Diffraction grating theory

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CONCEPT OF DIFFRACTION GRATING

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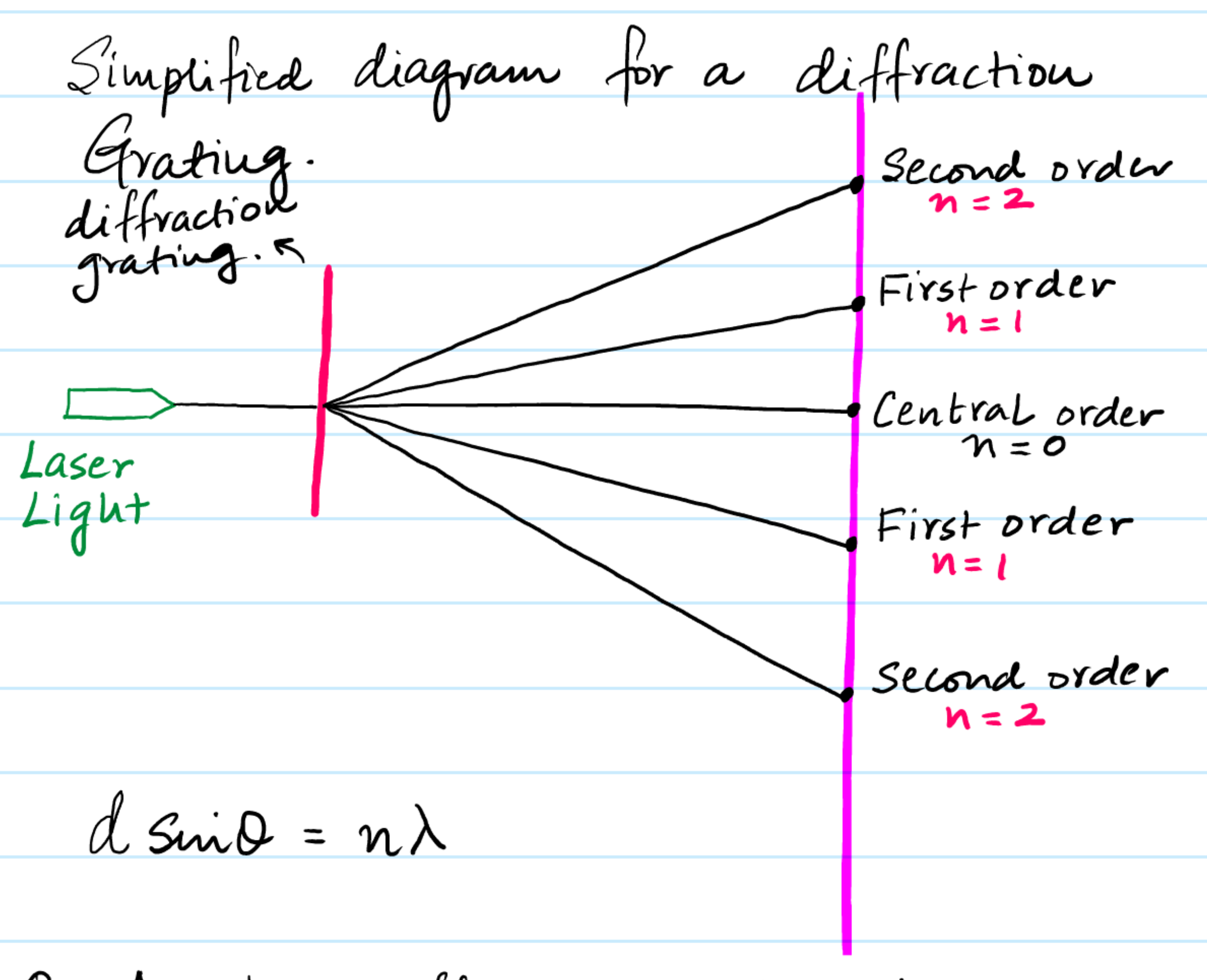
- A diffracting grating is an optical instrument constructed either using glass or Plastic
- This instrument has many microscopic slits on it, so that when light is allowed to fall on this instrument (diffraction grating), diffraction occurs, causing the light to spread.
- If a screen is positioned in the background (as shown on the next slide), than the spreading of light can be displayed on the screen.
- The angle through which the light spread is denoted as θ (it is generally measured from the central line). This angle θ can be worked out using the equation

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

where λ = wavelength of light
θ = angle through which the light diffracts
n denotes the number of order i.e $n = 1, 2, 3, 4, 5$ etc &
d is a constant known as the grating spacing. (This constant value is provided by the manufacturer in unit of m)

Simplified diagram for a diffraction Grating.



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

Q :: A certain diffraction grating has a grating spacing $(d) = 2.0 \times 10^{-6}$ m. Light of wavelength $(\lambda) = 450$ nm is allowed to fall onto the grating

(i) find angle for 1st order

$d \sin\theta = n\lambda$

$(2 \times 10^{-6}) \sin\theta = (1)(450 \times 10^{-9})$

$\theta = 13°$

(ii) find angle for 2nd order

$(2 \times 10^{-6}) \sin\theta = (2)(450 \times 10^{-9})$

$\theta = 26.7°$

(iii) find angle for 3rd order

$(2 \times 10^{-6}) \sin\theta = (3)(450 \times 10^{-9})$

$\theta = 42.5°$

(iv) find angle for 4th order.

$(2 \times 10^{-6}) \sin\theta = (4)(450 \times 10^{-9})$

$\theta = 64.2°$

(v) find angle for 5th order

$(2 \times 10^{-6}) \sin\theta = (5)(450 \times 10^{-9})$

θ = error

Conclusion max orders = 4.
Total # of order = 9
General formula = $(2n + 1)$

* What if we are asked to directly find the max orders?

$\theta < 90°$ $\sin 90 = 1$

$\sin\theta < 1$ → ①

$d \sin\theta = n\lambda$

$\sin\theta = \frac{n\lambda}{d}$ → ②

replace ② into eq ① to get a formula which "directly" gives you max order

g. formula $\frac{n\lambda}{d} < 1$

$\frac{n(450 \times 10^{-9})}{(2.0 \times 10^{-6})} < 1$

$n < 4.44$ ∴ $n = 4$

Q :: The experiment is now repeated using a different light whose wavelength $\lambda = 620$ nm

(i) find angle for 1st order

$(2.0 \times 10^{-6}) \sin\theta = (1)(620 \times 10^{-9})$

$\theta = 18.1°$

(ii) find angle for 2nd order

$(2.0 \times 10^{-6}) \sin\theta = (2)(620 \times 10^{-9})$

$\theta = 38.3°$

(iii) find angle for 3rd order

$(2.0 \times 10^{-6}) \sin\theta = (3)(620 \times 10^{-9})$

$\theta = 68.4°$

(iv) find angle for 4th order

θ = error

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

$\sin\theta \propto \lambda$ as $\lambda\uparrow$, the angle θ will also $\uparrow$.

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

$n \propto \frac{1}{\lambda}$ as $\lambda\uparrow$, the number of orders will $\downarrow$

Q :: Cal. the angular Seperation in the 1st order for the two wavelength ($\lambda = 450$ nm & $\lambda = 620$ nm)

$\theta_1 = 13°$ $\theta_1 = 18.1$

angular seperation = 5.1°

[difference b/w the angles in a particular order]

Q :: angular Seperation in the 2nd order

$\theta_2 = 26.7°$ $\theta_2 = 38.3°$

angular seperation = 11.6°

Q angular seperation in the 3rd order

$\theta_3 = 42.5°$ $\theta_3 = 68.4°$

angular seperation = 25.9°

Q angular seperation in the 4th order

$\theta_4 = 64.2°$ θ_4 = error

not possible.

Conclusion :: Angular Seperation INCREASES as the number of orders increase

∴ we can conclude that MAXIMUM ANGULAR SEPERATION WILL ALWAYS ARISE IN THE HIGHEST ORDER.