Thus the *resolving power of a grating is equal to the product of the order of the spectrum and the total number of lines on the grating.* It is obvious that the resolving power is independent of the spacing $(a + b)$ of the lines. The resolving power increases with order $n$ of the spectrum and the total number of lines $N$ in the effective part of the grating. However, for a given wavelength and in a given direction, it simply depends on the total width of the ruled surface. It may be seen by substituting $n = (a + b) \sin \theta/\lambda = W \sin\theta/\lambda$ in equation (2.38) when we get

$$\frac{\lambda}{d\lambda} = \frac{N(a+b)\sin\theta}{\lambda} = \frac{W\sin\theta}{\lambda} \quad ...(2.39)$$

where $W = N(a + b)$ is the total width of ruled space in the grating. It is obvious from this equation that the resolving power of the grating would not be effected if the number of lines $N$ in a given width of ruled space is changed. However, a change in $N$ would change the order $n$ of the spectrum in a given direction. It must be noted that although the resolving power increases with the order $n$ of the spectrum, the intensity of the second, third, etc. order spectrum goes on decreasing. (aff

If we put $\theta = 90°$ in eqn. (2.39), we get the maximum resolving power of a given grating. Thus

$$\text{Maximum Resolving power} = \frac{N(a+b)}{\lambda} = \frac{W}{\lambda} = \frac{\text{Total width}}{\lambda}$$

where the width of the grating is measured in wavelength.

Further the dispersive power of the grating, as given in eqn. (2.32), is

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

The resolving power of the grating

$$\frac{\lambda}{d\lambda} = Nn = N(a+b)\cos\theta \times \frac{n}{(a+b)\cos\theta}$$

or

$$\frac{\lambda}{d\lambda} = N(a+b)\cos\theta \cdot \frac{d\theta}{d\lambda}$$

but

$$N(a+b)\cos\theta = \text{total aperture}$$

$$\therefore \quad \frac{\lambda}{d\lambda} = \text{Resolving power of grating} = \text{Total aperture} \times \text{dispersive power}$$

## 2.11 DIFFERENCE BETWEEN DISPERSIVE POWER AND RESOLVING POWER OF A GRATING

1. The dispersive power

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

width

Thus the dispersive power increases with increase in $n$, the order of the spectrum and varies inversely as the grating element $(a + b)$ but it is independent of grating length. Further, the resolving power of a grating, $\lambda/d\lambda = nN$ *i.e.* the resolving power depends on '$n$' the order of the spectrum and total number of lines on the grating and hence on the width of the grating, since $N = \text{width}/(a + b)$. Therefore if

$1/(a+b)$, the number of lines per cm is same for two gratings then the dispersive power will be sam in the two cases but one with the larger width of grating surface will be having high resolving power and the images would be narrower and sharper. If $N$ is smaller or width is smaller, the spectra would be wider and over-lapping, see Fig. 2.15.

2. High dispersive power refers to wide separation of the spectral lines whereas high resolving power refers to the ability of the instrument to show close spectral lines as separate ones.

3. The dispersive power involves merely the angular separation of lines (or wavelengths) in the spectrum. The resolving power, however, involves the width of a maximum.

4. The dispersive power of the grating is given as

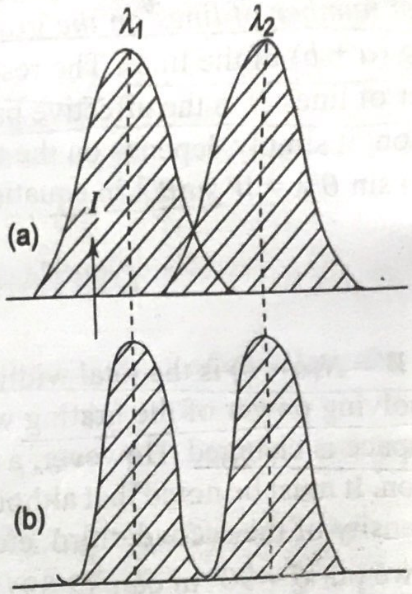


**Fig. 2.15.** *Width of maxima (a) is large over-lapping occurs (b) i small, no overlapping rathe lines are sharp and bright*

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

and the resolving power of the grating is given by

$$\frac{\lambda}{d\lambda} = Nn = N(a+b)\cos\theta \times \frac{n}{(a+b)\cos\theta}$$

or
$$\frac{\lambda}{d\lambda} = N(a+b)\cos\theta\,\frac{d\theta}{d\lambda}$$

but $\quad N(a+b)\cos\theta$ = total aperture

$\therefore \quad$ Resolving power = total aperture × dispersive power

## SOLVED EXAMPLES

### Examples on Fraunhofer Diffraction

**Example 1.** *Find the half angular width of the central bright maximum in the Fraunhofer diffraction pattern of a slit of width $12 \times 10^{-7}$ m when the slit is illuminated by a monochromatic light of wavelength 6000 Å.*

**Solution:** We know $\quad \sin\theta = \lambda/a$

where $\theta$ is half angular width of the central maximum

here $\quad a = 12 \times 10^{-7}$ m, $\lambda = 6000$ Å $= 6 \times 10^{-7}$ m

$$\sin\theta = \frac{\lambda}{a} = \frac{6\times10^{-7}}{12\times10^{-7}} = \frac{1}{2}$$

or $\quad \theta = 30°$

**Example 2.** *In Fraunhofer diffraction due to a narrow slit a screen is placed 2 m away from the le to obtain the pattern. If the slit width is 0.2 mm and the first minima lies 5 mm on either side of t central maxima, find the wave length of light.*

$= 2y = 2 \times 0.589 = 1.178$ cm.

**Example 6.** *Light of wavelength 5500 Å falls normally on a slit of width $22.0 \times 10^{-5}$ cm. Calculate the angular position of the first two minima on either side of the central maximum.*

**Solution:** The angular positions of minima in a single slit diffraction pattern are given by

$$a \sin \theta = \pm n\lambda \text{ or } \sin \theta = n\,\lambda/a, \quad \text{where } n = 1, 2, 3, ...$$

here $a = 22 \times 10^{-5}$ cm and $\lambda = 5500 \times 10^{-8}$ cm.

for first order minimum, $n = 1$

$$\therefore \quad \sin \theta_1 = \frac{\lambda}{a} = \frac{5500\ \ 10^{-8}}{22\ \ 10^{-5}} = 0.25$$

or $\theta_1 = \sin^{-1}(0.25) = 14° - 29'$

for second order minimum, $n = 2$

$\therefore$ $\sin \theta_2 = 2\,\lambda/a = 2 \times 0.25 = 0.5$

or $\theta_2 = \sin^{-1}(0.5) = 30°$

Thus the first two minima shall occur at angle $14° - 29'$ and $30°$ on either side of central maximum.

**Example 7.** *Calculate the angles at which the first dark band and next bright band are formed in the Fraunhofer diffraction pattern of a slit 0.3 mm wide. Given the wave length of light $\lambda = 5890$Å*

**Solution:** The conditions for nth minimum is given by

$$a \sin \theta_n = n\lambda$$

where $\theta_n$ is the direction of nth minimum.

For first dark band $n = 1$, $\lambda = 5890$ Å, $a = 0.3 \times 10^{-3}$ m

$\therefore$ $a \sin \theta = \lambda$

or
$$\sin \theta = \frac{\lambda}{a} = \frac{5890 \times 10^{-10}}{3 \times 10^{-4}} = .001963$$

or
$$\theta = \sin^{-1}(0.001963) = 6° - 7'$$

The diffraction angle $\theta$ corresponding to the first bright band on either side of the central maxima is given by

$a \sin \theta = (2n+1)\frac{\lambda}{2}$

$$a \sin \theta = \frac{3\lambda}{2}$$

$\frac{3\lambda}{2}$

or
$$\sin \theta = \frac{3\lambda}{2a} = \frac{3}{2} \times (0.001963)$$

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$$x_2 = 5.868 \times 10^{-5} \text{ m}$$
$$\therefore \quad x_2 - x_1 = (5.868 - 3.912) \times 10^{-5} = 1.596 \times 10^{-5} \text{ m}$$

## Examples on Diffraction Grating

**Example 9.** *What is the highest order spectrum which may be seen with monochromatic light of wavelength 5000 Å by means of a diffraction grating with 5000 lines/cm?*

**Solution:** We know $(a + b) \sin \theta_n = n\lambda$

maximum value of $\sin \theta_n = 1$ (highest value)

$$\therefore \quad (a + b) \times 1 = n\lambda \quad \text{where} \quad (a + b) = \frac{1}{5000}, \quad \lambda = 5000 \times 10^{-8} \text{ cm}$$

$$\therefore \quad n = \frac{(a+b)}{\lambda} = \frac{1}{5000 \times 5000 \times 10^{-8}} = 4.$$

**Example 10.** *Find the angular separation between two sodium lines 5890 Å and 5896 Å in the second order spectrum of a grating with 5000 lines/cm. The width of the grating is 1/2 cm. Can they be seen distinctly.*

**Solution:** We know $(a + b) \sin \theta_n = n\lambda$

width $= 0.5$ cm

No. of lines/cm $= 5000$ or $(a + b) = \dfrac{1}{5000}$

$a+b = \dfrac{1}{5000}$ cm

(*i*) here $\lambda_1 = 5890 \text{ Å} = 5890 \times 10^{-8}$ cm, $n = 2$

$$\therefore \quad \frac{1}{5000} \cdot \sin\theta_1 = 2 \times \lambda_1 = 2 \times 5890 \times 10^{-8}$$

or
$$\sin\theta_1 = 0.5890$$
$$\theta_1 = 36° - 5'$$

(*ii*) for $\lambda_2 = 5896 \times 10^{-8}$ cm, $n = 2$

$$\frac{1}{5000} \cdot \sin\theta_2 = 2 \times \lambda_2 = 2 \times 5896 \times 10^{-8}$$
$$\sin\theta_2 = 2 \times 5896 \times 10^{-8} \times 5000$$
$$\sin\theta_2 = 0.5896$$
$$\theta_2 = 36° - 8'$$

Angular separation $= \theta_2 - \theta_1 = 3$ minutes of an arc

(*iii*) Condition for just resolution. $\lambda = \frac{\lambda_1 + \lambda_2}{2}.$

$$\frac{\lambda}{d\lambda} = nN, \qquad \lambda_2 - \lambda_1 = d\lambda$$
$$\lambda = 5893 \times 10^{-8} \text{ cm}, \quad d\lambda = 6 \times 10^{-8} \text{ cm}, \quad n = 2, N = ?$$
$$\therefore \quad \frac{5893 \times 10^{-8}}{6 \times 10^{-8}} = 2 \times N \quad \text{or} \quad N \cong 491$$

In the given grating total number of lines = 5000 × 0.5 = 2500. The two lines will be well resolved as the number of lines required is 491 and given grating has total of 2500 lines.

**Example 11.** *Calculate the minimum number of lines in a grating which will just resolve the sodium lines in the first order spectrum. The wavelengths are 5890Å and 5896Å.*

**Solution:** Wavelength of the sodium D lines are

$$\lambda_1 = 5890 \text{ Å} = 5890 \times 10^{-8} \text{ cm}, \lambda_2 = 5896 \text{ Å} = 5896 \times 10^{-8} \text{ cm}$$
$$\therefore \quad \lambda = 5893 \times 10^{-8} \text{ cm and } d\lambda = 6 \times 10^{-8} \text{ cm}$$

The resolving power of the grating $\frac{\lambda}{d\lambda}$ = nN where n is the order of the spectrum and N the number of lines on the grating.

$$\therefore \quad \frac{\lambda}{d\lambda} = \frac{5893 \times 10^{-8}}{6 \times 10^{-8}} \approx 982 = nN$$

or
$$N = \frac{982}{1} = 982$$

The two lines will be just resolve in the first order with a minimum of 982 lines.

**Example 12.** *The second order maximum for a wavelength of 6360Å in a transmisson grating coincides with third order maximum of an unknown light. Determine the wavelength of the unknown light.*

**Solution:** Here we have

$$n_1 = 2, \quad n_2 = 3, \quad \lambda_1 = 6360\text{Å} \quad \lambda_2 = ?$$

As second order maximum of $\lambda_1$ coincides with third order maximum of $\lambda_2$, thus

$$n_1\lambda_1 = n_2\lambda_2$$

or $$\lambda_2 = \frac{n_1\lambda_1}{n_2} = \frac{2}{3}\times 6360 = 4240 \text{ Å}$$

**Example 13.** *A diffraction grating used at normal incidence gives a line (5400 Å) in a certain order superposed on the violet line (4050 Å) of the next higher order. How many lines per cm are there in the grating if angle of diffraction is 30°?*

**Solution:** Condition for principal maxima is $(a+b)\sin\theta = n\lambda$

Let wave length $\lambda_1$ of $n$th order is superimposed on wave length $\lambda_2$ of next higher order *i.e.* $(n+1)$

$$\therefore \quad (a+b)\sin\theta = n\lambda_1 = (n+1)\lambda_2$$

or $$n = \frac{(a+b)\sin\theta}{\lambda_1}, \quad \text{and} \quad n+1 = \frac{(a+b)\sin\theta}{\lambda_2}.$$

Eliminating $n$ from these two equations, we get

$$\left(\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right)(a+b)\sin\theta = 1 \quad \text{or} \quad (a+b) = \frac{\lambda_1\lambda_2}{\lambda_1-\lambda_2}\cdot\frac{1}{\sin\theta}$$

given $\lambda_1 = 5400 \text{ Å} = 5400\times 10^{-8}$ cm, $\lambda_2 = 4050\times 10^{-8}$ cm, $\theta = 30°$

$$\therefore \quad (a+b) = \frac{5400\times 10^{-8}\times 4050\times 10^{-8}}{1350\times 10^{-8}}\cdot\frac{1}{1/2} = \frac{5400\times 4050\times 2}{1350}\times 10^{-8}$$

$$\text{No. of lines/cm} = \frac{1}{a+b} = \frac{1350\times 10^{8}}{5400\times 4050\times 2} = 3086$$

**Example 14.** *A plane transmission grating produces an angular separation of 0.01 radian between two wavelengths observed at an angle of 30°. Given mean value of the wave length as 5000 Å. Calculate difference in two wavelengths if the spectrum is observed in the second order.*

**Solution:** We know that $(a+b)\sin\theta = n\lambda$

differentiating $(a+b)\cos\theta\, d\theta = n d\lambda$

Dividing, we get $$\frac{\cos\theta}{\sin\theta}d\theta = \frac{d\lambda}{\lambda} \quad \text{or} \quad d\lambda = \lambda\cot\theta\cdot d\theta$$

where $d\lambda$ is the difference in two wave lengths.

given $\theta = 30°$, $d\theta = 0.01$ radian, $\lambda = 5000\times 10^{-8}$ cm

$$\therefore \quad d\lambda = 5000\times 10^{-8}\times \cot 30°\times 0.01 = 86.6 \text{ Å}$$

**Example 15.** *A diffraction grating having 4000 lines/cm is illuminated normally by light of wavelength 5000 Å. Calculate its dispersive power in third order spectrum.*

**Solution:** The dispersive power is defined as

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\cos\theta} = \frac{n}{(a+b)\sqrt{1-\sin^2\theta}}$$

but we have $(a+b)\sin\theta = n\lambda$

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

$\therefore$
$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\sqrt{1-(n\lambda/a+b)^2}}$$

given
$$(a+b) = \frac{1}{4000},\ n = 3 \text{ and } \lambda = 5000 \times 10^{-8} \text{ cm}$$

Thus
$$\frac{d\theta}{d\lambda} = \frac{3}{\left(\frac{1}{4000}\right)\sqrt{1-\left(3\times\frac{5\times10^{-5}}{1/4000}\right)^2}}$$

or
$$\frac{d\theta}{d\lambda} = \frac{3\times4000}{\sqrt{1-0.36}} = \frac{3\times4000}{0.916} = 1.875 \times 10^4 \text{ radians/cm}$$

**Examples 16.** *A parallel beam of sodium light is allowed to be incident normally on a plane grating having 5000 lines/cm and a second order spectral line is observed to be deviated through 30°. Calculate the wavelength of light used.*

**Solution:** Number of lines per cm = 5000

$\therefore$ grating element $(a + b)$ = 1/5000

$\theta = 30°,\quad n = 2,\quad \lambda = ?$

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

or
$$\lambda = \frac{(a+b)\sin\theta}{n} = \frac{1\times\sin 30"}{5000\times2}$$

or
$$\lambda = 0.5\times10^{-4} \text{ cm} = 5000 \text{ Å}$$

## Examples on Resolving Power

**Example 17.** *A plane transmission grating has 16000 lines to an inch over a length of 5 inches. Find (i) the resolving power of the grating in the second order and (ii) the smallest wavelength difference that can be resolved for the light of the wavelength 6000 Å.*

**Solution:** The resolving power of the grating is = $nN$

= order of spectrum × No. of lines on the grating.

Length of grating = 5 inches.

No. of lines per inch on the grating = 16000

Total number of lines on the grating = 16000 × 5 = 80000

$\lambda = 6000 \times 10^{-8}$ cm, $n = 2$

(*i*) resolving power $\frac{\lambda}{d\lambda}$ = 80000 × 2 = 160000

(*ii*) Smallest wavelength difference $d\lambda$ that can be resolved is given as

$$\frac{\lambda}{d\lambda} = Nn \quad \text{or} \quad d\lambda = \frac{\lambda}{Nn}$$

or
$$d\lambda = \frac{6000\times10^{-8}}{160000} = 0.0375 \text{ Å}$$

**Example 18.** *A diffraction grating is just able to resolve two lines of wavelengths 5500 Å and 5501 Å in the first order. Will it resolve the lines of wavelength 8500 Å and 8501 Å in the second order.*

**Solution:** The resolving power of the grating is

$$\frac{\lambda}{d\lambda} = Nn = \text{order of spectrum} \times \text{No. of lines on the grating}$$

for the first case

$$\lambda_1 = 5500\ \text{Å and } \lambda_2 = 5501\ \text{Å}$$

$$\lambda = \frac{\lambda_1 + \lambda_2}{2} = 5500.5\ \text{Å}$$

$$d\lambda = \lambda_2 - \lambda_1 = 5501 - 5500 = 1\ \text{Å}$$

$$n = 1$$

$$\therefore \quad \frac{\lambda}{d\lambda} = \frac{5500.5}{1} = nN = 1 \times N$$

or

$$N = 5500.5$$

For the second order $n = 2$,

the resolving power $= 2N = 2 \times 5500.5 = 11001.0$

In second case

$$\lambda_1 = 8500\ \text{Å and } \lambda_2 = 8501\ \text{Å}$$

here

$$\lambda = \frac{\lambda_1 + \lambda_2}{2} = 8500.1\ \text{Å}$$

and

$$d\lambda = 8501 - 8500 = 1\ \text{Å}$$

resolving power required to resolve these two lines in the second order is

$$\frac{\lambda}{d\lambda} = \frac{8500.1}{1} = 8500.1$$

The required resolving power 8500.1 is less than the actual resolving power 11001.0 of the given grating, therefore the given lines will be resolved in the second order.

**Example 19.** *A plane transmission diffraction grating has 40000 lines. The grating element is $12.5 \times 10^{-5}$ cm. Calculate the maximum resolving power for which it can be used in the range of wave length 5000 Å.*

**Solution:** Condition for principal maxima in the grating is

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

or

$$n = \frac{(a+b)\sin\theta}{\lambda}, \text{ where } n \text{ is order of spectrum.}$$

for maximum order $\quad \sin\theta_{max} = 1$

The maximum observable order in the given grating

$$n_{max} = \frac{(a+b)}{\lambda},$$

where

$$(a + b) = 12.5 \times 10^{-5}\ \text{cm and } \lambda = 5000 \times 10^{-8}\ \text{cm}$$

$$\therefore \quad n_{max} = \frac{12.5 \times 10^{-5}}{5000 \times 10^{-8}} = 2.5$$

Second order is the highest observable order in this grating.

Maximum resolving power $= nN = 2 \times 40000 = 80000$

**Example 20.** Light is incident normally on a grating of total ruled width $5 \times 10^{-3}$ m with 2500 lines in all. Calculate the angular separation of the two sodium lines in the first order spectrum. Can they be seen distinctly?

**Solution:** The directions of spectral lines are given by

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

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

where
$$(a+b) = \frac{\text{width of the grating}}{\text{total no. of lines on grating}} = \frac{0.5}{2500} = \frac{1}{5000}$$

and
$$n = \text{order of spectrum} = 1, \text{ width} = 0.5 \times 10^{-3} \text{ m} = 0.5 \text{ cm}$$

Let $\theta_1$ and $\theta_2$ be the angles of diffraction corresponding to two $D$ lines of sodium. Thus

(*i*) for $\lambda_1 = 5890 = 5890 \times 10^{-8}$ cm, $\theta_1 = ?, n = 1$

thus
$$\frac{1}{5000}\sin\theta_1 = 1 \times \lambda_1 = 5890 \times 10^{-8}$$

or
$$\sin\theta_1 = 5890 \times 10^{-8} \times 5000 = 0.2945$$
$$\theta_1 = 17° - 8'$$

(*ii*) for $\lambda_2 = 5896 \times 10^{-8}$ cm, $\theta_2 = ?, n = 1$

$$\frac{1}{5000}\sin\theta_2 = 1 \times \lambda_2 = 5896 \times 10^{-8}$$

or
$$\sin\theta_2 = 5896 \times 10^{-8} \times 5000 = 0.2948$$
$$\theta_2 = 17° - 9'$$

$$\text{Angular separation} = \theta_2 - \theta_1 = 1'$$

(*iii*) Condition for just resolution

$$\lambda/d\lambda = nN, \text{ where } d\lambda = \lambda_2 - \lambda_1$$
$$\lambda = 5893 \times 10^{-8} \text{ cm}, d\lambda = 6 \times 10^{-8} \text{ cm}, n = 1, N = ?$$

$$\therefore \quad \frac{5893 \times 10^{-8}}{6 \times 10^{-8}} = 1 \times N \text{ or } N = 982 \text{ lines.}$$

Two lines will be well resolved as the minimum number of lines required are 982 while the given grating has total of 2500 lines

**Example 21.** *A plane transmission grating has 40,000 lines per inch. If length of diffraction grating is 2 inch then determine the resolving power in third order (n=3) for a wave length of 5000 Å.*

**Solution:** The resolving power of the grating $= nN$

$= \text{order of spectrum} \times \text{no. of lines on the grating}$

Length of grating $= 2$ inches

Number of lines per inch of the grating $= 40000$

Total number of lines on a grating $= 40000 \times 2 = 80000$

resolving power $= \lambda/d\lambda = nN = 3 \times 80000 = 24000$

**Example 22.** *A plane transmission grating has 40000 lines in all with grating element $12.5 \times 10^{-5}$ cm. If the maximum resolving power of the grating is 80000, find out the range of wave length for which* *it can be used.*

**Solution:** Given $N = 40000$

$$(a+b) = 12.5 \times 10^{-5} \text{ cm}$$

$$\text{maximum Resolving power} = 80000 = \frac{\lambda}{d\lambda}$$

but
$$\frac{\lambda}{d\lambda} = nN$$

$\therefore$
$$nN = 80000$$

or
$$n = \frac{80000}{40000} = 2$$

For maximum,
$$(a+b)\sin 90° = n\lambda$$

$$\lambda = \frac{(a+b)}{2} = \frac{12.5 \times 10^{-5}}{2} = 6.5 \times 10^{-5}\text{cm} = 6500 \text{ Å}$$

Smallest wave length difference,
$$\frac{\lambda}{d\lambda} = nN$$

or
$$d\lambda = \frac{\lambda}{nN} = \frac{65}{8} \times 10^{-2} = 8.33 \times 10^{-2} = 0.08 \text{ Å}$$

thus
$$\lambda_1 = 6500 \text{ A°}$$

and
$$\lambda_2 = 6500 + 0.08 = 6500.08 \text{Å}$$

**Example 23.** *In the second order spectrum of a plane diffraction grating a certain spectral line appears at an angle of 10°, while another line of wave length $5. \times 10^{-9}$ cm greater appears at an angle 3° greater. Find the wavelength of the lines and the minimum grating width required of the lines and the minimum grating width required to resolve them. Given sin 10° = 0.1736 and cos 10° = 0.9848.*

**Solution:** The direction of maxima in grating is given by

$$(a+b)\sin\theta = n\lambda \quad \text{... (i)}$$

Differentiating,
$$(a+b)\cos\theta = nd\lambda \quad \text{...(ii)}$$

Dividing (i) by (ii), we get

$$\frac{\sin\theta}{\cos\theta \, d\theta} = \frac{\lambda}{d\lambda}$$

or
$$\lambda = \frac{\sin\theta \, d\lambda}{\cos\theta \, d\theta}$$

here
$$\theta = 10° \text{ and } d\theta = 3° = \left(\frac{3}{60 \times 60}\right) = \frac{3}{60 \times 60} \times \frac{\pi}{180} \text{ radians.}$$

and
$$d\lambda = 5 \times 10^{-9} \text{ cm} = 0.5 \times 10^{-8}\text{cm}$$

$\therefore$
$$\lambda = \frac{\sin 10°}{\cos 10°} \times \frac{0.5 \times 10^{-8}}{\left(\frac{3}{60 \times 60}\right) \times \frac{\pi}{180}}$$

$$= \frac{0.1736 \times 0.5 \times 10^{-8} \times 60 \times 60 \times 180}{0.9848 \times 3 \times 3.14} = 6063 \times 10^{-8} \text{ cm.}$$

$$\lambda + d\lambda = 6063 \times 10^{-8} + 0.5 \times 10^{-8} = 6063.5 \times 10^{-8}\text{cm.}$$