this entire light is concentrated into one spectrum while in grating it is distributed in the different order.

Why is the light incident on the side of the grating which has no ruling?

To avoid refraction of diffracted light.

Dispersion?

Splitting of light into its constituents

What should be the order of size of obstacle/aperture for diffraction of light

Size of obstacle/aperure should be of the same order as that of wavelength of light.

What are the uses of diffraction grating.

It helps us to study spectra and measure wavelengths.

Does the seperation of spectral lines remainthe same in different orders of spectra?.

No, it increases with the order of the spectrum.

1. What is the main difference between the spectrum obtained by grating and that due to a prism?
Ans: In grating spectrum, red color is deviated (diffracted) most and violet least. The sequence of the colors in grating spectrum is reversed than that of prism spectrum.

2. How many types of gratings are known to you?
Ans: There are two types of gratings:
Transmission grating
Reflection grating

Examples and Application of diffraction in real life:

1. CD reflecting rainbow colours
2. Holograms
3. Sun appears red during sunset
4. From the shadow of an object
5. Bending of light at the corners of the door

1. Spectrometer
2. X-ray diffraction
3. To separate white light