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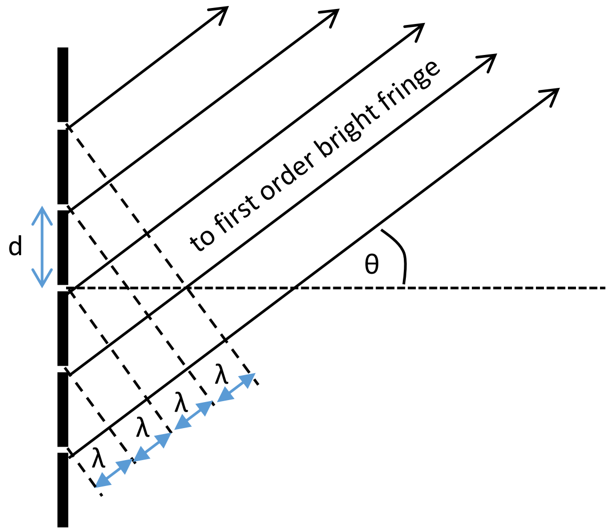
3.5.3 Diffraction gratings

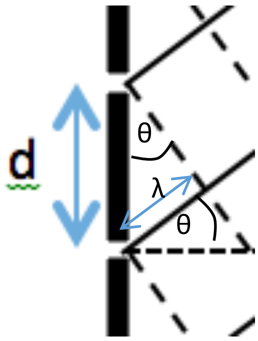
A diffraction grating consists of multiple slits through which light can pass. The light diffracts on passing through the slits and produces an interference pattern. The advantage of using multiple slits is that the bright fringes are narrower and brighter.

Let us look at a section of a diffraction grating:



At a particular angle waves passing through a slit in the diffraction grating are one wavelength ahead or behind the neighbouring slit. This means that in this particular direction they are in phase and will produce constructive interference. The example shown in the diagram is for the first order bright fringe. A second order bright fringe would be occur when there is a difference of 2 whole wavelengths between adjacent slits and so on.

Because there are multiple slits, a lot of light can pass through and so the slits can be made very narrow to reduce the single slit width effect.



From the diagram we can find a formula for the angle θ to the first order bright fringe:

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

To the second order bright fringe:

$$\frac{2\lambda}{d} = \sin\theta$$

A general expression to the nth order bright fringe is:

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

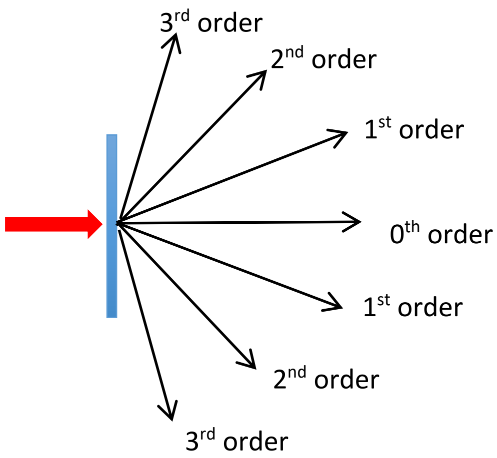
where n=1,2,3,4..., etc., and d is the slit spacing

The slit spacing is usually not given in problems on diffraction gratings. Usually the 'number of lines per mm' is stated. This means the number of slits in 1mm. To work out the slit spacing you need to divide 1mm (in metres) by the number of lines per mm.

(1)✎What is the slit spacing for a diffraction grating that has 100 lines per mm?

(2)✎Red light with a wavelength of 700nm is incident on this diffraction grating. At what angle would the 1st order bright fringe occur? At what angle would the 3rd order bright fringe occur?

The greater the order, the greater the angle. At some point the angle will reach 90°, beyond which the bright fringes can't be detected.



For the example above, all the orders up to n=3 can be detected. n=4 is not possible.

If we wan't to find how many orders that can be detected we can plug in θ=90° into the equation:

$$n\lambda \le d \sin 90°$$

Therefore:

$$n \le \frac{d}{\lambda}$$

(3)✎What is the maximum order that can be detected using a diffraction grating with 300 lines per mm and light with wavelength of 450nm?

(4)✏Looking at the formula $n\lambda = d sin\theta$, what would you observe if you shone white light at a diffraction grating?

Diffraction gratings are often used in spectroscopy to disperse light containing different frequencies, instead of glass prisms. This is because the light can be dispersed over much greater angles.

(5)✏What factor would determine how big an angle the light would be dispersed over?