B.Sc Physics (Hons) Part II
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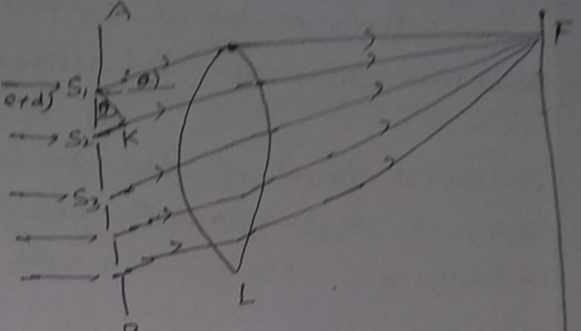
Q. Give the theory of plane transmission diffraction grating and show how you would use it to find the wavelength of light

Ans

Plane Transmission Grating:-

Let AB be the section of a plane transmission grating placed ⊥ to the plane of the paper. Let 'e' be the width of each transparent space and 'd' be the width of each opaque portion. Then (e+d) is the grating element.



Let a parallel beam of light of wavelength λ be incident normally on the grating. By Huyghen's principle, all the points in each transparent space (slit) send out secondary wavelets in all directions. Let us consider the wavelets starting from the middle point S_1, S_2 ..... of the slits and diffracted at angle θ.

Let us draw $S_1 a \perp S_1 K$ on the diffracted ray S_2K. Then the path difference between the diffracted waves from S_1 and S_2 is

$$K = S_1S_2 \sin\theta - (e+d)\sin\theta$$

The two waves will reinforce each other when brought to a focus P by the lens. If this path difference is a whole number of wavelengths. Thus for reinforcement:

$$(e+d)\sin\theta = n\lambda$$

Here $n = 0, \pm 1, \pm 2$ ------

What applies to this pair of corresponding waves, will apply to any other pair of corresponding waves from these slits. Thus all the waves from one

Slit will reinforce with the corresponding waves from the adjacent slit. Further what applies to one pair of consecutive slits. We apply to any other pairs of consecutive slits. Under the above equation all the waves diffracted at an angle θ will reinforce at P producing maximum intensity. Hence the condition of maximum intensity is

$$(e+d)\sin\theta = n\lambda$$

This is usual grating equation.

Determination of wavelength of light by Grating :→

It is evident from the above relation that if the grating element $(e+d)$ and the angle of diffraction θ for a particular ~~orb~~ order n be determined, the wavelength λ can be determined.

Determination of $(e+d)$:→

The grating element $(e+d)$ is determined from the number of rulings per inch on the grating (This is written on the grating). If this number is N' then

$$N(e+d) = 1 \text{ inch} = 2.54 \text{ cm}$$

$$(e+d) = \frac{2.54}{N} \text{ cm}$$

Determination of θ :→

This is done with the help of a spectrometer. Slit of the spectrometer is illuminated by the given light and the following adjustment are made:-

1. The eyepiece of the Telescope is focussed on the cross wire.
2. The collimator and the Telescope are adjusted for parallel rays. This is done by Schuster's method using prism.
3. The grating is adjusted on the prism such that light from the collimator falls normally on it. To do this, the telescope is set in the line with

the collimator so that the direct image of the slit falls on the intersection of the cross wires. The position of the telescope is noted. The telescope is turned through 90° from this position and clamped. The axis of the Telescope is now ⊥ to that of the collimator. The grating is placed on the prism table such that its ruled surface lies over the centre of the table and is ⊥ to the line joining the leveling screws A and B. The prism table is now rotated till the image of the slit obtained by reflection from the surface of the grating is obtained on the intersection of the cross wires. The levelling screws A and B are adjusted until the image lies equally above and below the intersection of the cross-wires.

In this position the grating surface is at 45° to the incident light. The prism table is rotated through 45° in the proper direction so that the ruled surface of the grating is normal to the incident light and faces the telescope. The prism table is clamped in that position.

(4) The rulings of the grating are adjusted parallel to the axis of the spectrometer. To do this, the diffracted images of the slit are observed through the telescope. The screw is now adjusted until the centre of all the different diffracted images lie at the same height in the field of view.

(5) The rulings are adjusted parallel to the slit. To do this the slit is rotated in its own plane until the diffracted images are sharp as possible.

Now to determine θ for the line whose wavelength is to be determined, the telescope is rotated to see that line in the first order on either side of direct image. The Telescope is turned to the other side of the direct image and the corresponding readings for the same line in the first order are again taken. The difference between the two readings of the same vernier gives 2θ for that line from which θ is found. The process is repeated for the 2nd order.

Hence knowing $(e+d)$, θ and n, the wavelength λ can be calculated with the help of the equation $(e+d)\sin\theta = n\lambda$